# TECHNICAL MANUAL

## OPERATOR, UNIT, DIRECT SUPPORT AND GENERAL SUPPORT MAINTENANCE MANUAL (INCLUDING REPAIR PARTS AND SPECIAL TOOLS LIST)

## FOR

## WATER PURIFICATION BARGES (NSN 1930-01-234-2165) VOLUME 9-4 ELECTRIC POWER SYSTEM

**This technical manual is an authentication of the manufacturer's commercial literature and does not conform with the format and content requirements normally associated with the Army technical manuals. This technical manual does, however, contain all essential information required to operate and maintain the equipment.**



**HEADQUARTERS, DEPARTMENT OF THE ARMY**
**15 OCTOBER 1992**

# WARNINGS AND SAFETY NOTICES

## WARNING

DANGEROUS VOLTAGES AND HAZARDOUS MATERIALS
ARE USED IN THIS EQUIPMENT.
DO NOT TAKE CHANCES!

## GENERAL WARNINGS

- Always redtag electrical equipment, controls, circuits, and switches before beginning repairs.
- Do not service or adjust high voltage electrical equipment when alone.
- Do not overload circuits.
- Always use authorized, insulated tools and test equipment when working on electrical equipment.
- Remove all jewelry before working on or around electrical equipment with exposed current-carrying areas.
- Do not wear clothing with exposed metal fasteners when working on electrical equipment.

Always use approved breathing apparatus when working with chemicals.

- Avoid chemical contact with eyes, skin, and clothing.
- Always wear safety glasses, gloves, and rubber aprons when handling chemicals.
- Wear protective clothing and safety glasses as required when working on barge equipment.
- Always wear approved ear protection in noise hazard areas.

## SPECIFIC WARNINGS

- Do not connect any new circuit to an existing circuit.
- Do not energize circuits if water condensation is present.
- If any sparks are seen, stop operation immediately. Determine cause and take corrective action.
- Never touch radio antennas of fixed-base radio transmitters. When transmitting, antennas contain high voltage.
- Always use approved breathing apparatus when handling material in multimediafilters and chlorination unit descaling acid crystals. Do not breathe dust from these materials.
- Avoid breathing vapors from coagulant aid chemicals. Use in a well-ventilated area In case of chemical contact with skin, wash with water. For eyes, immediately flush at eyewash station and obtain medical help as soon as possible.
- Always wear work gloves and shirts with full length buttoned sleeves when handling fuel oil and gasoline.

- Do not smoke or' have open flames within 10 feet when handling fuel oil or gas. Only minimum number of personnel necessary to conduct fueling operation is permitted in area.
- Before starting any repairs on compressed air system, always release pressure from air receiver and compressor and open and redtag circuit breakers. On air compressor, do not adjust automatic regulator switch (pressure switch. and pilot valve settings.
- To avoid flying particles lodging in eyes, do not use compressed air to "dust-off" clothing or workspace.
- Stay dear of anchor cables when operating anchor winches.
- Always wear safety glasses or face shield when using power tools.
- Always wear lifevests when on weatherdeck and throughout the barge during storm conditions.
- Lifevests are to be worn at all times aboard workboat.
- Only qualified persons will operate and maintain arc and fuel gas welders.
- When welding, always make sure those working with or near the welder wear proper clothing: heavy, hole-free gloves, heavy shirt, cuffless trousers, high shoes, and cap. Keep clothing dry and free of oil and other flammable substances.
- Use dry heavy canvas drop cloth to cover work area and adjacent deck when arc welding.
- Before welding on bulkheads, deck plating and similar surfaces, always check carefully to make sure that the other side of the surface to be welded does not hide fuel or compressed gas tanks, flammable or hazardous materials, or electrical equipment or wiring.
- When welding, keep your head out of the fumes and make sure area is well ventilated.
- Before welding on surfaces which have been cleaned with cleaning solutions containing chlorinated hydrocarbons, always wash with water, dry and ventilate area thoroughly.
- Use shield with proper filter lens when welding. Do not allow others near welding operations to assist or observe without proper eye protection. This must include side shields during slag chipping operations.
- Warn personnel in area during welding operations not to look at arc or expose themselves to hot spatter or metal.
- In an extreme emergency, when welding is required in void 2 port, shut down chlorination system. Close all valves. Cover the parts of chlorination system not being welded with a heavy canvas drop cloth. Turn on vent 8 and, if available, provide additional forced air ventilation.

- Before welding on fuel oil or sludge tank, make sure tank is gas-free by: 1) removing all liquid from tank, 2) cleaning tank thoroughly, 3) seeing that tank is thoroughly dry, and 4) force ventilating tank.
- Connect arc welding work cable as dose to welding area as possible. Work cables connected to barge framework or other locations far from welding site increase the possibility of the welding current passing through lifting chains, crane cables or other possible circuit paths. This can create fire hazards or weaken lifting chains or crane, cables until they break or fall.
- Always weld with all doors, portholes, and hatches propped open and necessary ventilation systems operating.
- Take frequent breaks away from the area where you are welding.
- Do not take oxygen and acetylene tanks into confined areas when welding.
- Always use a friction lighter to start oxyacetylene torch.
- Always maintain all welding equipment in proper working condition. If you have any doubts about the safety of any welding equipment do not use the welder.

## ELECTRICAL SHOCK SAFETY STEPS

Five safety steps to follow if someone is the victim of electrical shock.

1. Do not try to pull or grab individual.
2. Turn off electrical power when possible.
3. If you can not turn off electrical power, pull, push, or lift person to safety using a wooden pole, rope, or some other insulating material.
4. Get medical help as soon as possible.
5. After the injured person is free of contact with the source of electrical shock, move the person a short distance away and, if needed, start CPR immediately.

# INTRODUCTION TO

# TM 55-1930-209-14&P-9-4

You can help improve this manual. If you find any mistakes or if you know of away to improve the procedures, please let us know. Mail your letter, DA Form 2028 (Recommended Changes to Publications and Blank Forms), or DA Form 2028-2 located in the back of this manual direct to: Commander, US Army Troop Support Command, ATTN: AMSTR-MMTS, 4300 Goodfellow Blvd., St. Louis, MO 63120-1798. A reply will be furnished directly to you.

1. SCOPE

TM 55-1930-209-14&P covers the Reverse Osmosis Water Purification Barges, Models 300-WPB-1, 300-WPB-2 and 300WPB-3, NSN 1930-01-234-2165. This manual consists of twenty-one volumes.

2. REVERSE OSMOSIS WATER PURIFICATION BARGES

The Reverse Osmosis Water Purification Barges provide up to 300,000 gallons of drinking water per 24-hour period. The drinking water, converted from seawater or brackish water, is for use by a Rapid Deployment Force in a forward area. When needed, the drinking water can be pumped to a shore facility or to another vessel. This manual provides operation and maintenance procedures for all the component systems on the barges.

3. VOLUME 1 -- NORMAL OPERATIONS

This volume provides information and procedures on normal Reverse Osmosis Water Purification Barge operations, including barge movement and deployment, communications and electrical power systems, drinking water production, shutdown, and required operational maintenance. Emergency shutdown procedures are also provided.

4. VOLUME 2 -- SEAWATER SYSTEM

This volume describes operation and maintenance of the seawater system which supplies seawater to the Reverse Osmosis Water Purification Units (ROWPUs) for processing to the air conditioning unit for cooling to the ballast tank for barge trimming to the chlorination unit for priming and cooling, and to the diesel generators for cooling.

5. VOLUME 3 -- REVERSE OSMOSIS WATER PURIFICATION UNIT (ROWPU) SYSTEM

Volume 3 provides operation and maintenance procedures for the ROWPU System which processes seawater or brackish water to produce drinking water. Normally, this system processes seawater supplied by the seawater system (TM 55-1930-209-14&P-2) to create product water. Chlorine is then added to this product water by the chlorination system (TM 55-1930-209-14&P-4). The resultant drinking water is discharged into four storage tanks that are part of the drinking water system (TM 55-1930-209-14&P-5).

6. VOLUME 4-- CHLORINATION SYSTEM

Operation and maintenance procedures for the chlorination system onboard the Water Purification Barges are contained in this volume. This system produces chlorine in a sodium hypochlorite solution, upon demand, to water processed by the ROWPU system just before the water enters the four drinking water storage tanks.

7. VOLUME 5 -- DRINKING WATER SYSTEM The drinking water system provides storage for water produced by the ROWPUs and includes pumps and valves to move this water from onboard storage tanks to the shore discharge system, to another vessel, or overboard. The drinking water system also provides a pressurized water supply for drinking and washing onboard the barges.

8. VOLUME 6 --SHORE DISCHARGE SYSTEM This volume provides operation and maintenance procedures for the shore discharge system which transfers drinking water from barge storage tanks to holding/storage facilities ashore.

9. VOLUME 7 --COMPRESSED AIR SYSTEM Volume 7 describes the operation and maintenance of the compressed air system which provides compressed air to five air stations in the ROWPU space, one in the workshop, and one on stem weatherdeck This system also provides compressed air to two air stations for blowdown of seachests in void 2 starboard and void 4 port. Compressed air is used on the barges to operate air-powered impact tools, to propel air through the shore discharge hose, to blowdown seachest, and for general cleaning blowdown.

10. VOLUME 8 --FUEL OIL SYSTEM This volume provides operation and maintenance procedures for the fuel oil system which functions as a centralized receiving storage and distribution system for diesel fuel used for barge operations. This onboard fuel system provides fuel for two 155 kW diesel ship service generators, a 20 kW ship auxiliary generator, two ROWPU high-pressure pump diesel engines, and a fueling station for the barge workboat.

11. VOLUME 9 --ELECTRICAL POWER SYSTEMS Operation and maintenance procedures for the two electrical power systems installed aboard the Water Purification Barges are contained in Volume 9. The normal electrical power system generates, controls and distributes all electrical power for operating the water purification system and its auxiliary systems. The emergency electrical system supplies 24 Vdc from a battery bank to 24 Vdc equipment and converts to 24 Vdc through an inverter to 120 Vac to power emergency lighting and equipment.

12. VOLUME 10 -- LIGHTING SYSTEM Volume 10 contains operation and maintenance procedures for the onboard lighting systems for the Water Purification Barges. This system supplies interior and exterior lighting. Normal and emergency interior lighting is provided in the deckhouse ROWPU space, dayroom, workshop, and voids. Exterior lighting consists of searchlights and floodlights for use at night or during reduced visibility. Lights on the weatherdecks and standard navigation and status lights are for use during operation and towing.

13. VOLUME 11 -- EQUIPMENT MONITORING SYSTEM This volume provides operation and maintenance procedures for the equipment monitoring system which monitors the operation of several equipment components onboard the Water Purification Barges.This system monitors operating conditions such as amount of drinking water in storage tanks and temperature of diesel engine cooling water. Sensors detect unacceptable operating conditions, the main processor flashes at double intensity and remote alarms (horns, strobe lights and buzzer alert crewmembers that corrective action is necessary.

14. VOLUME 12 -- COMMUNICATIONS SYSTEM

Operation and maintenance procedures for the communications system are provided in Volume 12. This system consists of three separate communications methods, radio communications, foghorn and intercom telephones.

15. VOLUME 13 -HANDLING EQUIPMENT

This volume contains operation and maintenance procedures for handling equipment used for lifting, transporting and repositioning equipment and materials onboard the barges. The system includes a bridge crane, bow crane and a void 4-trolley hoist.

16. VOLUME 14 -ANCHOR, MOORING, AND TOWING EQUIPMENT

Volume 14 describes the operation and maintenance procedures for the anchor mooring, and towing equipment on the Water Purification Barges. This equipment provides a method to hold (anchor) the barges in a fixed position offshore, at dockside, or next to another vessel and a method to move the barges from one location to another.

17. VOLUME 15 -MISCELLANEOUS EQUIPMENT (DAYROOM, WORKSHOP, ACCESSES, AND SANITATION SYSTEMS)

Volume 15 addresses operation and maintenance procedures for miscellaneous equipment installed on the Water Purification Barges. This equipment includes the dayroom on the forward starboard side of deckhouse, the workshop on the forward portside of deckhouse, accesses such as deckhouse doors and portholes and various accesses to and from the voids, and two separate sanitation systems (toilets and bilge). Additional equipment addressed in this volume includes: guard rails, rubber fendering, removable rubber floor mats, eyewash stations, component labels, caution, warning and danger signs, and storage areas.

18. VOLUME 16 -VENTILATION, HEATING, AND AIR CONDITIONING SYSTEMS

This volume contains operation and maintenance procedures for the deckhouse and voids ventilation systems and the heating and air conditioning (HAC) system installed on the Water Purification Barges.The ventilation system provides fresh air circulation in the deckhouse and voids with 17 hatches and 10 ventilation fans. The HAC controls the temperature in the dayroom and deckhouse.

19. VOLUME 17 -WORKBOAT, LIFESAVING, AND FIREFIGHTING EQUIPMENT

Volume 17 includes procedures for the operation and maintenance of:

a. Workboat -provides water transportation for crew members and visitors, small cargo items, transportation of the messenger line for the shore discharge hose and similar work-related tasks associated with operating the Water Purification Barges.
b. Lifesaving Equipment -installed on the barges and consisting of 2 liferafts, 15 Type II and 24 Type V lifevests and 4 lifesaving rings.
c. Firefighting Equipment -installed on the barges and consisting of Halon 1301 system, 2 CO2 hose reel units, a smoke detector system, 17 portable CO2 fire extinguishers, 5 dry chemical fire extinguishers, 5 self-contained breathing apparatuses, and a portable, engine driven firefighting pump. The workboat also has a 10-pound, portable, dry chemical fire extinguisher.

20. VOLUME 18 SUPPORTING APPENDICES FOR VOLUMES 1-17.

Volume 18 contains the Maintenance Allocation Chart, Components of End Item List, Tools and Test Equipment List, Expendable/Durable Supplies and Materials List and the Repair Parts and Special

All of the information contained in this volume is common to volumes 1-17 and does not appear in each individual volume.

Appendix A in volumes 1-17 provides information unique to each volume. Appendix B in volumes 1-17 provides manufacturers manuals and instructions unique to the system described in each volume. Appendixes C-G are located in Volume 18.

21. VOLUME 19 -PREVENTIVE MAINTENANCE CHECKS AND SERVICES (PMCS)
Volume 19 contains PMCS pertinent to all onboard systems for the Reverse Osmosis Water Purification Barges.

22. VOLUME 20 -SUPPLEMENTAL DATA

Volume 20 contains the Basic Issue Items List, and additional Authorization List for all onboard systems for the Reverse Osmosis Water Purification Barges.

23. VOLUME 21 -WINCH, DOUBLE DRUM, DIESEL

This volume contains operation and maintenance procedures for the 20-ton double drum diesel engine winch used on the Water Purification Barges. Appendix B of Volume 21 contains the Maintenance Allocation Chart and the Repair Parts and Special Tools List for the winch.

TECHNICAL MANUAL
NO. 55-1930-209-14&P-9-4

HEADQUARTERS
DEPARTMENT OF THE ARMY,
WASHINGTON D.C., 15 OCTOBER 1992

TECHNICAL MANUAL

# OPERATORS', UNIT, DIRECT SUPPORT AND GENERAL SUPPORT MAINTENANCE MANUAL (INCLUDING REPAIR PARTS AND SPECIAL TOOLS LIST)

FOR

# WATER PURIFICATION BARGES (NSN 1930-01-234-2165) VOLUME 9-4 ELECTRICAL POWER SYSTEM

**REPORTING ERRORS AND RECOMMENDING IMPROVEMENTS**

You can help improve this manual. If you find any mistakes or if you know of a way to improve the procedures, please let us know. Mail your letter, DA Form 2028 (Recommended Changes to Publications and Blank Forms), or DA Form 2028-2 located in the back of this manual direct to: Commander, US Army Troop Support Command, ATTN: AMSTR-MMTS, 4300 Goodfellow Blvd., St. Louis, MO 63120-1798. A reply will be furnished directly to you.

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## VOLUME 9-4



**NOTE**

The following appendices, common to all TM's in this series, are in TM-55-1930-209-14&P-18.

MAINTENANCE ALLOCATION CHART (MAC) TOOLS AND TEST EQUIPMENT LIST (TTEL) EXPENDABLE/DURABLE SUPPLIES AND MATERIALS LIST (ESML) REPAIR PARTS AND SPECIAL TOOLS LIST (RPSTL) REPAIR PARTS LIST TO FIGURE NUMBER CROSS-REFERENCE LIST

**NOTE**

The following appendices, common to all TM's in this series, are in TM 55-1930-209-14&P-20.

COMPONENTS OF END ITEM LIST (COEIL) AND BASIC ISSUE ITEMS LIST (BIIL) ADDITIONAL AUTHORIZED ITEMS LIST (AAL)

# APPENDIX B
# MANUFACTURERS' SERVICE MANUALS/INSTRUCTION

## B-1. Normal Electric System

**NOTE**
**The following documents can be found in TM 55-1930-209-14&P-9-2**

| Component | Document title | Manufacturer |
|---|---|---|
| Switchboard | Electric Power Controls Operation Manual for Main Service Generation and Distribution Switchboard | Electric Power Controls<br>P.O. Box 5146<br>Springfield, IL 62705<br>Ph: (217) 629-8506 |

## B-2. Emergency Electrical System

**NOTE**
**The following documents can be found in TM 55-1930-209-14&P-9-2**

| Component | Document title | Manufacturer |
|---|---|---|
| Inverter | LaMarche Instruction Manual for Model A-51 Inverter with Trouble Shooting Information | LaMarche Manufacturing Co.<br>106 Braddock Drive<br>Des Plaines, IL 60018<br>Ph: (312) 299-1188 |
| Battery charger | LaMarche Installation Instruction Manual for Model A33-60-24V-A1 | |

## B-3. 155 kW Ship Service Generators

**NOTE**
**The following documents can be found in TM 55-1930-209-14&P-9-2**

| Component | Document title | Manufacturer |
|---|---|---|
| 3306TA engine | Caterpillar Operation and Maintenance Manual for 3304, 3306, 3304B and 3306B Industrial Engines, SEBU5779-01 | Caterpillar Tractor Co,<br>100 N.E. Adams St.<br>Peoria, IL 61629 |
| | Caterpillar Specifications for 3304B and 3306B Generator Set Engine Attachments, SENR2798 | |
| | Caterpillar Systems Operation Testing and Adjusting Manual for 3304B and 3306B Generator Set Engine Attachments, SENR2799 | |

| Component | Document title | Manufacturer |
|---|---|---|

**NOTE**
**The following document can be found in TM 55-1930-209-14&P-9-2**

| | | |
|---|---|---|
| | Caterpillar Disassembly and Assembly Manual for 3304B and 3306B Generator Set Engines, SENR2800 | |

**NOTE**
**The following documents can be found in TM 55-1930-209-14&P-9-3**

| | | |
|---|---|---|
| | Caterpillar Parts Manual for 3306 Generator Set Engine, SEBP1406 | |

**NOTE**
**The following documents can be found in TM 55-1930-209-14&P-9-4**

| Component | Document title | Manufacturer |
|---|---|---|
| SR4 generator | Caterpillar Operation and Maintenance Manual for SR4 and SRCR Generators, SEBUS5717-02 | |
| | Caterpillar Service Manual for SR4 Generator SENR7968 | |
| | Caterpillar Special Instructions for Alignment of Single Bearing Generators, SMHS7259 | |
| Spring isolators | Ace Mounting Co. Series 630 Spring Isolators for Seismic, Marine, & Mobile Applications, catalog 83A-170 | Ace Mountings Co., Inc. 11 Cross Avenue South Amboy, NJ 08879 Ph: (201) 721-6200 |
| Battery charger | Master Control Systems Bulletin for Regulated Two Rate Battery Charger, Model MBC8, 474-2 | Master Controls Systems 910 N. Shore Drive Lake Bluff, IL 60044 Ph: (312) 295--1010 Telex: 25-4636 |
| | Master Control Systems Installation and Operation Instructions for Models MBC8, MBC8/9(10000)-3 | |
| Engine crankcase filter system, Oildex XCAD-13T | Oildex - How It Operates, Installation, Instructions, Dwg no. XCAD-12T/XCAD-14T | Oildex Corporation P.O. Box 3755 Long Beach, CA 90803 |

**B-4. 20 kW Ship Auxiliary Generator Set**

**NOTE**
**The following documents can be found In TM 55-1930-209-14&P-9-4**

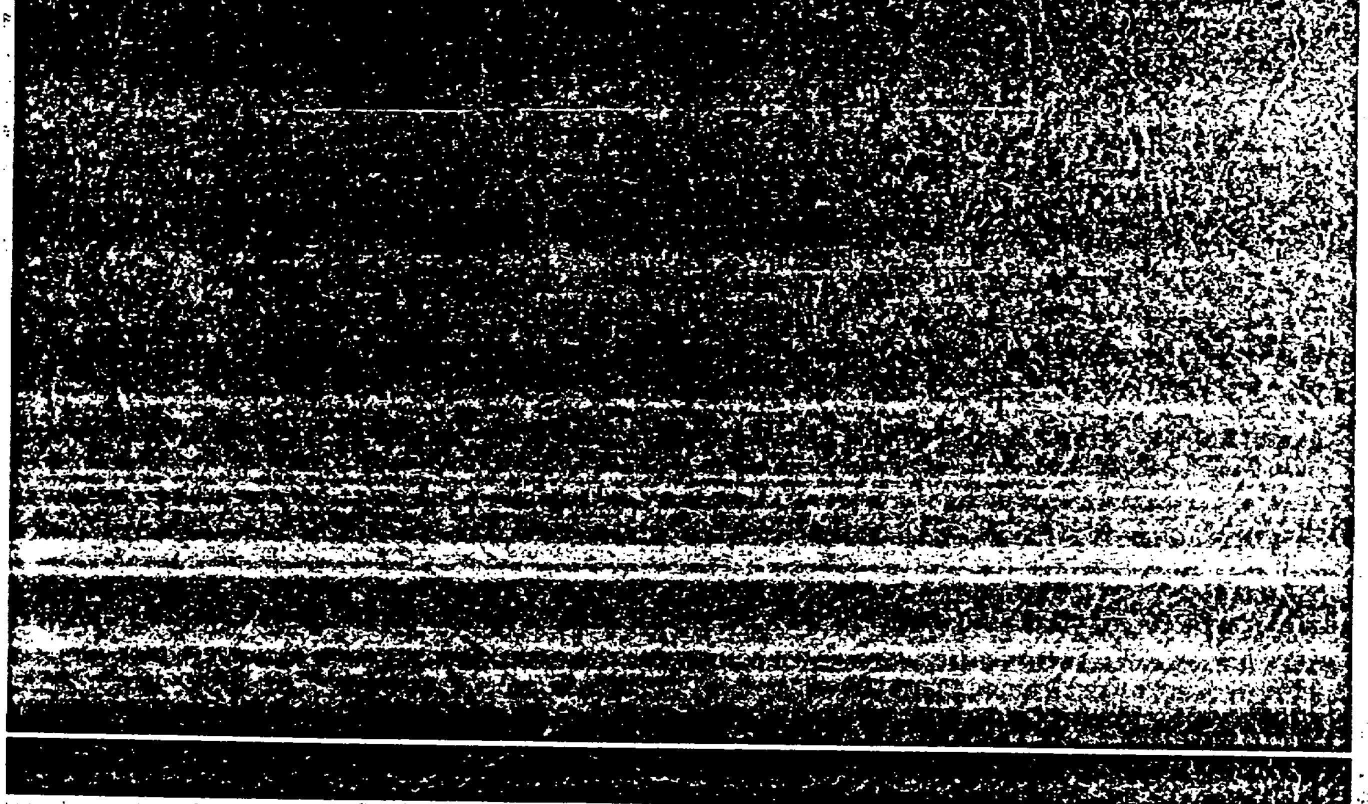
| Component | Document title | Manufacturer |
|---|---|---|
| 4.236M engine | Perkins Engines Operators Manual for Marine Diesel Engines, 4.236M<br><br>Perkins Engines Workshop Manual, 4.236M<br><br>Perkins Engines Parts Manual, 4.236M | Perkins Engines Inc.<br>32500 Van Bom Rd<br>P.O. Box 697<br>Wayne, Ml 48184<br>Ph: (313) 595-9600<br>Telex: 234002 |
| SC144E generator | Newage Stamford 'C' Generator Range Frames 1, 2, & 3 Series 4 A.V.R., Controlled Operation and Maintenance Manual Machine Designations PC1 64SC and MSC 144, 244, 344, publication no. 1 H-059 1 st edition<br><br>Newage Stamford 'C' Range Frames 1, 2, & 3 Series 4 A.V.R. Parts Manual | Newage Engineers, Ltd.<br>3 Independence Court<br>Folcraft, PA 19032<br>Ph: (215) 534-9500<br>Telex: 43551 |
| Spring Isolators | Series 630 Spring isolators for Seismic, Marine, & Mobile Applications, catalog 83A-170 | Ace Mounting Co., Inc.<br>11 Cross Avenue<br>South Amboy, NJ 08879<br>Ph: (201) 721-6200 |
| Battery charger | Master Control Systems Bulletin for Regulated Two Rate Battery Charger, Model MBC8, 474-2<br><br>Master Control Systems Installation & Operation Instructions for Models MBC8, Regulated Two Rate Battery Charger, MBC8/9(10000)-3 | Master Controls Systems, Inc.<br>910 N. Shore Drive<br>Lane Bluff, IL 60044<br>Ph: (312) 925--1010<br>Telex 25-4636 |
| Gages | Murphy A20T Series Temperature Swich-gages Bulletin A20T-7974, effective 5-1 - 5-79, Catalog Section 10, Class R<br><br>Murphy A20 Series Pressure Murphygages and Swichgages, Bulletin A20P-7973, revised 12-30-81, Catalog Section 05, Class (5) | Frank W. Murphy & Co.<br>P.O. Box 470248<br>Tulsa, OK 74147<br>Ph: (918) 627-3550<br>Telex: 492332 |

| Component | Document title | Manufacturer |
|---|---|---|
| | Murphy Instructions for Installation & Maintenance of Pressure & Vacuum Swichgages, Series 20-P, 25-P, A20-P, A25-P, Instruction Booklet 2025P-INS, revised 9-28-84<br>Murphy Instructions for Installation & Maintenance of Temperature Swichgages, Installation Sheet 2520T-INS, revised 2-1-85 | |
| Exhaust silencers | Nelson Industrial "100" Level Exhaust Silencers, two page fact sheet | Nelson Manufacturing |
| Oildex crankcase filter system | Oildex - How It Operates, Installation Instructions, Dwg. No. XPERK-1 | Oildex Corporation<br>P.O. Box 3755<br>Long Beach, CA 90803 |

CATERPILLAR

# operation & maintenance

## SR4 and SRCR Generators



## Foreword

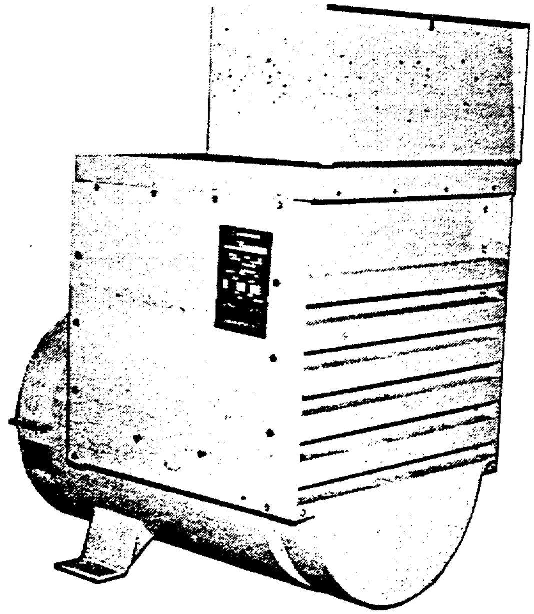
This Operation and Maintenance Guide contains operation instructions, and lubrication, and maintenance information application of this information should maximize' performance and life of the generator '

Whenever a question arises regarding your Caterpillar.product.or this publication, please consult your Caterpillar dealer for the latest available information.

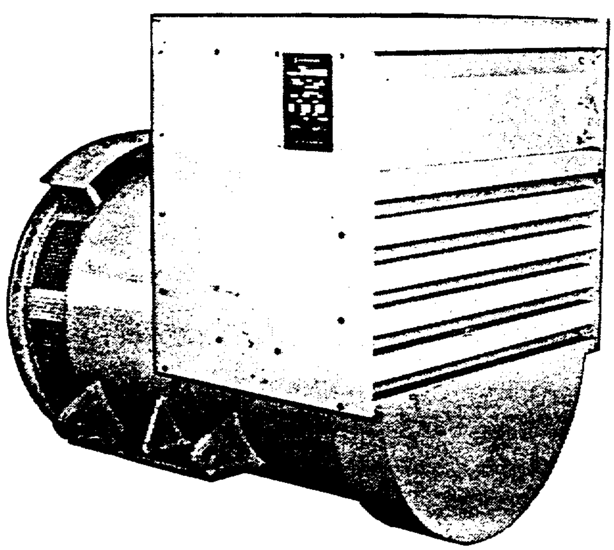
'The services of authorized Caterpillar dealers are recommended.  Your dealer is staffed with trained personnel who are equipped with proper tools necessary Caterpillar part, and are trained in the latest service procedures.

## Table of Contents

## Model Views



SR4



SRCR

# Safety

**⚠ THIS SYMBOL WARNS OF POSSIBLE PERSONAL INJURY**

Do not wear loose clothing around machinery.

Observe NO SMOKING signs.

Do not smoke around batteries. Hydrogen gas generated by charging batteries is explosive. Keep batteries in a well-ventilated area.

Be sure the engine room is properly ventilated.

All electrical equipment must be grounded according to local building codes.

Remove tools and electrical cords from the engine before starting.

All fans, shafts, pulleys, etc. must have guards.

Check all connections periodically for tightness and insulation.

Insulate all connections and disconnected wires.

Do not work on electrically "hot" equipment.

Do not use carbon tetrachloride fire extinguishers. Fumes are toxic and the liquid has a deteriorating effect on insulation.

Never operate a diesel engine with the governor linkage disconnected. Human reactions are not fast enough to control the fuel rack.

Never adjust or repair a machine while in operation.

Do not touch the heat sink on the generator regulator when the generator is running. It is electrically "hot".

Store oily rags in metal covered containers.

Never store flammable liquids near the engine.

Always disconnect and tape the ground battery lead before working on the electrical system.

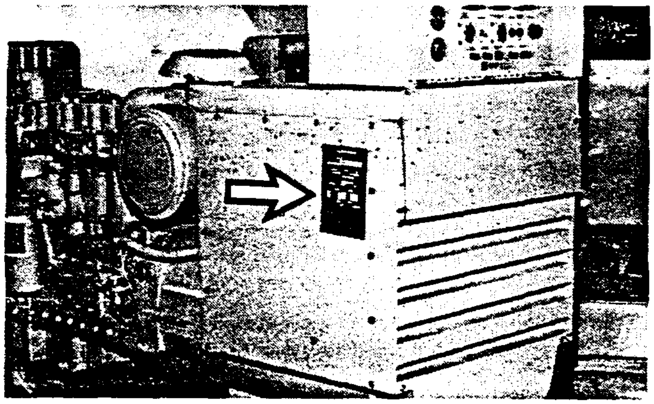
Be sure the remote starting system is inoperative when the engine is being worked on. Disconnect the starter from the start switch.

Always disconnect the engine starter circuit when working on the generator.

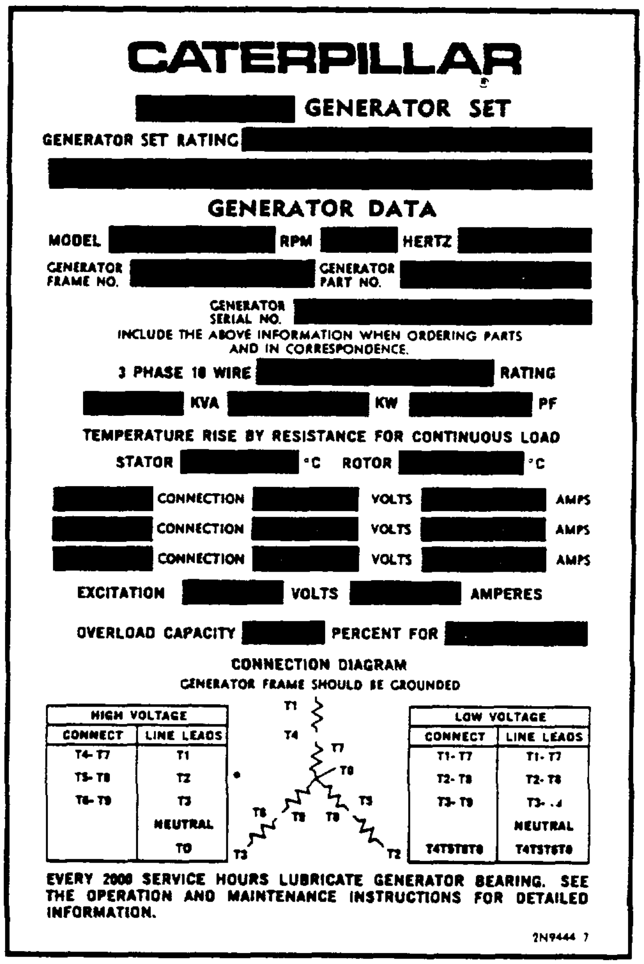
Keep the engine room and floor area clean.

**Generator Identification**

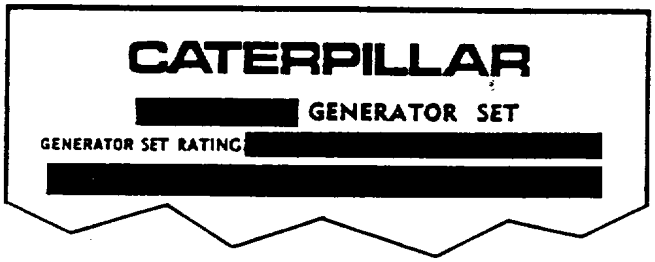
**Identification Plate**



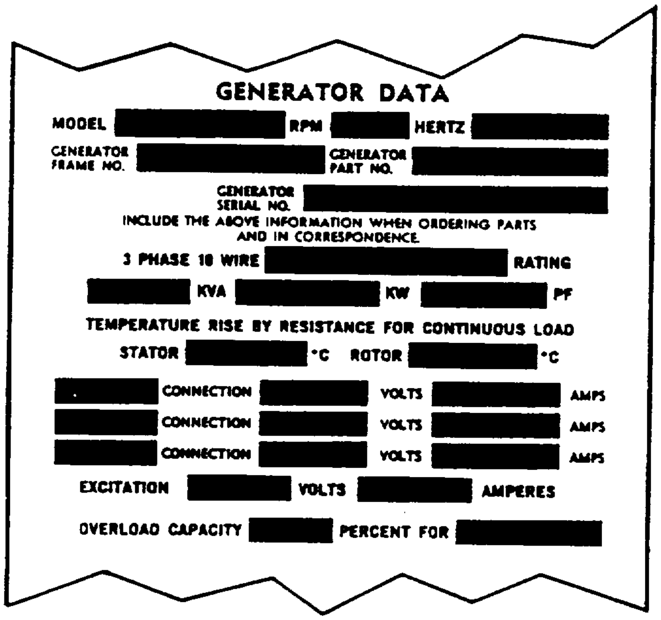
The generator Information Plate is located on the left-hand side of the generator.



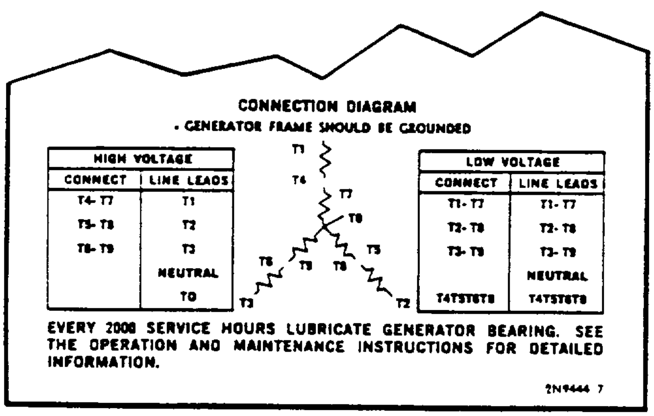

When service is required, use the information given on the Identification Plate.




This section of the Identification Plate tells the engine model and the generator set (engine and generator) rating.




This section of the Identification Plate states all the Generator Data. This portion gives the necessary information when ordering parts.



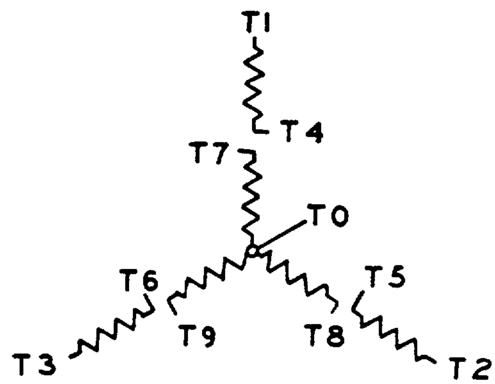

This section of the Identification Plate gives the wiring diagram for high and low voltage connections.

## Generator Lead Connections

### Lead Numbering

Each coil lead is marked according to the following diagram.

Numbering is clockwise from the top and from the outside in. Terminal TO is the neutral lead on all high voltage connections. On low voltage connections TO is connected with T4, T5, and T6 to form the neutral terminal. The standard generator diagram and the terminal connections are on the nameplate of each generator.




## Neutral Connections

### Single Units

Three Wire: In a three phase, three wire system, the generator should normally be grounded according to local wiring codes. In some cases, however, it is undesirable to ground the neutral wire. For example, on boats a grounded neutral may increase the problem of electrolysis. In applications where definite measures are taken to prevent grounds to the load leads, an ungrounded neutral can be used. Be sure to check your local wiring codes.

Four Wire: In a three phase, four wire system, the neutral wire should be grounded according to local wiring codes. For only single unit operation, there should never be a need for a disconnect switch, or device, in the neutral line.

### Multiple Units

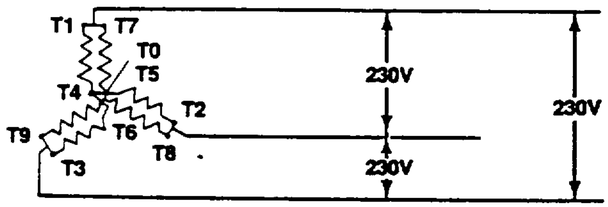
Operation of multiple generators in parallel, having all neutrals grounded, may result in current circulating through the neutral connections. To eliminate the possibility of circulating currents, ground the neutral of only one generator. If multiple generators are alternated on line, a single pole single throw knife switch should be installed in the neutral ground circuit of each generator, so all but one neutral ground circuit can be opened. Be sure one neutral ground circuit is closed.

## Voltage Connections

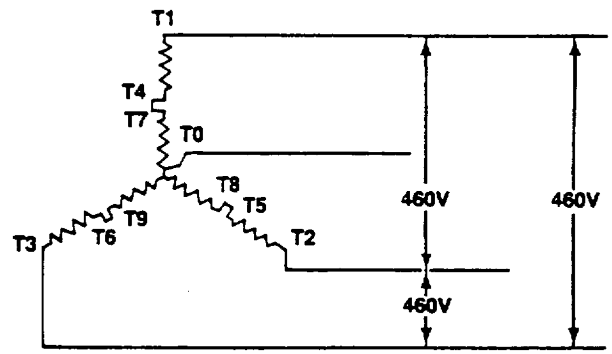
### Three Phase

The connections for both high and low voltage are given in the following diagrams.

The terminals must be connected securely and insulated with a good quality electrical tape.

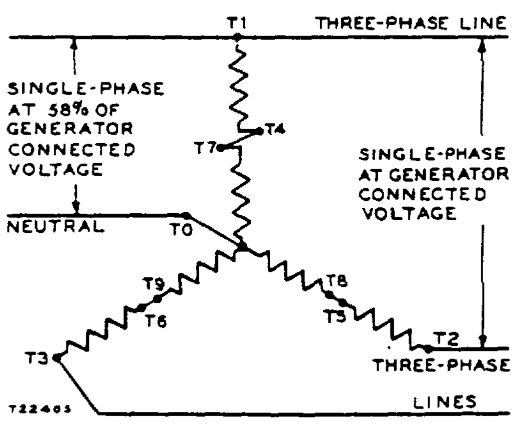



TYPICAL LOW VOLTAGE CONNECTION




TYPICAL HIGH VOLTAGE CONNECTION

### Single Phase Current From A Three-Phase Generator




Three phase and single phase current can be taken simultaneously from a generator connected for three-phase service. Connecting the load to any two of the three phase leads will provide single-phase voltage at the same voltage as three-phase power. Connecting the load to any phase lead and to neutral will produce voltage at 58% of the three-phase voltage. DO NOT exceed the nameplate current rating for any one phase.

Single-phase power taken from a three-phase source can be a problem unless the single-phase loading is equally distributed.

# Generator Performance

## Generator Loading

When a generator is installed or reconnected, be sure the total current in one phase does not exceed the nameplate rating. Each phase should carry the same load, allowing the engine to work at its rated capacity.
An electrical unbalance can result in an electrical overload and overheating if one phase exceeds the nameplate amperage. Any unbalanced load that's required should be placed on phase 2, since current sensing for voltage regulator is on that phase.

# Power Factor

Power factor may be thought of as the efficiency of the load the ratio of apparent power to total power. Power factor is expressed as a decimal and denotes that portion of current supplied to a system doing useful work. The portion of current not doing useful work is absorbed in maintaining the magnetic field in motors. This current, although it is called the reactive load, does not require engine horsepower to maintain it.

In most applications electric motors and transformers determine the power factor of the system. Induction motors usually have a .8 power factor. Incandescent lighting is a resistive load for about 1.0 power factor, or unity.

The power factor of a system may be determined by a power factor meter or by calculations. Determine the power requirement in KW by multiplying the power factor by the KVA supplied to the system. As the power factor goes up the total current supplied to a constant power demand will go down. A 100 KW load at a .8 power factor will draw more current than a 100 KW load at .9 power factor. A higher power factor increases the possibility of overloading the engine.

A lower power factor increases the possibility of overloading the generator.

# Low Idle Adjustment

Electric sets require higher low idle setting than do industrial engines. Low idle must not be below 2/3 the full load speed of 60 Hz units (4/5 full load speed of 50 Hz units).

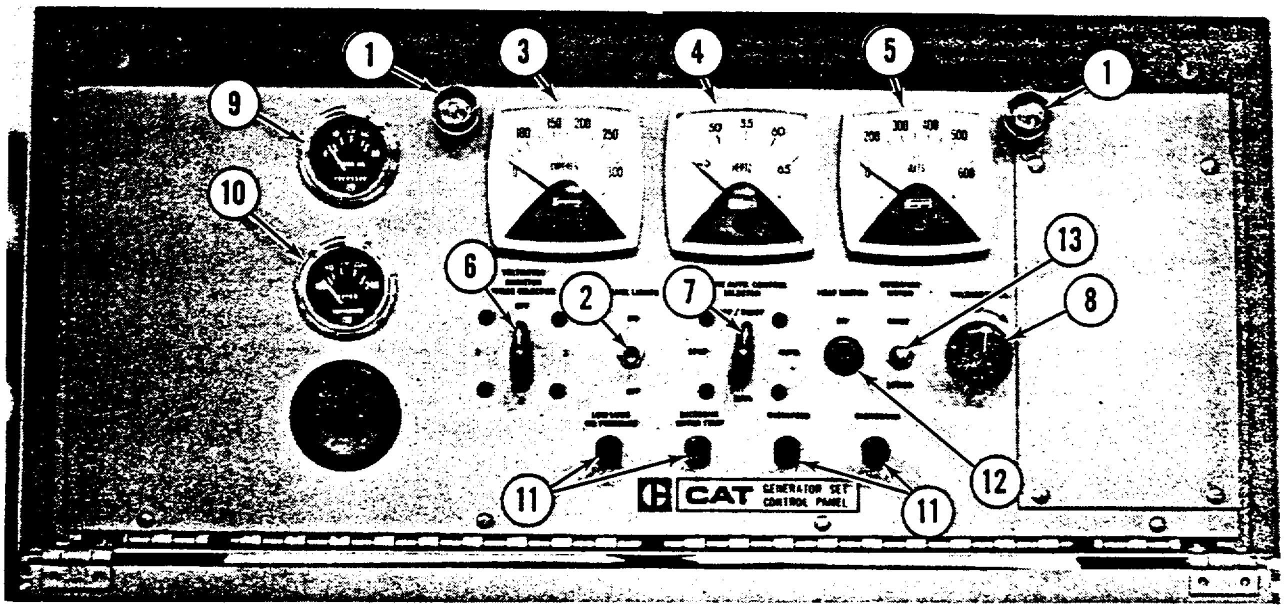
**CAUTION**

**Disconnect the exciter circuit by removing fuses F1 and F2 (on SRCR) or Fuse F1 (on SR 4) before operating the engine below the low Idle rating. Failure to do this will result in generator damage.**

On electric sets with Woodward governors, there is no low idle stop. On electric sets with mechanical governors and natural gas electric sets, the low idle is set at the factory, and should only be adjusted by your Caterpillar dealer if adjustment is required.

## Generator Set Control Panel (If Equipped)

The generator set control panel is located on top of the generator, and is equipped with the following controls and gauges.




**CONTROL PANEL**

1. Panel lights
2. Panel lights ON/OFF switch
3. Alternating current ammeter
4. Frequency meter
5. Alternating current voltmeter
6. Voltmeter/Ammeter phase selector
7. Engine control selector
8. Voltage level rheostat
9. Oil pressure gauge
10. Water temperature gauge
11. Shutdown Indicators
12. Heat switch (if equipped)
13. Governor motor control switch (if engine is equipped with PSG governor)

Panel lights (1) are controlled by an ON/OFF switch (2).

An ammeter (3), frequency meter (4) and a voltmeter (5) show output of the generator. The voltmeter/ammeter phase selector switch) selects which (6) phase (T1, T2, or T3) of generator output will be monitored on the ammeter (3) or the voltmeter (5).

The engine control switch (7) allows manual or automatic operation of the engine and generator set.

The engine control switch has four positions: MANUAL, AUTOMATIC, STOP AND OFF/RESET.

Placing the control in MANUAL will start the engine.

In Automatic position, the Generator Set can be started when a customer supplied contact closes.

Both the Off and Stop positions stop the engine immediately, regardless of the cool-down timer. The cool-down timer is optional and functions only when the engine is controlled remotely, using the Automatic position of the engine control switch.

The voltage level rheostat (8) replaces the rheostat in the generator regulator assembly.

Gauge (9) indicates engine oil pressure and gauge (10) indicates engine water temperature.

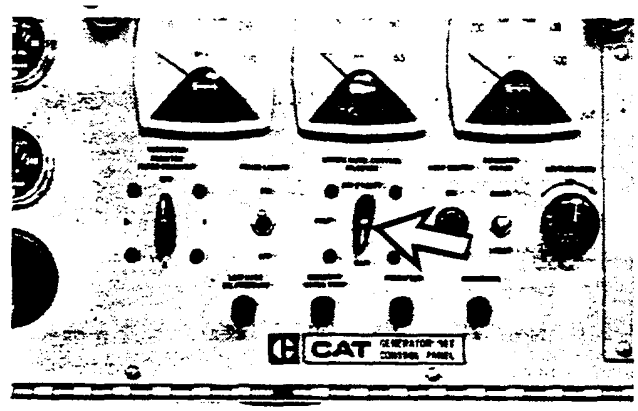
If the engine has a malfunction, the panel will activate a shutdown relay to stop the engine. The shutdown lights (11) indicate if the fault has either oil pressure, water temperature, overspeed or an overcrank condition.

If the engine is equipped with glow plugs, they are controlled by an ON/OFF switch (12).

If engine is equipped with a PSG governor, governor motor switch (13) allows the operator to control the engine RPM from a panel.

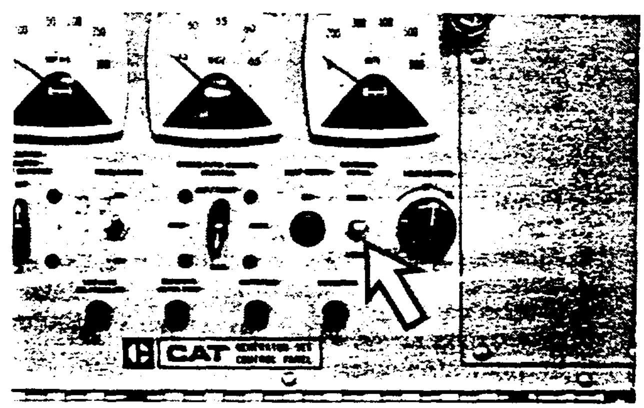
## Generator Set Control Panel (If Equipped)
## Manual Operation of Generator Set Control Panel
### Starting the Engine

1. Perform all before starting inspections. See Before Starting in Engine Operation and Maintenance Guide.



2. Turn Engine Automatic Control Selector switch to Manual position

3. After the engine starts and its systems have stabilized, apply the load.



4. Regulate the frequency of the generator with the Governor Motor Raise-Lower switch or Manual Governor Control Lever.

### Stopping the Engine

1. Remove the load from the engine.

2. Reduce engine speed to low idle. Push down and hold Governor Motor Raise-Lower switch in the Lower position or move governor control lever to low idle position.

3. Release switch when low idle is reached.

4. While the engine is at low idle, measure the engine oil level. Oil level must be maintained between the ADD and FULL mark on the ENGINE RUNNING side of the dipstick.

5. After engine cools, turn Engine Auto. Control Selector switch to STOP. Move the selector to OFF after the engine stops.

Refer to Engine Operation and Maintenance Guide for other methods to stop the engine.

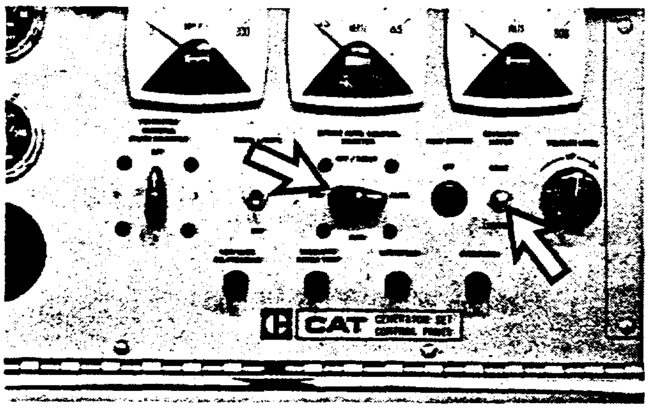
Move the shutoff lever forward. Hold lever in this position until engine stops.

## Automatic Start-Stop Operation of Generator Set Control Panel

An automatic start-stop system is used when an engine must start with no one in attendance.

To start the engine when unattended, the ambient (engine room) temperature must be at least 70°F (20°C) or, the engine jacket water temperature must be at least 90°F (32°C).

One or two 3kw jacket water heaters can maintain this temperature.



In the AUTO. position, the engine will automatically start and take up the load when remote starting contacts are dosed. When used together with an automatic transfer switch, the engine can be signaled to start and the load automatically transferred when commercial power fails.

The automatic transfer switch will also remove the load, cool and stop the engine.

If the unit is used for standby application with a remote transfer switch, place the Engine Control Selector switch in the AUTO. position, and adjust speed for proper operation of the generator with load after starting.

When in the AUTO. position, the engine will automatically stop if commercial power has been restored or if the engine has a fault. The optional cool down timer will allow engine to idle before shutting down.

Placing the Engine Control Selector in the STOP position will stop the engine.

## Overcranking

A timer allows the engine to crank either once for 30 seconds, or through 5 ten-second cranking cycles (depending upon the device used) while unattended.

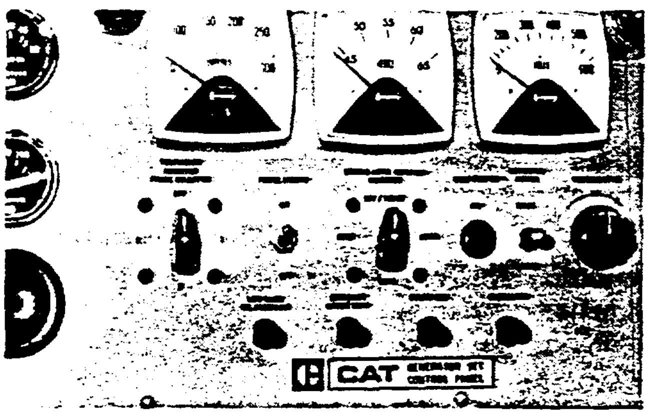
If the engine does not start before the time has elapsed, the cranking motor will shut off, the overcrank light will come on.

## Generator Set Control Panel (If Equipped)

### Shutting Down

A timer in the transfer switch allows transfer of the load to another source and the cool down timer in the control panel allows the engine to continue running for up to 2 minutes before stopping.

### Starting the Engine After a Shutdown Caused by Engine Failure




1. Turn engine control switch to STOP position.

2. Find cause of shutdown and correct it.

3. Turn control switch to OFF/RESET position.

4. Operate the engine with the engine control switch in MANUAL. Make tests as necessary to make sure the condition that caused the shutdown has been corrected.

### Oilfield Generator

### For SCR Controlled Electric Rigs

Oilfield generators are now available for use with SCR controlled electric oil rigs, that do not use a voltage regulator. The function of the generator control is performed by the drilling electrical control system.

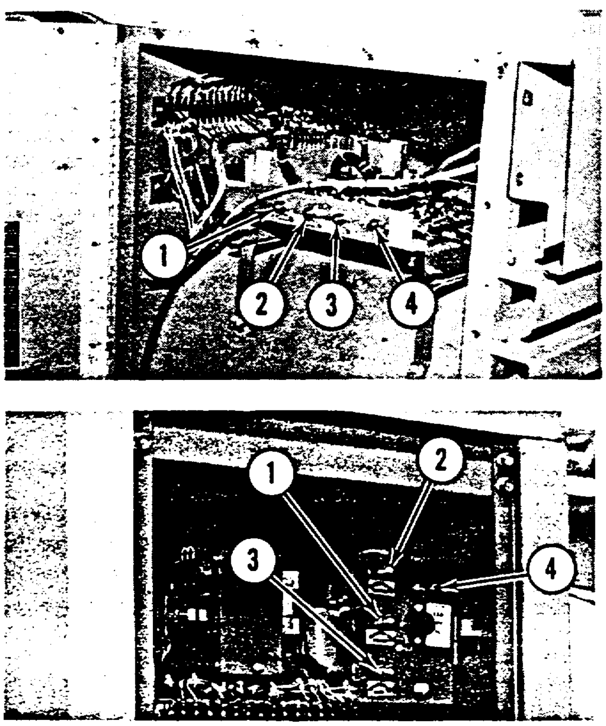
Consult the drill rig builder on questions pertaining to generator control (voltage regulation, paralleling, loadsharing, etc.).

## Single Unit Operation

### Initial Start-Up

Before initial startup, megger test main stator winding. Refer to Service Manuals SENR2180 or SENR7968.

1. Remove the left side access panel of the generator.
2. Loosen the locknuts on the voltage droop, voltage level, and voltage gain controls.
3. Turn the voltage droop control (1) counterclockwise to zero droop and tighten the locknut.




**VOLTAGE ADJUSTMENT CONTROLS (SR4 Generator Shown)**
**1. Voltage Droop 2. Voltage Level 3. Voltage Gain**
**4. Circuit Breaker (SR4 Generator Only)**

4. Turn the gain control (3) counterclockwise to zero, then turn the gain control to about 1/4 of full range of clockwise travel.

5. Perform required maintenance on engine before starting.

6. Start the engine and allow it to warm.

7. Increase engine speed to full governed speed (high idle).

8. Observe the voltmeter reading. If desired voltage is not indicated, set no load voltage with voltage level control (2).

9. Close the load circuit breaker and apply full load gradually. Adjust governor control until nameplate frequency is on the Hertz meter.

10. a. If voltmeter reading increases with full load applied, turn gain control (3) slightly in counterclockwise direction.

b. If voltmeter reading decreases with full load applied, turn gain control (3) slightly in clockwise direction.

11. Remove load, adjust voltage level control (2) if necessary to obtain desired voltage.

12. Apply the load, observe voltmeter reading. Repeat steps 9 thru 12 until no load voltage equals full load voltage.

13. Tighten the locknuts on all controls and install the access panel of the generator.

14. Circuit breaker (4) will open if excessive field current should occur. Push to reset the circuit breaker. If breaker opens again, contact your Caterpillar dealer.

### Starting

1. Make all preliminary engine starting checks.
2. Be sure the main or line circuit breaker is open.
3. Start the engine and allow it to warm up.
4. Adjust to full load RPM.
5. Close the main circuit breaker.
6. Apply the load. Do not try to apply full load in one move, rather apply the load in increments to maintain system frequency at a constant level.
7. Readjust governor for rated frequency.

### Stopping

1. Remove the load in increments.
2. Open the circuit breaker
3. Allow the engine to run for 5 minutes to cool.
4. Stop the engine.

## Parallel Operation

### Initial Start-Up

Preparing a generator for parallel operation requires special attention. Before attempting to parallel units for the first time, all units must be checked to be sure the following three conditions are met:

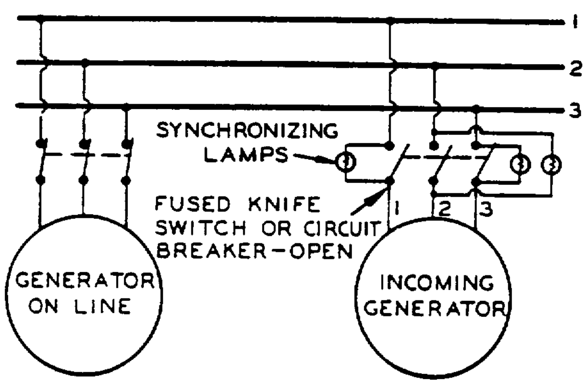
1. Same phase rotation
2. Same alternating current frequency.
3. Same voltage adjustment

### Phase Rotation

The phase rotation must be the same. A set of three light bulbs is used to determine whether the phase rotation of the incoming unit and the phase rotation of the line are the same.

1. Connect the light bulbs between the generator leads and the corresponding line phase, i.e., terminal 1 to line 1 across the open circuit breaker.

2. Start the units to be paralleled and bring them up to speed. As they approach the same speed the lights will start to blink.




a. If the lights blink in sequence one of the units is connected backward. To correct this remove generator leads 1 and 3 at the circuit breaker and exchange them. This reverses the direction of phase rotation. Line 2 should always be connected to line 2.

**⚠ WARNING**

**Never attempt to work on electrically hot wiring. Stop the electric set before rewiring generator leads. Open circuit breakers before working on the equipment which they control.**

b. If lights blink in unison the phase rotation of both engines is the same, and condition 1 has been met.

### Frequency Adjustment

The speed of units to be paralleled must be the same. Speed refers to the alternating current frequency.

1. Allow each electric set to run under load long enough for the internal temperatures to stabilize (about one hour).

2. Adjust the governor control to give rated frequency at full load.

3. Remove the load and check the high idle speed; it should be approximately 3% above full load speed. If these speeds can not be obtained, contact your Caterpillar dealer.

4. For the most consistent results, repeat steps 2 and 3 until condition 2 has been met.

## Voltage Adjustment

The voltage level and voltage droop adjustments determine the amount of circulating currents between generators. Carefully matched voltage regulator adjustments will reduce the circulating currents. Loads of .8 power factor (primarily motors) require a generator voltage droop of about 5%. Voltage droop is expressed as the percentage of voltage change from no load to full load. Use the same voltmeter to make adjustments on each unit to be paralleled.

1. Adjust voltage as described for Single Unit Operation, Initial Start-Up.

2. With the engine running at high idle, turn the voltage droop clockwise about 1/2 of full range. If driven load is to be unity power factor, set the voltage droop control on all generators at 1/2 of full range and proceed to Step 7. If driven load is to be normal (0.8 power factor) proceed to Step 3.

3. Readjust the voltage level control until the voltage is about 5% above desired voltage.

4. Apply full load at .8 power factor.

**NOTE: If a generator is to be paralleled with other generators, the voltage droop of each generator must be the same to satisfactorily divide reactive load.**

5. Readjust the voltage droop control to obtain desired voltage with full load at .8 power factor.

6. Repeat Steps 3, 4 and 5 for each generator to be paralleled until line voltage is equal to desired level at .8 power factor and no load voltage is approximately 5% above rated voltage.

7. Parallel generators and apply the driven load (see the topic Operation/Paralleling). If the sum of the amps of the individual generator amperes exceeds the total amps going to the load by 10% at full load, adjust voltage droop controls to share current proportionally between generators.

**CAUTION**
**Do NOT exceed rated ampere load on any single generator.**

8. Tighten the locknuts on all controls and install the access cover. Condition 3 has been met.

## Starting Multiple Units

Starting-Units are started the same as single units.

## Paralleling

Units may be paralleled at no load or paralleled with units under load. To parallel two or more units the following conditions must be met:

1. Same phase rotation.
2. Same voltage level.
3. Same voltage droop.
4. Same frequency.
5. Voltages must be in phase.

The first three conditions have been met in the initial start-up for parallel operation.

1. Start the unit to be paralleled according to the procedure in the engine operation section.

2. Turn the synchronizer lights on.

## Parallel Operation

3. After the engine has run long enough to warm up, bring it up to synchronous speed (the same frequency as the unit on the line). The synchronizing lights will begin to blink.

4. Using the governor control adjust the speed until the lights blink very slowly.

5. The lights are off when the voltages of the two units are in phase. At this point very quickly close the breaker while the lights are out.

6. Use governor controls to share KW load between engines

7. After generator temperature has stabilized (1 hr.), adjust the droop control of each generator so as to share the reactive load and to limit the circulating currents. Less droop (moving control CCW) increases the reactive current carried by the generator.

The frequency of the incoming unit should be slightly greater than the line frequency. This will allow the incoming unit to assume some of the load rather than add to the system load.

## Load Division--(Speed Droop)

Once two units have been paralleled their share of the load is determined by the governor control setting. If two units of the same capacity and the same governor characteristics have the same governor control settings they will share the load equally.

To transfer the load from one engine to the other follow this procedure:

The total load must not exceed the capacity of the engine.

1. Increase the governor speed control of one unit to increase the load.

2. Reduce the governor speed control of the other unit to decrease the load on that unit.

3. Raise or lower the governor speed control of both units to change system frequency.

## Circulating Currents

When two units are paralleled there will be circulating currents. These currents are not doing useful work, but are flowing between the generators. By determining the total generator amperage and subtracting the amperage going to the load, the amount of circulating current can be determined.

Circulating currents are caused by voltage differences between the two units.

With cold generator sets, circulating current may be as high as 25% of rated amperes, without being considered harmful. Circulating current is part of the total generator current and this total must not exceed the amperage rating.

As the generators warm, the circulating currents will decrease. The ammeter readings should decrease slightly, but the voltage meter readings should remain constant.

## Parallel Operation of Governors

This section is a general description of the function of the engine governor in relation to load division between parallel electric sets. For detailed information on governor controls and adjustments, see the Operation Guide and Service Manual for the engine.

It is very important that two basic facts be understood concerning load division between generator sets operating in parallel. First, the power supplied to the generator and thus to the load is a function of the engine. The engine governor settings and the positions of the governor controls determine the amount of power delivered by the engine and the KW load carried by the generator. If the governor control setting is advanced, the engine and generator will assume more KW load. Likewise, decreasing the governor control setting will result in a reduction of load on the unit. Any other units on the line will, conversely, either reduce or gain load at the same time, assuming no change in total load or no change in the governor settings of the other units has taken place. Second, the division of power is not determined by generator excitation or terminal voltage. The Power Factor at which a generator will operate when paralleled with other generators is determined by its excitation. For more discussion on this subject, refer to the section on Parallel Operation of generators.

Governors furnished with Caterpillar Powered Electric Sets can be either of two types, governors with fixed speed droop or governors with adjustable speed droop. The values of speed droop used are commonly 3% and 0%. Governors with adjustable speed droop can be adjusted so their characteristics match quite closely the characteristics of governors with fixed speed droop. The operating characteristics of the following combinations of governors on paralleled electric sets will be described.

1. Two 3% governors.

2. One 3% governor and one 0% (isochronous) governor.

### Example 1 - Two 3% Governors

When paralleling A.C. Generators, the engine governors must have the same speed droop characteristics if the sets are to divide the load in proportion to their ratings throughout the entire operating range.

The governor speed droop characteristics of these two units are similar. This is shown by lines "A" and "B" coinciding in Figure 1. If both units are started, set for high idle speed and paralleled at no load, the system frequency will be 61.8 cycles or 103% of rated frequency. As load is applied to the system, the frequency will decrease along the speed droop characteristic until the frequency at full load is 60 cycles.

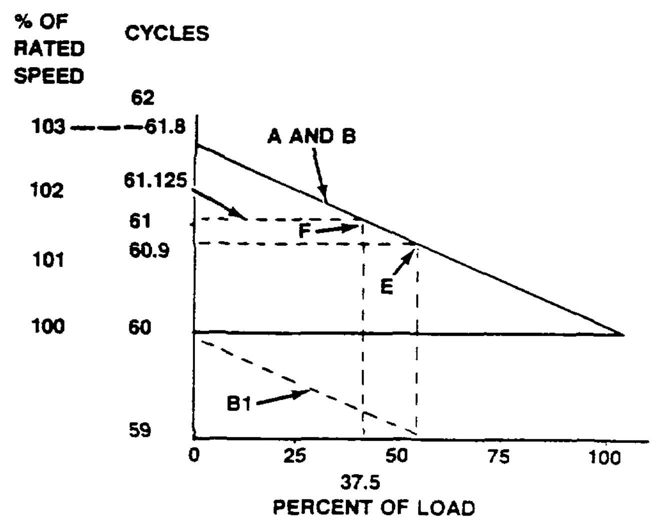



*Figure 1 - Paralleling two units with similar speed droop characteristics.*

If Unit A had been operating alone carrying full load, the system frequency would be 60 cycles as shown by Line "A" at 60 cycles and 100% load. Now, if the frequency of Unit B is adjusted by the engine speed control to be equal to that of Unit A and the circuit breaker of Unit B is closed, the system would be operating under the following conditions:

1. Unit A is at 60 cycles and 100% load.

2. Unit B is at 60 cycles and 0% load. The characteristic of the governor of Unit B at this time is shown by the dotted line B.

In order for Unit B to carry load, it is necessary to advance the speed setting of the governor. If it is advanced to the full load position, the governor characteristic of B will coincide with the characteristic of A. Since the load on the system was 100% of one unit, no change was made in total load, and the available capacity is now 200%, the system will operate at 50% load on each unit, and 60.9 cycles for two units of equal capacity (Point E). For units of unequal capacity, the load will be divided in proportion to the ratio of the capacity of each to the total capacity. The system frequency will be determined by the points on the governor characteristics corresponding to these loads. The frequency will be the same for both units since paralleled alternators must operate at the same speed.

If Unit A had been a 60 KW unit fully loaded and a 100 KW Unit B was paralleled with it and the governor adjusted to the full load position, the final load division and frequency would be determined as follows:

a. System load - 60 KW

b. System capacity - 160 KW

System Load KW rating for unit

c. The 60 KW unit will carry $\frac{60}{160}$ x 60 KW = 22.5 KW

System capacity KW load for unit

d. 100 KW unit will carry $\frac{60}{160}$ x 100 KW = 37.5 KW

e. The system frequency can be determined readily from step c or step d. The load carried by each

unit is $\frac{22.5}{60}$ or $\frac{37.5}{100}$ which figures out to be

37.% of the capacity of either unit Again, using Figure 1 for the governor characteristic of the 100 KW unit and reading up from the value of load (37.5% to point F), we find the system frequency to be 61.125 cycles.

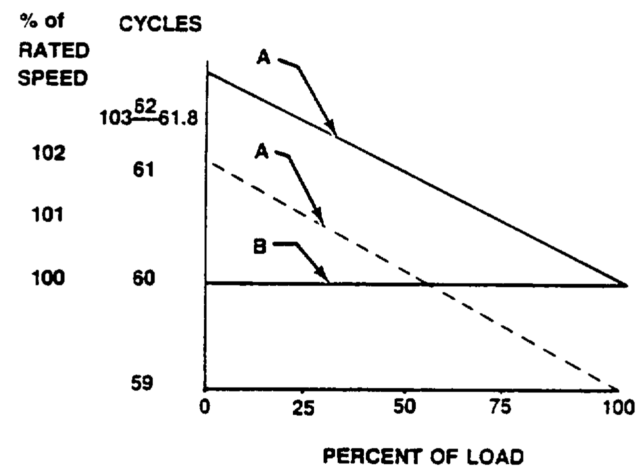



*Figure 2-Paralleling two units, one with a 3% governor and the other with a hydraulic governor set for isochronous operation.*

**Example 2-One 3% Governor and one 0% (Isochronous) Governor.**

The characteristics of the 3% governor (Unit A) is shown by line A of Figure 2 and the characteristics of the isochronous governor (Unit B) is shown by line B. Only at full load, 60 cycles, do the frequencies of the units have the same value. It is customary to operate a system of this type with a system load greater than the capacity of Unit A. In this way Unit A carries its full load at 60 cycles and the additional load and load swings are handled by Unit B, also at 60 cycles. The system can maintain constant frequency by this method of operation. The system described in example 1 cannot maintain constant frequency with load changes because of the speed droop characteristics of the governors.

In the system described in this example, if the load is less than the capacity of Unit A (which has the 3% governor) and can be carried by Unit B, the governor setting of Unit A can be reduced to give a governor characteristic such as A, so Unit A will still carry the steady part of the load and Unit B will carry the load swings. If the system load is reduced to the point where Unit A is not operating at the 60 cycle point of its governor characteristic, Unit A will try to motor Unit B and the system frequency may be greater than 60 cycles. The reason for using an isochronous governor in a power system is to maintain constant frequency above approximately 40% load.

## Summary

The preceding discussion and examples of governor operation can be summarized as follows:

1. The simplest governor combination for paralleled electric sets is to have a 3% speed droop characteristic for each governor. If a constant frequency from no-load to full-load is required, one governor can be adjusted for isochronous operation. This is called a "lead unit".

2. In order for all paralleled units to accept their full share of the load, the following governor adjustments are required:

a. The same full load speed.

b. The same high idle (no-load) speed in the case of governors adjusted for speed droop operation.

c. Governor controls set to the high idle position so the full governor range is available.

3. Operation of an isochronous governor in parallel with speed droop governors requires the special techniques described in example 2.

4. Any number of electric sets can be operated in parallel. However, only one governor of the group can be adjusted for isochronous operation except in the special cases of electronic governors with automatic load sharing.

## Electronic (2301) Governor

When using Electronic Governors (2301) load sharing will be done automatically if it is a load sharing Governor.

## Stopping

To remove a generator from the line do the following:

1. Check the load. It must be less than the rated capacity of the remaining units.

2. Be sure the neutral of one of the remaining units is grounded.

3. Remove the load from the outgoing unit as described in LOAD DIVISION. The amperage may never go to zero due to circulating currents.

4. Open the circuit breaker.

5. Allow the engine to cool for 5 minutes.

6. Stop the engine.

## Standby Electric Sets

Most standby units are automatic. They start, pick up the load, run and stop without an operator in attendance.

Standby units can not change the governor control setting automatically. The governor control must be preset for the proper operation of that unit. Whenever the set is exercised or operated manually, be sure the governor speed setting is correct for automatic operation. Check all switches to see they are properly set: Start Selector Switch in AUTOMATIC position and any Emergency Stop Switches in RUN position.

## Generator Storage

### Storage Procedure

When a generator is in storage for any length of time, moisture condenses in the windings. Minimize the condensation by use of a dry storage space and space heaters.

If a brush-type generator (SRCR) is to be in storage for a year or more, lift the brushes off the slip ring to prevent damage to the slip ring by chemical action.

### After Storage

**NOTE: Test the main stator windings with a megohm meter in the following situations:**

1. Before initial startup of generator set.
2. Every 3 months* if generator is operating in a humid environment.
3. If generator has not been run under load for 3 months* or more.

The megohmmeter test is described in Service Manuals SENR2180 or SENR7968. A reading of 1 meghom or less indicates that the winding has absorbed too much moisture.

To remove moisture caused by high humidity, use one of the following methods to make the generator dry:

1. Energize space heaters in generator if so equipped.
2. Put the generator in an oven at a temperature of not more than 85°C (185°F) for four hours.

**CAUTION**

**If an oven is used for drying, use a forced air type rather than a radiant type. Radiant ovens can cause localized overheating.**

3. Space heaters of the same type used in marine applications, can be installed on generators. (See the Parts Book.) These heaters heat the windings to remove moisture and should be connected at all times in high humidity conditions whenever the generator is not running.

4. Use a canvas enclosure around the generator and heating lamps to increase the temperature. Make an opening in the top for release of moisture.

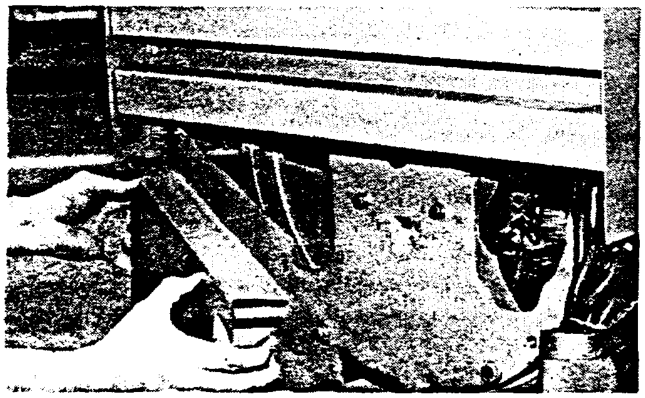
5. Send a low voltage current through the windings to increase the temperature of the windings. Do not exceed 85°C (185°F).

If the megohmmeter test reads under 1 megohm after the drying or if it goes below 1 megohm shortly after drying, contact your Caterpillar dealer. The insulation has deteriorated and should be reconditioned.

*This is a guideline only. It may be necessary to megger more frequently if environment is extremely humid, salty or if the last megger test was close to 1 megohm.

## Every 500 Service Meter Units

### Inspecting Slip Rings-SRCR Only



1. Remove the three lower panels from the rear of the generator housing.

2. Inspect the color of each slip ring.

The color may be shiny copper, straw, chocolate or black. The important thing is the color must be uniform to indicate a satisfactory condition.

3. If a ring contains blotches of green, blue or black, clean the ring with a cleaning solvent that does not leave an oily film such as Naptha.

**WARNING**
**Do not use gasoline or carbon tetrachloride. The vapors from carbon tetrachloride can be extremely harmful when inhaled. Either solvent will dissolve insulation.**

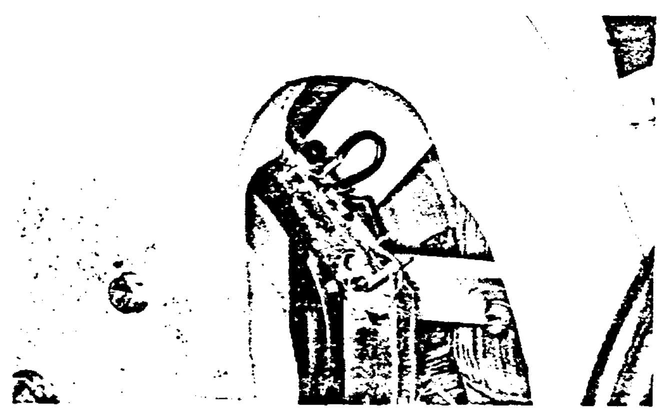
4. Inspect each ring for pitting, roughness, or eccentric wear. If any of these conditions are present, contact your Caterpillar dealer; the rings must be reconditioned.

5. If pitting is found, determine if the cause is (a) or (b):

a. Check the rating on the generator nameplate. The generator load must be within this rating. Determine if the generator may have been operated in an overload condition.

b. Check the brushes for incorrect spring tension.

Each brush must move freely within its holder and have enough spring load to prevent brush flotation.



Using a small spring scale, calibrated in ounces, lift each spring and check the spring tension for each brush.

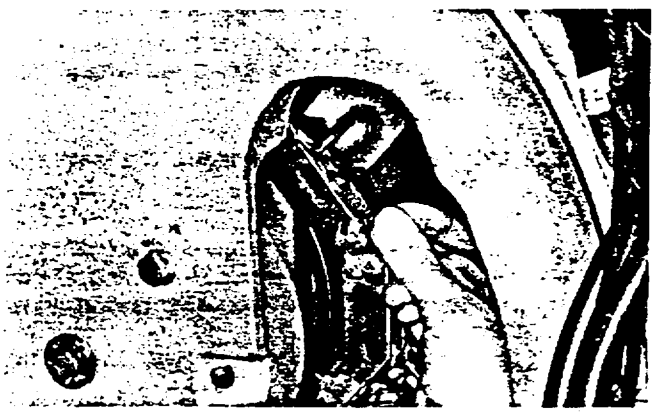
| BRUSH CONTACT AREA | | SPRING TENSION | | MINIMUM LENGTH | |
|---|---|---|---|---|---|
| Inch | mm | Ounce | Gram | Inch | mm |
| 5/8 x 5/16 | 16 x 8 | 14 | 400 | 9/16 | 14 |
| 7/8 x 5/16 | 22 x 8 | 20 | 550 | 9/16 | 14 |
| 11/8 x 1/2 | 28 x 13 | 40 | 1100 | 3/4 | 19 |

a. If spring tension is less than shown in the chart: Push the spring forward one notch in the retainer clip. Check the spring tension.

b. If the spring tension is greater than shown in the chart: Release the spring by one notch. Check the spring tension.

c. If the spring tension is less than shown in the chart and the spring is in the forward notch, remove the brush and check the brush length.

## Removing and Installing Brushes - SRCR Only



1. Release the spring from the retainer.

2. Disconnect the lead wire of the brush.

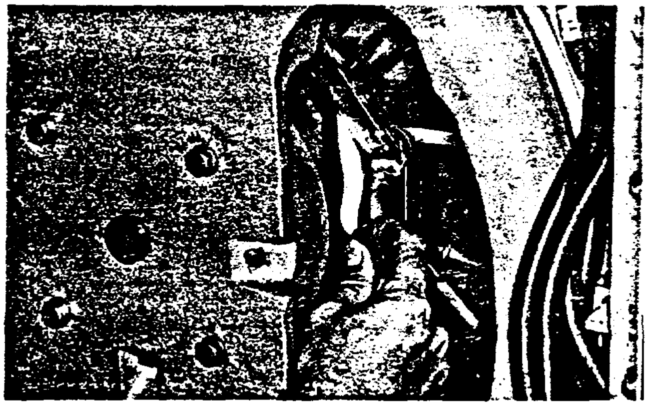
3. Remove and inspect the brush. If the brush length is less than the minimum shown or if badly pitted, install a new brush.

4. Connect the lead wire of the brush.

5. Place the brush in the brush holder. Be sure the brush moves freely in the holder.

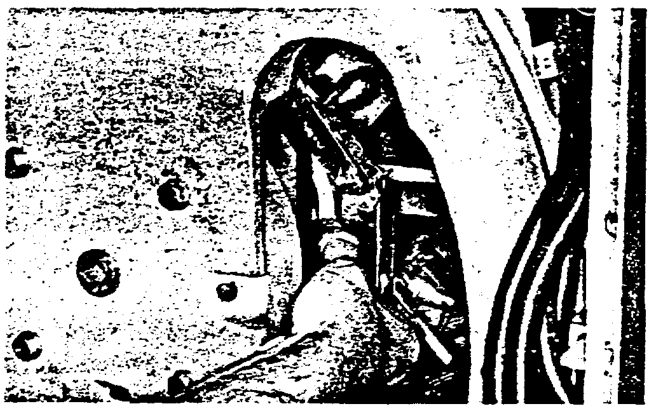
6. Cut a strip of "00" sandpaper the width of the brush.

Never use emery cloth for this purpose. Emery contains small metallic particles which can damage the copper rings.



7.  Place the sandpaper between the brush and slip ring with the abrasive side of the sandpaper against the brush.

8.  Place the spring in the middle notch of the retainer.



9.  Slowly pull the sandpaper from beneath the brush.

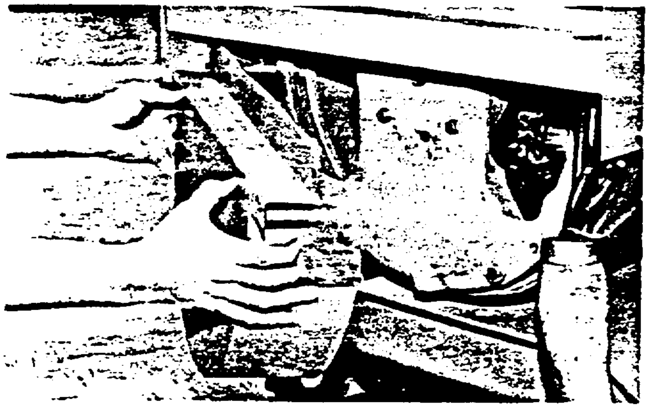
10.  Remove all dust with a suction hose.  If suction is not available, use a maximum air pressure of 30 psi (2 $kg/cm^2$).  Do not use metal tips.

11.  Check brush tension and adjust if necessary.

12.  Install the three rear panels that were removed.

## Generator Lubrication and Maintenance

**Every 4000 Service Meter Units**
**Lubricate Rear Bearing**



1. Remove the two lower panels from the rear of the generator housing.

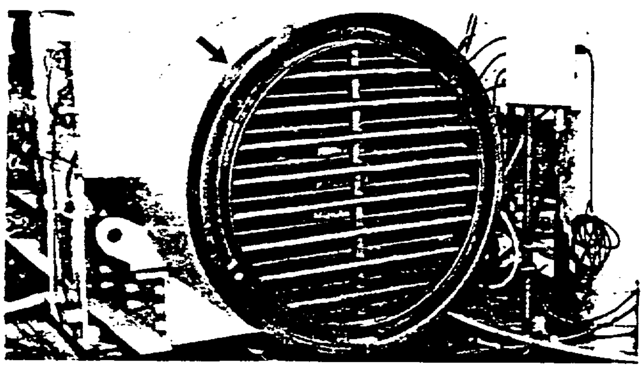
2. Remove the upper and lower grease fitting plugs.

3. Install a grease fitting in the upper threaded hole.

4. Lubricate with grease gun, two pumps.*

5. Install the lower plug. Wipe off excess grease.

**Inboard Bearing**

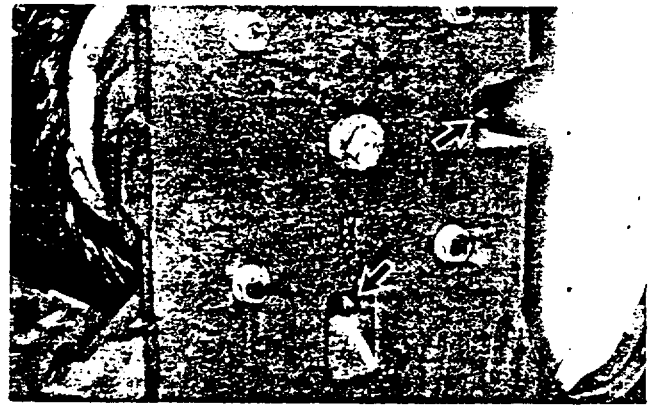


1. Remove the cowl cover from the rear of the generator housing.

2. Remove the right side and lower grease pipe plugs.

3. Install a grease fitting in the right side threaded grease pipe.

4. Lubricate with grease gun, two pumps.'*
Use Multipurpose-type Grease (MPG). NLGI No. 2 Grade is suitable for most temperatures. Use NLGI No. 1 or 0 Grade for extremely low temperatures.



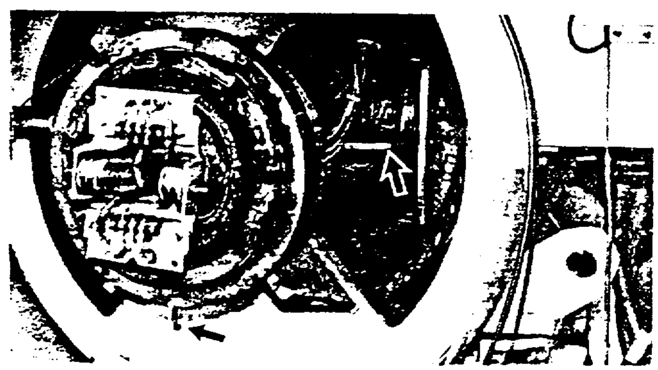
Use Multipurpose-type Grease (MPG). NLGI No. 2 Grade is suitable for most temperatures. Use NLGI No. 1 or 0 Grade for extremely low temperatures.

6. Remove the fitting from the upper threaded hole.

7. Start the engine and allow the grease to expand.

8. Stop the engine. Install the plug in the lower hole and wipe off excess grease.

9. Install the two panels.



5. Install the lower plug. Wipe off excess grease.

6. Remove the fitting from the right side grease pipe.

7. Start the engine and allow the grease to expand.

8. Stop the engine. Install the plug in the lower grease pipe and wipe off excess grease.

9. Install the cowl cover.

*Use three pumps of grease from grease gun if you are lubricating a 680 or 800 frame size generator.

# Caterpillar Warranty

## INDUSTRIAL, AGRICULTURAL, AND MARINE ENGINES, MARINE TRANSMISSIONS AND ELECTRICAL POWER GENERATION PRODUCTS

This warranty applies to the following products delivered to the first user on or after January 1, 1982.

Caterpillar warrants new engines for industrial, agricultural, and marine applications, marine transmissions and electrical power generation products ("products") sold by it (except products installed in on-highway vehicles, in machines manufactured by Caterpillar, or in marine pleasure craft) sold in the United States of America, to which different warranties apply) to be free from defects in material and workmanship subject to the following provisions.

**Warranty Period**

The warranty period is 12 months (24 months for standby electric generators and mobile agricultural machines), starting from date of delivery to the first user.

**Caterpillar Responsibilities**

If a defect in material or workmanship is found during the warranty period Caterpillar will provide through a Caterpillar dealer or other source approved by Caterpillar:

- New or repaired parts at Caterpillar's choice.
- Reasonable and customary labor during normal working hours needed to make the warranty repair.
- Labor needed to disconnect and reconnect the product from its attached equipment, mounting, and support systems.
- Reasonable travel expenses if Caterpillar chooses to perform the repair in the field.
- Usual and customary parts shipping charges to the approved source.
- Lubricating oil, filters, antifreeze and other service items made unusable by the warranty failure.

**User Responsibilities**

User is responsible for:

- All costs for transporting the product or equipment in which the product is installed.
- Travel expenses for field repair of products in remote places.
- Premium or overtime labor costs.
- Any removal and installation costs beyond those required to disconnect and reconnect the product from its attached equipment, mounting, and support systems.
- Parts shipping charges in excess of those which are usual and customary.
- Costs to investigate performance complaints unless the problem is caused by a defect in Caterpillar material or workmanship.
- Giving timely notice of a warrantable failure and promptly making the product available for repair.

**Limitations**

Caterpillar is not responsible for failures resulting from:

- Any use or installation which Caterpillar judges improper.
- Attachments, accessory items and parts not sold or approved by Caterpillar.
- Abuse, neglect and improper repair.
- User's unreasonable delay in making the product available after notice, for product improvements ordered by Caterpillar.
- Caterpillar does not warrant items sold by it which are warranted by another maker.

**This warranty is expressly in lieu of any other warranties, express or implied, including any warranty of merchantability or fitness for a particular purpose. Remedies under this warranty are limited to the provision of material and services, as specified above. Caterpillar is not responsible for incidental or consequential damages.**

As used in this warranty the term "Caterpillar" means Caterpillar Tractor Co. or one of its subsidiaries whichever last sold the product involved.

SELF5018-01 (1-82)

CATERPILLAR





PRINTED IN USA

FORM NO. SENR7968-03

FOR USE IN SERVICE MANUAL:
ELECTRIC SET GENERATORS.
SENR7958

CATERPILLAR
SERVICE
MANUAL

**SR 4**
**GENERATOR**

Single Phase Half Wave
Excitation and Regulation

**WARNING**

**IMPORTANT SAFETY NOTICE**

**Proper repair is important to the safe and reliable operation of a machine. This Service Manual outlines basic recommended procedures. some of which require special tools, devices or work methods. Although not necessarily all inclusive, a list of additional skills, precautions and knowledge required to safely perform repairs is provided in the SAFETY section of this Manual.**

**Improper repair procedures can be dangerous and could result in injury or death.**

**READ AND UNDERSTAND ALL SAFETY PRECAUTIONS AND WARNINGS BEFORE PERFORMING REPAIRS ON THIS MACHINE**

Basic safety precautions, skills and knowledge are listed in the SAFETY section of this Manual and in the descriptions of operations where hazards exist. Warning labels have also been put on the machine to provide instructions and identify specific hazards which if not heeded could cause bodily injury or death to you or other persons. These labels identify hazards which may not be apparent to a trained mechanic. There are many potential hazards during repair for an untrained mechanic and there is no way to label. the machine against all such hazards. These warnings in the Service Manual and on the machine are identified by this symbol:

**WARNING**

**Operations that may result only in machine damage are identified by labels on the machine and in the Service Manual by the word NOTICE.**

**Caterpillar cannot anticipate every possible circumstance that might involve a potential hazard. The warnings in this Manual are therefore not all inclusive. If a procedure, tool, device or work method not specifically recommended by Caterpillar is used, you must satisfy yourself that it is safe for you and others. You should also ensure that the machine will not be damaged or made unsafe by the procedures you choose.**

**IMPORTANT**

The information, specifications and illustrations in this book are on the basis of information available at the time it was written. The specifications, torques, pressures of operation, measurements, adjustments, illustrations and other items can change at any time. These changes can effect the service given to the product. Get the complete and most current information before you start any job. Caterpillar Dealers have the most current information which is available. For a list of the most current modules and form numbers available for each Service Manual, see the SERVICE MANUAL CONTENTS MICROFICHE REG1139F.

## SYSTEMS OPERATION

## TROUBLESHOOTING



## DISASSEMBLY AND ASSEMBLY



**NOTE: For Rewind Data and Connection Diagrams, see Rewind Data for SR 4 Generators, Form No. SENR2924.**

**NOTE: The "C" is an indication of a change from the former issue.**

## GLOSSARY

anode: The positive end of a diode or rectifier.

blocking rectifier: Permits current flow in only one direction. This keeps the polarity of the exciter in the correct direction.

bolted: Use of a bolt to hold two or more parts together.

breaker: An automatic switch used to open a circuit.

bridge: A circuit used to change AC to DC and to measure small quantities of current, voltage or resistance.

build-up: (Voltage) A gradual increase.

cathode: The negative end of a diode or rectifier.

capacitance: The measure of a capacitors ability to take and hold a charge.

circulating current: The flow of current between two generators working in parallel.

commutator: A part of the shaft used to remove DC voltage for excitation.

conduct: Give path for current flow.

consideration: factor.

continuity: A circuit that is not open.

control: One that controls.

controlled rectifier: A rectifier that lets current flow only after it has "turned on."

DC controlled reactor: Gives resistance to current flow to the rectifier according to the voltage droop setting. Same as saturable reactor, DC.

damping: To smooth out.

de-energize: To stop current from going to a component.

distribution winding: An arrangement of windings, in groups that are in several slots, that go from one end of the core to the other end.

droop: decrease.

effective: Gives the desired effect.

elementary: simple.

excitation: DC current (controlled) used to make a magnetic field.

energize: To cause current to go to a component.

electrostatic charges: Electricity caused by friction.

exciter: Gives DC current to the field windings of the generator.

field: Magnetic lines of force around a conductor caused by current flow.

field windings: Many turns of wire wrapped around an iron core. When a DC current flows through the field windings it causes a magnetic field (like that of a bar magnet).

flashing: A process of putting DC current.  from an outside source, into the field windings to get residual magnetism.

fluctuate: change.
flux: Magnetic lines of force.
full wave rectifier: Changes AC to DC current.
gain: A change in quantity of voltage.
gate: An electronic part of a controlled rectifier (thyristor).
generate: To make electricity.
grounded: To make a connection to ground or to a component with similar effect.
impedance: A combination of resistances.
induced: caused.
interference: Mixture of signals.
instrumentation: Group of instruments.
insulated: A component with insulation.
induce (to): To send DC current to a coil and make a magnetic field.
*C* layer wound: Method of placing a large wire (instead of four small wires as in random wound) in uniform and parallel layers around a generator rotor.

lead: wire.
line voltage: The output voltage of the generator.
lock in: When a contact closes to keep a solenoid energized.
lock out: When a contact opens to keep a solenoid de-energized.
magnetic: Having the characteristics of a magnet.
magnification: make larger.
module: An assembly of electronic components and circuits.
moisture: The water content in the air.
oscillation: A flow of electricity that periodically changes direction.
phase winding: Group of generator stator coils in which electric power for the load is induced.

polarity: The positive or negative characteristics of two poles.
pulsating: Characteristic of rectified current similar to mechanical vibration.
radio suppression: Reduce the cause of radio frequency interference.
*C* random wound: A method of placing four small wires around a generator rotor.  Each wire can cross the other while being wound.

reciprocating: Movement in a straight line first one direction then the other.
regenerative power:  Power that works against the primary power.
reset: To put a switch in a ready condition.

residual magnetism: The characteristic of a magnet after removal of excitation.
saturable reactor: Acts as a valve, as load changes, valve opens or closes to give more or less current to the rectifier.

saturated: Magnetized to the point where an increase in current will give no increase in magnetic force.

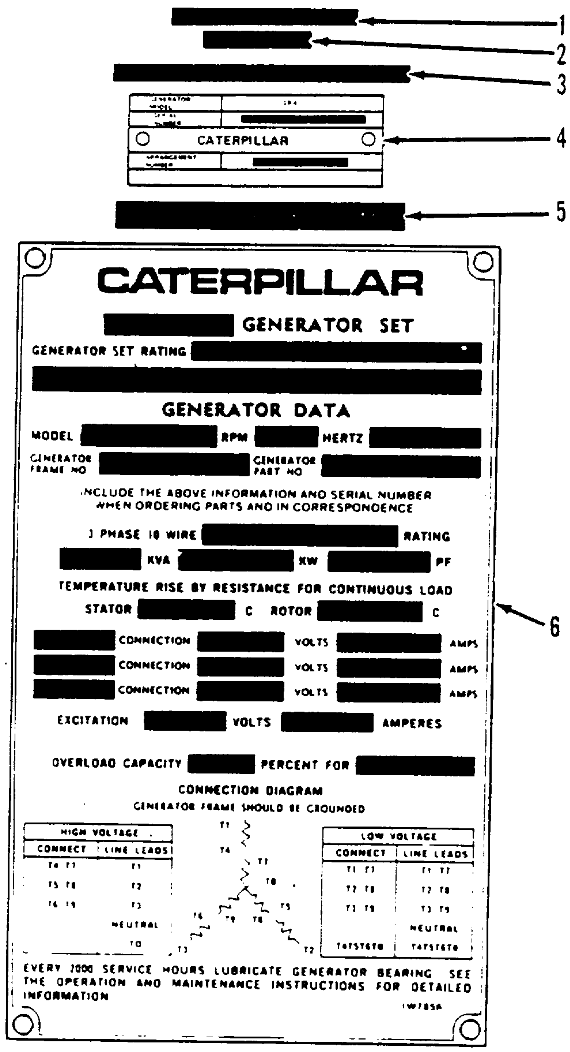
satisfactorily: correctly.
SCR: Silicon Controlled Rectifier (semiconductor)
selinium (Se): A metallic (like metal) element the with electrical characteristic of being a semiconductor.

semiconductor: Components like, transistors, diodes, thyristors, etc. Has electrical characteristics between a conductor and insulation.

short: Any connection between two or more components that is not desired.
shutdown: When the engine is stopped either automatically or manually.
simultaneous: At the same time.
solid-state: An electronic component with no moving parts
surge: A sudden increase in voltage or current.
tap: Connection to get power from a circuit.
tested: When a test has been made.
transfer: change.
transient peak voltage: A high voltage condition for a short time period.
trigger: activate.
turn-on: To start, as current flow through the controlled rectifier: to activate.
uniform: Always the same form or pattern. *C*
voltage droop resistor: Variable resistor for control of voltage change from full load to no load.

voltage level resistor: Gives wider range of voltage control.
voltage level rheostat: Control for adjusting voltage output level.
voltage spike: Temporary high voltage, lasts only a moment.
windings: Layers of wire on a core.
wiring: The wires of a circuit.
wound: circled.

## IDENTIFICATION




B34445X1

*IDENTIFICATION PLATES (Typical)*
*1. Generator voltage location. 2. Generator group part number. 3. Sequence number location. 4. Serial No. Plate. 5. Caterpillar serial number location. 6. Caterpillar nameplate.*

A sequence number (3) is stamped on the upper right hand side of the generator stator assembly located between the generator drive adapter face and the terminal box. This number will be stamped in a position below the generator voltage (1) and the generator group part number (2). These are stamped at the time of manufacture.

Caterpillar Tractor Co. will assign the Caterpillar serial number at the time of the generator use.

A serial number plate (4) will be attached to the generator by Caterpillar. This plate will be stamped with the generator model number. Caterpillar serial number. and the generator arrangement number.

Below the serial number plate. Caterpillar will stamp the Caterpillar serial number (5).

A Caterpillar data nameplate (6) is located below the stamped serial number.

## 3 PHASE 4 POLE GENERATORS

| ENGINE MODEL | GEN. FRAME | GEN. ARRANGEMENT NO. | GEN. PART NO. | VOLTAGE: at 60Hz freq. (at 50 Hz freq.) | BEGINNING SEQUENCE NO. | CATERPILLAR BEGINNING SERIAL NO. | SEE NOTE |
|---|---|---|---|---|---|---|---|
| 3304 NA | 365 | — | 5N1 | | M35BH300 | • | (1) |
| 3304 T | 444 | — | 5N2 | | M44BH300 | • | (1) |
| 3304 T, 3306 T | | 5N5034 | | | M44BH8000 | 5CA1 | (1) |
| 3306 T | 445 | — | 5N3 | | M135BH100 | • | (1) |
| | | 5N5035 | | 240-480 | M45BH8000 | 5DA1 | (1) |
| D334 | 447 | — | 5N4 | (200-400) | M175BH100 | • | (1) |
| D343 | 449 | — | 5N5 | | M250BH100 | • | (1) |
| 3406 PC, TA | 448 | — | 5N6 | | M48BH300 | • | (1) |
| 3406 DI, T | 447 | — | 5N7 | | M47BH600 | • | (1) |
| D333T | 445 | — | 5N10 | 208-416 | T135BS100 | • | (2) |
| | | — | 5N11 | 240-480 | T135BH100 | • | (2) |
| D343 | 449 | — | 5N12 | (200-400) | T250BH100 | • | (2) |
| 3408 DI, T | 449A | — | 5N13 | | MA49BH600 | • | (1) |
| 3304T | | — | 5N14 | 208-416 | 44BS300 | • | (3) |
| 3304 T, 3306 T | | 5N5046 | | | 44BS8000 | 5CA1 | |
| 3304 T | 444 | — | 5N15 | 240-480 | 44BH300 | • | (3) |
| 3304 T, 3306 T | | 5N5047 | | (200-400) | 44BH8000 | 5CA1 | |
| 3304 T | | — | 5N16 | 300-600 | 44BG300 | • | (3) |
| 3304 T, 3306 T | | 5N5048 | | (240-480) | 44BG8000 | 5CA1 | |
| | | — | 5N17 | 208-416 | 135BS1 | • | |
| | | 5N5049 | | | 45BS8000 | 5DA1 | |
| 3306 T | 445 | — | 5N18 | 240-480 | 135BH1 | • | |
| | | 5N5050 | | (200-400) | 45BH8000 | 5DA1 | |
| | | — | 5N19 | 300-600 | 135BG1 | • | |
| | | 5N5051 | | (240-480) | 45BG8000 | 5DA1 | |
| | | — | 5N20 | 208-416 | 175BS1 | • | |
| D334 | 447 | — | 5N21 | 240-480 (200-400) | 175BH1 | • | |
| | | — | 5N22 | 300-600 (240-480) | 175BG1 | • | |
| | | — | 5N23 | 208-416 | 250BS1 | • | |
| D343 | 449 | — | 5N24 | 240-480 (200-400) | 250BH1 | • | |
| | | — | 5N25 | 300-600 (240-480) | 250BG1 | • | |
| D334 | 447 | — | 5N26 | 240-480 (200-400) | T175BH100 | • | (2) |
| | | — | 5N27 | 208-416 | 46BS300 | • | |
| | | 5N5059 | | | 46BS8000 | 5EA1 | |
| 3306 TA, T | 446 | — | 5N28 | 240-280 | 46BH300 | • | |
| | | 5N5060 | | (200-400) | 46BH8000 | 5EA1 | |
| | | — | 5N29 | 300-600 | 46BG300 | • | |
| | | 5N5061 | | (240-480) | 46BG8000 | 5EA1 | |
| | | — | 5N30 | 208-416 | 47BS300 | • | |
| 3406 DI, T | 447 | — | 5N31 | 240-280 (200-400) | 47BH300 | • | |
| | | — | 5N32 | 300-600 (240-480) | 47BG300 | • | |

* And Notes - See Page 13

| ENGINE MODEL | GEN. FRAME | GEN. ARRANGEMENT NO. | GEN. PART NO. | VOLTAGE: at 60Hz freq. (at 50 Hz freq.) | BEGINNING SEQUENCE NO. | CATERPILLAR BEGINNING SERIAL NO. | SEE NOTE |
|---|---|---|---|---|---|---|---|
| 3406 PC, TA | 448 | — | 5N33 | 208-416 | 48BS300 | * | |
| | | — | 5N34 | 240-480 (200-400) | 48BH300 | * | |
| | | — | 5N35 | 300-600 (240-480) | 48BG300 | — | |
| 3408 DI, T | 449A | — | 5N36 | 208-416 | A49BS300 | * | |
| | | — | 5N37 | 240-480 (200-400) | A49BH300 | * | |
| | | — | 5N38 | 300-600 (240-480) | A49BG300 | * | |
| 3408 PC, TA | 449 | — | 5N39 | 208-416 | 49BS300 | * | |
| | | — | 5N40 | 240-480 (200-400) | 49BH300 | * | |
| | | — | 5N41 | 300-600 (240-480) | 49BG300 | * | |
| | | — | 5N42 | 240-480 | M49BH600 | * | (1) |
| 3412 DI, T | 584 | — | 5N43 | (200-400) | 54BH300 | * | |
| | | 5N5075 | | | 54BH8000 | 5LA1 | |
| | | — | 5N44 | 300-600 | 54BG300 | * | |
| | | 5N5076 | | (240-480) | 54BG8000 | 5LA1 | |
| D346 | 586 | — | 5N45 | 240-480 (200-400) | M56BH300 | * | (1) |
| 3412 PC, TA | 588 | — | 5N46 | 240-480 | 58BH300 | * | |
| 3412 DI, TA/PC, TA | | 5N5078 | | (200-400) | 58BH8000 | 5NA1 | |
| 3412 PC, TA | | — | 5N47 | 300-600 | 58BG300 | * | |
| 3412 DI, TA/PC, TA | | 5N5079 | | (240-480) | 58BG8000 | 5NA1 | |
| D343 | 584 | — | 5N48 | 240-480 (200-400) | A54BH300 | * | |
| | | — | 5N49 | 300-600 (240-480) | A54BG300 | * | |
| 3304 NA | 365 | — | 5N50 | 208-416 | 35BS300 | * | |
| | | — | 5N51 | 240-480 (200-400) | 35BH300 | * | |
| | | — | 5N52 | 300-600 (240-480) | 35BG300 | * | |
| Derated 3304 T | 366 | — | 5N53 | 208-416 | 36BS300 | * | |
| | | — | 5N54 | 240-480 (200-400) | 36BH300 | * | |
| | | — | 5N55 | 300-600 (240-480) | 36BG300 | * | |
| D346 | 586 | — | 5N56 | 240-480 (200-400) | 56BH300 | * | |
| | | — | 5N57 | 300-600 (240-480) | 56BG300 | * | |
| D348 | 589 | — | 5N58 | 240-480 | 59BH300 | * | |
| D348 TA | | 5N5090 | | (200-400) | 59BH8000 | 5PA1 | |
| D348 | | — | 5N59 | 300-600 | 59BG300 | * | |
| D348 TA | | 5N5091 | | (240-480) | 59BG8000 | 5PA1 | |

* And Notes - See Page 13

| ENGINE MODEL | GEN. FRAME | GEN. ARRANGEMENT NO. | GEN. PART NO. | VOLTAGE: at 60Hz freq. (at 50 Hz freq.) | BEGINNING SEQUENCE NO. | CATERPILLAR BEGINNING SERIAL NO. | SEE NOTE |
|---|---|---|---|---|---|---|---|
| 3412 DI, T | 584 | — | 5N60 | | M54BH300 | • | (1) |
| | | 5N5092 | | | M54BH8000 | 5LA1 | (1) |
| 3412 PC, TA | 588 | — | 5N61 | | M58BH300 | • | (1) |
| 3412 DI, TA/PC, TA | | 5N5093 | | | M58BH8000 | 5NA1 | (1) |
| D348 | 589 | — | 5N62 | 240-480 | M59BH600 | • | (1) |
| D348 TA | | 5N5094 | | (200-400) | M59BH8000 | 5PA1 | (1) |
| 3306 TA | 446 | — | 5N63 | | M56BH800 | • | (1) |
| | | 5N5094 | | | M56BH8000 | 5EA1 | (1) |
| 3406 PC, TA | 448 | — | 5N64 | | 448BH3000 | • | |
| | 449 | — | 5N65 | | 449BH3000 | • | |
| | 448 | — | 5N66 | 208-416 | 448BS3000 | • | |
| | | — | 5N67 | 300-600 (240-480) | 448BG3000 | • | |
| | | — | 5N68 | 240-480 (200-400) | M448BH3000 | • | (4) |
| | 449 | — | 5N69 | 208-416 | 449BS3000 | • | |
| 3406 PC, TA | 449 | — | 5N70 | 300-600 (240-480) | 449BG3000 | • | |
| | | — | 5N71 | 240-480 (200-400) | M449BH3000 | • | (4) |
| 3306 TA | 447 | — | 5N72 | 300-600 (240-480) | A47BG3000 | • | |
| | | — | 5N74 | | MA47BH3000 | • | (1) |
| | | — | 5N75 | 240-480 | A47BH3000 | • | |
| 3304 NA | 365 | — | 5N76 | (200-400) | M35BH | • | (1) |
| | | 5N7076 | | | M35BH8000 | 5AA1 | (1) |
| | | — | 5N77 | 208-416 | 35BS | • | |
| | | 5N7077 | | | 35BS8000 | 5AA1 | |
| | | — | 5N78 | 240-480 | 35BH | • | |
| | | 5N7078 | | (200-400) | 35BH8000 | 5AA1 | |
| | | — | 5N79 | 300-600 | 35BG | • | |
| | | 5N7079 | | (240-480) | 35BG8000 | 5AA1 | |
| Derated 3304 T | 366 | — | 5N80 | 208-416 | 36BS | • | |
| | | 5N7080 | | | 36BS8000 | 5BA1 | |
| | | — | 5N81 | 240-480 | 36BH | • | |
| | | 5N7081 | | (200-400) | 36BH8000 | 5BA1 | |
| | | — | 5N82 | 300-600 | 36BG | • | |
| | | 5N7082 | | (240-480) | 36BG8000 | 5BA1 | |
| 3408 DI, T | 448 | — | 5N83 | 208-416 | B48BS6000 | • | |
| | | — | 5N84 | 240-480 (200-400) | B48BH6000 | • | |
| | | — | 5N85 | 300-600 (240-480) | B48BG6000 | • | |
| | | — | 5N86 | 240-480 (200-400) | MB48BH600 | • | (1) |
| 3408 PC, TA | 449 | — | 5N87 | 208-416 | B49BS6000 | • | |
| | | — | 5N88 | 240-480 (200-400) | B49BH6000 | • | |
| | | — | 5N89 | 300-600 (240-480) | B49BG6000 | • | |

* And Notes - See Page 13

| ENGINE MODEL | GEN. FRAME | GEN. ARRANGEMENT NO. | GEN. PART NO. | VOLTAGE: at 60Hz freq. (at 50 Hz freq.) | BEGINNING SEQUENCE NO. | CATERPILLAR BEGINNING SERIAL NO. | SEE NOTE |
|---|---|---|---|---|---|---|---|
| 3408 PC, TA (Cont.) | 449 | — | 5N90 | 240-480 | B49BH6000 | * | |
| 3408 DI, TA/PC, TA | | 5N7088 | 5N4999 | (200-400) | B49BH8000 | 5KA1 | (1) |
| | | 5N7089 | 5N5000 | 300-600 (240-480) | B49BG8000 | | |
| | | 5N7090 | 5N5001 | 240-480 (200-400) | MB49BH8000 | | |
| 3412 DI, TA | 589 | 5N8670 | 5N5026 | 240-480 | A59BH600 | 6FA1 | |
| 3408 DI, T | 582 | 5N8664 | 5N7064 | (200-400) 208-416 | 52BH500 | 6CA1 | |
| | | 5N8665 | 5N7065 | 300-600 (240-480) | 52BG500 | | |
| 3408 DI, TA | 584 | 5N8666 | 5N7066 | 240-480 (200-400) 208-416 | B54BH500 | 6DA1 | |
| | | 5N8667 | 5N7067 | 300-600 (240-480) | B54BG500 | | |
| 3412 DI, T | 586 | 5N8668 | 5N7068 | 240-480 (200-400) 208-416 | A56BH500 | 6EA1 | |
| | | 5N8669 | 5N7069 | 300-600 (240-480) | B56BG500 | | |
| | 589 | 5N8670 | 5N7070 | 240-480 (200-400) 208-416 | A59BH500 | 6FA1 | |
| | | 5N8671 | 5N7071 | 300-600 | A59BG500 | | |
| 3412 DI, TA | | | 5N7308 | (240-480) | A59BG600 | | |
| | | 5N9516 | 5N7309 | 300-600 | P59BG600 | | |
| 3306 TA, T | 447 | 5N7072 | 5N8891 | 300-600 (240-480) | A47BG8000 | 5FA1 | (1) |
| | | 5N7073 | 5N8892 | 208-416 | A47BS8000 | | |
| | | 5N7074 | 5N8893 | 240-480 (200-400) | MA47BH8000 | | |
| | | 5N7075 | 5N8894 | 240-480 (200-400) | A47BH8000 | | |
| 3406 DI, T | | 5N5039 | 5N8895 | 300-600 (240-480) | M47BH8000 | 5GA1 | (1) |
| | | 5N5062 | 5N8896 | 208-416 | 47BS8000 | | |
| 3406 DI, T | 447 | 5N5063 | 5N8897 | 240-480 (200-400) | 47BH8000 | 5GA1 | |
| | | 5N5064 | 5N8898 | 300-600 (240-480) | 47BG8000 | | |
| 3408 DI, T | 448 | 5N7083 | 5N8899 | 208-416 | B48BS8000 | 5JA1 | (1) |
| | | 5N7084 | 5N8900 | 240-480 (200-400) | B48BH8000 | | |
| | | 5N7085 | 5N8901 | 300-600 (240-480) | B48BG8000 | | |
| | | 5N7086 | 5N8902 | 240-480 (200-400) | MB48BH8000 | | |
| 3406 DI, TA/PC, TA | | 5N5038 | 5N8903 | 240-480 (200-400) | M48BH8000 | 5HA1 | (1) |
| | | 5N5065 | 5N8904 | 208-416 | 48BS8000 | | |
| | | 5N5066 | 5N8905 | 240-480 (200-400) | 48BH8000 | | |
| | | 5N5067 | 5N8906 | 300-600 (240-480) | 48BG8000 | | |

* And Notes - See Page 13

*Use Sequence No. for Identification.

GENERAL NOTES:

GENERATORS RATED: 3 PHASE, 60 HERTZ, 240-480 VOLTS ALSO USED FOR 3 PHASE, 50 HERTZ, 200-400 VOLTS AT NOMINALLY 5/6 OF 60 HERTZ KILOWATT RATING.

GENERATORS RATED: 3 PHASE, 60 HERTZ, 300-600 VOLTS ALSO USED FOR 3 PHASE, 50 HERTZ, 240-480 VOLTS AT NOMINALLY 5/6 OF 50 HERTZ KILOWATT RATING.
ALL GENERATORS S/N 3000 & UP WILL HAVE SERIES BOOST CAPABILITIES.

NOTE: (1) MARINE SOCIETY APPROVED GENERATORS. MEETS REQUIREMENTS OF ABS, LLOYD'S & DN V.

(2) TROPICALIZED GENERATORS THAT WERE BUILT TO CUSTOMER ORDERS PRIOR TO STANDARDIZING ON THIS INSULATION SYSTEM FOR ALL GENERATORS. THIS CHANGE WAS EFFECTIVE WITH SIN 100 & UP.

(3) FIRST PRODUCTION RELEASE THAT USED THERMAL PROTECTOR (KUXON BREAKER) IN REGULATOR ASSEMBLY. STANDARD ON ALL SR 4 GENERATORS EFFECTIVE WITH S/N 300 & UP.

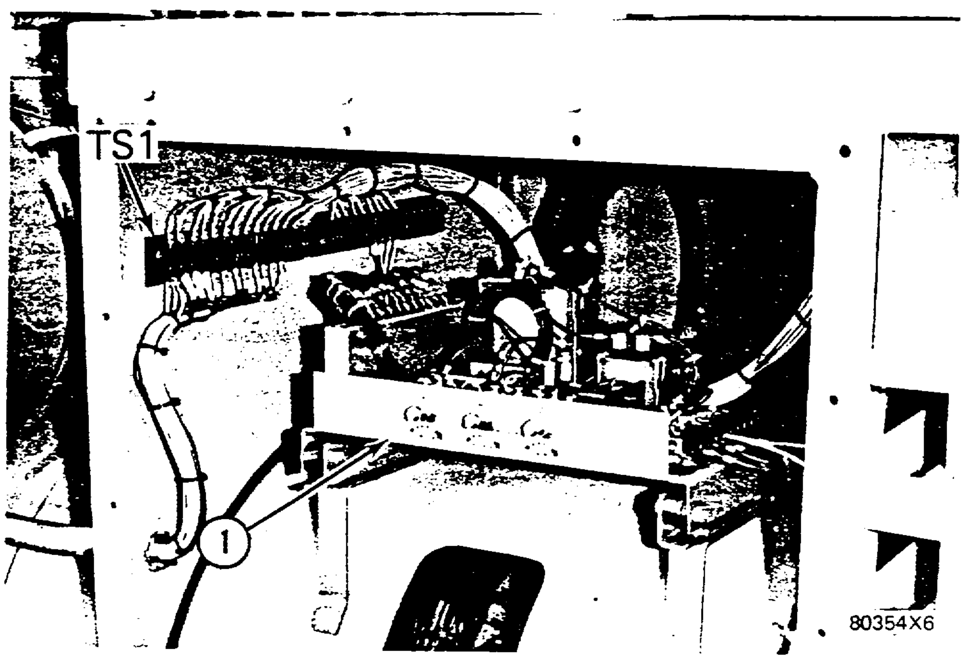
(4) GENERATOR TO INCLUDE SPACE HEATER IN ACCORDANCE TO MARINE SOCIETY SPEC.

## GENERATOR AND REGULATOR COMPONENTS

| COMPONENT | SEE FIGURE(S) | DESCRIPTION |
|---|---|---|
| A1 | 3 | Sealed, non-serviceable, unit that controls the generator output. |
| A2 | 2,4 | Holds SCR CR9, diode CR10 and resistance capacitance circuits to give protection to these solid state components. |
| C1,3 | 2,3 | Capacitors that reduce voltage spikes that could cause radio interference. |
| C2 | 2 | Capacitor that accepts a charge when CR9 is "off" and gives first current flow when CR9 turns "on". |
| CR1-6 | 7,8,9,10,11 | Diodes that change the AC current from exciter armature L4 to DC current. |
| CR7,8 | 7,8,9,10,11 | Diodes that reduce voltage spikes that could damage CR1-6. Conducts current around CR1-6 when the voltage gets to a certain level. |
| CR9 | 4 | Silicon controlled rectifier (SCR) that acts as a valve to limit current flow through exciter field L3. |
| CR10 | 4 | Diode that gives a path for current flow through the exciter field when CR9 is "off". |
| CR11 | 2 | Diode that decreases voltage spikes that could damage CR9 and CR10. Conducts current around CR9 and CR10 when the voltage gets to a certain level. |
| E1-4 | 4,5,7,8,9,10,11,12 | Heat sinks act as heat exchangers to lower the temperature of rectifiers. |
| F1 | 2 | Fuse that gives protection to regulator circuit. |
| L1 | 3 | Iron core suppression reactor decreases the shock load on the stator windings when CR9 turns "on". |
| L2 | 2 | Air core reactor that limits the current rise time when CR9 turns "on". |
| L3 | 14 | Copper windings on generator end housing. Current through these windings causes an induced three phase AC current in exciter armature L4. |
| L4 | 5,12,13,14 | Copper windings on the rotating field assembly. Rectified current from this armature is the source for rotating field L5. |
| L5 | 5,12,13 | Copper winding on poles attached to the rotating field assembly. Current through these windings causes an induced three phase AC current in stator L6. |
| L6 | 16 | Copper windings attached to the generator housing. Current induced in these windings is the power for the load. |
| TP | 2 | Gives protection against too much heat in the stator windings. |
| R1 | 2 | Rheostat that gives adjustment for voltage droop. |
| R2 | 2 | Rheostat that gives adjustment for generator output voltage. |

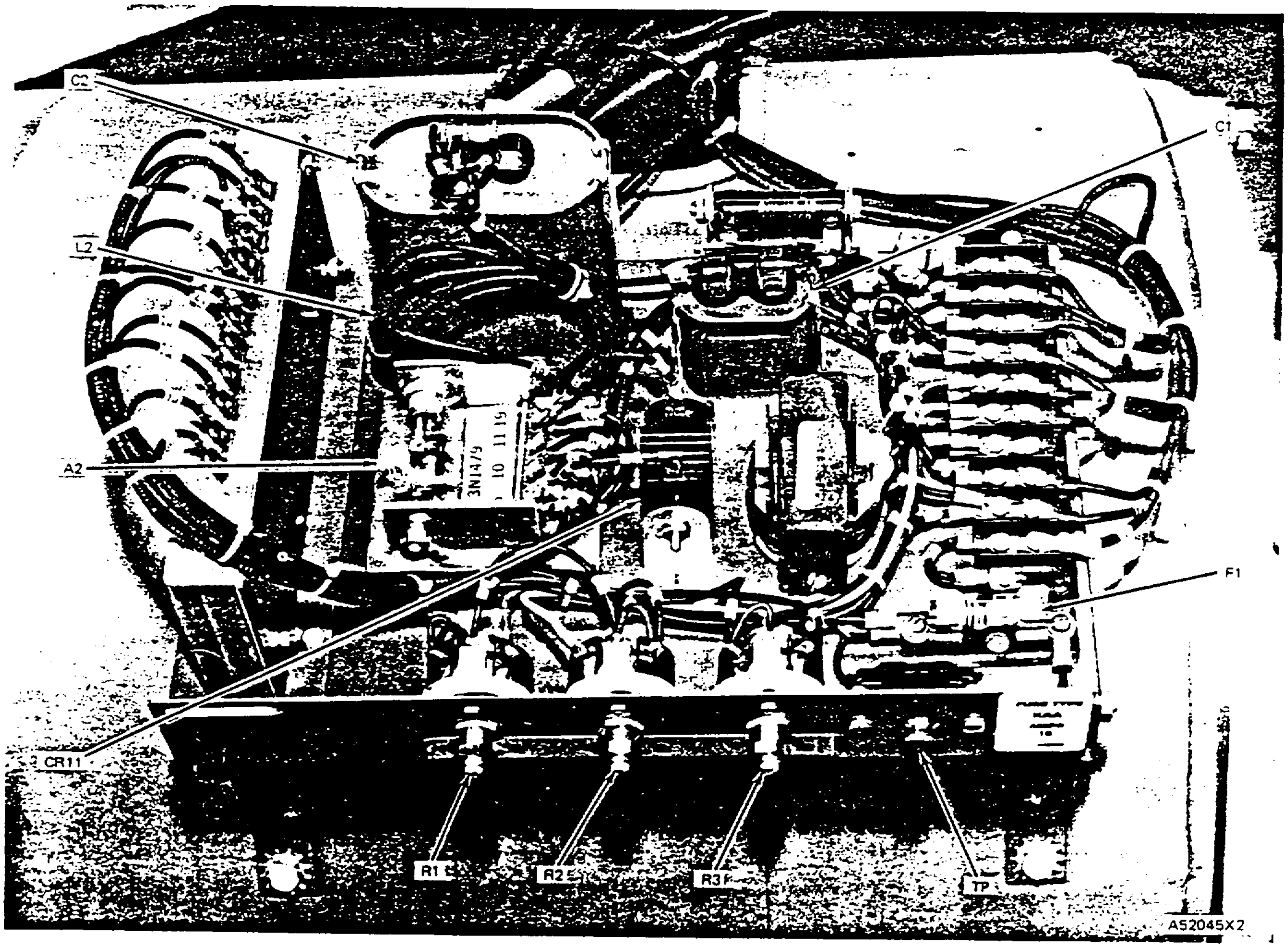
## GENERATOR AND REGULATOR COMPONENTS (Cont.)

| | | |
|---|---|---|
| R3 | 2 | Rheostat that gives adjustment for regulator gain. |
| R4 | 3 | Resistor that limits current and voltage to regulator module A1. |
| R5 | 3 | Resistor connected in parallel with L1 that causes a reduction of current oscillations in L1. |
| R6 | 8 | Resistor that gives a high resistance path to ground from the (RFA). This prevents the build-up of a capacitive charge in the (RFA). |
| R7 | -- | Resistor that limits current and voltage to regulator module A1 on 580 frame generators. |
| RFA | 5,6 | Part of the generator that is driven by the engine. |
| T1 | 3 | Feels generator output voltage for voltage droop circuit. |
| TS1 | 1 | Generator terminal strip. |




*GENERATOR REGULATOR HOUSING, FIG. 1.*

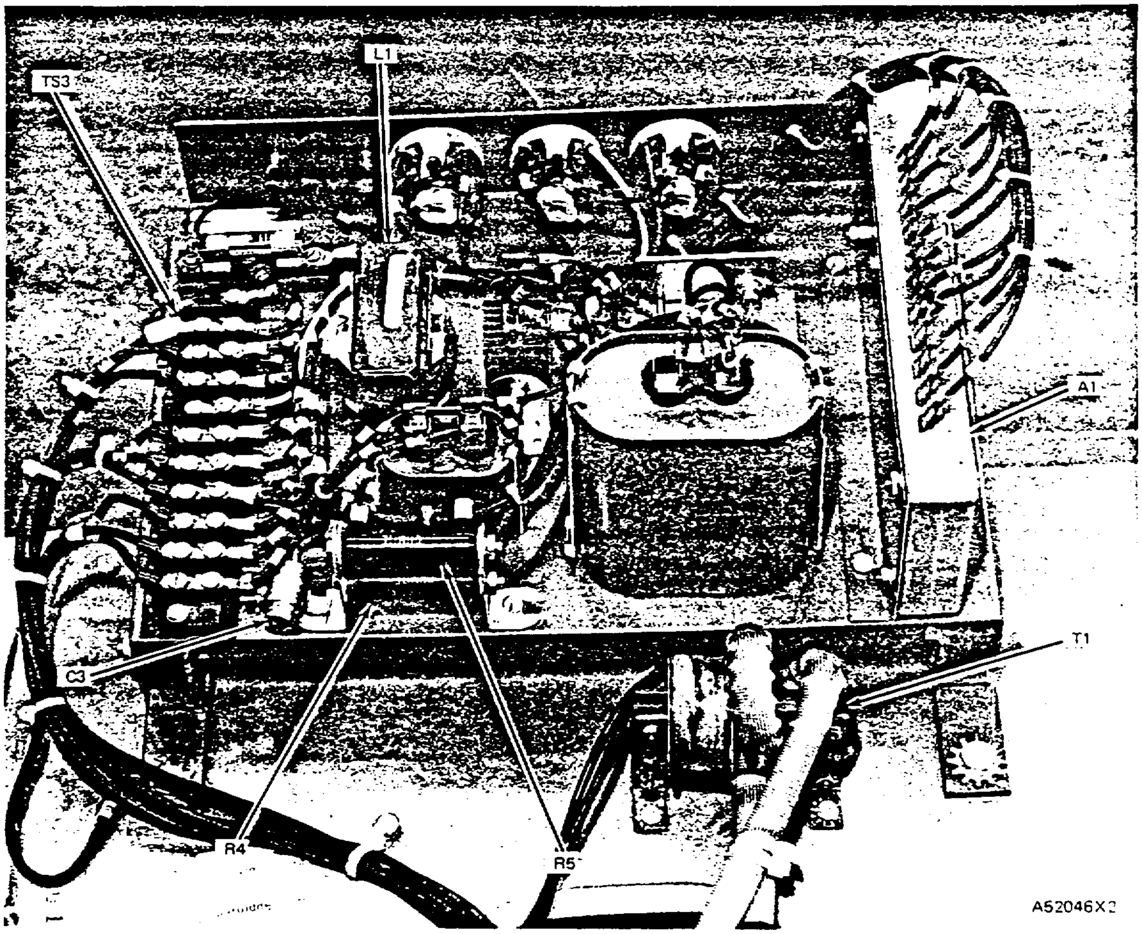
**1. Generator regulator assembly. TS1. Generator terminal strip.**




*GENERATOR REGULATOR ASSEMBLY, FIG. 2*
*(left side)*

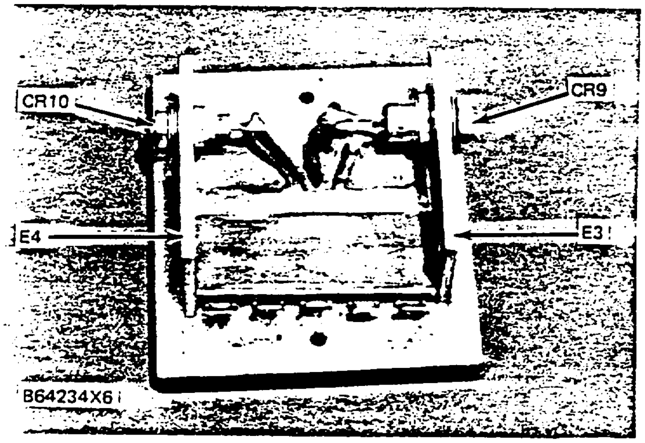
| | |
|---|---|
| A2 | Rectifier module |
| C1 | RFI Suppression capacitor |
| C2 | Suppression capacitor |
| CR11 | Surge suppression diode |
| F1 | Fuse |
| L2 | SCR reactor |
| R1 | Voltage droop potentiometer |
| R2 | Voltage level rheostat |
| R3 | Regulator gain rheostat |
| TP | Thermal protector |

**NOTE: Earlier generators do not have a thermal protector.**



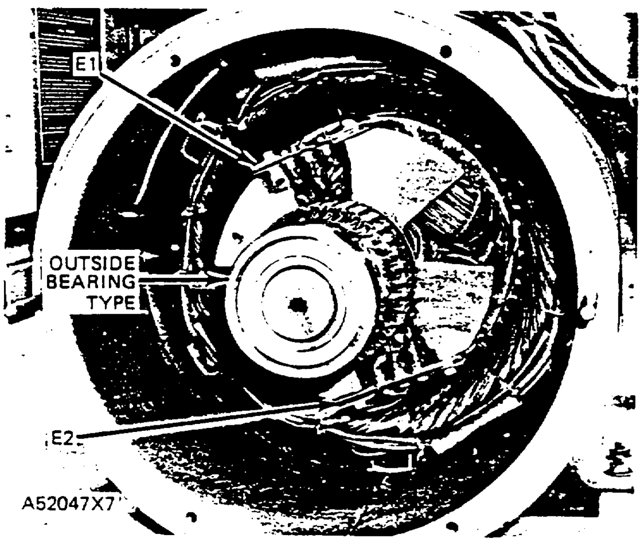

*GENERATOR REGULATOR ASSEMBLY, FIG. 3*
*(right side)*

| | |
|---|---|
| A1 | Regulator module |
| C3 | RFI Suppression capacitor |
| L1 | Suppression reactor |
| R4 | Regulator power resistor |
| R5 | Damping resistor |
| T1 | Voltage droop transformer |
| TS3 | Voltage regulator terminal strip |



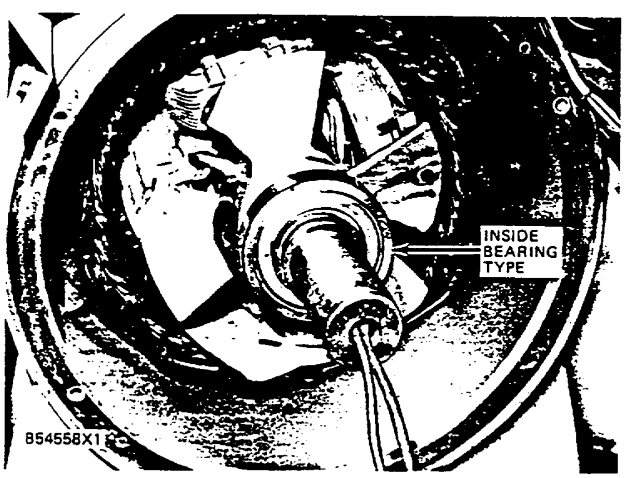

*A2 RECTIFIER MODULE, FIG. 4*

CR9 Controlled rectifier
CR10 Field Rectifier
E3 SCR Heat sink
E4 Field rectifier heat sink

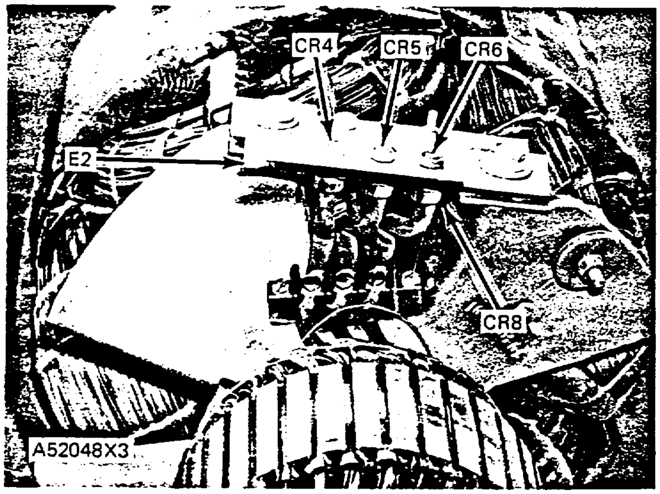



*ROTATING FIELD ASSEMBLY, FIG. 5*
*(OUTSIDE BEARING TYPE RFA)*

E1 Negative heat sink
E2 Positive heat sink

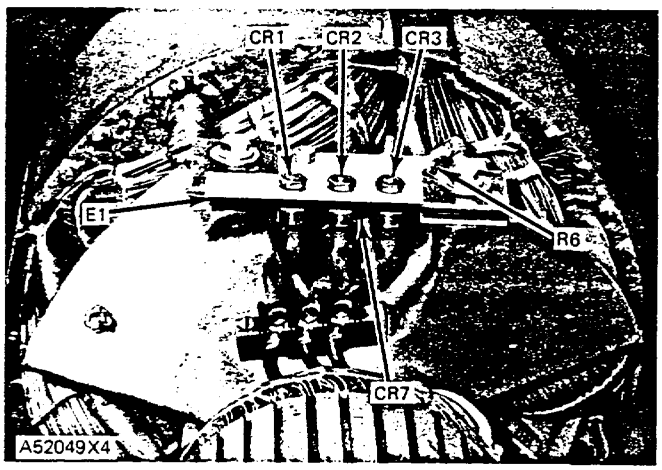



*ROTATING FIELD ASSEMBLY, FIG. 6*
*(INSIDE BEARING TYPE RFA)*



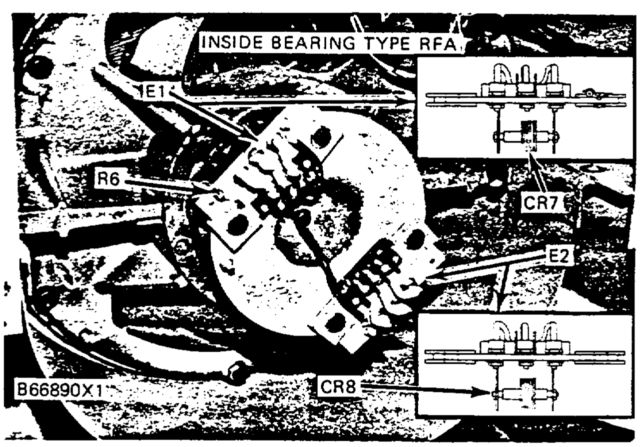

*NEGATIVE HEAT SINK ASSEMBLY, FIG. 7*
*(OUTSIDE BEARING TYPE RFA)*

| | |
|---|---|
| E2 | Negative heat sink |
| CR4,5,6 | Rotating rectifiers |
| CR8 | Surge suppression diode |




*POSITIVE HEAT SINK ASSEMBLY, FIG. 8*
*(OUTSIDE BEARING TYPE RFA)*

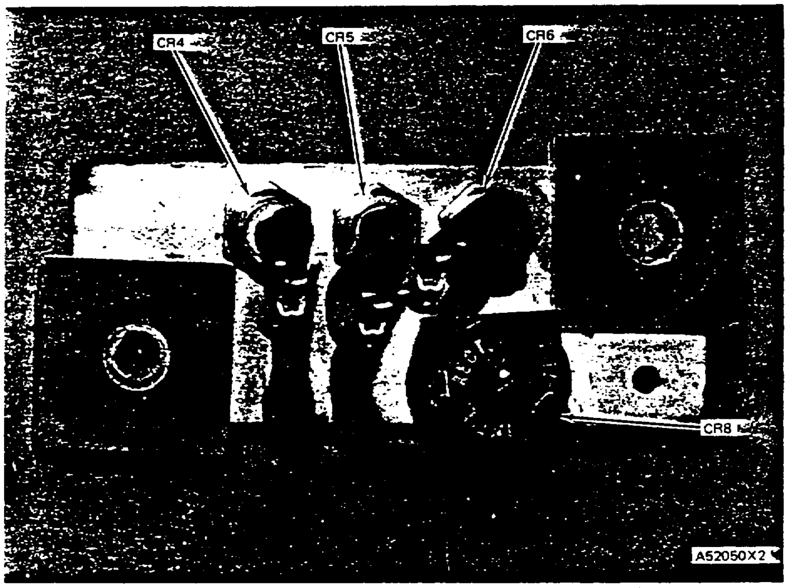
| | |
|---|---|
| E1 | Positive heat sink |
| CR1,2,3 | Rotating rectifier |
| CR7 | Surge suppression diode |
| R6 | Suppression resistor |




*EXCITER AND HEAT SINK ASSEMBLY, FIG. 9*
*(INSIDE BEARING TYPE RFA)*

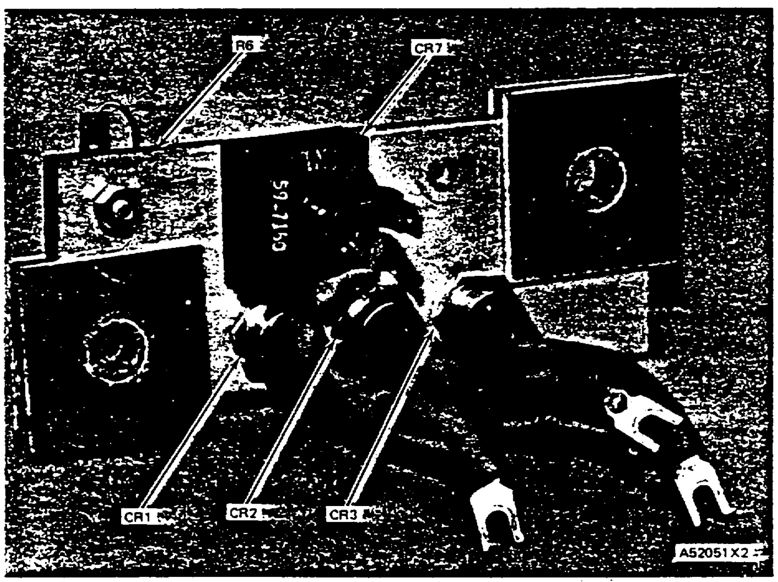
| | |
|---|---|
| E1 | Positive heat sink |
| E2 | Negative heat sink |
| CR7,8 | Surge suppression diodes |
| R6 | Suppression resistor |

C



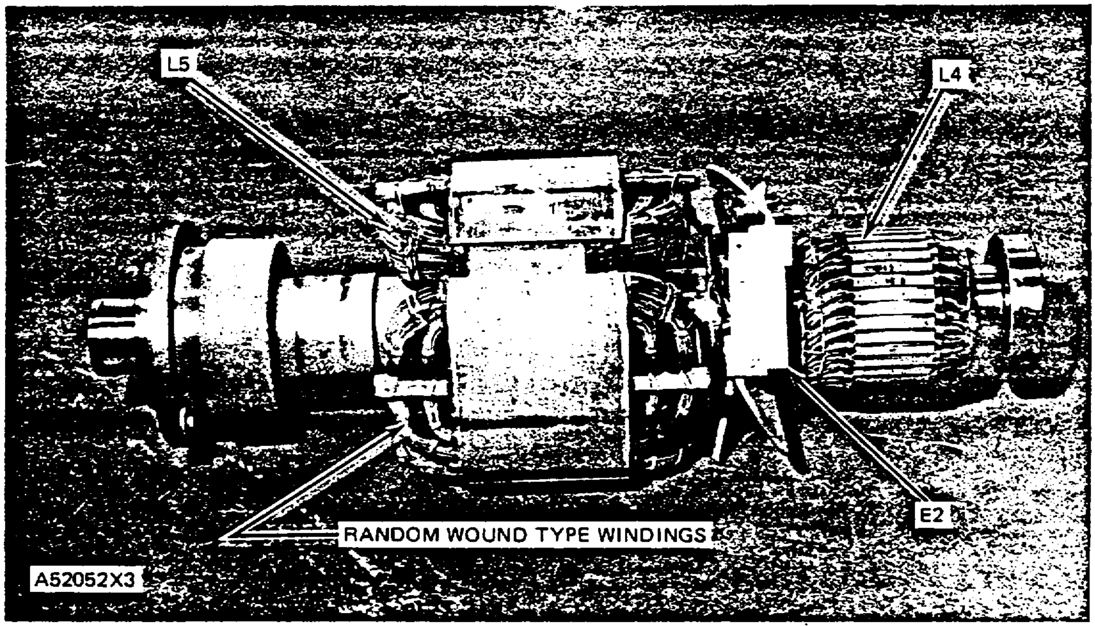

CR4,5,6 Rotating rectifiers
CR8 Surge suppression diode

*NEGATIVE HEAT SINK ASSEMBLY, FIG. 10*
*(FROM OUTSIDE BEARING TYPE RFA)*




CR1,2,3 Rotating rectifiers
CR7 Surge suppression diode
R6 Suppression resistor

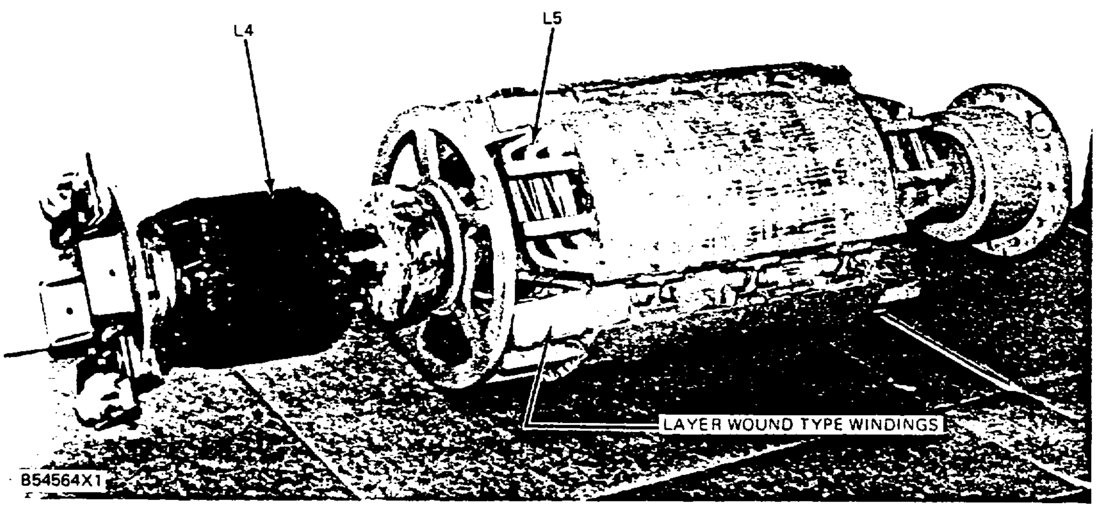
*POSITIVE HEAT SINK ASSEMBLY, FIG. 11*
*(FROM OUTSIDE BEARING TYPE RFA)*




*ROTATING FIELD ASSEMBLY (RFA), FIG. 12*
*(OUTSIDE BEARING TYPE RFA)*

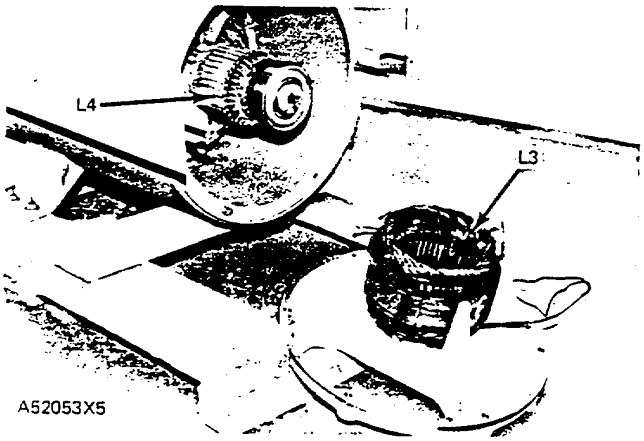
| | |
|---|---|
| L4 | Exciter armature |
| L5 | Rotating field |
| E2 | Negative heat sink |

**NOTE: Earlier rotating field assemblies had two fans.**




*ROTATING FIELD ASSEMBLY (RFA), FIG. 13*
*(INSIDE BEARING TYPE RFA)*

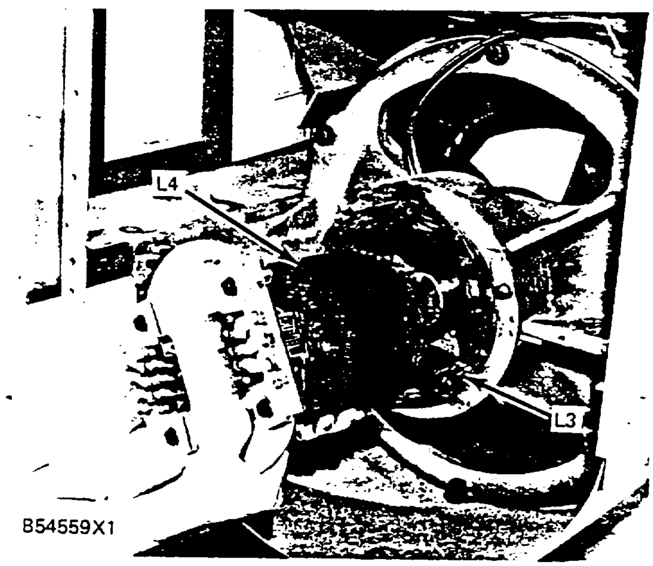
| | |
|---|---|
| L4 | Exciter armature |
| L5 | Rotating field |




*END HOUSING, FIG. 14*
*(OUTSIDE BEARING TYPE RFA)*

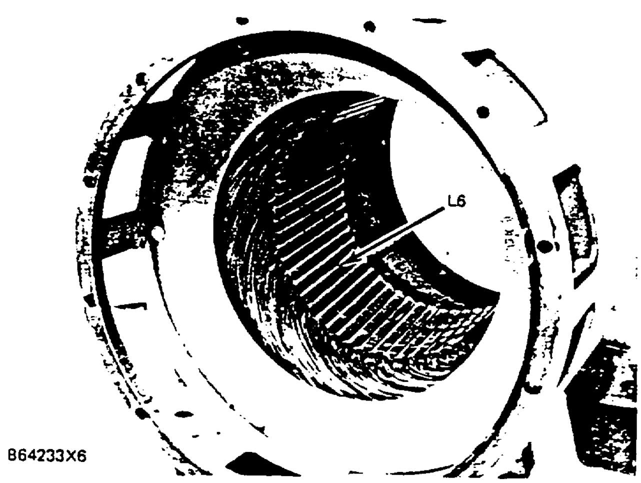
L3 Exciter field
L4 Exciter armature

C




*EXCITER FIELD AND ARMATURE, FIG. 15*
*(INSIDE BEARING TYPE RFA)*

L3 Exciter field
L4 Exciter armature




*GENERATOR HOUSING, FIG. 16*

L6 Stator

# OPERATION OF GENERATOR

## INTRODUCTION

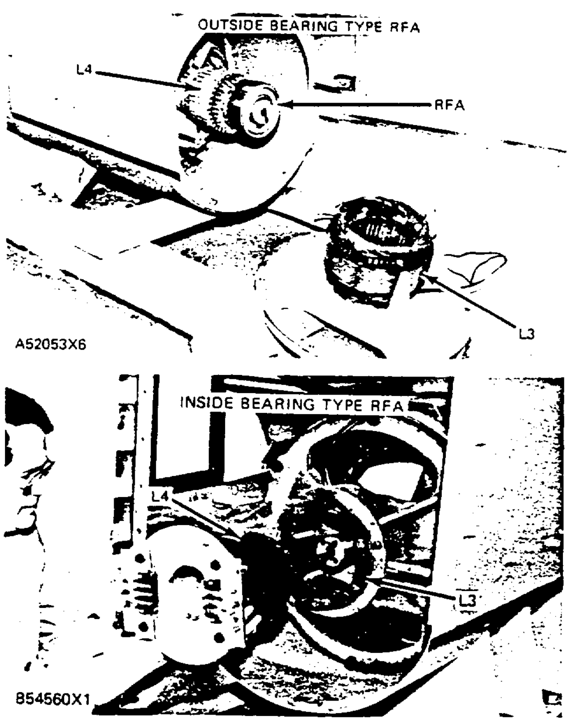
The SR 4 Generator has no brushes and no commutator. This gives better performance and longer service life. It uses a solid-state, automatic voltage regulator. This regulator has only one moving part in the voltage build-up system. This part is a completely sealed relay that is activated only when the generator is started or stopped.

From the outside, the SR 4 Generator looks very similar to the SRCR generators.

Here are the design characteristics of the SR 4 Generator:

The windings of the alternator coils are the stator (L6). The windings of the alternator field coils are the poles of the rotor, shown in the wiring diagram as rotating field (L5). The rotating field assembly (RFA) also has:

1. Exciter armature (L4).
2. Rotating rectifiers (CR1 thru CR6).
3. Surge suppression diodes (CR7 and CR8).
4. Positive (E1) and negative (E2) heat sinks.
5. Suppression resistor (R6).



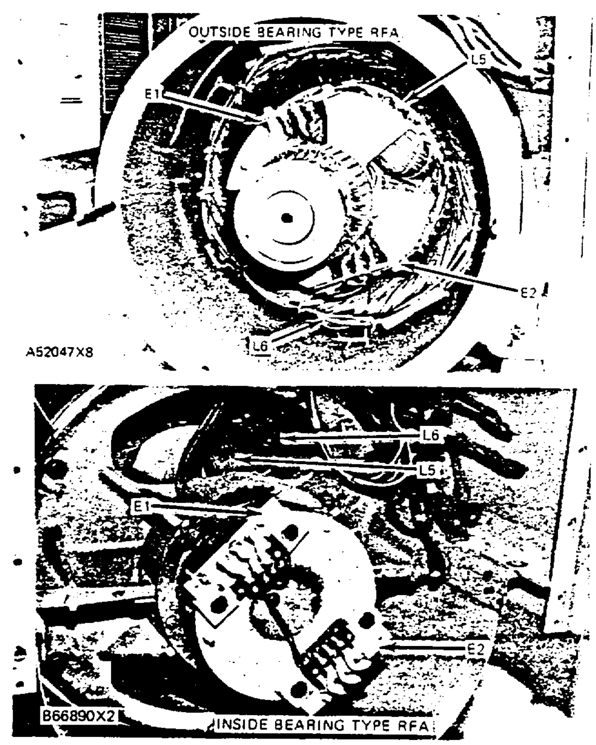

*REAR OF GENERATOR*

L3 Exciter field L4 Exciter armature

All of these components are installed on the rotor shaft. The shaft is connected through a flexible plate-type coupling to the flywheel of the engine. The rear end of the rotor shaft uses an anti-friction bearing for support. The stationary exciter field (L3) has a six-pole distributive winding on a core that is part of the generator end housing. Both the field coils of the exciter and the alternator have their windings on magnetic steel. This metal keeps a small amount of residual magnetism.

## START UP VOLTAGE GENERATION

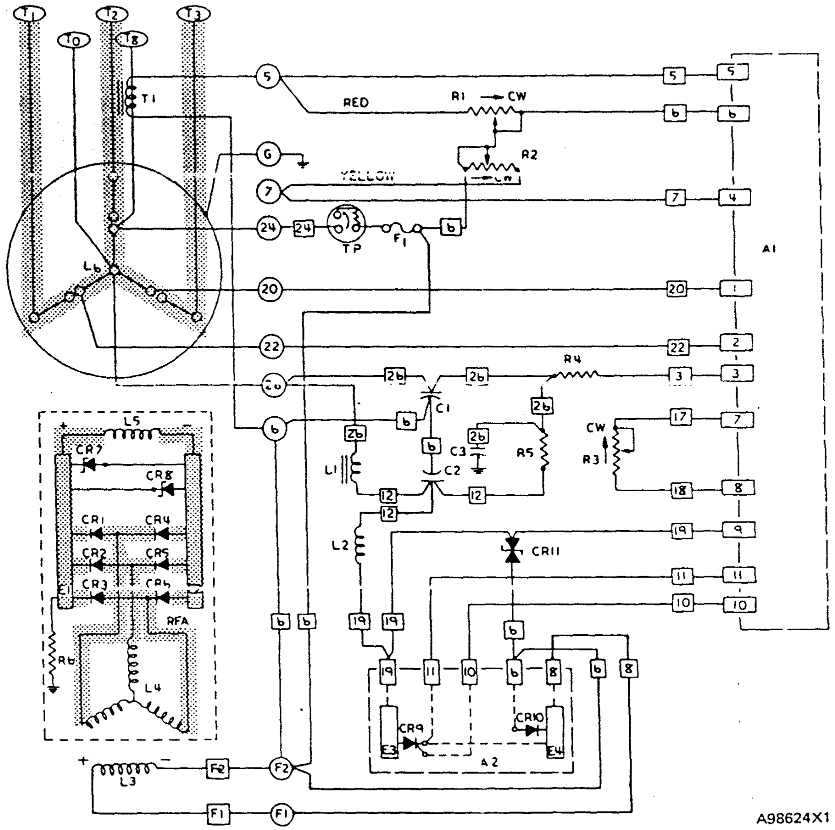
When the engine starts turning the rotating field assembly (RFA), the residual magnetism in the exciter field (L3) causes a small amount of alternating current (AC) voltage to be generated in the exciter armature (L4). This voltage causes an AC current to flow which is changed to direct current (D.C.) by the three-phase full-wave bridge rectifier circuit (CR1 thru CR6). The DC current then goes to the rotating field (L5) of the alternator. Here it adds to the residual magnetism of the rotating field (L5). With this field turning, an AC voltage is generated in stator (L6) which causes a current to flow to the output terminals (T0, T1, T2 and T3). Part of this AC current is changed to half wave DC and is sent back to exciter field (L3). As a result, the magnetic field in the exciter becomes stronger. The flow of current back to (L3) is explained in more detail on the pages that follow.




*INSIDE GENERATOR HOUSING*

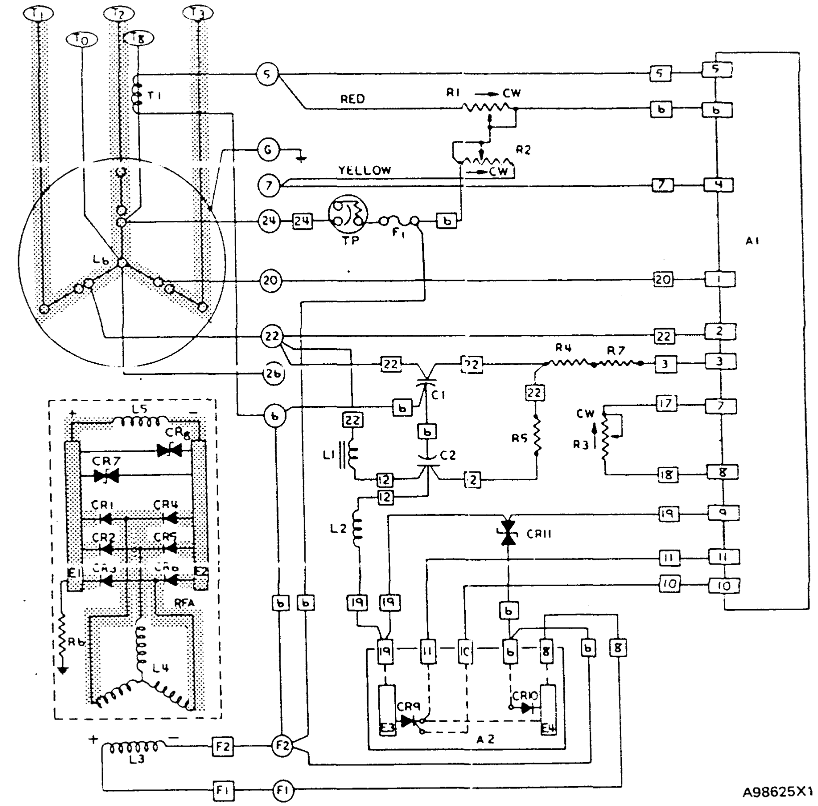
E1 Positive heat sink L5 Rotating field
E2 Negative heat sink L6 Stator

# SR 4 GENERATOR




FOR SR 4 GENERATORS —
LINE TO NEUTRAL POWER FOR EXCITATION AND REGULATION*

| *SR 4 GENERATORS (Line to Neutral Power For Excitation & Regulation) | |
|---|---|
| INCLUDES | 447, 448 and 449 frame — 208 V ONLY (With Layer Wound Rotor) |
| | All other frames (Random & Layer Wound Rotors) |
| DOES NOT INCLUDE | 580 frames |
| | 447, 448 and 449 frame (With Layer Wound Rotor) |




FOR SR 4 GENERATORS —
LINE TO LINE POWER FOR EXCITATION AND REGULATION**

- A1 REGULATOR MODULE
- A2 RECTIFIER MODULE
- C1,3 RFI SUPPRESSION CAPACITOR
- C2 SUPPRESSION CAPACITOR
- CR1-6 ROTATING RECTIFIERS
- CR7,8 SURGE SUPPRESSION DIODES
- CR9 CONTROLLED RECTIFIER
- CR10 FIELD RECTIFIER
- CR11 SURGE SUPPRESSSION DIODE
- E1 POSITIVE HEAT SINK
- E2 NEGATIVE HEAT SINK
- E3 SCR HEAT SINK
- E4 FIELD RECTIFIER HEAT SINK
- F1 FUSE
- L1 SUPPRESSION REACTOR
- L2 SCR REACTOR
- L3 EXCITER FIELD
- L4 EXCITER ARMATURE
- L5 ROTATING FIELD
- L6 STATOR
- *TP THERMAL PROTECTOR
- R1 VOLTAGE DROOP POTENTIOMETER
- R2 VOLTAGE LEVEL RHEOSTAT
- R3 REGULATOR GAIN RHEOSTAT
- R4 REGULATOR POWER RESISTOR
- R5 DAMPING RESISTOR
- R6 SUPPRESSION RESISTOR
- R7 REGULATOR POWER RESISTOR
- RFA REVOLVING FIELD ASSEMBLY
- T1 VOLTAGE DROOP TRANSFORMER
- ○ TERMINAL BOARD NUMBER
- □ WIRE NUMBER
- ▭ SPADE TERMINAL NUMBER

*Thermal protector is not found on some earlier models.

| **SR 4 GENERATORS (Line to Line Power For Excitation & Regulation) | |
|---|---|
| INCLUDES | 580 frames |
| | 447, 448, and 449 frames With Layer Wound Rotor) |
| DOES NOT INCLUDE | 447, 448 and 449 frame — 208 V (With Layer Wound Rotor) |
| | All others (Random & Layer Wound Rotors) |

NOTE: Current production and replacement A1 modules (black in color) for the line to line generator regulators require a wiring change from that for regulators using earlier A1 modules (brown in color). The lead connections from L1 and C1 change their terminal connections from terminal 22 to terminal 20.

C **EXCITATION CIRCUIT**

Power for excitation comes from stator (L6) during the negative half cycle. That is, when (T0) is positive and (T3) is negative. The current flow is shown on the opposite page.

**For SR 4 Generators with line to neutral power for excitation & regulation**

From (T0) to terminal (26).

From terminal (26) through wire (26) to suppression reactor (L1).

**For SR 4 Generators with line to line power for excitation & regulation**

Front the tapped connection of' phase 1 of stator (L6) to terminal (22).

From terminal (22) through wire (22) to suppression reactor (L1).

**For A SR 4 Generators**

Through suppression reactor (L1) and wire (12) to suppression capacitor (C2).

From suppression capacitor (C2) through wire (12) to SCR reactor (L2).

Through SCR reactor (L2) and wire (19) to spade terminal (19) of rectifier module (A2).

From spade terminal (19) of rectifier module (A2) to heat sink (E3) and the anode terminal of controlled rectifier (CR9).

**NOTE: To make this current flow through the controlled rectifier possible, a signal voltage must be sent to the gate of (CR9). Until this signal turns (CR9) on, the current puts a charge on suppression capacitor (C2). When the signal is sent to the gate, controlled rectifier (CR9) "turns on." Current flows through controlled rectifier (CR9).**

From the cathode terminal of controlled rectifier (CR9) to heat sink (E4).

From heat sink (E4) to spade terminal (8) of rectifier module (A2).

Through wire (8) to terminal (F1).

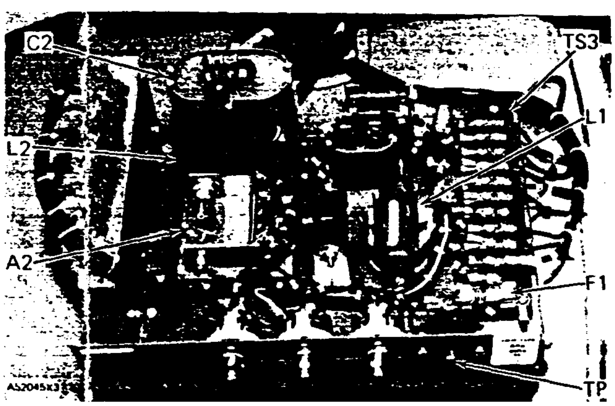
Through wire (F1) to the positive end of exciter field (L3).

Through exciter field (L3) to terminal (F2).

From terminal (F2) through wire (6) to fuse (F1).

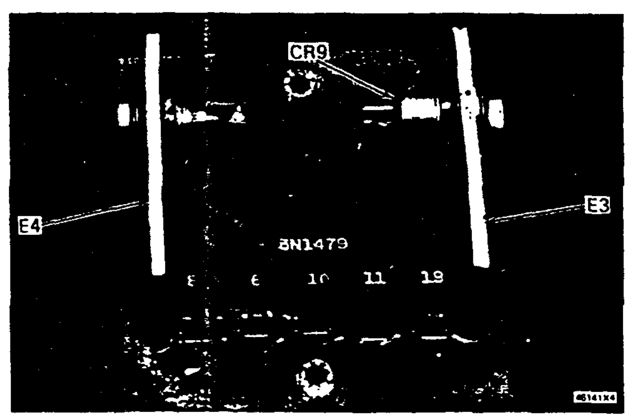
From fuse (F1) through thermal protector (TP) and wire (24) to terminal (24).

From terminal (24) to connection on phase 2 of stator (L6).



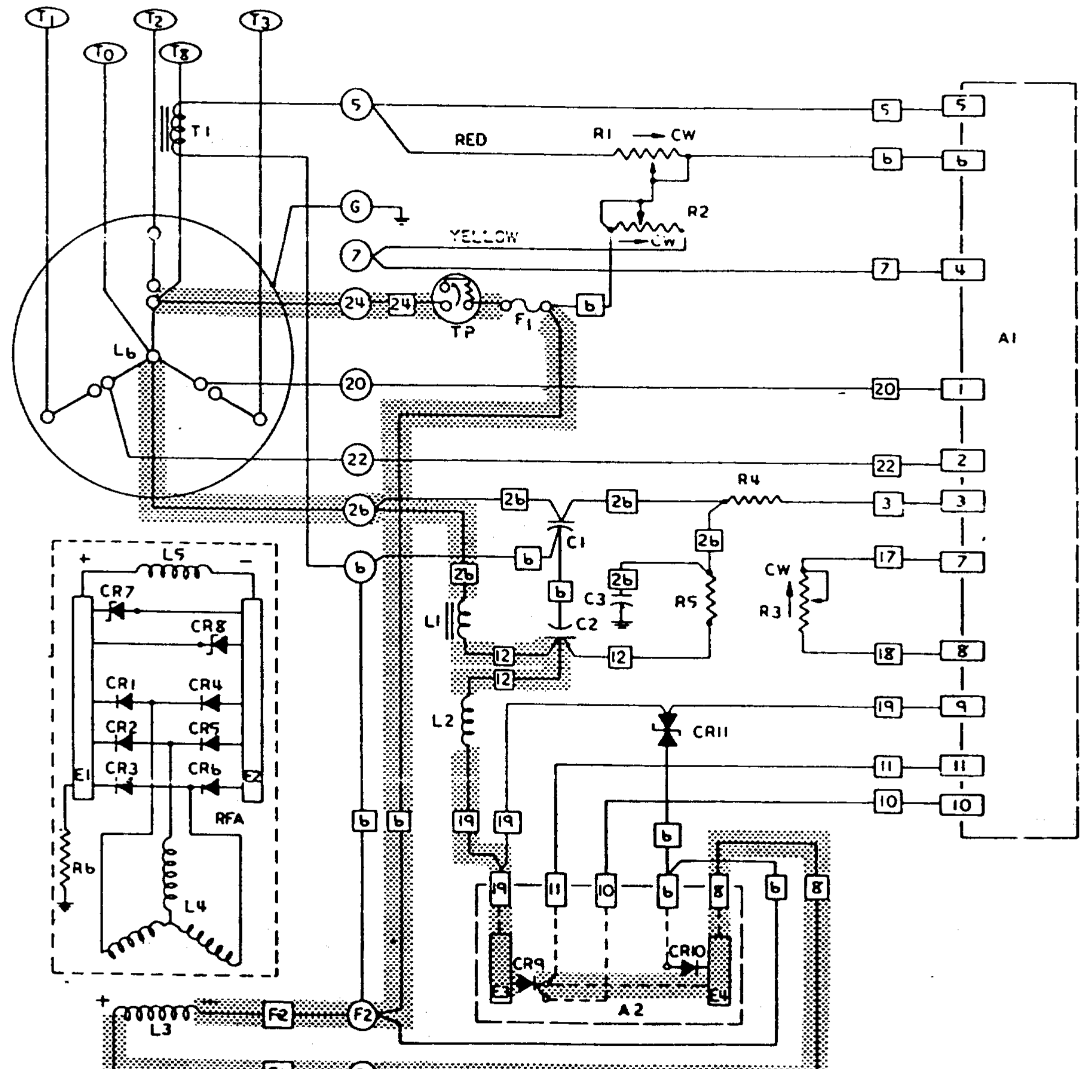

*GENERATOR REGULATOR ASSEMBLY*

A2 Rectifier module
C2 Suppression capacitor
F1 Fuse
L1 Suppression reactor
L2 SCR Reactor
TP Thermal protector (it so equipped)
TS3 Voltage regulator terminal strip

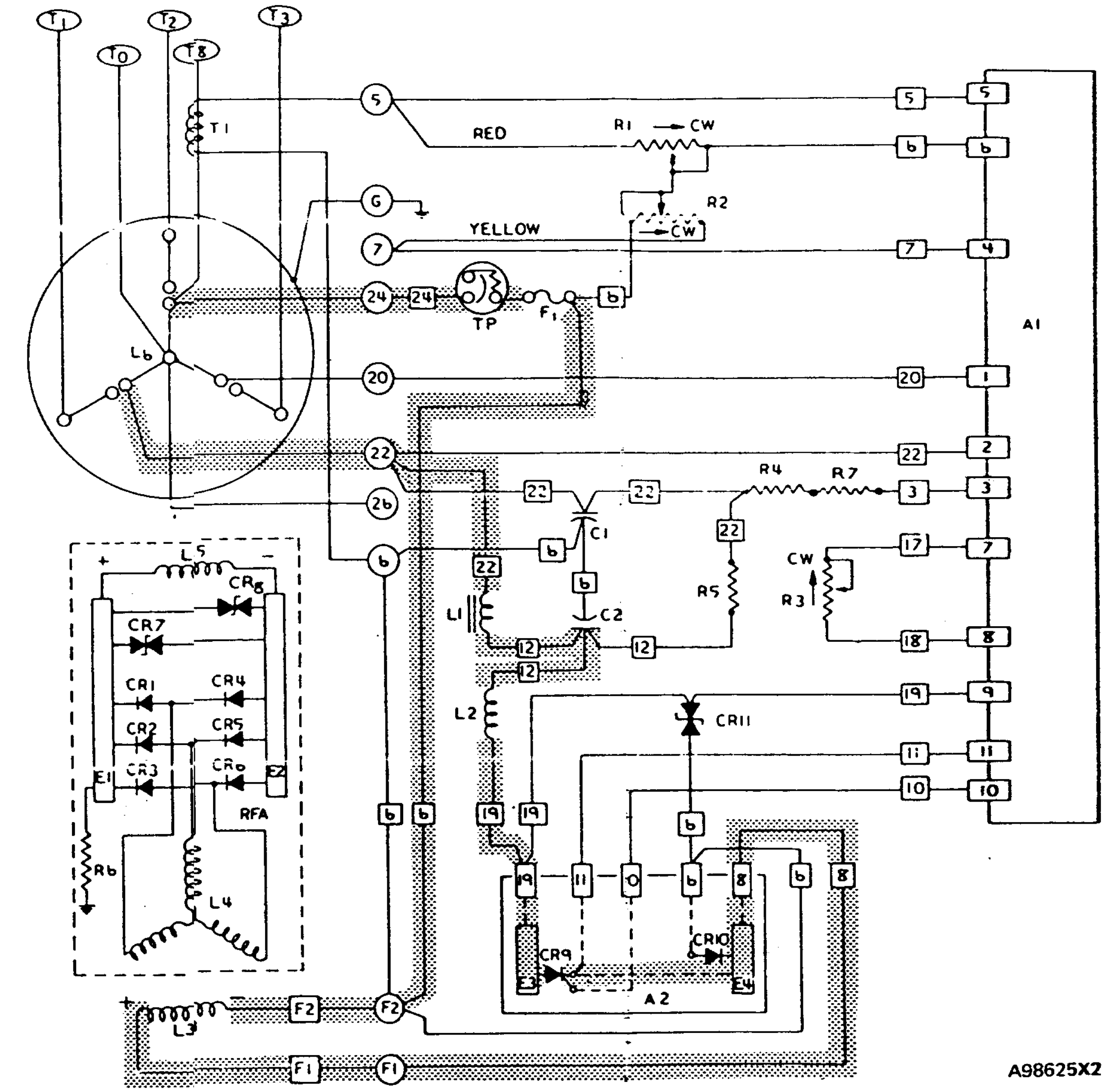



*A2 RECTIFIER MODULE*

E3 SCR Heat sink
E4 Field rectifier heat sink
CR9 Controlled rectifier




**FOR SR 4 GENERATORS**
**LINE TO NEUTRAL POWER FOR EXCITATION AND REGULATION***




**FOR SR 4 GENERATORS**
**LINE TO LINE POWER FOR EXCITATION AND REGULATION****

*C*

| *SR 4 GENERATORS (Line to Neutral Power For Excitation & Regulation) | |
|---|---|
| INCLUDES | 447, 448 and 449 frame — 208 V ONLY (With Layer Wound Rotor) |
| | All other frames (Random & Layer Wound Rotors) |
| DOES NOT INCLUDE | 580 frames |
| | 447, 448 and 449 frame (With Layer Wound Rotor) |

A1 REGULATOR MODULE
A2 RECTIFIER MODULE
C1,3 RFI SUPPRESSION CAPACITOR
C2 SUPPRESSION CAPACITOR
CR1-6 ROTATING RECTIFIERS
CR7,8 SURGE SUPPRESSION DIODES
CR9 CONTROLLED RECTIFIER
CR10 FIELD RECTIFIER
CR11 SURGE SUPPRESSSION DIODE
E1 POSITIVE HEAT SINK
E2 NEGATIVE HEAT SINK
E3 SCR HEAT SINK
E4 FIELD RECTIFIER HEAT SINK
F1 FUSE
L1 SUPPRESSION REACTOR
L2 SCR REACTOR
L3 EXCITER FIELD
L4 EXCITER ARMATURE
L5 ROTATING FIELD
L6 STATOR
*TP THERMAL PROTECTOR
R1 VOLTAGE DROOP POTENTIOMETER
R2 VOLTAGE LEVEL RHEOSTAT
R3 REGULATOR GAIN RHEOSTAT
R4 REGULATOR POWER RESISTOR
R5 DAMPING RESISTOR
R6 SUPPRESSION RESISTOR
R7 REGULATOR POWER RESISTOR
RFA REVOLVING FIELD ASSEMBLY
T1 VOLTAGE DROOP TRANSFORMER
○ TERMINAL BOARD NUMBER
□ WIRE NUMBER
▭ SPADE TERMINAL NUMBER

*Thermal protector is not found on some earlier models.

*C*

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NOTE: Current production and replacement A1 modules (black in color) for the line to line generator regulators require a wiring change from that for regulators using earlier A1 modules (brown in color). The lead connections from L1 and C1 change their terminal connections from terminal 22 to terminal 20.

## VOLTAGE BUILD-UP CIRCUIT

To send the gate signal to controlled rectifier (CR9) to let voltage increase from residual magnetism, a circuit goes:

Front spade terminal (19) of rectifier module (A2), through wire (19) to spade terminal (9) of regulator module (A1).

Through regulator module (A1) to spade terminal (10).

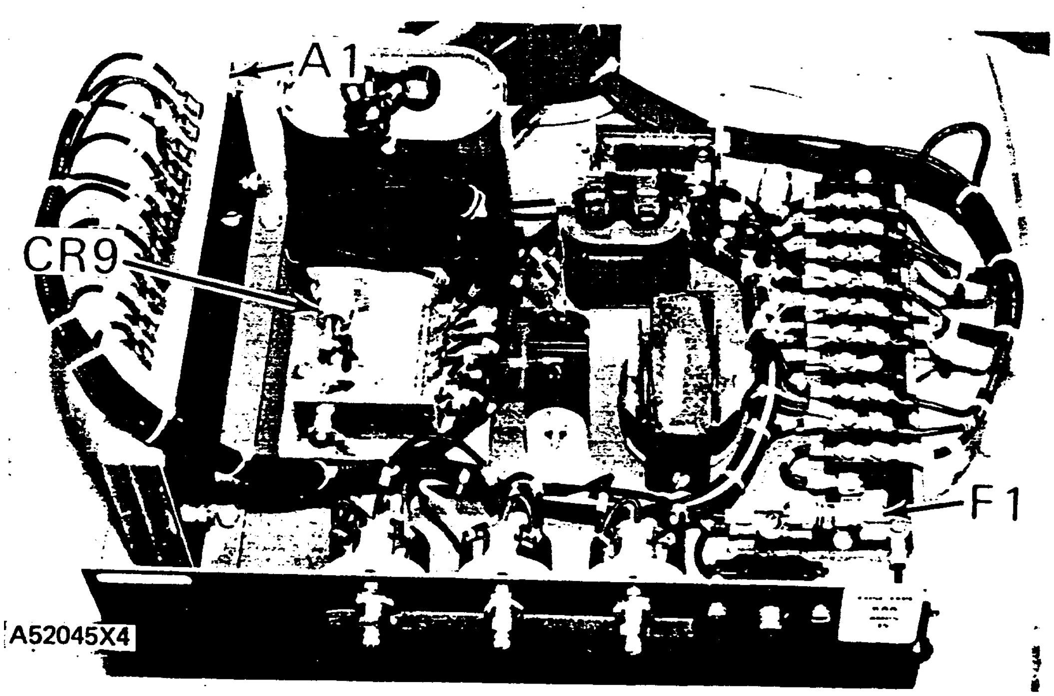
From spade terminal (10) of regulator module (A1) through wire (10) to spade terminal (10) of rectifier module (A2).

From spade terminal (10) on rectifier module (A2) to the gate terminal on controlled rectifier (CR9).

**NOTE: The voltage build-up circuit in regulator module (A1) has a normally closed relay, a diode rectifier and a current limiting impedance in it.**

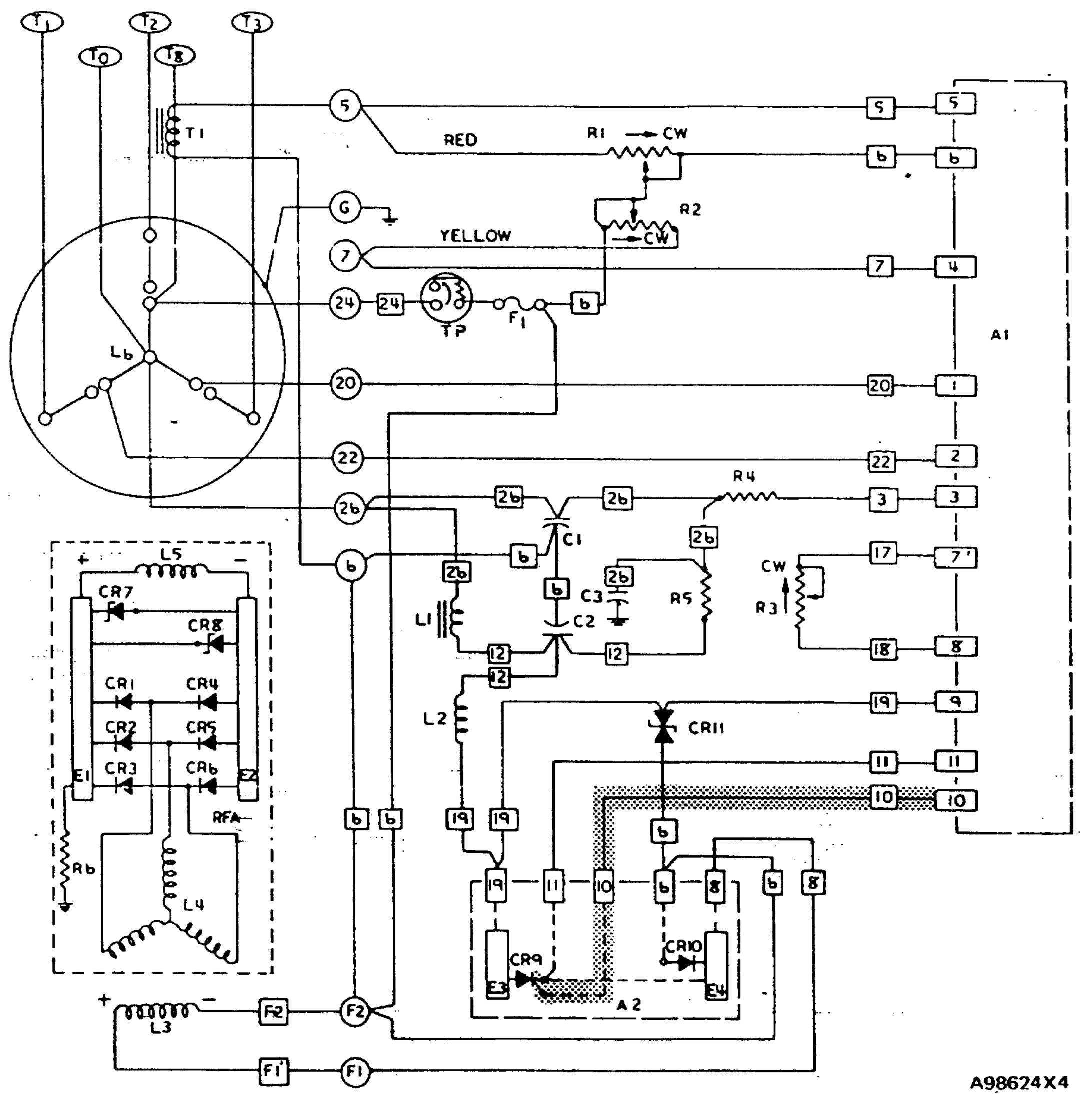
When generator voltage at the relay coil is at pickup value (60 to 70% of rated voltage), the coil causes the relay contact to open. Another circuit in regulator module (A1) sends the gate signal to controlled rectifier (CR9) one time each cycle. When engine speed is lowered, voltage at the relay coil is lower. When the voltage is less than the drop-out voltage, the relay contact closes. Pickup voltage is generated at an engine rpm less than the factory setting of low idle rpm. The relay contact will open and close rapidly at an engine speed of approximately 800 to 900 rpm. If it is necessary to operate the engine at a speed less than the factory setting of low idle, either fuse (F1) must be removed or a single pole, single-throw toggle switch must be installed between fuse (F1) and terminal (24) in place of wire (24). The switch rating must be 250 volts, 15 amperes. When the fuse (F1) is removed or the switch is open, the voltage can not go up and no damage can come to the regulator.

Regulator module (A1) is sealed in an insulation of epoxy. Inside the epoxy module (A1) are resistors, capacitors, rectifiers, zener diodes, transistors and amplifiers in circuits that are fastened to terminals (1 thru 11). This component is only available as a complete unit:

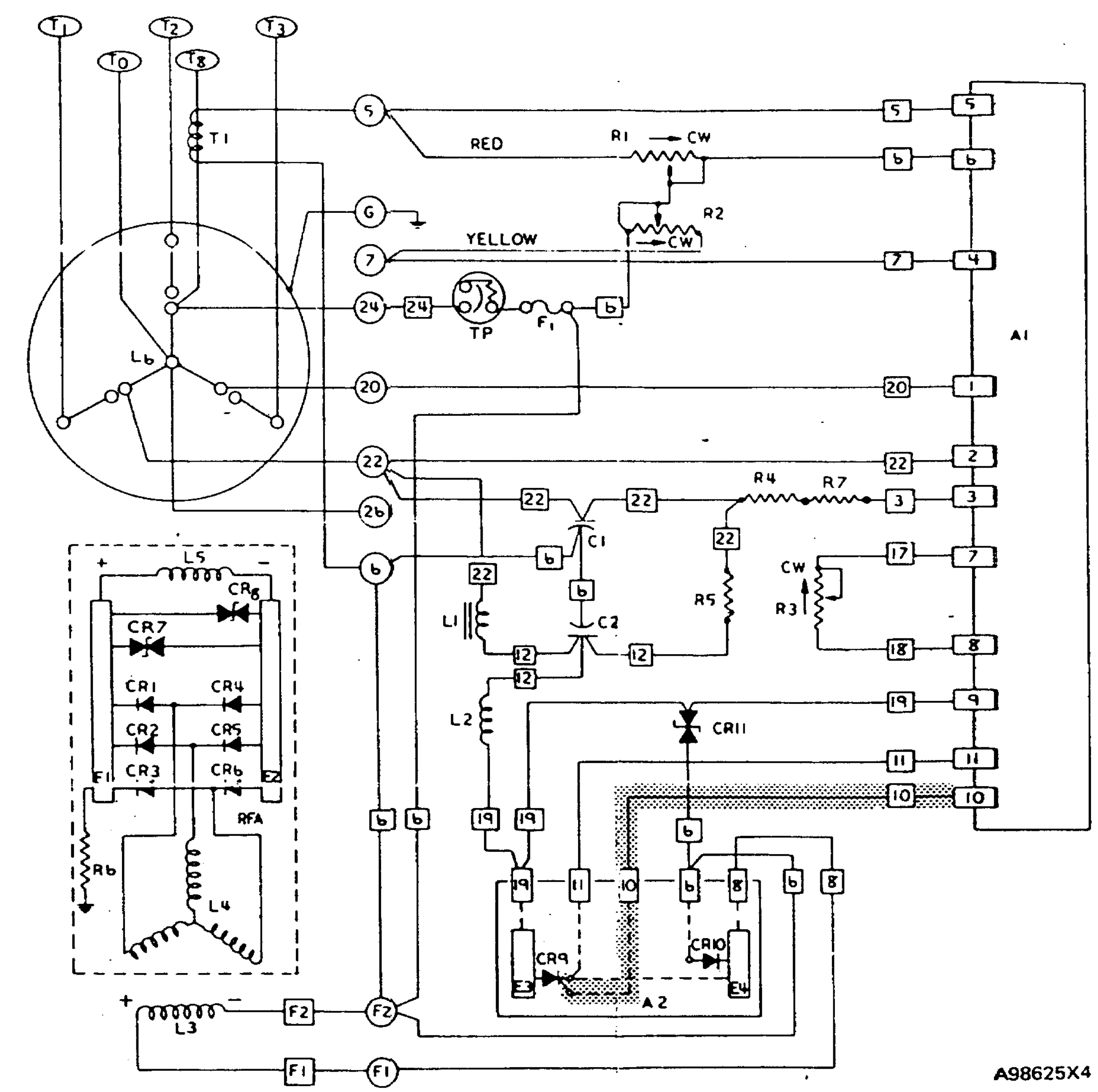



*GENERATOR REGULATOR ASSEMBLY*

A1 Regulator module
CR9 Controlled rectifier
F1 Fuse




FOR SR 4 GENERATORS
LINE TO NEUTRAL POWER FOR EXCITATION AND REGULATION*




FOR SR 4 GENERATORS
LINE TO LINE POWER FOR EXCITATION AND REGULATION**

C

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|---|---|
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A1 REGULATOR MODULE
A2 RECTIFIER MODULE
C1,3 RFI SUPPRESSION CAPACITOR
C2 SUPPRESSION CAPACITOR
CR1-6 ROTATING RECTIFIERS
CR7,8 SURGE SUPPRESSION DIODES
CR9 CONTROLLED RECTIFIER
CR10 FIELD RECTIFIER
CR11 SURGE SUPPRESSSION DIODE
E1 POSITIVE HEAT SINK
E2 NEGATIVE HEAT SINK
E3 SCR HEAT SINK
E4 FIELD RECTIFIER HEAT SINK
F1 FUSE
L1 SUPPRESSION REACTOR
L2 SCR REACTOR
L3 EXCITER FIELD
L4 EXCITER ARMATURE
L5 ROTATING FIELD
L6 STATOR
*TP THERMAL PROTECTOR
R1 VOLTAGE DROOP POTENTIOMETER
R2 VOLTAGE LEVEL RHEOSTAT
R3 REGULATOR GAIN RHEOSTAT
R4 REGULATOR POWER RESISTOR
R5 DAMPING RESISTOR
R6 SUPPRESSION RESISTOR
R7 REGULATOR POWER RESISTOR
RFA REVOLVING FIELD ASSEMBLY
T1 VOLTAGE DROOP TRANSFORMER
O TERMINAL BOARD NUMBER
□ WIRE NUMBER
▭ SPADE TERMINAL NUMBER

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C

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**NOTE:** Current production and replacement A1 modules (black in color) for the line to line generator regulators require a wiring change from that for regulators using earlier A1 modules (brown in color). The lead connections from L1 and C1 change their terminal connections from terminal 22 to terminal 20.

C **FLYBACK CIRCUIT**

A circuit from the negative (-) end to the positive (+) end of the exciter field (L3) permits a current flow in' the exciter field, when the controlled rectifier (CR9) is "turned off." That is, when (T0) is negative and (T1) is positive. The flow is as follows:

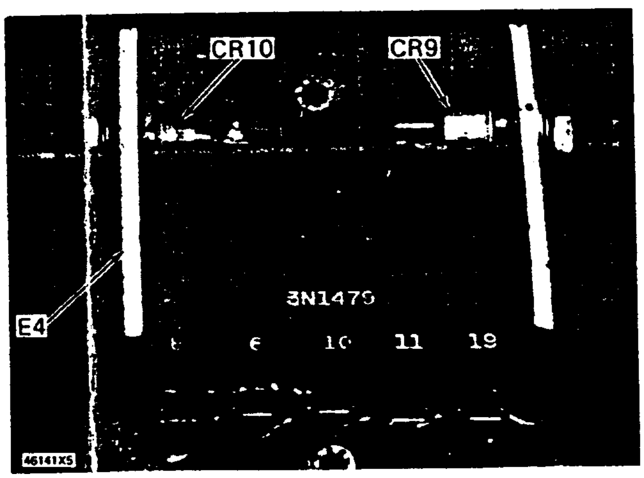
From the negative (-) end of exciter field (L3) through wire (F2) to terminal (F2).

From terminal (F2) through wire (6) to spade terminal (6) on rectifier module (A2).

From spade terminal (6) on-rectifier module (A2) to the anode (terminal end) of field rectifier (CR10).

From the cathode (stud end) of field rectifier (CR10) to heat sink (E4).

From heat sink (E4) to spade terminal (8) on rectifier module (A2).

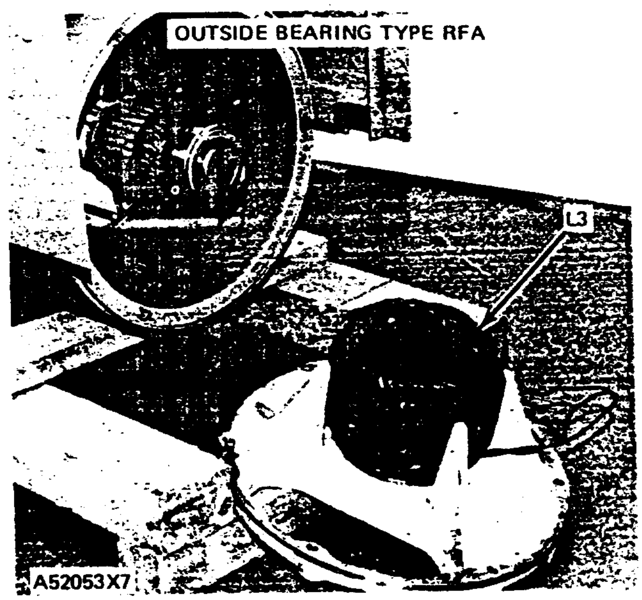



*A2 RECTIFIER MODULE*

CR9 Controlled rectifier
CR10 Field rectifier
E4 Heat sink

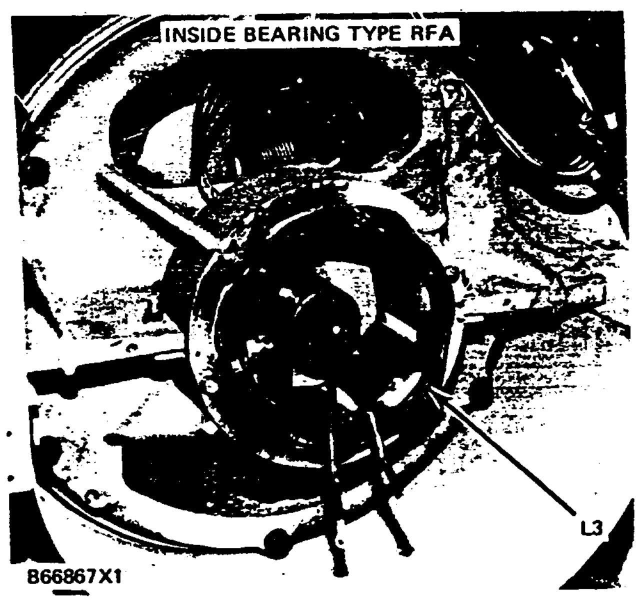
From spade terminal (8) on rectifier module (A2) through wire (8) to terminal (F1).

When the current flow goes through exciter field (L3) it causes a magnetic field around the coils of the field. The strength of the magnetic field is in relation to the current going through the exciter field. An increase in current flow makes the magnetic field stronger, and a decrease in current flow makes the magnetic field weaker. When the current through the exciter field (L3) stops because controlled rectifier (CR9) has cut-off the flow, the magnetic field strength is maximum. The field now starts to collapse (grow weaker) back into the conductors of the coil. As a result of this, a voltage is induced in the coil. The voltage causes a current flow, as shown in the circuit schematic. This circuit helps to keep current flow through exciter field (L3) constant.



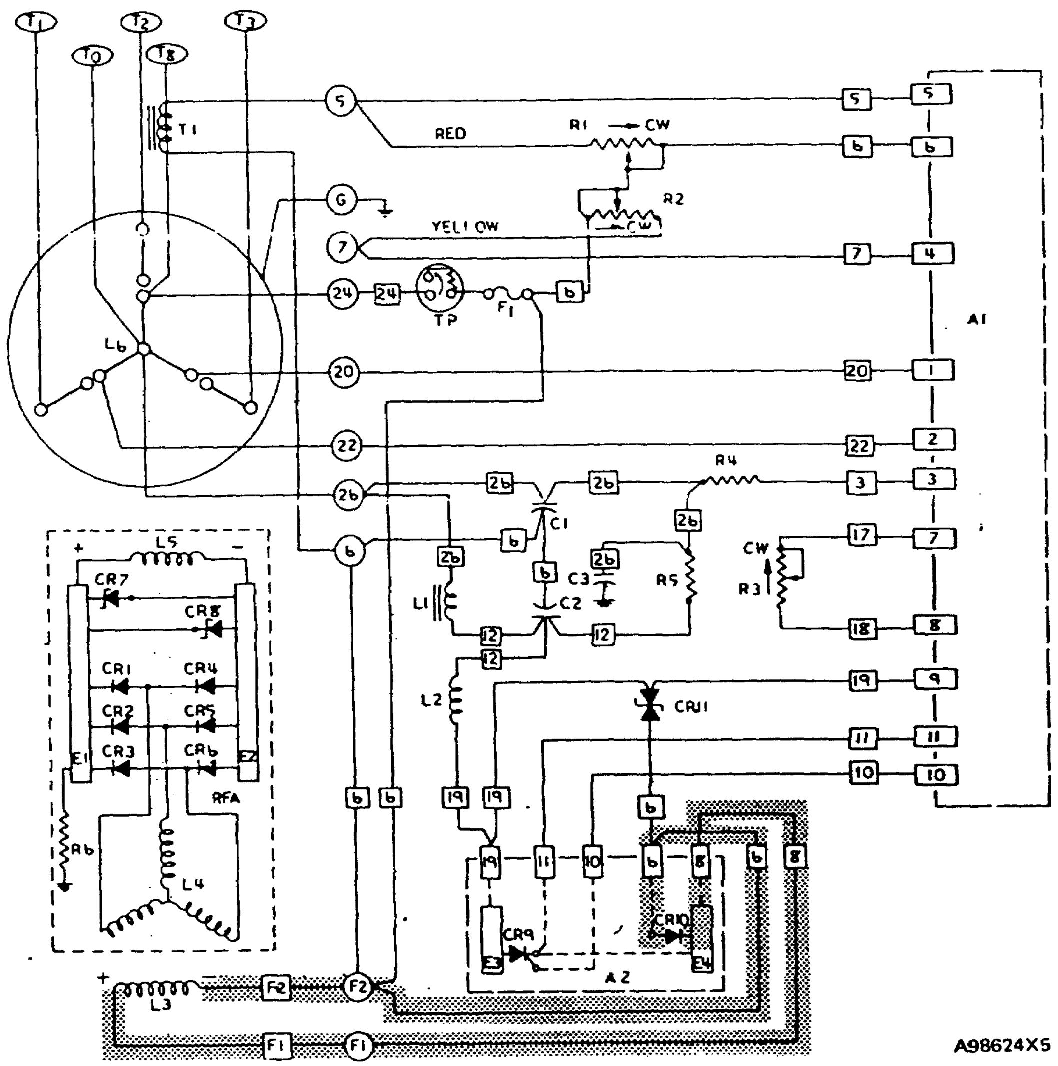

*END HOUSING*

L3 Exciter field

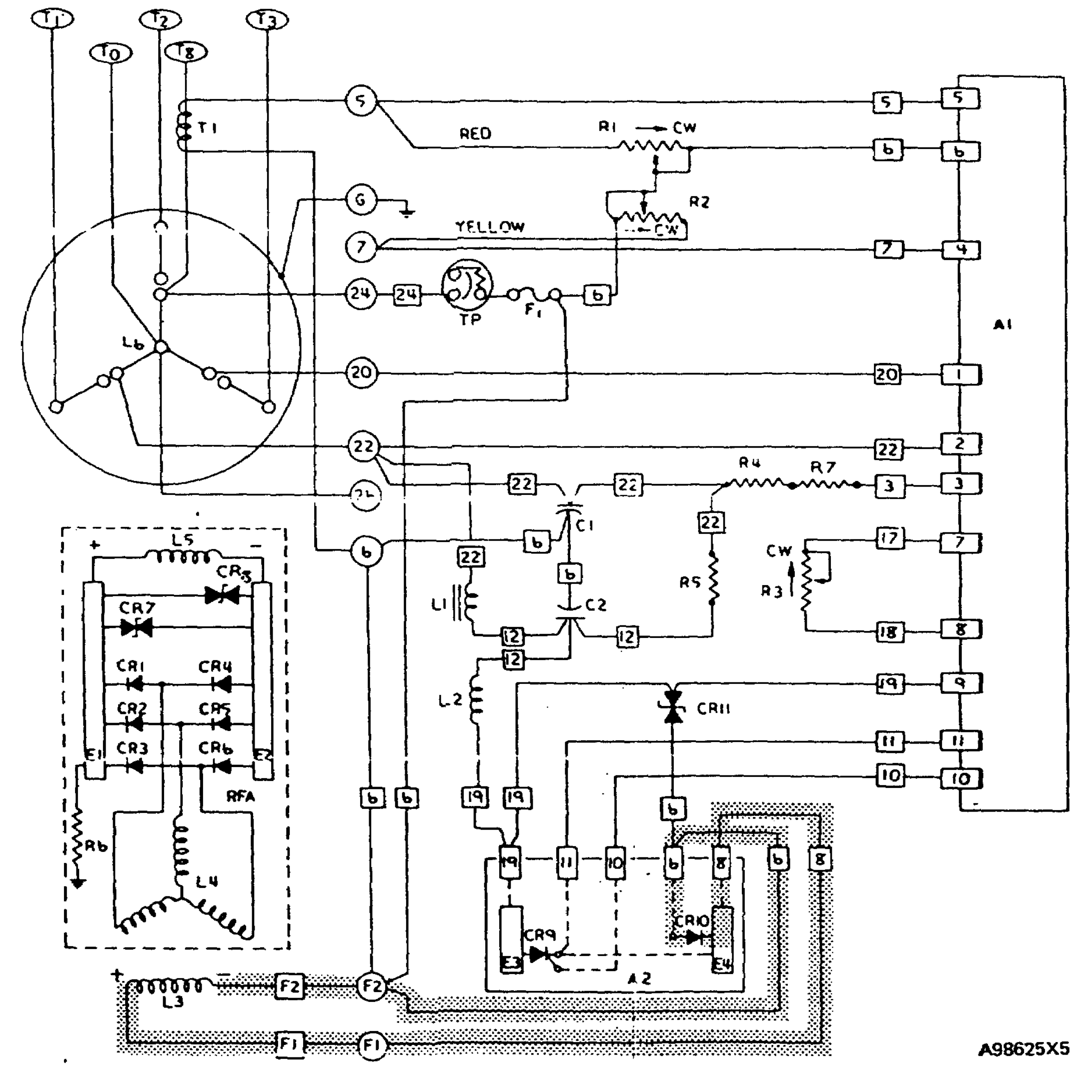



*INSIDE GENERATOR HOUSING*

L3 Exciter Field




FOR SR 4 GENERATORS
LINE TO NEUTRAL POWER FOR EXCITATION AND REGULATION*




FOR SR 4 GENERATORS
LINE TO LINE POWER FOR EXCITATION AND REGULATION**

C

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| | 447, 448 and 449 frame (With Layer Wound Rotor) |

| | |
|---|---|
| A1 | REGULATOR MODULE |
| A2 | RECTIFIER MODULE |
| C1,3 | RFI SUPPRESSION CAPACITOR |
| C2 | SUPPRESSION CAPACITOR |
| CR1-6 | ROTATING RECTIFIERS |
| CR7,8 | SURGE SUPPRESSION DIODES |
| CR9 | CONTROLLED RECTIFIER |
| CR10 | FIELD RECTIFIER |
| CR11 | SURGE SUPPRESSSION DIODE |
| E1 | POSITIVE HEAT SINK |
| E2 | NEGATIVE HEAT SINK |
| E3 | SCR HEAT SINK |
| E4 | FIELD RECTIFIER HEAT SINK |
| F1 | FUSE |
| L1 | SUPPRESSION REACTOR |
| L2 | SCR REACTOR |
| L3 | EXCITER FIELD |
| L4 | EXCITER ARMATURE |
| L5 | ROTATING FIELD |
| L6 | STATOR |
| *TP | THERMAL PROTECTOR |
| R1 | VOLTAGE DROOP POTENTIOMETER |
| R2 | VOLTAGE LEVEL RHEOSTAT |
| R3 | REGULATOR GAIN RHEOSTAT |
| R4 | REGULATOR POWER RESISTOR |
| R5 | DAMPING RESISTOR |
| R6 | SUPPRESSION RESISTOR |
| R7 | REGULATOR POWER RESISTOR |
| RFA | REVOLVING FIELD ASSEMBLY |
| T1 | VOLTAGE DROOP TRANSFORMER |
| O | TERMINAL BOARD NUMBER |
| □ | WIRE NUMBER |
| ▭ | SPADE TERMINAL NUMBER |

C

| **SR 4 GENERATORS (Line to Line Power For Excitation & Regulation) | |
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*Thermal protector is not found on some earlier models.

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## OUTPUT VOLTAGE SENSING

Voltage sensing by regulator module (A1) is through a circuit from connections in phases 1 and 3 of stator (L6) to terminals (20) and (22). The circuit then goes:

From terminals (20) and (22) through wires (20) and (22) to spade terminals (1) and (2) on regulator module (A1).

Through regulator module (A1) to spade terminal (5).

From spade terminal (5) on regulator module (A1) through wire (5) through the red wire to voltage droop rheostat (R1).

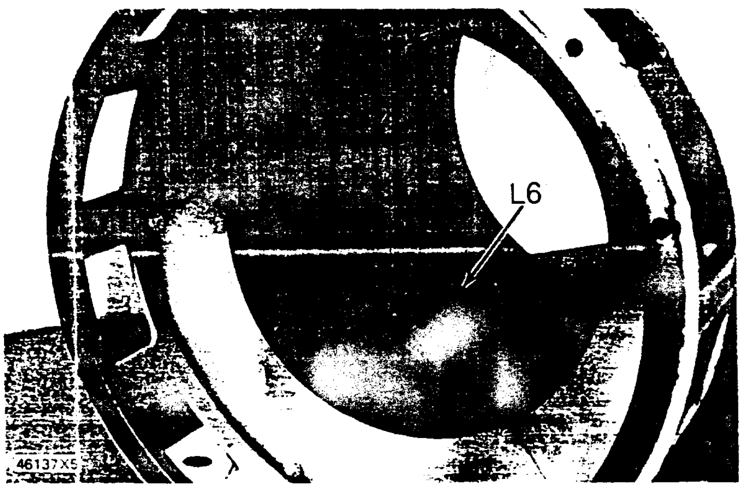
From voltage droop rheostat (R1) to voltage level rheostat (R2).

From voltage level rheostat (R2) through wire (6) to fuse (F1).

Through fuse (F1 ), thermal protector (TP) and wire (24) to terminal (24).

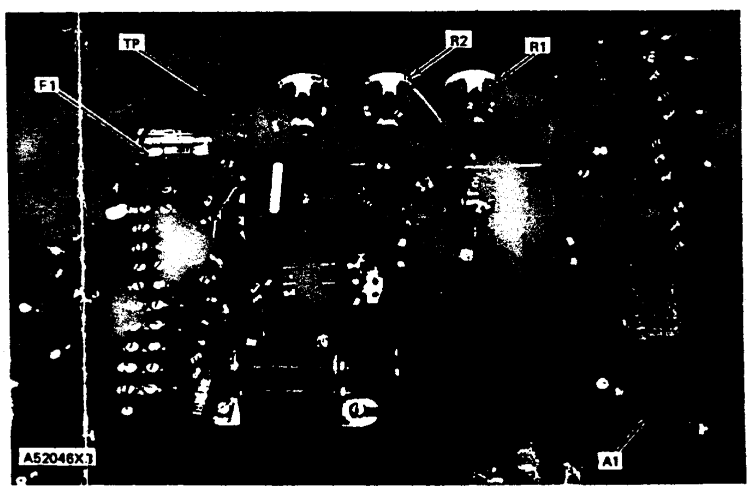
From terminal (24) to the tapped connection in phase 2 of stator (L6).

The voltage divider in regulator module (A1) has a capacitive reactance. Since capacitive reactance will go up as frequency goes down or will go down as frequency goes up. the regulator module gives a voltage control on the basis of volts per hertz.



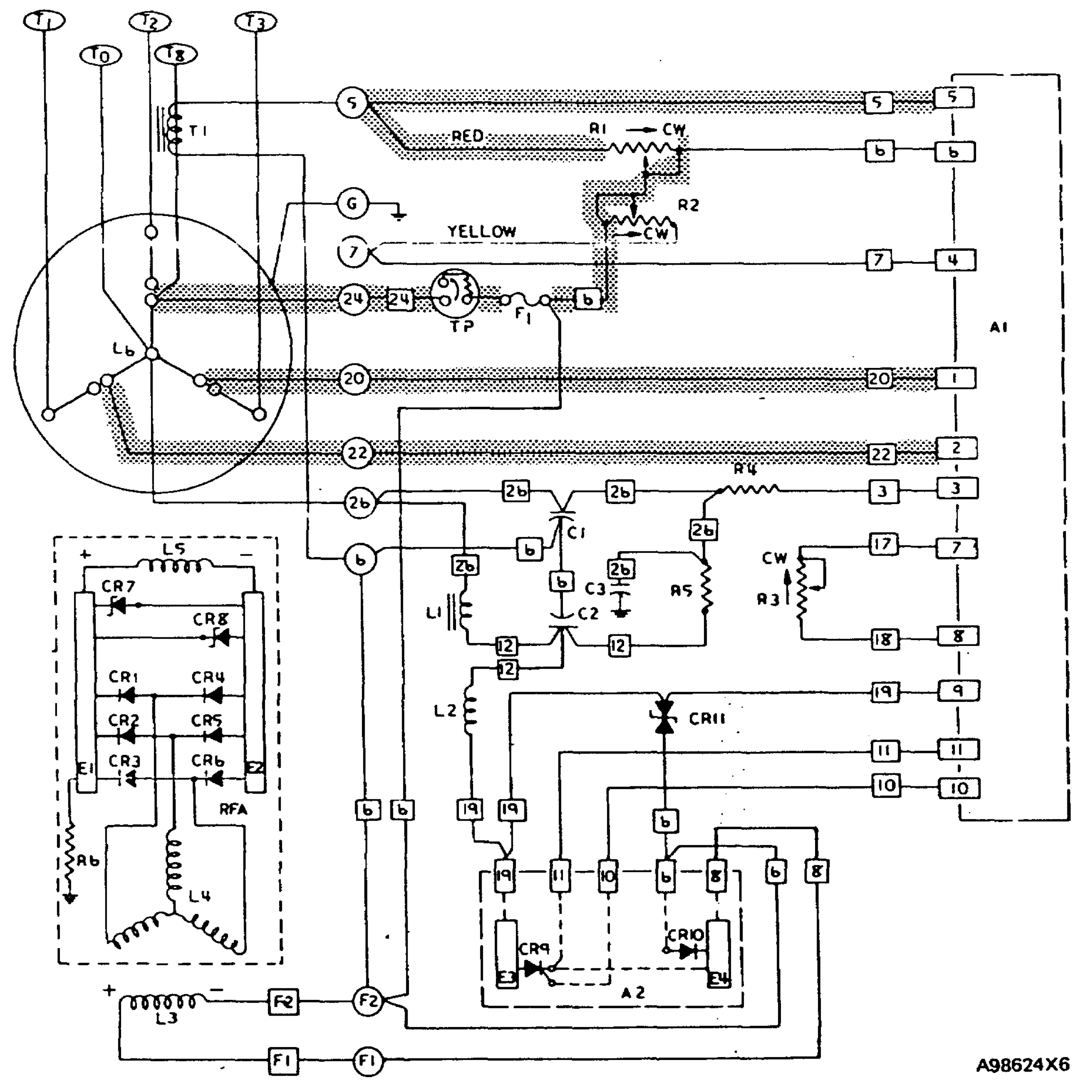

GENERATOR HOUSING

L6 Stator

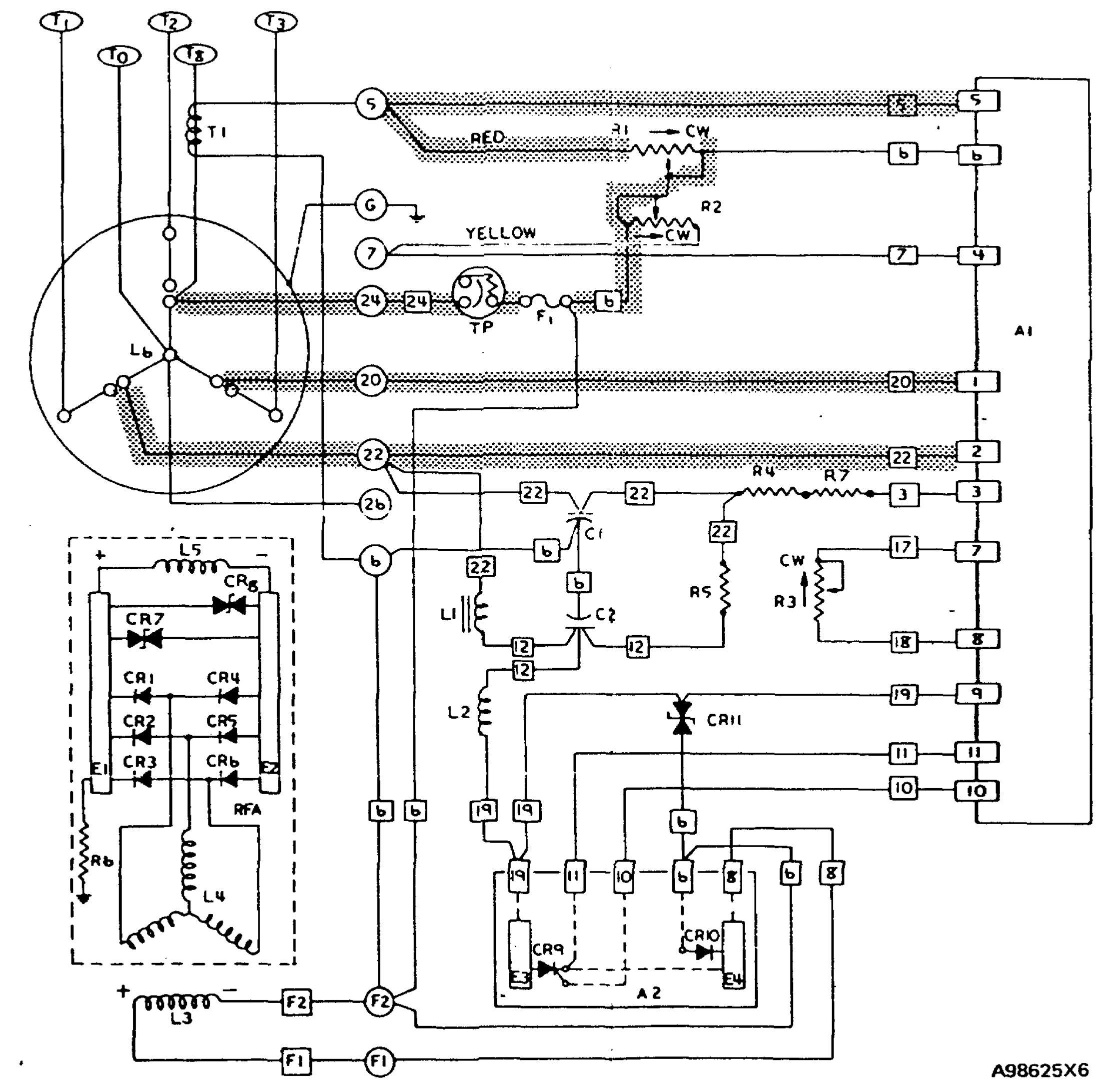



GENERATOR REGULATOR ASSEMBLY

A1 Regulator module
F1 Fuse
R1 Voltage droop potentiometer
R2 Voltage level rheostat
TP Thermal protector




FOR SR 4 GENERATORS
LINE TO NEUTRAL POWER FOR EXCITATION AND REGULATION*




FOR SR 4 GENERATORS
LINE TO LINE POWER FOR EXCITATION AND REGULATION**

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- A1 REGULATOR MODULE
- A2 RECTIFIER MODULE
- C1,3 RFI SUPPRESSION CAPACITOR
- C2 SUPPRESSION CAPACITOR
- CR1-6 ROTATING RECTIFIERS
- CR7,8 SURGE SUPPRESSION DIODES
- CR9 CONTROLLED RECTIFIER
- CR10 FIELD RECTIFIER
- CR11 SURGE SUPPRESSSION DIODE
- E1 POSITIVE HEAT SINK
- E2 NEGATIVE HEAT SINK
- E3 SCR HEAT SINK
- E4 FIELD RECTIFIER HEAT SINK
- F1 FUSE
- L1 SUPPRESSION REACTOR
- L2 SCR REACTOR
- L3 EXCITER FIELD
- L4 EXCITER ARMATURE
- L5 ROTATING FIELD
- L6 STATOR
- *TP THERMAL PROTECTOR
- R1 VOLTAGE DROOP POTENTIOMETER
- R2 VOLTAGE LEVEL RHEOSTAT
- R3 REGULATOR GAIN RHEOSTAT
- R4 REGULATOR POWER RESISTOR
- R5 DAMPING RESISTOR
- R6 SUPPRESSION RESISTOR
- R7 REGULATOR POWER RESISTOR
- RFA REVOLVING FIELD ASSEMBLY
- T1 VOLTAGE DROOP TRANSFORMER
- O TERMINAL BOARD NUMBER
- ▢ WIRE NUMBER
- ▭ SPADE TERMINAL NUMBER

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**NOTE: Current production and replacement A1 modules (black in color) for the line to line generator regulators require a wiring change from that for regulators using earlier A1 modules (brown in color). The lead connections from L1 and C1 change their terminal connections from terminal 22 to terminal 20.**

## POWER SUPPLY FOR REGULATOR MODULE A1

### For SR 4 Generators with line to neutral power for excitation & regulation

The following circuit gives power to the regulator module (A1):

From neutral (T0) of stator (L6) to terminal (261).

From terminal (26) through wire (26) to regulator power resistor (R4).

Through regulator power resistor (R4) and wire (3) to regulator module (A1).

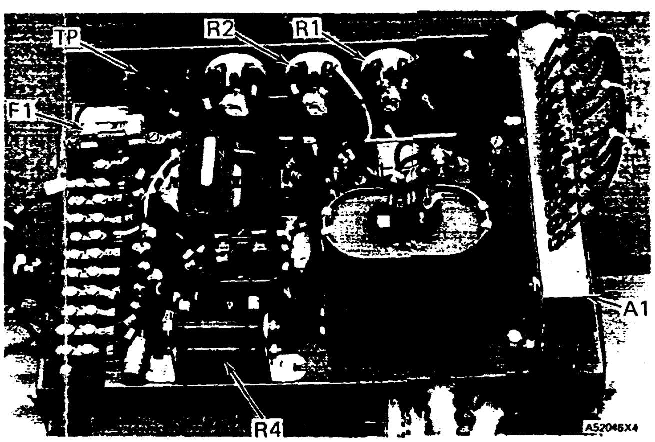
Through regulator module (A1) to terminal (6).

From terminal (6) of regulator module (A1) to potentiometer (R1) (voltage droop).

From potentiometer (R1) (voltage droop) to rheostat (R2) (voltage level).

From rheostat (R2) (voltage level) through wire (6). fuse (F1), thermal protector (TP) and wire (24) to terminal (24).

From terminal (24) to the tapped connection of phase 2 of stator (L6).




*GENERATOR REGULATOR ASSEMBLY*

### For SR 4 Generators with line to line power for excitation & regulation

The following circuit gives power to the regulator module (A1):

From the tapped connected of phase 1 of stator (L6) to terminal (22).

From terminal (22) through wire (22) to regulator power resistors (R4,7).

Through regulator power resistors (R4,7) and wire (3) of regulator (A1).

Through regulator module (A1) to terminal (6).

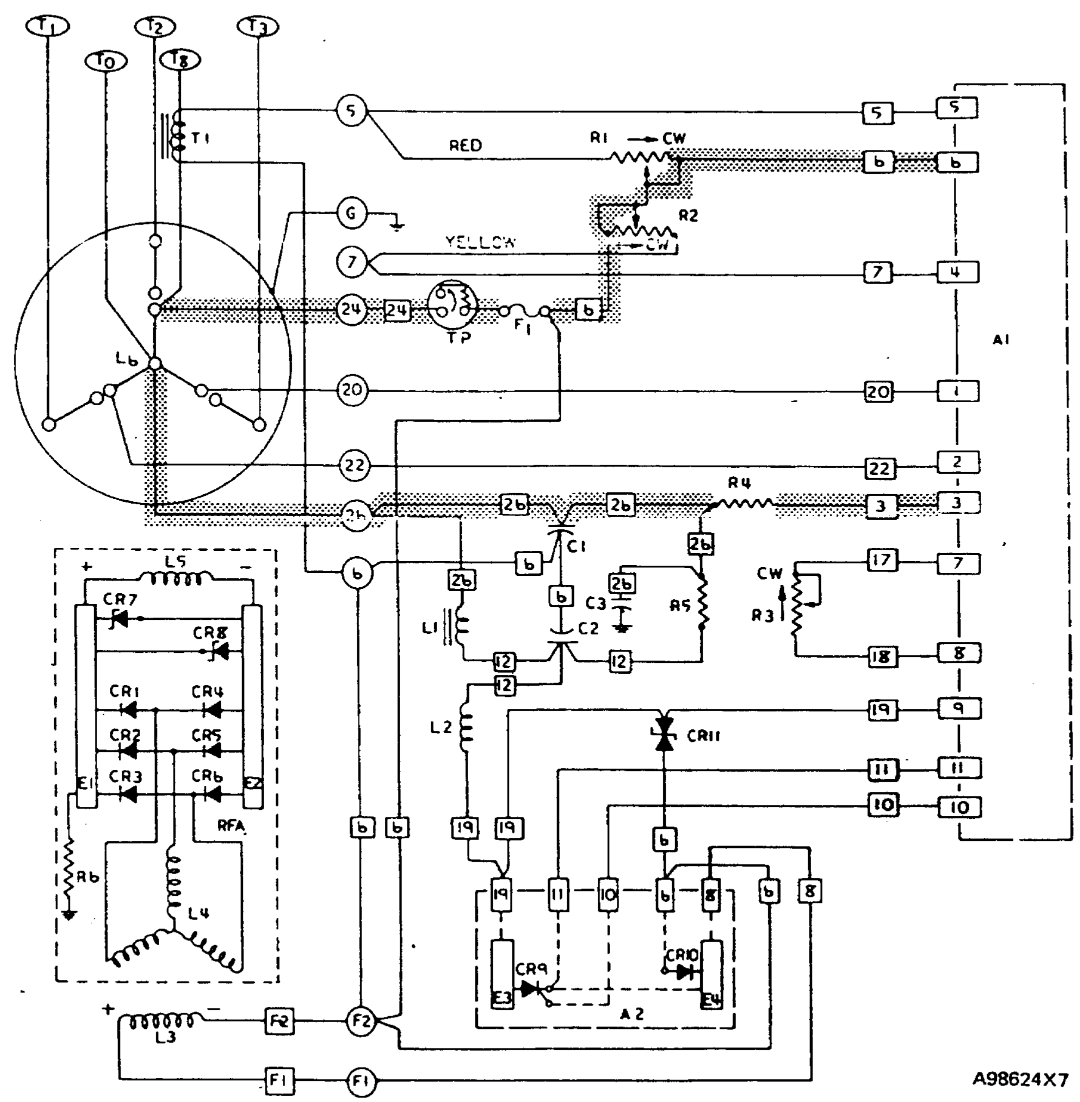
From terminal (6) of regulator module (A1) to potentiometer (R1) (voltage droop).

From potentiometer (R1) (voltage droop) to rheostat (R2) (voltage level).

From rheostat (R2) (voltage level) through wire (6), fuse (F1), thermal protector (TP) and wire (24) to terminal (24).

From terminal (24) to the tapped connection of phase 2 of stator (L6).

A1 Regulator module
F1 Fuse
R1 Voltage droop potentiometer
R2 Voltage level rheostat
R4 Regulator power resistor
TP Thermal protector




FOR SR 4 GENERATORS
LINE TO NEUTRAL POWER FOR EXCITATION AND REGULATION*

C

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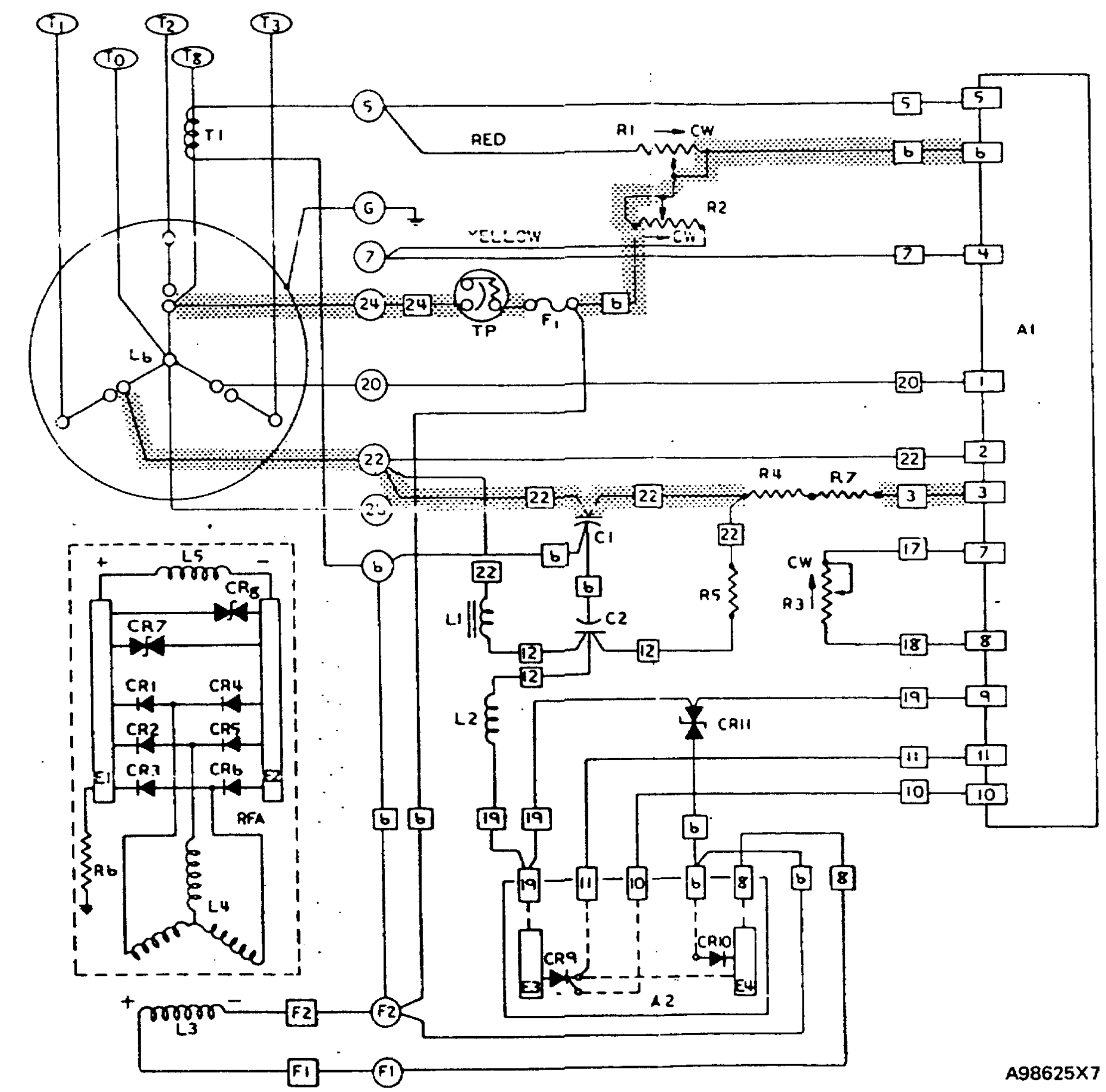


FOR SR 4 GENERATORS
LINE TO LINE POWER FOR EXCITATION AND REGULATION**

C

A1 REGULATOR MODULE
A2 RECTIFIER MODULE
C1,3 RFI SUPPRESSION CAPACITOR
C2 SUPPRESSION CAPACITOR
CR1-6 ROTATING RECTIFIERS
CR7,8 SURGE SUPPRESSION DIODES
CR9 CONTROLLED RECTIFIER
CR10 FIELD RECTIFIER
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E3 SCR HEAT SINK
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R1 VOLTAGE DROOP POTENTIOMETER
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R5 DAMPING RESISTOR
R6 SUPPRESSION RESISTOR
R7 REGULATOR POWER RESISTOR
RFA REVOLVING FIELD ASSEMBLY
T1 VOLTAGE DROOP TRANSFORMER
○ TERMINAL BOARD NUMBER
□ WIRE NUMBER
▭ SPADE TERMINAL NUMBER

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## REGULATOR GAIN CIRCUIT

Regulator gain is an adjustment to compensate for voltage drop caused by generator load or governor speed droop. A circuit to control regulator gain goes:

From spade terminal (7) of regulator module (A1) through: wire (17) to regulator gain rheostat (R3).

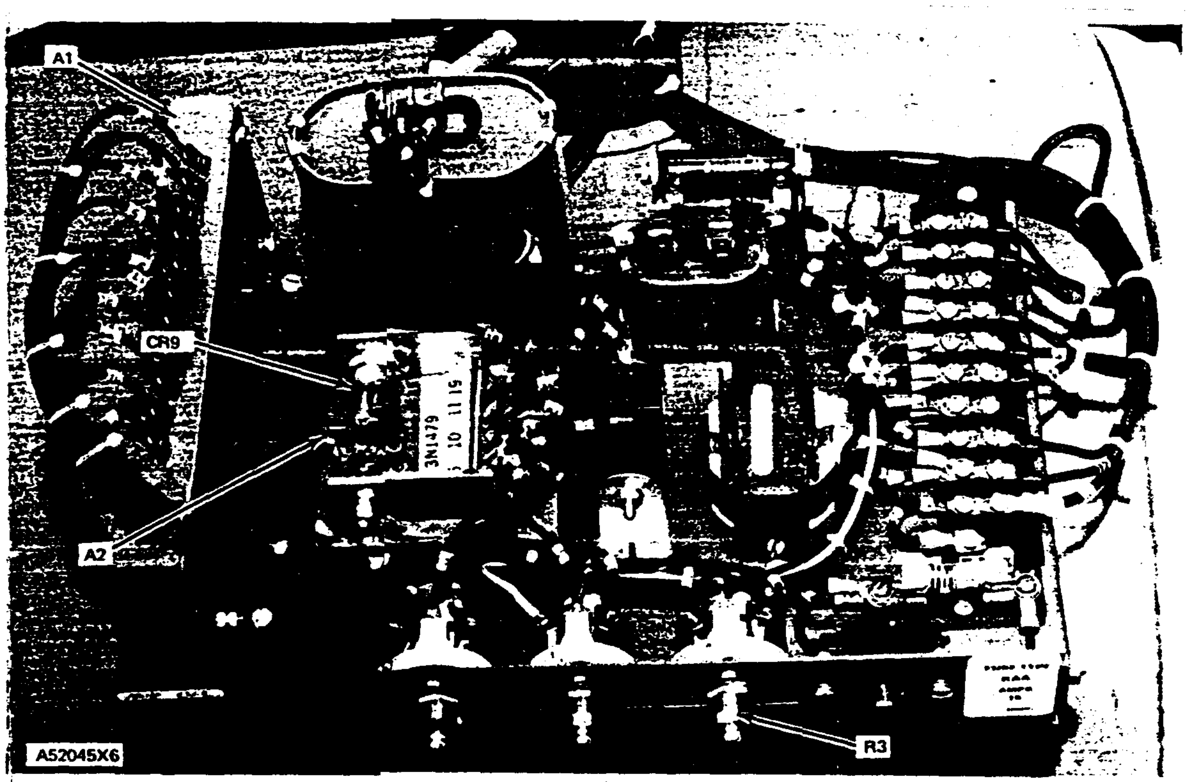
From regulator gain rheostat (R3) through wire (18) to spade terminal (8) on regulator module (A1).

There is a feedback circuit to regulator module (A1). This circuit gives a voltage signal to regulator module (A1). The signal changes at the same rate as the voltage of exciter field (L3). The following circuit gives the signal voltage.

From the cathode of controlled rectifier (CR9) to terminal (11) on rectifier module (A2).

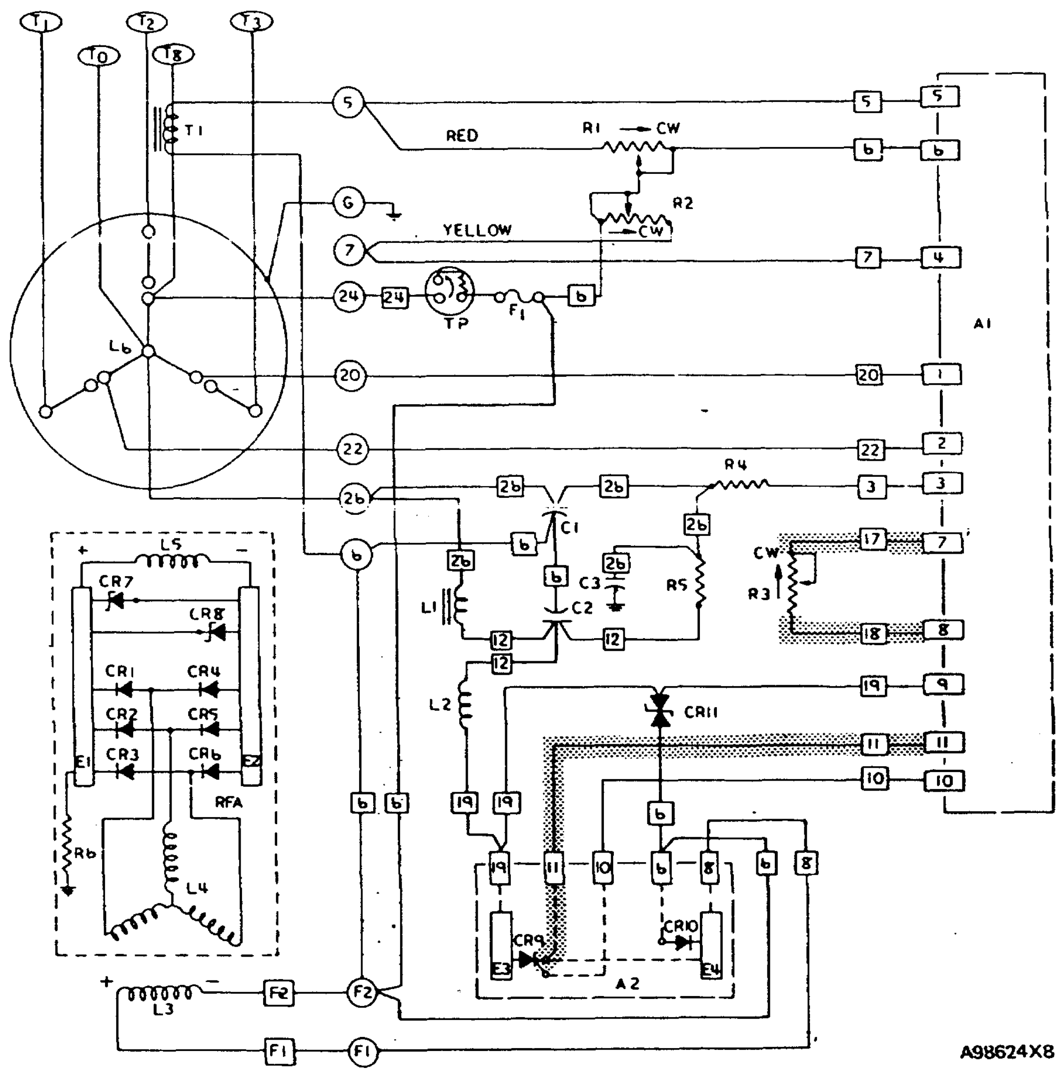
From terminal (11) through wire (11) to terminal (11) of regulator module (A1).

The input received by the regulator module is used by electrical circuits in the module to determine regulator gain.

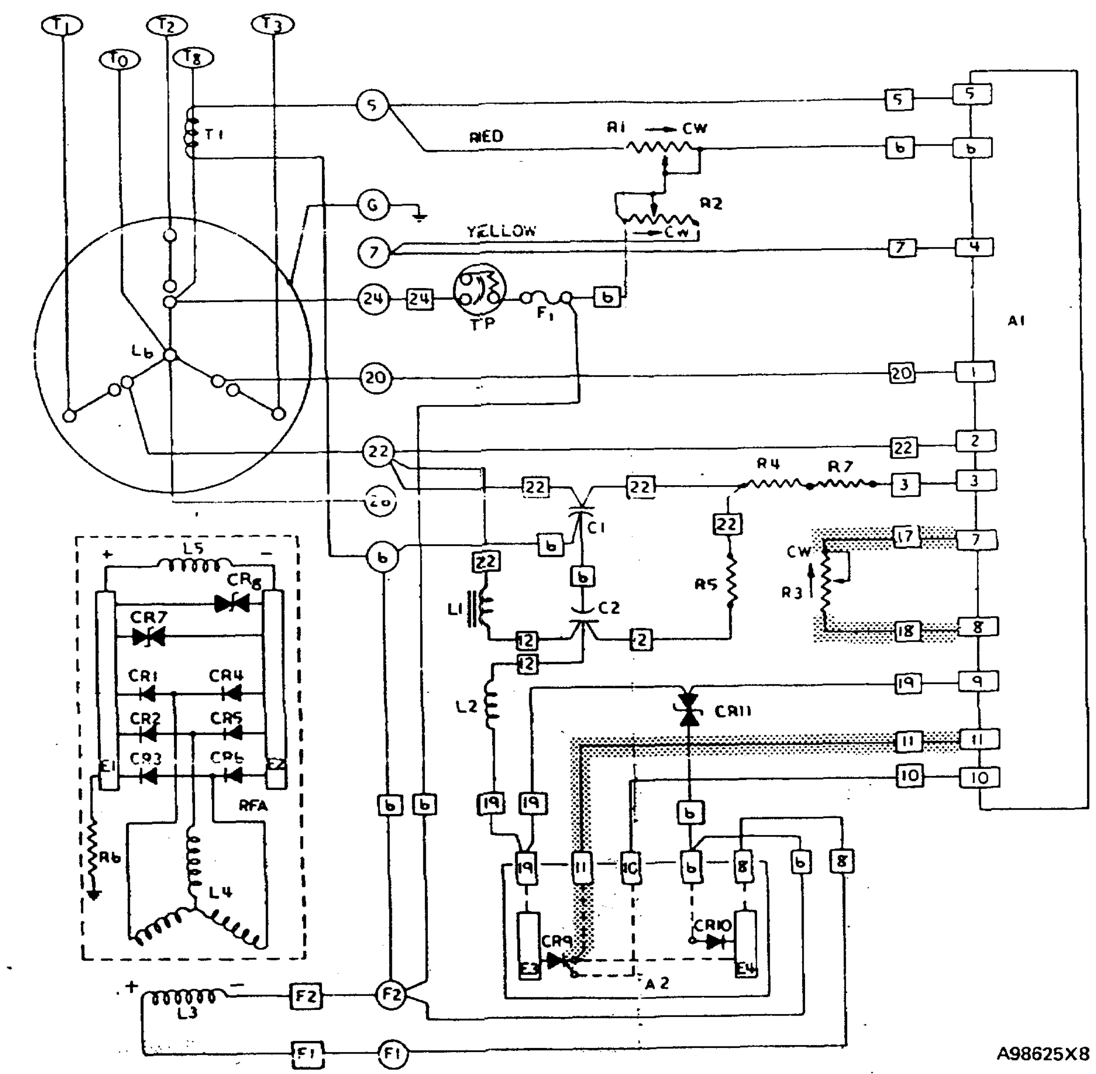



*GENERATOR REGULATOR ASSEMBLY*

| | |
|---|---|
| A1 | Regulator module |
| A2 | Rectifier module |
| CR9 | Controlled rectifier |
| R3 | Regulator gain rheostat |




FOR SR 4 GENERATORS
LINE TO NEUTRAL POWER FOR EXCITATION AND REGULATION*




FOR SR 4 GENERATORS
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C2 SUPPRESSION CAPACITOR
CR1-6 ROTATING RECTIFIERS
CR7,8 SURGE SUPPRESSION DIODES
CR9 CONTROLLED RECTIFIER
CR10 FIELD RECTIFIER
CR11 SURGE SUPPRESSSION DIODE
E1 POSITIVE HEAT SINK
E2 NEGATIVE HEAT SINK
E3 SCR HEAT SINK
E4 FIELD RECTIFIER HEAT SINK
F1 FUSE
L1 SUPPRESSION REACTOR
L2 SCR REACTOR
L3 EXCITER FIELD
L4 EXCITER ARMATURE
L5 ROTATING FIELD
L6 STATOR
*TP THERMAL PROTECTOR
R1 VOLTAGE DROOP POTENTIOMETER
R2 VOLTAGE LEVEL RHEOSTAT
R3 REGULATOR GAIN RHEOSTAT
R4 REGULATOR POWER RESISTOR
R5 DAMPING RESISTOR
R6 SUPPRESSION RESISTOR
R7 REGULATOR POWER RESISTOR
RFA REVOLVING FIELD ASSEMBLY
T1 VOLTAGE DROOP TRANSFORMER
O TERMINAL BOARD NUMBER
□ WIRE NUMBER
▭ SPADE TERMINAL NUMBER

*Thermal protector is not found on some earlier models.

C

| **SR 4 GENERATORS (Line to Line Power For Excitation & Regulation) | |
|---|---|
| INCLUDES | 580 frames |
| | 447, 448, and 449 frames With Layer Wound Rotor) |
| DOES NOT INCLUDE | 447, 448 and 449 frame — 208 V (With Layer Wound Rotor) |
| | All others (Random & Layer Wound Rotors) |

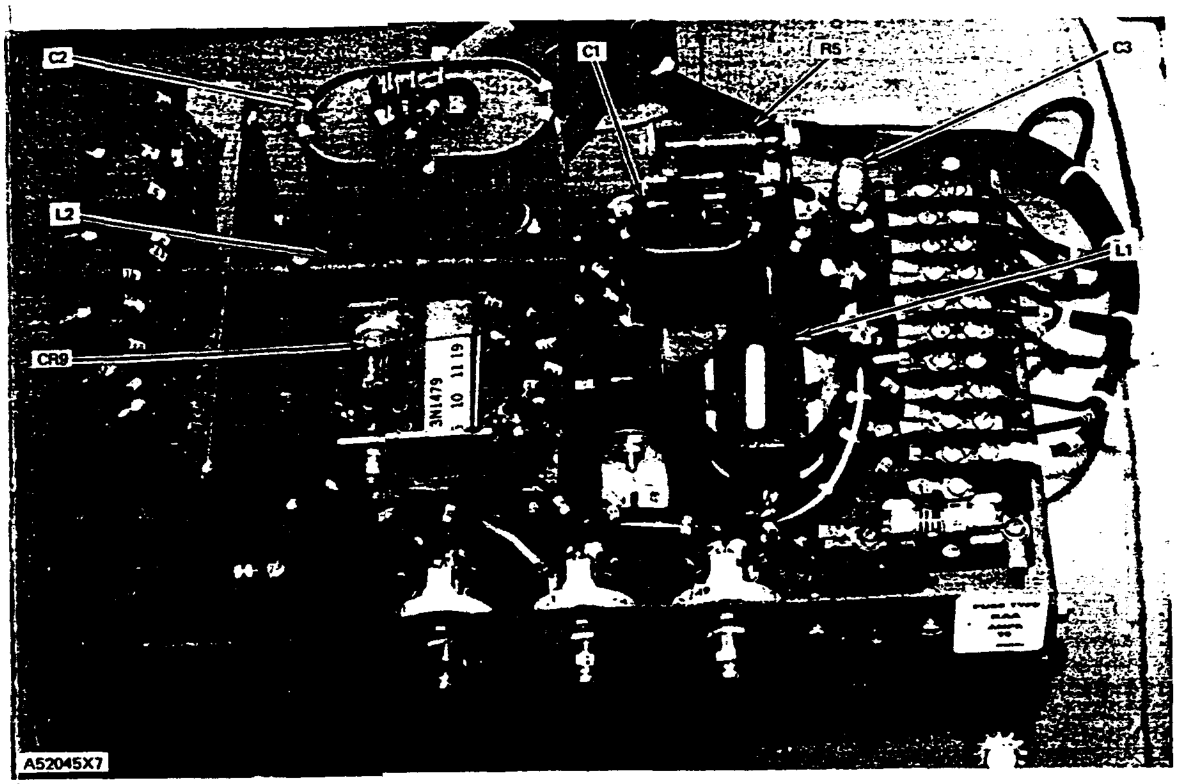
**NOTE:** Current production and replacement A1 modules (black in color) for the line to line generator regulators require a wiring change from that for regulators using earlier A1 modules (brown in color). The lead connections from L1 and C1 change their terminal connections from terminal 22 to terminal 20.

## RADIO FREQUENCY INTERFERENCE (RFI) SUPPRESSION

When controlled rectifier (CR9) "turns on", it is very rapid (approximately three microseconds). This causes a shock load on the stator (L6). AC voltage shocks till cause harmonics (frequency multiplications) at radio frequencies. For many applications, these harmonics will cause electronic equipment to operate very badly.

The action of suppression capacitor (C2) and SCR reactor (L2) gives a reduction of the shock load on stator (L6). As said earlier, suppression capacitor (C2) gets a charge during the time (T0) is positive and (T8) is negative and controlled rectifier (CR9) is not "turned on".

When a gate signal is sent to controlled rectifier (CR9) the first surge of current is caused by the voltage charge on (C2). The current increase time is made longer by SCR reactor (L2). Suppression reactor (L1) and RFI suppression capacitors (C1) and (C3) cause a reduction of interference with radio frequencies. Damping Resistor (R5) is connected in parallel with suppression reactor (L1) to prevent any voltage oscillations that start in (L1). RFI suppression capacitor (C1) is connected from neutral to (T8) on phase 2 of stator (L6). Suppression capacitor (C3) is connected from neutral to generator frame ground. To get the maximum effect from the RFI suppression capacitors, the generator frame must be connected to an earth or building (station) ground.

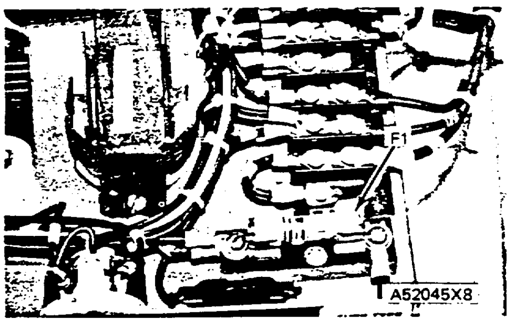



*GENERATOR REGULATOR ASSEMBLY*

C1,3 RFI Suppression capacitors
C2 Suppression capacitor
CR9 Controlled rectifier
L1 Suppression reactor
L2 SCR Reactor
R5 Damping resistor

## *C* PROTECTION OF GENERATOR CIRCUITS

The SR 4 Generator regulator and excitation circuits use many components for protection. Fuse (F1) is the type that opens very rapidly and gives protection against secondary damage caused by another component failure. This type of fuse is used because it is specifically made to work in circuits that have semiconductors. If the fuse needs replacement, it is important that the same amperage rating and type is used. A larger amperage rating or a fuse that does not open rapidly will not prevent damage to other components.



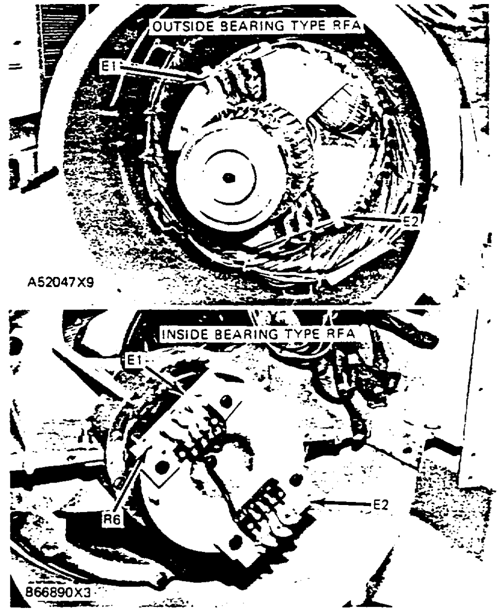

*F1 FUSE*

Surge suppression diode (CR11) prevents too high voltages that are abnormal (not normal) and transient (temporary) from causing damage to controlled rectifier (CR9) or field rectifier (CR10). Inside of rectifier module (A2) there are resistance capacitance circuits connected from anode to cathode of both controlled rectifier (CR9) and field rectifier (CR10). These circuits give added protection for abnormal transient peak voltages that can cause damage at (CR9) or (CR10).


*GENERATOR REGULATOR ASSEMBLY*

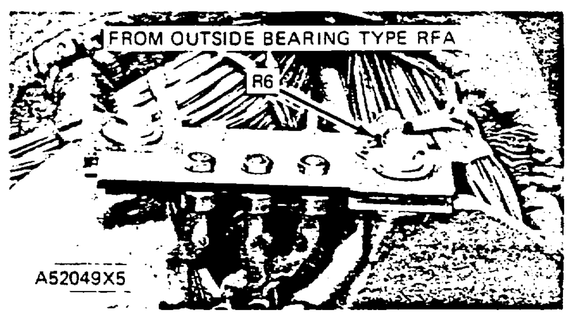
**A2. Rectifier module. CR9. Controlled rectifier. CR10. Field rectifier. CR11. Surge suppression diode.**

Surge suppression diodes (CR7) and (CR8) are connected in parallel, electrically. CR7 is installed on the positive heat sink (E1) and CR8 is installed on the negative heat sink (E2). These diodes are connected in parallel to give the current capacity needed for suppression of any abnormal transient peak voltages that can cause damage to the rotating rectifiers (CR1 thru CR6).




*ROTATING FIELD ASSEMBLY (RFA)*

**E1. Positive heat sink. E2. Negative heat sink. R6. Suppression resistor.**

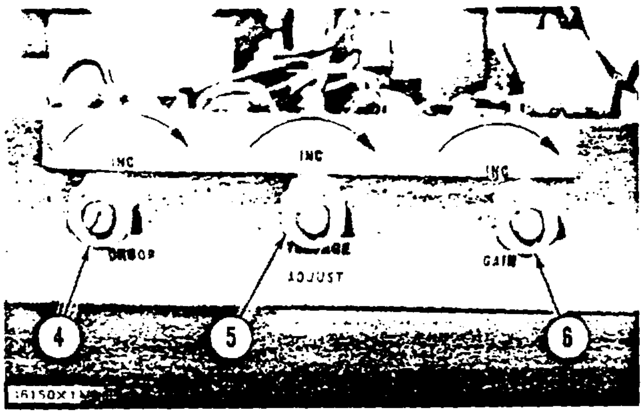



*E1 POSITIVE HEAT SINK*

**R6. Suppression resistor.**

Suppression resistor (R6) gives a low resistance circuit from the insulated windings to the shaft and cores of the revolving field assembly (RFA). It this resistor was not installed, air friction on the windings and heat sinks can cause electrostatic charges. These charges can cause voltages to become high enough to destroy the insulation. Resistor (R6) is a 27,000 ohm resistor that lets these electrostatic charges run off as they are generated and prevents any voltage build-up. Because of the Value and power rating of resistor (R6). a ground failure at any point on the revolving field assembly (RFA) will not prevent the generator from operating normally and it will not cause damage to (R6).

## *D* REGULATOR ADJUSTMENT




*GENERATOR VOLTAGE ADJUSTMENT CONTROLS*

**4. Voltage droop control. 5. Voltage level control. 6. Regulator gain control.**

Adjustment of voltage level rheostat (R2) is done with voltage level control (5). This is done when an increase or decrease of the generator voltage is necessary to get correct line voltage. Adjustment of regulator gain rheostat (R3) is done with regulator gain control (6). Adjustment of regulator gain rheostat (R3) and voltage level rheostat (R2) must be made in sequence to get exact generator voltage regulation when the engine is equipped with either a mechanical speed droop or an isochronous (0% speed droop) governor. Do the steps that follow:

1. Remove the access panel on the left side of the generator. Loosen the locknuts on the voltage adjustment controls. Turn voltage droop control (4) fully counterclockwise.

2. Start the engine. Increase engine speed to nameplate rating.

3. Adjust voltage level control (5) to give nameplate rated voltage. Put a normal load on the generator. Let the generator warm up to normal temperature for operation.

4. Remove the load from the generator. Adjust the voltage level control if necessary. Put a normal load on the generator. Check generator voltage. If the voltage stays at nameplate rating, regulator gain control (6) is adjusted correctly. Tighten all locknuts.

5. If generator VOLTAGE INCREASES, turn the regulator gain control a small amount counterclockwise. If generator VOLTAGE DECREASES, turn the regulator gain control a small amount clockwise. Remove the load. Adjust the voltage level control if necessary.

6. Put a normal load on the generator. If the voltage does not stay at nameplate. rating see Step 5. If it does, tighten all locknuts and install the access panel.

**NOTE**

**Generator sets equipped with a control panel on top of the generator have the voltage level rheostat in the control panel. The yellow wire from terminal 7 on the terminal strip of the regulator assembly is disconnected. The voltage level rheostat on the control panel is then connected to terminals 6 and 7 on the terminal strip. The same sequence of adjustments must be made.**

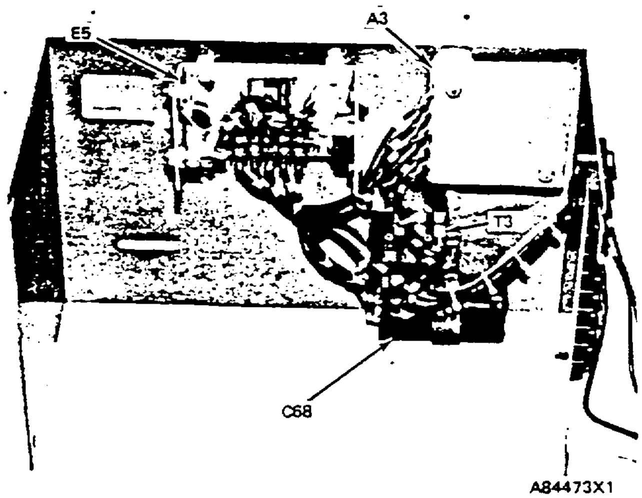
In order to get an even distribution of reactive load and to keep circulating currents to a minimum when two or more generators are operated in parallel. it is necessary to have a specific decrease in voltage, at each generator, with an increase in generator load. This decrease in voltage is the voltage droop. Adjustment of voltage droop potentiometer (R1) is done with voltage droop control (4). Correction to the voltage droop can be made by turning (R1) from counterclockwise for no voltage droop to clockwise for an increase In voltage droop. Adjustment of voltage droop control (4) must be in sequence with voltage level control (5) and regulator gain control (6). See OPERATION GUIDE for engine.

## SERIES BOOST ATTACHMENT

Series boost lets SR 4 generators stay on the line, for approximately 10 seconds, when there is a short in the generating or load circuits. This gives circuit breakers a chance to trip in sequence. When circuit breakers trip in sequence, there is less chance for a loss of power to all of the electrical system.

The series boost panel group has a control module A3. voltage sensing transformer T3 and series boost heat sink E5. Current transformer T2 is external to the panel group.

Voltage sensing transformer T3 gets power from the same terminals on the regulator terminal strip as exciter field L3 (terminals 24 and 22 on 580 frame generators and terminals 24 and 26 on all others). Voltage sensing transformer T3 gives power to control module A3. The electrical action of control module A3 causes a gate signal through wire 34 to the triac on series boost heat sink E5. The triac short circuits current transformer T2. This prevents any series boost effect during normal operation.




*SERIES BOOST ASSEMBLY*

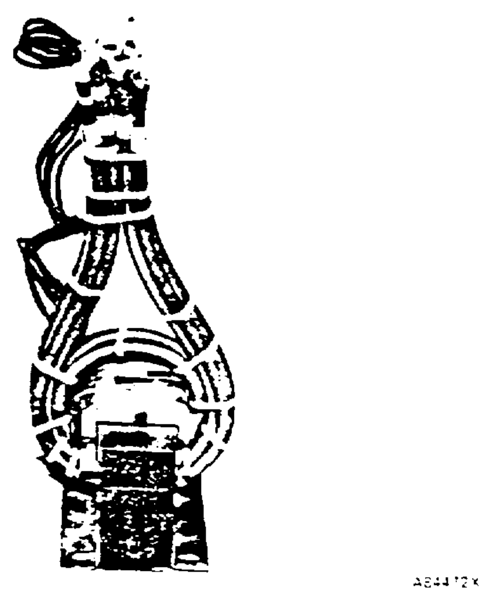
**A3** CONTROL MODULE
**C68** SERIES BOOST CAPACITOR
**E5** SERIES BOOST HEAT SINK
**T3** VOLTAGE SENSING TRANSFORMER

If there is a short circuit that causes the voltage to voltage sensing transformer T3 to drop to a low value, control module A3 will stop the gate signal to the triac. Current from current transformer T2, will go through the bridge rectifier on heat sink E5. be rectified and flow through wire 9 to exciter field L3. This field current will be enough to give at least three times full load current into a short circuit. After approximately 10 seconds electrical action of control module A3 will again cause a gate signal through wire 34 to the triac on series boost heat sink E5. The triac will short circuit current transformer T2. Current flow to exciter field will be zero until the short circuit is corrected.

Series boost connections are not the same for all generator sets. Make reference to Fig. 1 or Fig. 2 for series boost to regulator connection. For series boost current transformer T2 connection, make reference to Fig. 3, Fig. 4, Fig. 5 or Fig. 6.

**NOTE**

**For current transformer connection of machines not shown, make contact with Service Engineering; Caterpillar Tractor Co.**



*CURRENT TRANSFORMER T2*

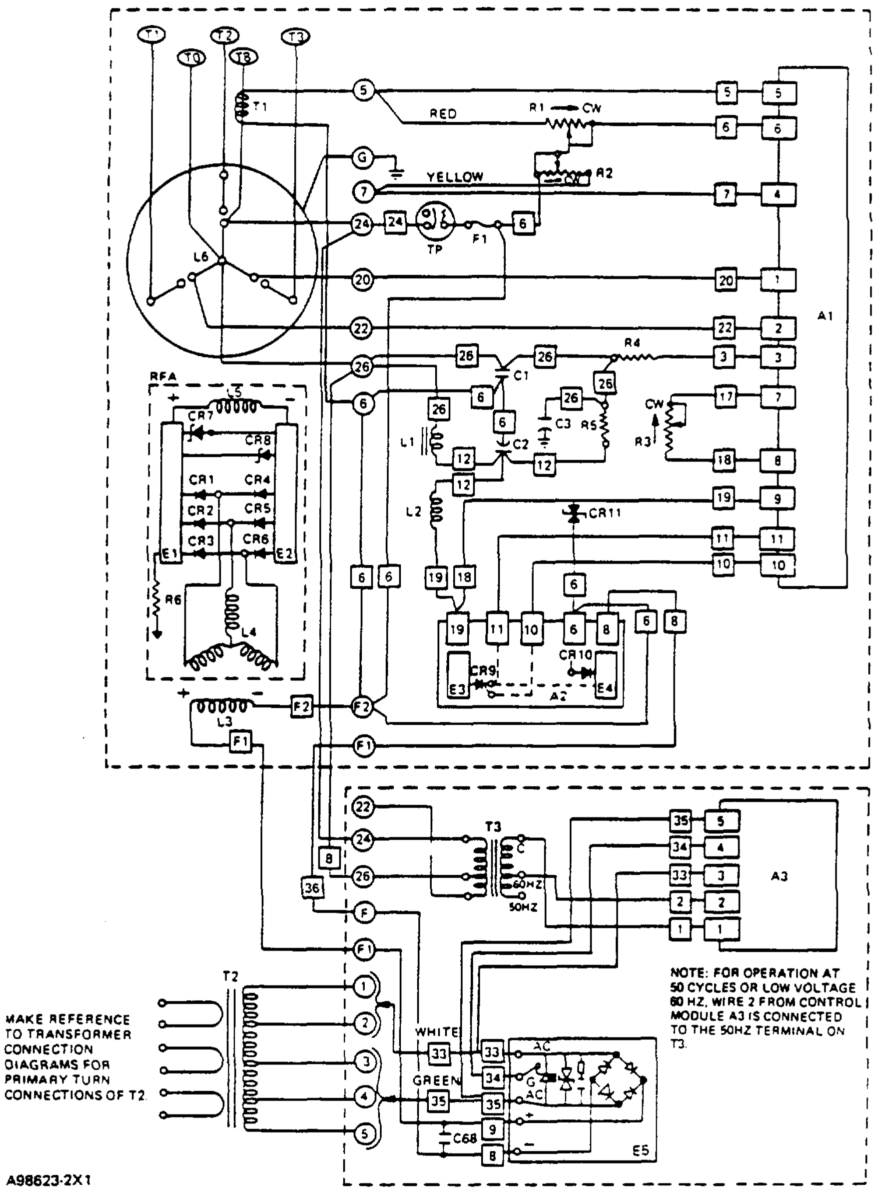



*FIG. 1 SR 4 GENERATOR WITH SERIES BOOST*

*C* **[Includes: 447, 448 & 449 frame (layer wound rotor - 208 V only); and all other frames (random and layer wound rotors) except 580 frame and 447, 448, and 449 frame (with layer wound rotor).]**

| | | | | | |
|---|---|---|---|---|---|
| **A1** | **REGULATOR MODULE** | **E3** | **SCR HEAT SINK** | **R2** | **VOLTAGE LEVEL RHEOSTAT** |
| **A2** | **RECTIFIER MODULE** | **E4** | **FIELD RECTIFIER HEAT SINK** | **R3** | **REGULATOR GAIN RHEOSTAT** |
| **A3** | **CONTROL MODULE** | **ES** | **SERIES BOOST HEAT SINK** | **R4** | **REGULATOR POWER RESISTOR** |
| **C1,3** | **RFI SUPPRESSION CAPACITOR** | **F1** | **FUSE** | **R5** | **DAMPING RESISTOR** |
| **C2** | **SUPPRESSION CAPACITOR** | **L1** | **SUPPRESSION REACTOR** | **R6** | **SUPPRESSION RESISTOR** |
| **C68** | **SERIES BOOST CAPACITOR** | **L2** | **SCR REACTOR** | **RFA** | **REVOLVING FIELD ASSEMBLY** |
| **CR1-6** | **ROTATING RECTIFIERS** | **L3** | **EXCITER FIELD** | **T1** | **VOLTAGE DROOP TRANSFORMER** |
| **CR7,8** | **SURGE SUPPRESSION DIODES** | **L4** | **EXCITER ARMATURE** | **T2** | **CURRENT TRANSFORMER** |
| **CR9** | **CONTROLLED RECTIFIER** | **L5** | **ROTATING FIELD** | **T3** | **VOLTAGE SENSING TRANSFORMER** |
| **CR10** | **FIELD RECTIFIER** | **L6** | **STATOR** | **O** | **TERMINAL BOARD NUMBER** |
| **CR11** | **SURGE SUPPRESSION DIODE** | **TP** | **THERMAL PROTECTOR** | □ | **WIRE NUMBER** |
| **E1** | **POSITIVE HEAT SINK** | **R1** | **VOLTAGE DROOP POTENTIOMETER** | ▭ | **SPADE TERMINAL NUMBER** |

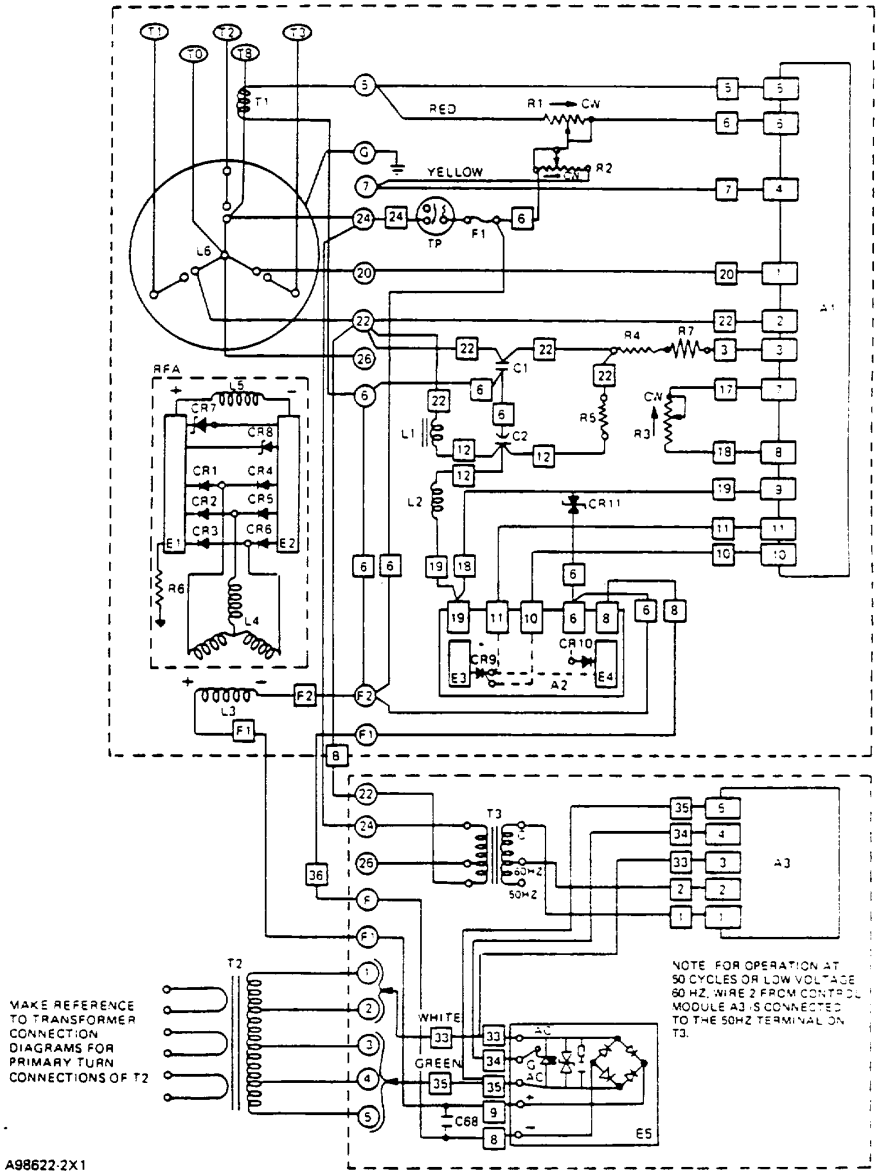
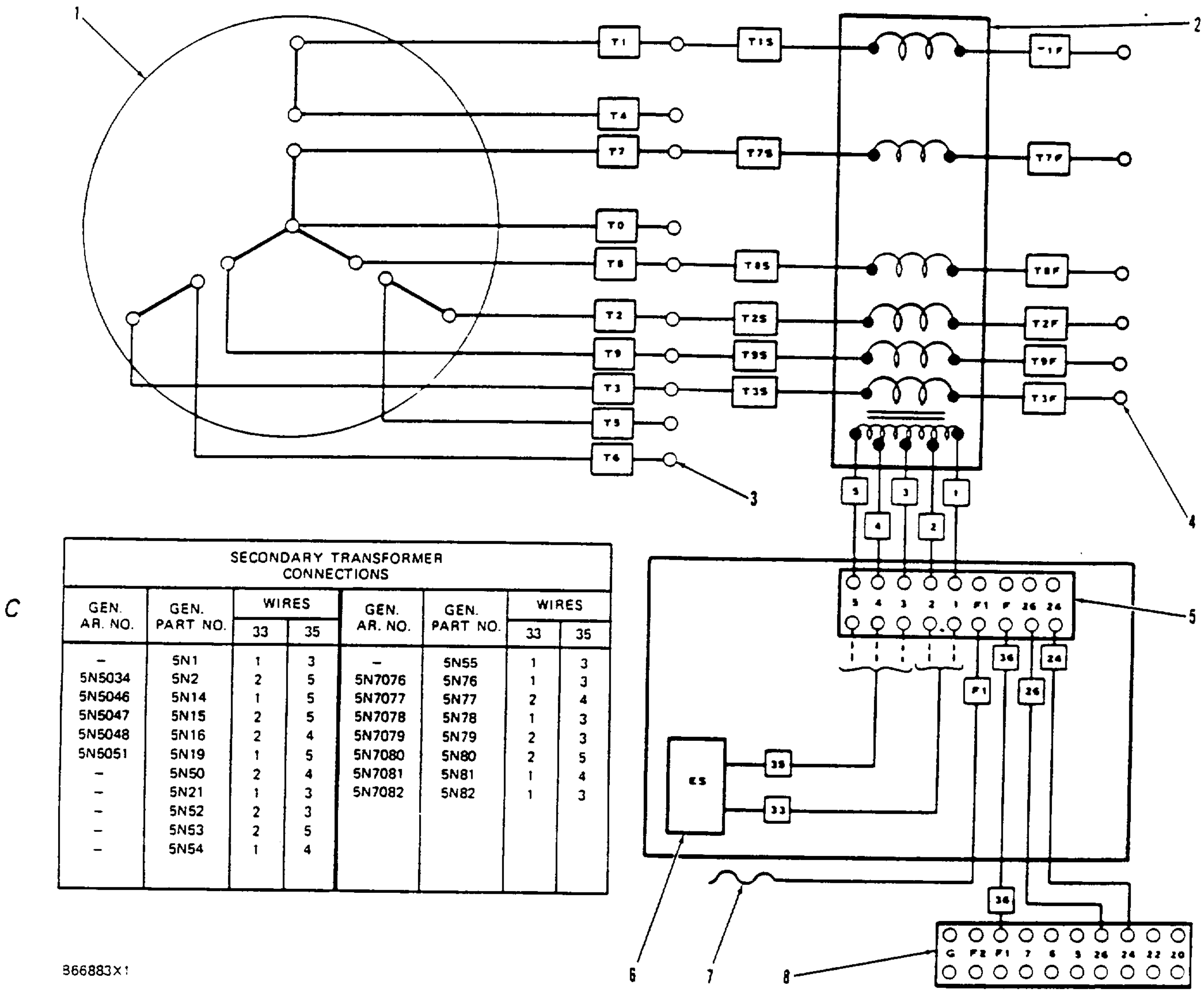



*FIG. 2 SR 4 GENERATOR WITH SERIES BOOST*

**[Includes: 580 frame and 447, 448 & 449 frames (with layer wound rotor) except 447. 448 & 449 frames with layer wound rotor - 208 V.]** *C*

| | | | | | |
|---|---|---|---|---|---|
| A1 | REGULATOR MODULE | E3 | SCR HEAT SINK | R2 | VOLTAGE LEVEL RHEOSTAT |
| A2 | RECTIFIER MODULE | E4 | FIELD RECTIFIER HEAT SINK | R3 | REGULATOR GAIN RHEOSTAT |
| A3 | CONTROL MODULE | ES | SERIES BOOST HEAT SINK | R4,7 | REGULATOR POWER RESISTOR |
| C1,3 | RFI SUPPRESSION CAPACITOR | F1 | FUSE | R5 | DAMPING RESISTOR |
| C2 | SUPPRESSION CAPACITOR | L1 | SUPPRESSION REACTOR | R6 | SUPPRESSION RESISTOR |
| C68 | SERIES BOOST CAPACITOR | L2 | SCR REACTOR | RFA | REVOLVING FIELD ASSEMBLY |
| CR1-6 | ROTATING RECTIFIERS | L3 | EXCITER FIELD | T1 | VOLTAGE DROOP TRANSFORMER |
| CR7,8 | SURGE SUPPRESSION DIODES | L4 | EXCITER ARMATURE | T2 | CURRENT TRANSFORMER |
| CR9 | CONTROLLED RECTIFIER | L5 | ROTATING FIELD | T3 | VOLTAGE SENSING TRANSFORMER |
| CR10 | FIELD RECTIFIER | L6 | STATOR | O | TERMINAL BOARD NUMBER |
| CR11 | SURGE SUPPRESSION DIODE | TP | THERMAL PROTECTOR | □ | WIRE NUMBER |
| E1 | POSITIVE HEAT SINK | R1 | VOLTAGE DROOP POTENTIOMETER | ▭ | SPADE TERMINAL NUMBER |



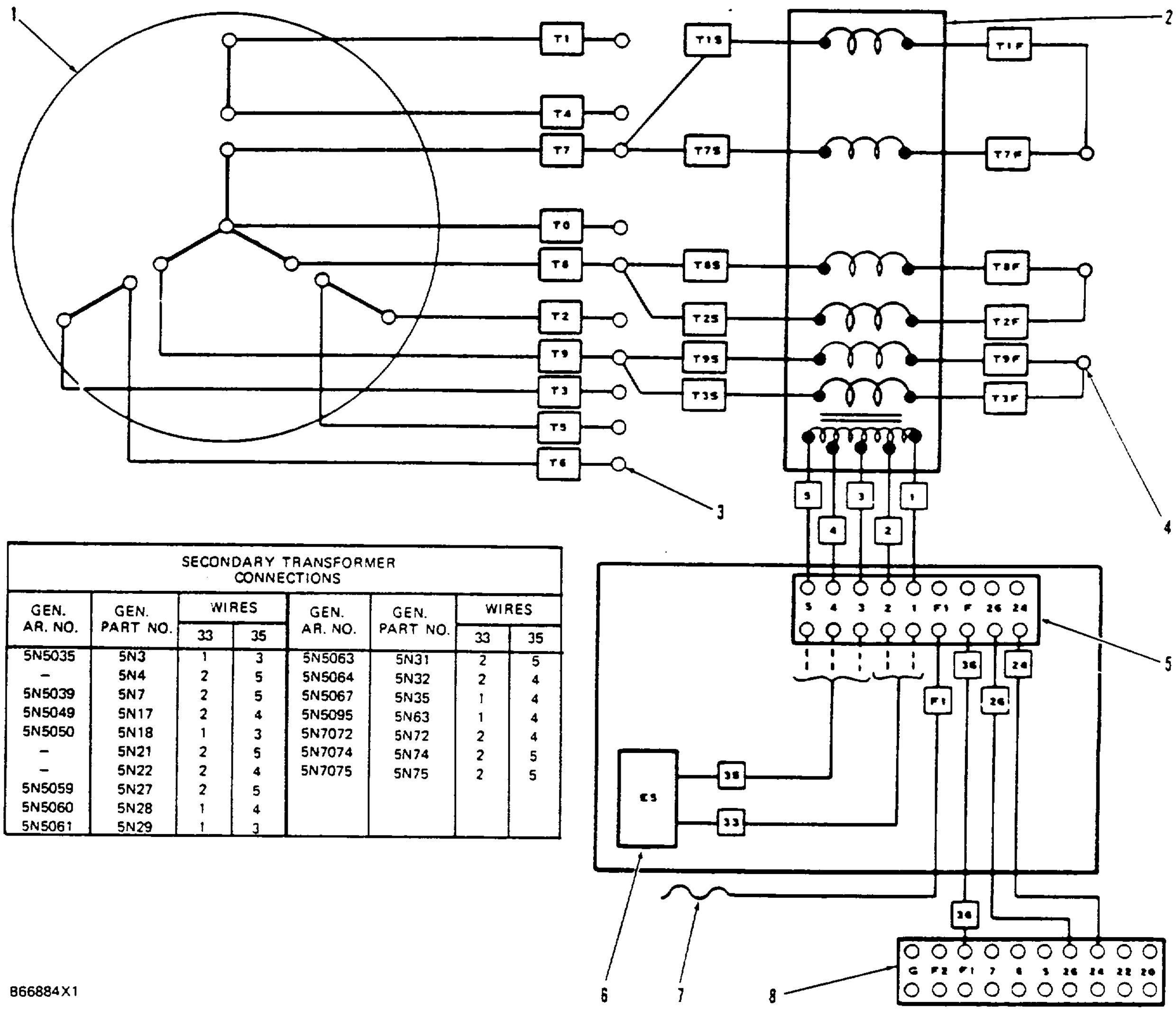

| SECONDARY TRANSFORMER CONNECTIONS | | | | | | | |
|---|---|---|---|---|---|---|---|
| GEN. AR. NO. | GEN. PART NO. | WIRES 33 | WIRES 35 | GEN. AR. NO. | GEN. PART NO. | WIRES 33 | WIRES 35 |
| – | 5N1 | 1 | 3 | – | 5N55 | 1 | 3 |
| 5N5034 | 5N2 | 2 | 5 | 5N7076 | 5N76 | 1 | 3 |
| 5N5046 | 5N14 | 1 | 5 | 5N7077 | 5N77 | 2 | 4 |
| 5N5047 | 5N15 | 2 | 5 | 5N7078 | 5N78 | 1 | 3 |
| 5N5048 | 5N16 | 2 | 4 | 5N7079 | 5N79 | 2 | 3 |
| 5N5051 | 5N19 | 1 | 5 | 5N7080 | 5N80 | 2 | 5 |
| – | 5N50 | 2 | 4 | 5N7081 | 5N81 | 1 | 4 |
| – | 5N21 | 1 | 3 | 5N7082 | 5N82 | 1 | 3 |
| – | 5N52 | 2 | 3 | | | | |
| – | 5N53 | 2 | 5 | | | | |
| – | 5N54 | 1 | 4 | | | | |

*FIG. 3 TRANSFORMER CONNECTIONS DIAGRAM*

**1. Generator.**
**2. Transformer (in series boost).**
**3. Load line leads (generator).**
**4. Load line leads (transformer).**
**5. Series boost terminal strip.**
**6. Heat sink (for connection to terminal strip, make reference to secondary transformer connections chart).**
**7. Wire from excitation field.**
**8. Terminal strip on generator regulator.**

| THREE PHASE LINE LEAD CONNECTIONS | | | |
|---|---|---|---|
| **LOW VOLTAGE** | | **HIGH VOLTAGE** | |
| **CONNECT** | **LINE LEADS** | **CONNECT** | **LINE LEADS** |
| T1F-T7F | T1F-T7F | T4-T7F | T1F |
| T2F-T8F | T2F-T8F | T5-T8F | T2F |
| T3F-T9F | T3F-T9F | T6-T9F | T3F |
| T4-T5-T6-TO | T4-T5-T6-TO NEUTRAL | | TO NEUTRAL |

**LINE LEAD CONNECTIONS FOR SR 4 GENERATORS IN FIG. 3**



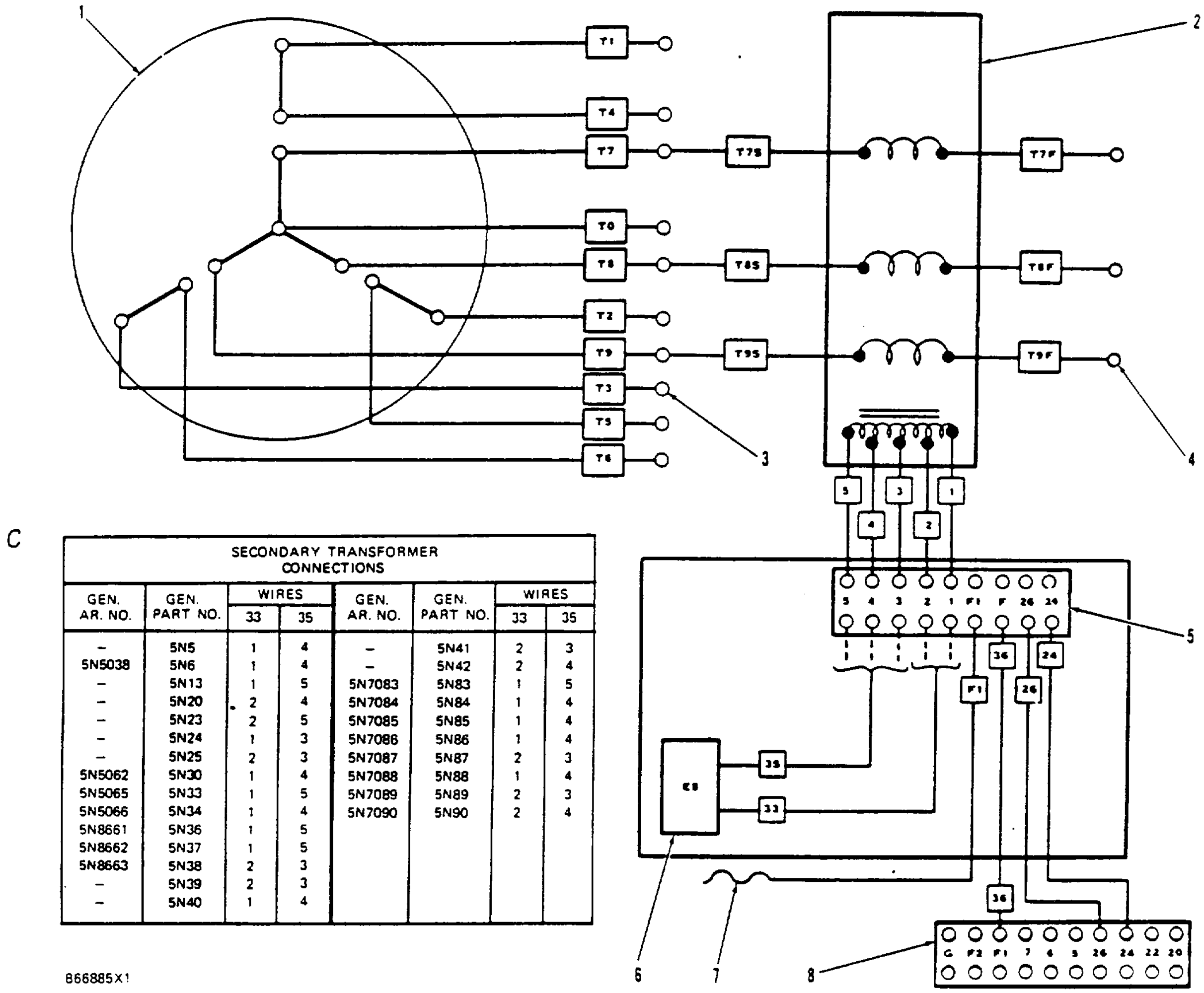

| SECONDARY TRANSFORMER CONNECTIONS | | | | | | | |
|---|---|---|---|---|---|---|---|
| GEN. AR. NO. | GEN. PART NO. | WIRES 33 | WIRES 35 | GEN. AR. NO. | GEN. PART NO. | WIRES 33 | WIRES 35 |
| 5N5035 | 5N3 | 1 | 3 | 5N5063 | 5N31 | 2 | 5 |
| – | 5N4 | 2 | 5 | 5N5064 | 5N32 | 2 | 4 |
| 5N5039 | 5N7 | 2 | 5 | 5N5067 | 5N35 | 1 | 4 |
| 5N5049 | 5N17 | 2 | 4 | 5N5095 | 5N63 | 1 | 4 |
| 5N5050 | 5N18 | 1 | 3 | 5N7072 | 5N72 | 2 | 4 |
| – | 5N21 | 2 | 5 | 5N7074 | 5N74 | 2 | 5 |
| – | 5N22 | 2 | 4 | 5N7075 | 5N75 | 2 | 5 |
| 5N5059 | 5N27 | 2 | 5 | | | | |
| 5N5060 | 5N28 | 1 | 4 | | | | |
| 5N5061 | 5N29 | 1 | 3 | | | | |

*FIG. 4 TRANSFORMER CONNECTIONS DIAGRAM*

**1. Generator.**
**2. Transformer (in series boost).**
**3. Load line leads (generator).**
**4. Load line leads (transformer).**
**5. Series boost terminal strip.**
**6. Heat sink (for connection to terminal strip, make reference to secondary transformer connections chart).**
**7. Wire from excitation field.**
**8. Terminal strip on generator regulator.**

| THREE PHASE LINE LEAD CONNECTIONS | | | |
|---|---|---|---|
| LOW VOLTAGE | | HIGH VOLTAGE | |
| CONNECT | LINE LEADS | CONNECT | LINE LEADS |
| T1-T1F-T7F | T1-T1F-T7F | T4-T1F-T7F | T1 |
| T2-T2F-T8F | T2-T2F-T8F | T5-T2F-T8F | T2 |
| T3-T3F-T9F | T3-T3F-T9F | T6-T3F-T9F | T3 |
| T4-T5-T6-TO | T4-T5-T6-TO NEUTRAL | | TO NEUTRAL |

**LINE LEAD CONNECTIONS FOR SR 4 GENERATORS IN FIG. 4**



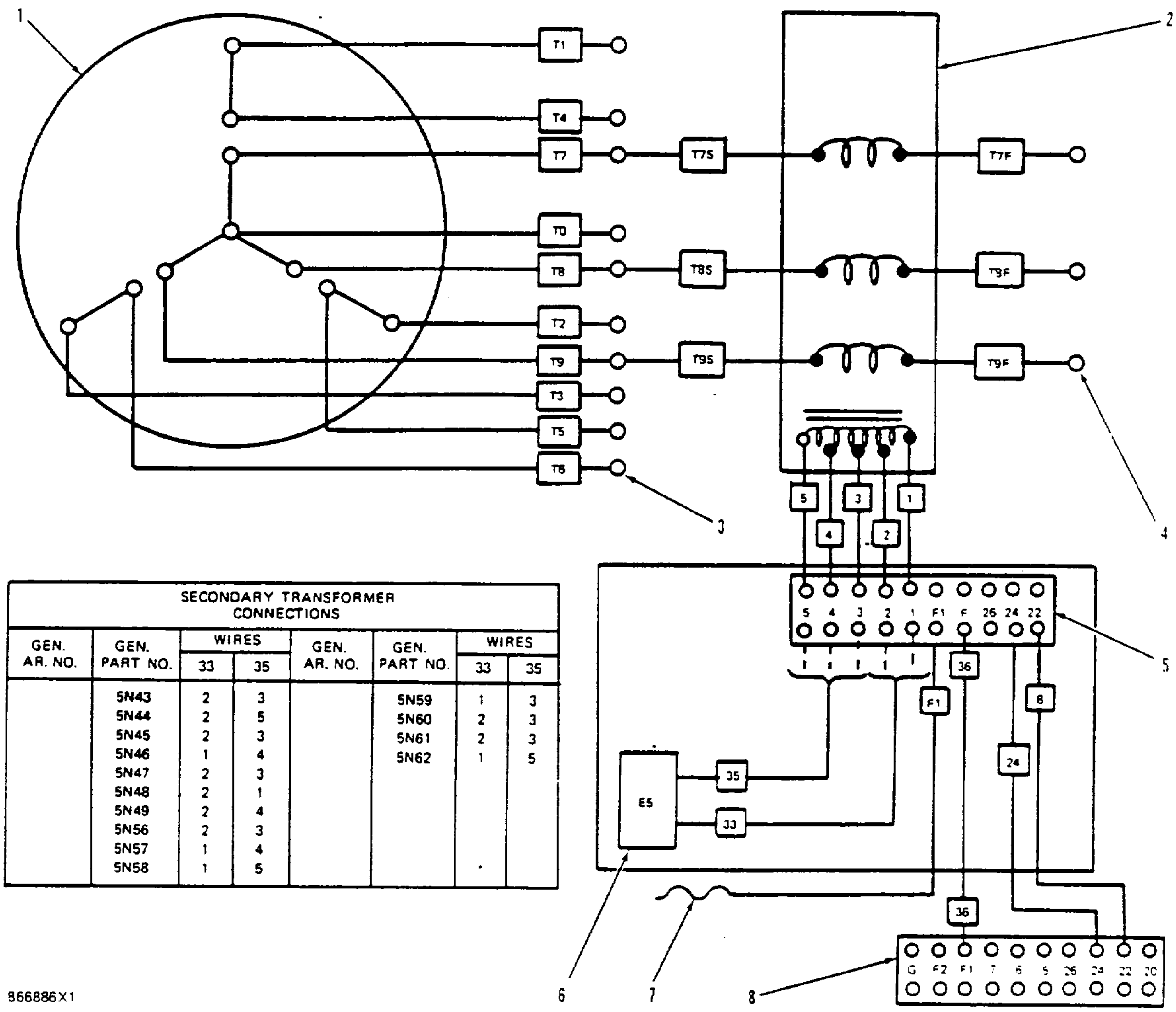

| SECONDARY TRANSFORMER CONNECTIONS | | | | | | | |
|---|---|---|---|---|---|---|---|
| GEN. AR. NO. | GEN. PART NO. | WIRES 33 | WIRES 35 | GEN. AR. NO. | GEN. PART NO. | WIRES 33 | WIRES 35 |
| – | 5N5 | 1 | 4 | – | 5N41 | 2 | 3 |
| 5N5038 | 5N6 | 1 | 4 | – | 5N42 | 2 | 4 |
| – | 5N13 | 1 | 5 | 5N7083 | 5N83 | 1 | 5 |
| – | 5N20 | 2 | 4 | 5N7084 | 5N84 | 1 | 4 |
| – | 5N23 | 2 | 5 | 5N7085 | 5N85 | 1 | 4 |
| – | 5N24 | 1 | 3 | 5N7086 | 5N86 | 1 | 4 |
| – | 5N25 | 2 | 3 | 5N7087 | 5N87 | 2 | 3 |
| 5N5062 | 5N30 | 1 | 4 | 5N7088 | 5N88 | 1 | 4 |
| 5N5065 | 5N33 | 1 | 5 | 5N7089 | 5N89 | 2 | 3 |
| 5N5066 | 5N34 | 1 | 4 | 5N7090 | 5N90 | 2 | 4 |
| 5N8661 | 5N36 | 1 | 5 | | | | |
| 5N8662 | 5N37 | 1 | 5 | | | | |
| 5N8663 | 5N38 | 2 | 3 | | | | |
| – | 5N39 | 2 | 3 | | | | |
| – | 5N40 | 1 | 4 | | | | |

*FIG. 5 TRANSFORMER CONNECTIONS DIAGRAM*

**1. Generator.**
**2. Transformer (in series boost).**
**3. Load line leads (generator).**
**4. Load line leads (transformer).**
**5. Series boost terminal strip.**
**6. Heat sink (for connection to terminal strip, make reference to secondary transformer connections chart).**
**7. Wire from excitation field.**
**8. Terminal strip on generator regulator.**

| THREE PHASE LINE LEAD CONNECTIONS | | | |
|---|---|---|---|
| **LOW VOLTAGE** | | **HIGH VOLTAGE** | |
| **CONNECT** | **LINE LEADS** | **CONNECT** | **LINE LEADS** |
| T1-T7F | T1-T7F | T4-T7F | T1 |
| T2-T8F | T2-T8F | T5-T8F | T2 |
| T3-T9F | T3-T9F | T6-T9F | T3 |
| T4-T5-T6-TO | T4-T5-T6-TO NEUTRAL | | TO NEUTRAL |

**LINE LEAD CONNECTIONS FOR**
**SR 4 GENERATORS IN FIG. 5**




| SECONDARY TRANSFORMER CONNECTIONS | | | | | | | |
|---|---|---|---|---|---|---|---|
| GEN. AR. NO. | GEN. PART NO. | WIRES 33 | WIRES 35 | GEN. AR. NO. | GEN. PART NO. | WIRES 33 | WIRES 35 |
| | 5N43 | 2 | 3 | | 5N59 | 1 | 3 |
| | 5N44 | 2 | 5 | | 5N60 | 2 | 3 |
| | 5N45 | 2 | 3 | | 5N61 | 2 | 3 |
| | 5N46 | 1 | 4 | | 5N62 | 1 | 5 |
| | 5N47 | 2 | 3 | | | | |
| | 5N48 | 2 | 1 | | | | |
| | 5N49 | 2 | 4 | | | | |
| | 5N56 | 2 | 3 | | | | |
| | 5N57 | 1 | 4 | | | | |
| | 5N58 | 1 | 5 | | | | |

*FIG. 6 TRANSFORMER CONNECTIONS DIAGRAM*

1. **Generator.**
2. **Transformer (in series boost).**
3. **Load line leads (generator).**
4. **Load line leads (transformer).**
5. **Series boost terminal strip.**
6. **Heat sink (for connection to terminal strip, make reference to secondary transformer connections chart).**
7. **Wire from excitation field.**
8. **Terminal strip on generator regulator.**

| THREE PHASE LINE LEAD CONNECTIONS | | | |
|---|---|---|---|
| LOW VOLTAGE | | HIGH VOLTAGE | |
| CONNECT | LINE LEADS | CONNECT | LINE LEADS |
| T1-T7F | T1-T7F | T4-T7F | T1 |
| T2-T8F | T2-T8F | T5-T2F-T8F | T2 |
| T3-T9F | T3-T9F | T6-T9F | T3 |
| T4-T5-T6-TO | T4-T5-T6-TO NEUTRAL | | TO NEUTRAL |

**LINE LEAD CONNECTIONS FOR SR 4 GENERATORS IN FIG. 6**

## MANUAL VOLTAGE CONTROL ATTACHMENT

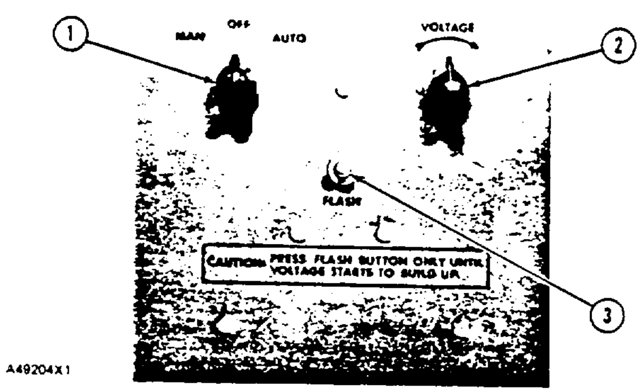
The location of the manual voltage control panel can be up to 76 ft. (23.2 meters) from the generator. Make reference to the chart.

| CONTROL PANEL LOCATION | |
|---|---|
| WIRE SIZE (AWG) | MAXIMUM CABLE LENGTH |
| No. 18 | 30 ft. (9.1 meters) |
| No. 16 | 48 ft. (14.6 meters) |
| No. 14 | 76 ft. (23.2 meters) |

The manual voltage control can be used to control generator voltage when there is a failure in the generator regulator assembly. It will manually control the rate at which control rectifier CR9 is turned on. For information on CR9 operation make reference to OPERATION OF GENERATOR.

**NOTE: CR9 and CR10 must be able to operate correctly for the manual voltage control to work.**

The manual voltage control has a switch (1), voltage control rheostat (2), flash button (3) and a control assembly.




*VOLTAGE CONTROL PANEL*

**1. Switch (OFF, AUTO and MAN positions). 2. Voltage control rheostat. 3. Flash button.**

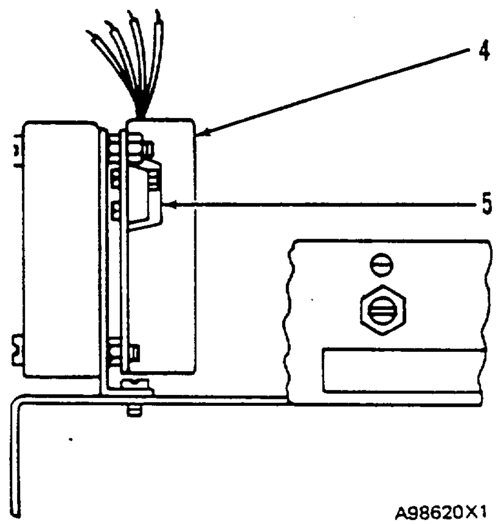
Switch (1) is used to make the' selection between AUTO, MAN and OFF. In the "AUTO" position the generator regulator assembly controls the generator voltage. In the “OFF" position the generator voltage will go to zero. In the "MAN" position generator voltage is controlled by voltage control rheostat (2).

Flash button (3) is used when the generator voltage does not build up. With switch (1) in the "MAN" position push flash button (3) until the generator voltage starts to build up.

**NOTICE**

**Press the flash button only until the generator voltage starts to build up. If the button is held too long the voltage will increase to above the capacity of the generator. This can cause the line circuit breaker to trip or the regulator fuse to open.**

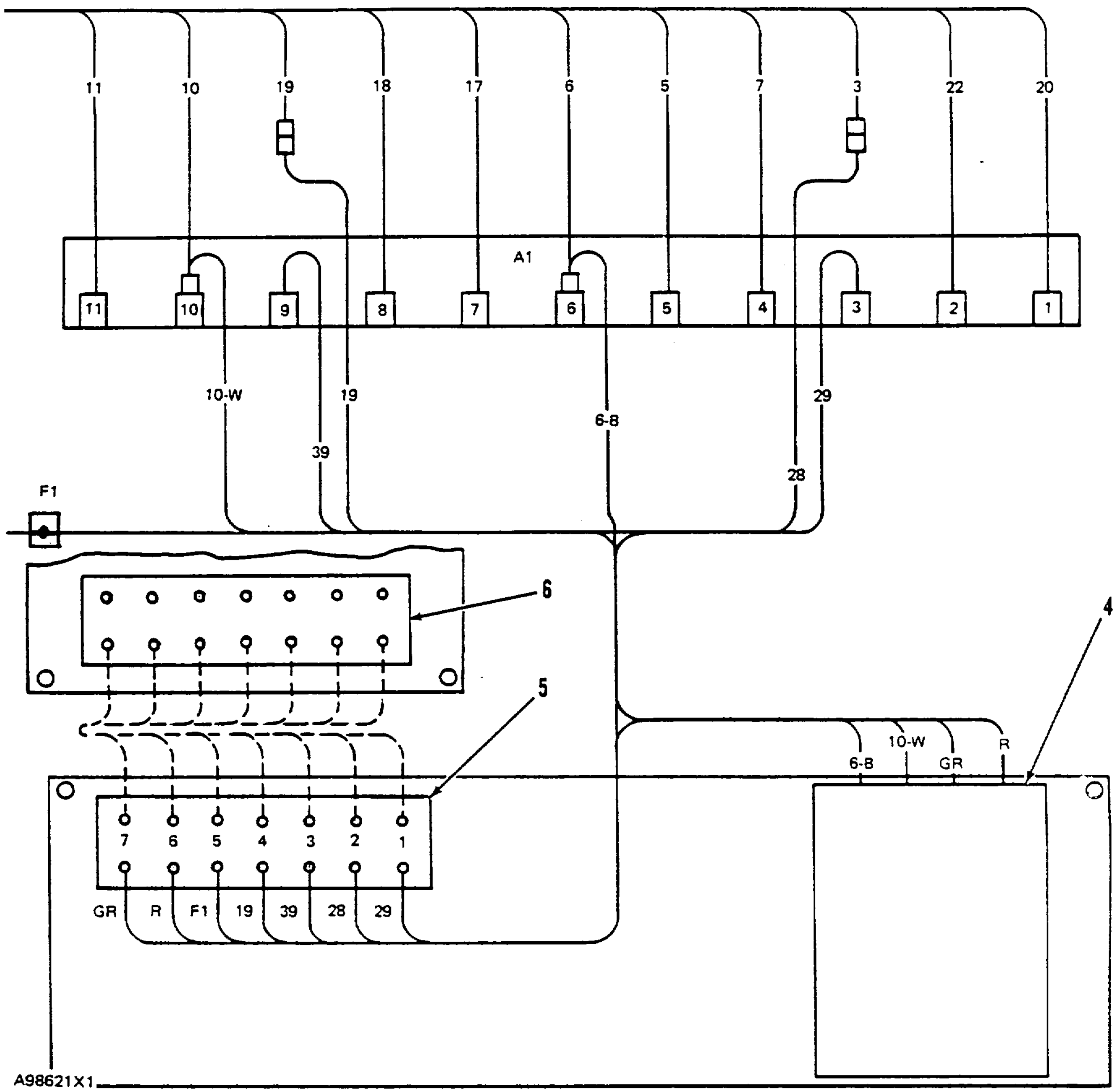
When flash button (3) is pushed AC current from the generator is rectified by a diode on the manual voltage control panel. This rectified (DC) current goes directly to the generator exciter field. It does not go through control rectifier CR9.




*CONTROL ASSEMBLY*

**4. Trigger module. 5. Terminal strip. (4 and 5 are not serviced separately - lowest serviceable level is Manual Voltage Control Assembly)**

The control assembly is on the back side of the mounting bracket for regulator module A1. The control assembly has terminal strip (5) and trigger module (4). When switch (1) is in the "MAN" position, the action of electrical circuits in trigger module (4) control the amount of "on" time for control rectifier CR9.




*WIRING DIAGRAM*

**4. Trigger module. 5. Terminal strip (control assembly). 6. Terminal strip (voltage control panel). A1. Regulator module F1. Terminal (regulator terminal strip).**

# TROUBLESHOOTING

## GENERAL

**⚠ WARNING**

**Before working inside the generator, make sure that the starter motor can not be activated by any automatic or manual signal.**

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**⚠ WARNING**

**When the engine-generator is operating, voltages up to 240 are present on the regulator terminal board. The heat sinks and other regulator components have an electric charge. Components will be damaged if a metal contact is made between the generator frame and the heat sinks or other regulator parts. Safety procedures must be followed.**

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A large percent of the electrical problems are caused by mechanical defects. Take time to carefully inspect the total installation. Keep the mechanical defects separate from the electrical defects.

For practical purposes. the generator is a constant speed unit. RPM that is 5 to 10 percent higher or lower than the rated rpm can cause terminal voltages that are 5 to 10 percent higher or lower than the rated output.

Generator heat is caused by line current. The higher the line current, the hotter the generator will become.

A voltmeter and ammeter or KW meter does not necessarily show the KVA load on a generator because of the power factor of the load.

Before working on the generator, be sure you understand the operating principles.

Find the operating trouble and use the wiring diagram and troubleshooting guide to find the probable cause.

When troubleshooting for voltage, a generator can normally be operated at a low rpm. Voltage and frequency will change directly with rpm. A four-pole, 60 Hertz, 240 volt, 1800 rpm generator at a low idle of 1200 rpm will have an output of 160 volts at 40 hertz.

**NOTE: For information on mechanical and electrical characteristics of SR 4 generators, make reference to the section INDUSTRIAL DIVISION DATA SHEETS: No. 70.0.1 and the TECHNICAL INFORMATION FILE (TIF).**

## TEST INSTRUMENTS

A volt-ohm-milliammeter with scales of approximately the following values:

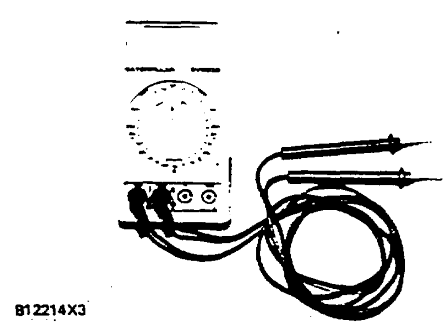
AC volts .......................... 0-12, 0-100, 0-300
DC volts .......................... 0-50, 0-100, 0-150
Ohms ..........................XI, X10, X100, X1000
DC Amps................................................ 0-3

The 6V3030 Digital Multimeter can also be used. By itself or with other tools, it can do the following:

1. Test rectifiers with the special diode function.

2. Measures resistance of the revolving field and stator winding of the generator or exciter winding.

3. With the 6V4960 AC Current Probe, the multimeter can measure current in the range 10A to 1000A rms (at a circuit-to-ground voltage of 650 V rms maximum.) See Special Instruction, Form SEHS801 I for warnings and more information on how to use the current probe.




*6V3030 DIGITAL MULTIMETER*

A circuit continuity tester, similar to the 8S4627 (circuit continuity tester) can be used for checking low resistance continuity. This tool can also be used to check rectifiers and controlled rectifiers. It uses a 3-volt battery source. This is all that is needed to activate the gate of a controlled rectifier.

A Kelvin or Wheatstone bridge can be used to measure the resistance of the revolving field and stator winding of the generator or the exciter armature.

A 500 to 1000 volts megohmeter is needed to measure the insulation resistance of the generator stator, revolving field, exciter armature, and exciter field.

A DC ammeter with the correct current shunt is used to measure the current of the exiter field.

A clamp-on volt-ammeter with a 0 to 600 volts and 0 to 600 amperes scales is used to measure line voltage and line current. Some generators are rated higher than 600 amperes, but these units are normally connected with two or more conductors in parallel per phase. To measure line current for these generators, measure the current in each conductor per phase and add the currents together.

**NOTE: See WARNING below, if generator is rated over 600 volts.**

A direct-reading tachometer is used to measure rpm. When exact frequency control is needed, a direct comparison can be made with outside line power.

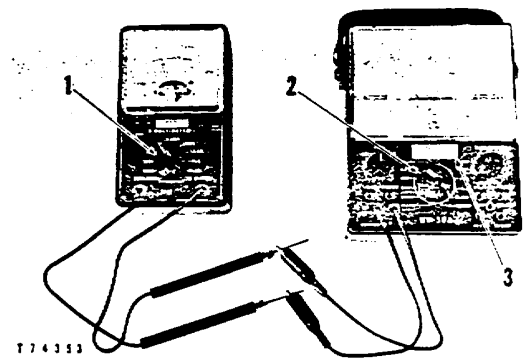
**WARNING**

**On generators with higher than 600 volts rating do hot use direct-reading test equipment to measure line voltage or line current, (even though the instrument has higher voltage capacity). Voltage and current transformers with a high voltage rating must be used. On power circuits higher than 600 volts, direct-reading meters CAN have failure of insulation.**

Where the same adjustments are necessary on two or more units, (as in parallel operation) use the same instrument for measuring all voltages.

In many of the following resistance test procedures, the ohmmeter connecting polarity (positive or negative) is given for testing the respective component.

**NOTE: The identification of lead polarity on ohmmeter instruments is not necessarily the same.**




*POLARITY CHECK OF OHMMETER TERMINAL*

**1. Selector switch. 2. Selector switch. 3. Mark to show polarity of ohmmeter cables.**

Volt-ohm-milliameter cable polarity must be known. The red, positive “+”, color on the cable of an ohmmeter can be either positive (+) or negative (-) and identification of each cable is needed.

A second volt-ohm-milliameter (multimeter) can be used with the test ohmmeter to find the correct polarity of the connecting cables.

Turn one instrument selector switch (1) to DC volts, and turn the test ohmmeter selector switch (2) to ohms (RX1). Connect the cables of both instruments together until both instruments have a meter indication at the same time. (Change the cables if necessary).

The red, positive “+”, lead from the instrument with selector switch (1) on DC volts is connected to the positive lead of the test ohmmeter. Put a mark on the ohmmeter to show the polarity of the ohmmeter cables (3). the correct positive and negative identification of the cables has been made.

On the digital multimeter, the above procedure is not necessary. Polarity is indicated on the readout.

For further information on using the digital multimeter, see Special Instruction, Form SEHS7734.

Temperature has an effect on electrical equipment. When measuring resistance of a cold components, you will get a lower indication than you will at higher temperatures. Ohmmeters in general are not accurate. Given values of resistance will be different (op to 10 percent), if the total error of instrument method, temperature and the tolerance of the part add in one direction.

## TROUBLESHOOTING PROCEDURES FOR GENERATOR/REGULATOR

There are four test sequence charts in Troubleshooting Procedures. Each is for a different problem. The problems are:

No AC Voltage
Low AC Voltage
High AC Voltage
Unstable AC Voltage

**NOTE: Before making any of the tests. first read all the information on this page and all the information in General and in Test Instruments.**

Follow the test sequence chart exactly. This test sequence chart is in a logical order to find the problem with the minimum amount of time and work. By making each test in the exact step-by-step order shown on the test sequence chart, the serviceman can be sure that, at the end of the test sequence chart, the components are all good.

**NOTE: If a bad part is found and a replacement part is installed, test the replacement part also. Then do the rest of the tests as shown in the test sequence chart. In this way all the bad parts will be found. This is important because one bad part can cause damage to several other parts. Then do the PROCEDURE FOR FIRST OPERATION AFTER REPAIR.**

**NOTE: If the AC voltage is less than 25 volt,. use the No AC Voltage test sequence chart.**

A separate section for troubleshooting problems with the generator mounted control panel, automatic start/stop system, follows the GENERATOR/REGULATOR test procedures.

## TEST SEQUENCE CHARTS

### NOTE

**If the serviceman is familiar with the troubleshooting procedure and procedures for checking components, the following table of resistance values may save time in troubleshooting. It should be noted that these values are approximate and could change with new component changes.**

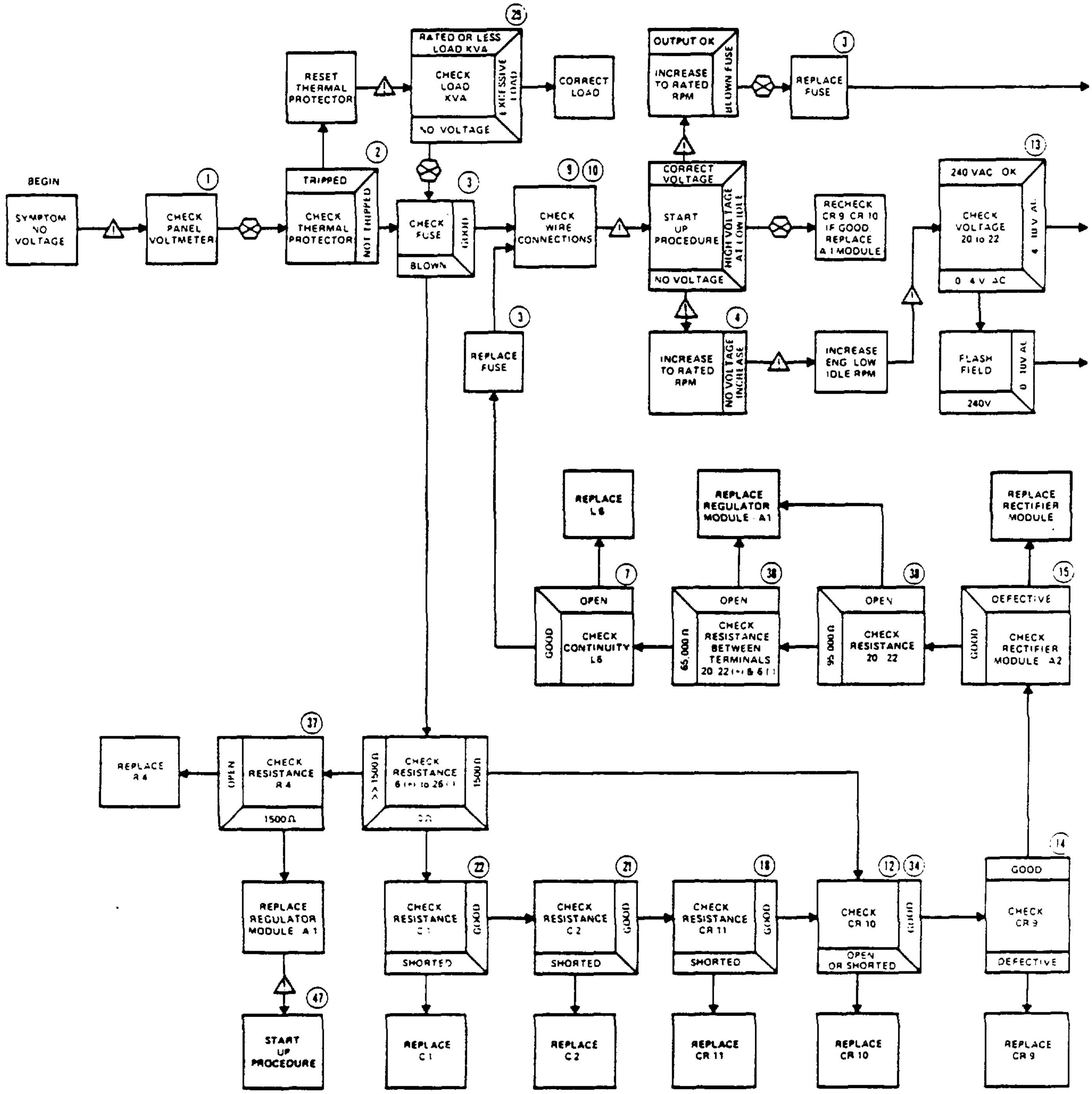
| Component Symbol | Component | Resistance Value (ohms) |
|---|---|---|
| C1, 3 | RFI Suppression Capacitor | Low then infinite |
| C2 | Suppression Capacitor | Low then infinite |
| CR1-6 | Rotating Rectifiers | Forward 10<br>Reverse 30K - 300K |
| CR7, 8 | Surge Suppression Diodes | Fwd. & Rev. 15K or more |
| CR9 | Controlled Rectifier | Fwd. & Rev. 30K - 3M (1) (2) |
| CR10 | Field Rectifier | Forward 10<br>Reverse 30K or more |
| CR11 | Surge Suppression Diode | Fwd. & Rev. 15K or more |
| L1 | Suppression Reactor | 0 |
| L2 | SCR Reactor | 0 |
| L3 | Exciter Field | 2 - 3 |
| L4 | Exciter Armature | Much less than 1 |
| L5 | Rotating Field | Less than 1 |
| L6 | Stator (Armature) | Much less than 1 |
| R1 | Voltage Droop Pot | 0 - 8 |
| R2 | Voltage Level Pot | 0 - 500 |
| R3 | Voltage Gain Pot | 0 - 5000 (3) |
| R4 | Regulator Power Resistor | 1500 |
| R7<br>(580 Frame Only) | Regulator Power Resistor | |
| R5 | Damping Resistor | 10 |
| R6 | Suppression Resistor | 27,000 |

(1) Forward & reverse resistance must be approximately the same.

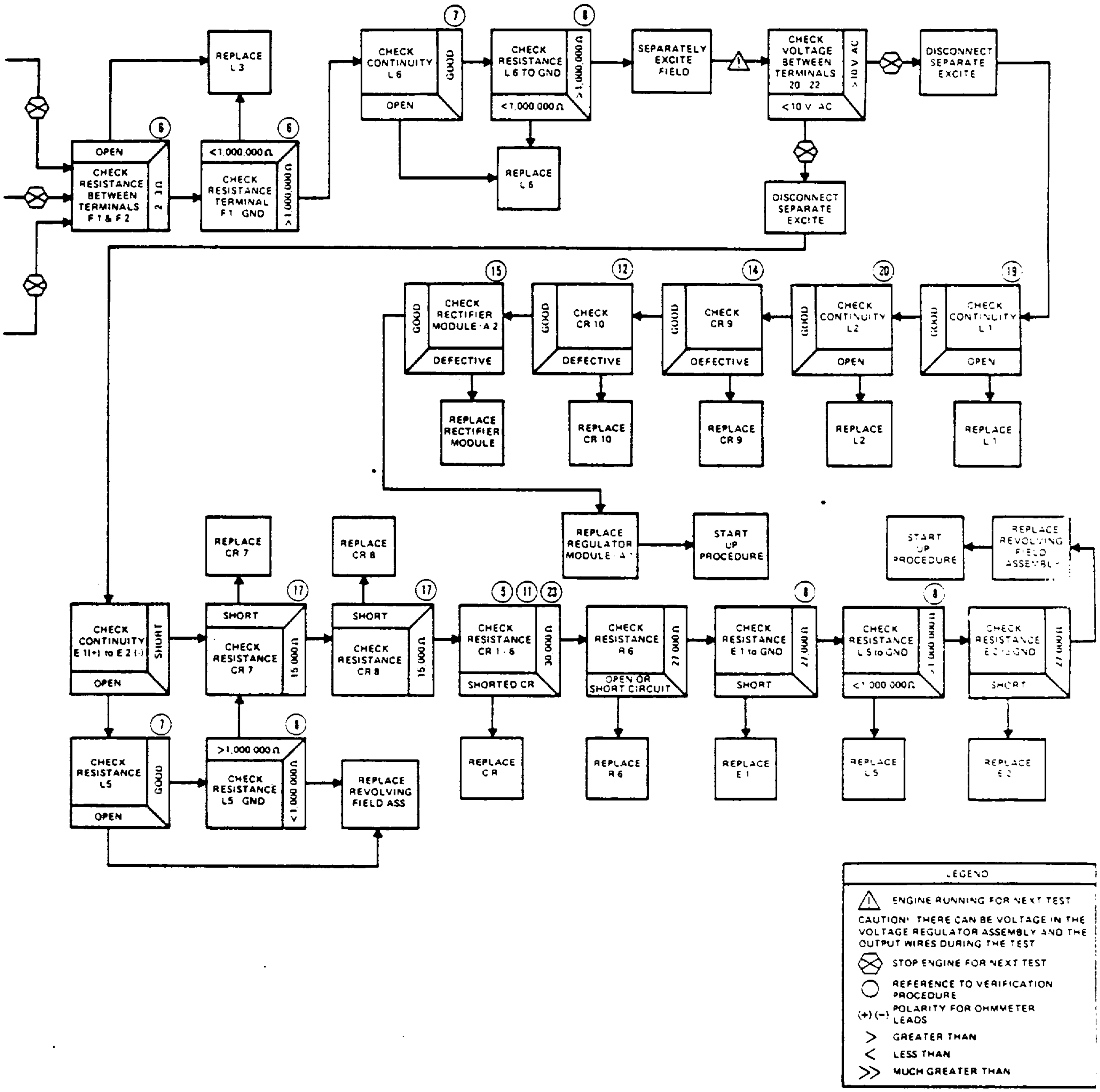
(2) Gate to cathode forward & reverse resistance Is 10 - 200 and should be about the same

(3) Earlier generators with old Al module (brown in color) - resistance should be 0-5000 ohms. Later generators or generators with replacement Al module (black In color) - resistance should be 0-500 ohms.

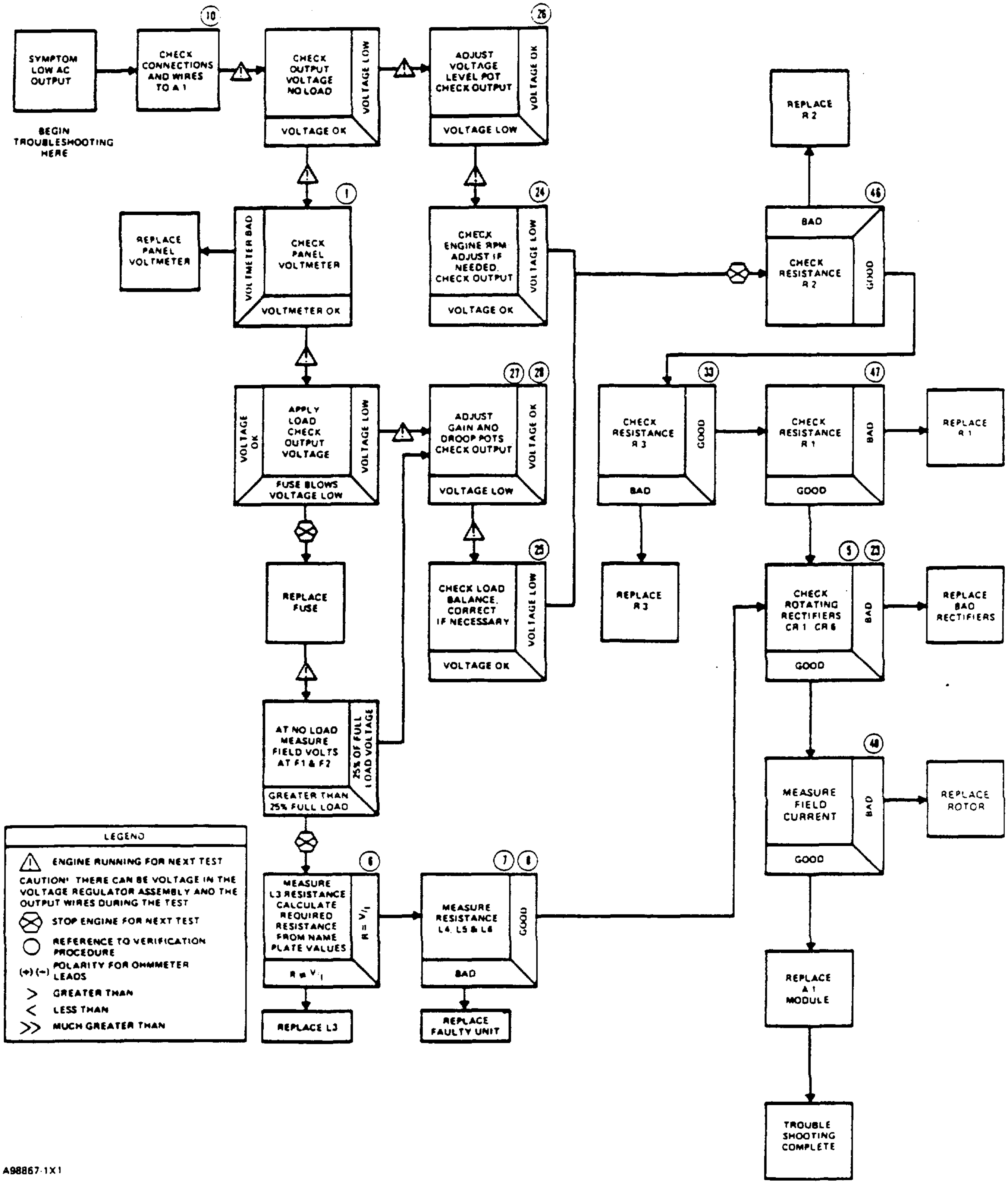
NO AC VOLTAGE



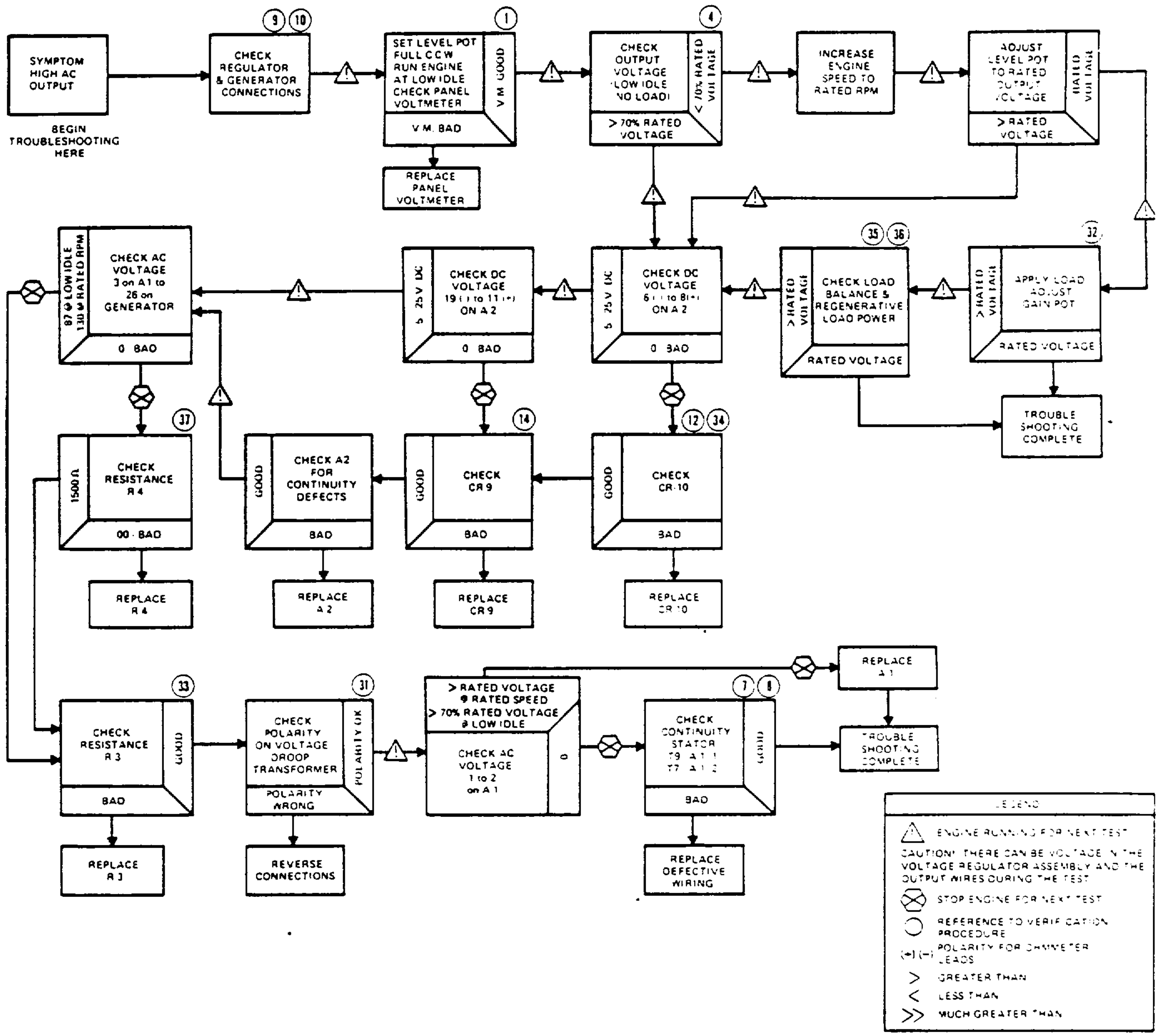
NO AC VOLTAGE (Cont.)



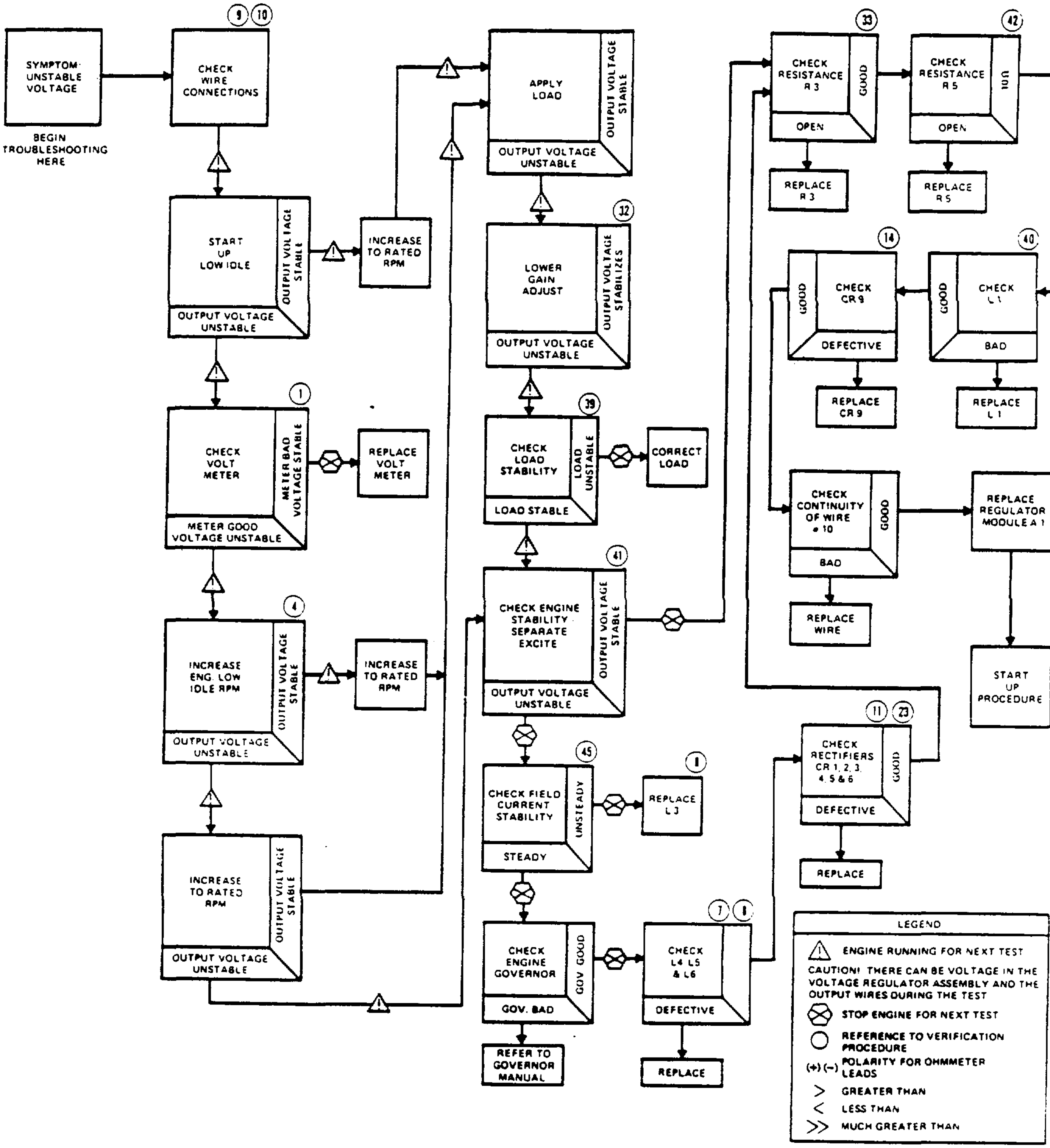
AC VOLTAGE TOO HIGH



## AC VOLTAGE TOO HIGH



LACK OF AC VOLTAGE STABILITY



## TROUBLESHOOTING CHART INDEX

### NO AC VOLTAGE

| Item | Possible Cause |
|---|---|
| 1. | Voltmeter Has a Defect. |
| 2. | Open (Tripped) Thermal Protector (TP). |
| 3. | Open Fuse (F1). |
| 4. | Engine Low Idle rpm Too Low. |
| 5. | Defect in Rotating Rectifiers (CR1 thru CR6): |
| C | Surge Suppression Diodes (CR7. 8); Exciter Armature (L4); or Exciter Field (L3). |
| 6. | Exciter Field (L3) is Open. |
| 7. | Open or Short Circuit. |
| 8. | Rounded Circuit. |
| 9. | Loose Wire Connections. |
| 10. | Wrong Regulator or Generator Connections. |
| 11. | Shorted Rotating Rectifiers (CR1 thru CR6). |
| 12. | Short Circuit in Field Rectifier (CR10). |
| 13. | Loss of Residual Magnetism. |
| 14. | Controlled Rectifier (CR9) Has a Defect. |
| 15. | Rectifier Module (A2) Has a Defect. |
| 16. | Regulator Module (Al) Has a Defect. |
| 17. | Shorted Surge Suppression Diode (CR7 or CR8). |
| 18. | Shorted Surge Suppression Diode (CR11). |
| 19. | Open Suppression Reactor (L1). |
| 20. | Open SCR Reactor (L2). |
| 21. | Shorted Suppression Capacitor (C2). |
| 22. | Shorted RFI Suppression Capacitor (C1). |

### AC VOLTAGE TOO LOW

| Item | Possible Cause |
|---|---|
| 1. | Voltmeter has a Defect. |
| 5. | Defect in Rotating Rectifiers (CR1 thru CR6); |
| C | Surge Suppression Diodes (CR7. 8); Exciter Armature (L4): or Exciter Field (L3). |
| 10. | Wrong Regulator or Generator Connections. |
| 16. | Regulator Module (A1) Has a Defect. |
| 23. | Open Rotating Rectifiers (CR1 thru CR6). |
| 24. | Engine rpm Too Low. |
| 25. | Load Too High or Not Balanced. |
| 26. | Voltage Level Control Setting Too Low (R2). |
| 27. | Voltage Droop Control Setting Too High (R1). |
| 28. | Regulator Gain Control Setting Too Low (R3). |

AC Voltage Too Low (Cont.)

| Item | Possible Cause |
|---|---|
| 45. | Current in Exciter Field (L3) Is Not Stable. |
| 46. | Defect in Voltage Level Rheostat (R2). |
| 47. | Defect in Voltage Droop Potentiometer (R1). |
| 48. | Rotor Winding (L5) Defect. |

### AC VOLTAGE TOO HIGH

| Item | Possible Cause |
|---|---|
| 1. | Voltmeter Has a Defect. |
| 10. | Wrong Regulator or Generator Connections. |
| 14. | Controlled Rectifier (CR9) Has a Defect.* |
| 15. | Rectifier Module (A2) Has a Defect.* |
| 16. | Regulator Module (A1) Has a Defect.'* |
| 29. | Engine rpm Too High. |
| 30. | Voltage Level Adjustment Too High (R2). |
| 31. | Reverse Polarity on Voltage Droop Transformer (T1). |
| 32. | Regulator Gain Control Setting Too High (R3). |
| 33. | Open Regulator Gain Rheostat (R3). |
| 34. | Open Field Rectifier (CR10).'* |
| 35. | Load Not Balanced. |
| 36. | Regenerative Load Power Too High. |
| 37. | Open Regulator Power Resistor (R4 ).* |
| 38. | Open Voltage Reference Circuit. |

### LACK OF AC VOLTAGE STABILITY

| Item | Possible Cause |
|---|---|
| 1. | Voltmeter Has a Defect. |
| 4. | Engine Low Idle rpm Too Low. |
| 9. | Loose Wire Connections. |
| 14. | Controlled Rectifier (CR9) Has a Defect. |
| 16. | Regulator Module (A1) Has a Defect. |
| 32. | Regulator Gain Control Setting Too High (R3). |
| 33. | Open Regulator Gain Rheostat X R3). |
| 39. | Lack of Load Stability. |
| 40. | Too Much Vibration of Suppression Reactor (L1). |
| 41. | Lack of Engine rpm Stability. |
| 42. | Damping Resistor Open (R5). |
| 43. | Temporary Short Circuit in RFI Suppression Capacitor (C1). |
| 44. | Temporary Short Circuit in Suppression Capacitor (C2). |

*This item can cause a condition of temporary high AC voltage. The result is normally permanent damage to components. The secondary or visible condition is no AC voltage and an open fuse (F1).

| POSSIBLE CAUSES | VERIFICATION PROCEDURE |
|---|---|
| **1. Voltmeter has a Defect** | Check voltage with a meter with known accuracy. Check fuses and connections in the control panel voltmeter circuit. **NOTE: The magnetic field caused by current flow in power cables that are close to the voltmeter can cause the voltmeter to be wrong. If the voltmeter is fastened to a part of the control panel that can be moved or opened, open or move it and read the meter in this position. If the meter indication is correct after being moved, change the position of the power cables or prevent the magnetic field from causing an error in the meter indication.** |
| **2. Open (Tripped) Thermal Protector (TP)** | Set the thermal protector (TP) again. The thermal protector opens (trips) when the load is too high or when the load is not in balance. Make the necessary corrections to the load. |
| **3. Open Fuse (F1)** | Remove the fuse and check it with an ohmmeter or continuity circuit tester, similar to 8S4627.<br><br>**NOTICE: An open fuse is normally caused by a high voltage condition. NOTE: Fuse (F1) Is the type that opens very rapidly and gives protection to the semiconductors used in the control circuits. Do not use a replacement of any other type, or of a higher rated amperage.** |
| **4. Engine Low Idle RPM Too Low** | Voltage does not get higher at factory set low idle of 1200 to 1250 rpm. If the outside temperature is low, the controlled rectifier (CR9) will be more difficult to "turn on" by residual voltage. An increase of the engine idle rpm of approximately 100 to 150 rpm must show an increase of voltage. |
| **5. Defect in Rotating Rectifiers (CR1 thru CR6); Surge Suppression Diodes (CR7, 8); Exciter Armature (L4) or Exciter Field (L3) (Use this method when 110V AC is available.)** | ⚠ **WARNING**<br>**Do what is necessary to keep the engine starting motor from being activated during this test.**<br>⚠ **WARNING**<br>**Be extra careful when using this procedure. The 110 V AC wires must be kept insulated from the generator frame.**<br><br>Disconnect its wires (F1) and (F2) from terminals (F1) and (F2) Check continuity through wires (F1) and (F2). Typical resistance is 2 to 3 ohms.<br><br>Now connect the 110V AC wires to wires (F1) and (F2). The 110V AC activates the exciter field (L3).<br><br>Connect a DC voltmeter between the positive heat sink (E1) and the negative heat sink (E2).<br><br>Using a bar or engine turning tools, slowly turn the engine flywheel approximately 90°. At the same time make a note of the measurement on the DC voltmeter. If all the parts are good, the voltage measurement will increase and decrease evenly and the minimum voltage will be at least 80% of the maximum voltage. If the minimum voltage is less than 80% of the maximum or less than 2 volts, check the parts one at a time according to the Troubleshooting Procedure. |
| **6. Exciter Field (L3) is Open** | Disconnect wire (F1) from terminal (F1). Check the continuity of exciter field ( L3) from wire(F1) to terminal (F2). Typical resistance values are found on EDS sheets 70.0.1 or on the current TIF. |

| POSSIBLE CAUSES | VERIFICATION PROCEDURE |
|---|---|
| **7. Open or Short Circuit** | Disconnect the rotating field (L5) by removing the wire- to positive heat sink (E1) and negative heat sink (E2). Check the continuity of rotating field (L5). **NOTE: To measure the resistance of the rotating field, use a Kelvin or Wheatstone Bridge.** Typical resistance is less than one ohm. Keep the wires from rotating field (L5) to heat sinks (E1) and (E2) disconnected.<br>Check the continuity of exciter armature (L4) at the terminal connections of rotating rectifiers (CR1 thru CR6). **NOTE: To measure the resistance of the exciter armature coils use a Kelvin Bridge.** Typical resistance is much less than one ohm, from terminals of rotating rectifiers (CR1) to (CR2) etc.<br>Disconnect load from generator, either by opening the line circuit breaker or disconnecting the load cables from (T1) (T2) (T3) and (T0). Disconnect the regulator assembly from stator (L6) removing the wires at terminals (20. 22. 24 and 26). Check the generator line lead connections against those shown on the generator name plate. Check continuity of stator (L6) windings.<br><br>**NOTE: To measure the resistance of the stator (L6) windings use a Kelvin Bridge. Typical resistance, between phases. is much less than one ohm.** |
| **8. Grounded Circuit** | Moisture (water), dust, grease and other foreign matter can cause a change in the resistance characteristics of the insulation on the conductors of the stator and rotor. This is "surface leakage." Measure the resistance of the insulation when the generator Is warmer than the air around it. Disconnect the rotating field (L5) by removing the wires to heat sinks (E1) and (E2). Check the resistance of the insulation of rotating field (L5) to ground.<br><br>**NOTE: Resistance of the insulation must be clone with a megohmeter. Resistance must not be less than on megohm (1,000,000 ohms).**<br>Connect the rotating field (L5) to the respective heat sink (E1) and negative end to heat sink (E2), Measure the resistance between heat sink (E1) and ground. Use a standard ohmmeter. Turn scale to RX1000. Resistance to ground will be through suppression resistor (R6) and must be 27,000 ohms plus or minus 10 percent.<br>Remove the bolts that connect the exciter armature (L4) cables to the terminals of rotating rectifiers (CR1 thru CR6). Temporarily use tape for insulation of all wires, except one. This will prevent an accident if one of the wires is grounded. Use a megohmeter to measure the resistance of the insulation on the exciter armature (L4) windings between the wire with no tape and ground. The resistance must be one megohm or more.<br>**NOTICE: The voltages from the megohmeter can cause permanent damage to the rotating rectifiers (CR1 thru CR6). They must not be connected to the exciter armature (L4) during the test.**<br>Remove wires (F1) and (F2) from terminal connections (F1) and (F2). Use a megohmeter and measure the resistance of the insulation of exciter field (L3). Connect the meter between either wire, (F1) or (F2) and ground. Resistance must be one megohm or more. |

**(Continued on next page)**

| POSSIBLE CAUSES | VERIFICATION PROCEDURE |
|---|---|
| | (Continued)<br><br>Remove the load from the generator by either opening the line circuit breaker or the load connections to (T1), (T2), (T3) and (T0). Separate stator (L6) from the regulator assembly by removing wires (20, 22, 24 and 26) from terminals (20, 22, 24 and 26). If neutral cable (T0) is connected to the generator frame or ground, open the connection. Use a megohmeter and measure the resistance of the insulation from each lead (T1 thru T0) of the stator winding to ground. Generators that are rated 600 volts or less must have a resistance of one megohm or more. Generators rated 2400 volts or higher must have a resistance of three megohms or more. |
| **9. Loose Wire Connections** | Visually check for loose or broken wires and connections. Check the wires and connections on the regulator assembly, the rotating rectifiers (CR1 thru CR6), and heat sinks (E1) and (E2). |
| **10. Wrong Regulator or Generator Connections** | Make a comparison of the generator line cable connections with those shown on the generator name plate. Check wiring of the regulator assembly and revolving field assembly (RFA) against the wiring diagram. |
| **11. Shorted Rotating Rectifiers (CR1 thru CR6)** | Remove the connection between rotating field (L5) and either heat sink (E1) or (E2). **NOTE: It is not necessary to remove both connections.** The rotating rectifiers can be checked in groups of three, (CR1, CR2 and CR3) or (CR4, CR5 and CR6). Use an ohmmeter or 8S4627 Continuity Tester. **NOTE: When using the 8S4627 Continuity Tester, the clip is the negative polarity terminal and the probe is the positive polarity terminal.** The instructions on the tester label are not correct. Connect the positive cable to heat sink (E1) and the negative cable to terminal connection of either (CR1, CR2 or CR3). The ohmmeter must be on the RX1000 scale. A very high resistance on the ohmmeter scale or no light with the continuity tester must be the result. Check the second group of rectifiers (CR4, CR5 and CR6). Connect the positive cable of the ohmmeter or continuity tester to the terminal connector of either (CR4, CR5 or CR6) and the negative cable to heat sink (E2). A very high resistance indication on ohmmeter scale (RX1000) or no light on the continuity tester must be the result.<br>**NOTE**<br>**If the test for high resistance or no light is not according to the description above, one or more of the rectifiers is shorted. To find the rectifier that is shorted it is necessary that each one be tested separately. Remove the wires bolted to the rectifier separately. For more information, see TESTING POWER RECTIFIERS AND CONTROLLED RECTIFIERS.** |
| **12. Shorted Circuit in Field Rectifier (CR10)** | Disconnect field rectifier (CR10) by removing wire (8) from spade terminal (8) of rectifier module (A2). Check reverse resistance of field rectifier (CR10) with an ohmmeter or continuity tester (8S4627). Connect the positive cable of the ohmmeter or continuity tester on spade terminal (8) and the negative cable on spade terminal (6). Typical reverse resistance is 30.000 ohms or more. **NOTE: Field rectifier (CR10) is in parallel with a resistance-capacitance circuit inside rectifier module (A2).** When the ohmmeter test cables are first connected to the circuit, a low |

**(Continued on next page)**

| POSSIBLE CAUSES | VERIFICATION PROCEDURE |
|---|---|
| | (Continued)<br><br>resistance will be seen. As a charge from the ohmmeter is put on the capacitor the resistance will increase to a constant reading. Set ohmmeter scale to RX1000. For more information, see TESTING POWER RECTIFIERS AND CONTROLLED RECTIFIERS. |
| **13. Loss of Residual Magnetism** | Check AC voltage at terminals (20) and (22) of regulator assembly. Less than 4 to 5 volts at 50 hertz or 8 to 9 volts at 60 hertz is an indication that residual magnetism has been lost.<br><br>See FLASHING THE FIELD. |
| **14. Controlled Rectifier (CR9) Has a Defect** | Disconnect controlled rectifier (CR9) by removing connections at spade terminals (10, 11 and 19) of rectifier module (A2). The ohmmeter scale must be on RX1000. Check forward and reverse resistance of (CR9) by connecting the positive cable of the meter to spade terminals (11) and the negative cable to terminal (19). Read the value of resistance. Reverse the cables and read the resistance again. Typical resistance in both directions is 300.000 ohms. **NOTE: Controlled rectifier (CR9) is connected in parallel with resistance-capacitance circuit in rectifier module (A2). When the ohmmeter test cables are first connected to the circuit, a low resistance will be seen. As a charge from the ohmmeter is put on the capacitor the resistance will increase to a constant high indication.**<br>Check the continuity of the gate to cathode circuit of (CR9). Connect the positive cable of ohmmeter to spade terminal 10, and the negative cable to spade terminal (11). Typical resistance !s 10 to 200 ohms.<br>The gate circuit can be checked with the continuity tester (8S4627). Connect the positive cable to spade terminal (191 and the negative cable to spade terminal (11). There must be no light or meter indication. Place a separate wire connection between spade terminals (19) and (10). Remove the wire connection as soon as the light comes on. The light will be on until the connection at either terminal (19) or (10) is broken. This is a test of the ability of (CR9) to "turn on." For more information, see TESTING POWER RECTIFIERS AND CONTROLLED RECTI-FIERS. |
| **15. Rectifier Module (A2) Has a Defect** | Disconnect rectifier module (A2) by removing the wires on spade terminals (6, 8, 10, 11 and 19). Check the continuity of the connections inside of (A2) with an ohmmeter or 8S4627 Continuity Tester.<br><br>Check the following:<br><br>FROM — TO<br>Spade Terminal (19) — Heat Sink (E3)<br>Spade Terminal (11) — Cathode terminal of (CR9)<br>Spade Terminal (10) — Gate terminal of (CR9)<br>Cathode terminal of (CR9) — Heat Sink (E4)<br>Spade Terminal (6) — Anode terminal of (CR10)<br>Spade Terminal (8) — Heat Sink (E4) |

**(Continued on next page)**

| POSSIBLE CAUSES | VERIFICATION PROCEDURE |
|---|---|
| | (Continued)<br><br>If all checks show continuity, remove the leads from the cathode of CR9 and from the anode of CR10. Check continuity from spade terminal (11) to spade terminal (19). Also check continuity between spade terminal (6) and spade terminal (8). If continuity is shown in either test, the module (A2) has an inside short circuit. Make a replacement of the module as necessary. |
| **16 Regulator Module (A1) Has a Defect** | Test procedures for this component are in the section on REGULATOR MODULE. |
| **17. Shorted Suppression Diode (CR7 or CR8)** | Surge suppression diode (CR7) is installed on positive heat sink (E1) and has a positive stud-type terminal. Surge suppression diode (CR8) is installed on negative heat sink (E2) and has a negative stud-type terminal. Disconnect (CR7 and CR8) by removing the wire to the spade terminal of each diode. Check the forward and reverse resistance of each diode. Typical resistance in both directions will be 15,000 ohms or more.<br><br>**NOTE: A suppression diode failure can normally be found visually or by the odor of selinium that has become too hot.** |
| **18. Shorted Surge Suppression Diode (CR11)** | Disconnect surge suppression diode (CR11) by removing wire (6) and both wires (19) connected to its spade terminals. Check the resistance of (CR11) with an ohmmeter connected to the spade terminals. Resistance must be 15,000 ohms or more.<br><br>**NOTE: A failure of the suppression diode can normally be found visually or by the odor of selinium that has become too hot.** |
| **19. Open Suppression Reactor (L1)** | Disconnect suppression reactor (L1) by removing wire (26) from terminal (26). Check continuity from wire (26), through suppression reactor (L1) to wire (12) at suppression capacitor (C2). Resistance is zero. |
| **20. Open SCR Reactor (L2)** | Disconnect SCR reactor (L2) by removing wire (19) from spade terminal (19) of rectifier module (A2). Check continuity from wire (19), through SCR reactor (L2) to wire (12) at suppression capacitor (C2).<br><br>**NOTE: Suppression reactor (L2) is several turns of wire with an air core. Resistance is zero.** |
| **21. Shorted Suppression Capacitor (C2)** | Disconnect suppression capacitor (C2) by removing wire (6) from the spade terminal on the capacitor. Ohmmeter scale must be on RX1000. Check continuity of (C2) from the spade terminal from which wire (6) was removed to the spade terminal that wires (12) are connected. When the ohmmeter test cables are first connected to the capacitor, a low resistance will be seen. As a charge from the ohmmeter is put on the capacitor, there will be an increase in resistance until a constant indication is seen. |
| **22. Shorted RFI Capacitor (C1)** | Disconnect the RFI suppression capacitor (C1) by removing both wires (6) from the spade terminal on the capacitor. Ohmmeter scale set to RX1000. Check continuity of the suppression capacitor (C1) from the spade terminal from which wires (6) were |

**(Continued on next page)**

| POSSIBLE CAUSES | VERIFICATION PROCEDURE |
|---|---|
| | (Continued)<br><br>removed to the spade terminal that wires (26) are connected. When the ohmmeter test cables are first connected to the capacitor, a low resistance will be seen. As a charge from the ohmmeter is put on the capacitor, the resistance will go up until a constant indication of near infinite resistance is seen. |
| **23. Open Rotating Rectifiers (CR1 through CR6)** | Disconnect the rotating rectifiers (CR1 through CR6) by removing the wires from exciter armature (L4) at the connections of each rectifier. Use an ohmmeter or continuity tester (8S4627) and put the negative cable to positive heat sink (E1) and positive cable to the terminal (anode) of each rectifier (CR1, CR2 and CR3). A low resistance (10 ohms or less) on ohmmeter scale (RX1) or a light with continuity tester (8S4627) must be seen. if not, the rectifier is open and must be changed.<br>Put the positive cable of the ohmmeter or continuity tester on the negative heat sink (E2) and the negative cable on the terminal (cathode) of each rectifier (CR4, CR5 and CR6). A low resistance (10 ohms or less) on ohmmeter scale (RX1) or a light with the continuity tester must be seen. If not, the rectifier is open and must be changed. For more information, see subject, TESTING POWER RECTIFIERS AND CONTROLLED RECTIFIERS. |
| **24. Engine RPM Too Low** | Check the engine rpm with tachometer of high accuracy or with E frequency meter. Make adjustments to the governor as needed to get correct engine rpm. |
| **25. Load Too High or Not Balanced** | Measure the load in amperes for each phase of the generator. The ampere load must not be higher than the rating given on the name plate of the generator. If necessary, make the load smaller. Toc high load on the engine (too many kilowatts) with low voltage car be caused by a high power factor. If the power factor is near 0.3 to 1.0, a reduction of the load must be made. Make this reduction to 80% of the rating In amperes. Too much load on the generator (too many kilovolt amperes) and low voltage can be caused by low power factor. If the power factor is less than 0.8, a reduction in the load is necessary.<br>When the load between the phases of the generator is not in. balance, low voltage can be the result. Sensing of the load on the generator (voltage sensing) is done from phase 1 to phase 2 and from phase 3 to phase 2. If the highest load is connected from phase 1 to phase 3 the indicated generator voltage will be low. |
| **26. Voltage Level Control Setting Too Low (R2)** | Get the voltage level higher by making an adjustment of voltage level control (R2). See Operation and Maintenance Instructions. Check for good contact between the moving brush and the turns of wire on voltage level rheostat (R2). Paint or other material car: prevent good electrical contact between these components. Bad contact will result in low voltage when it is not possible to get an adjustment of the voltage level when moving the voltage level rheostat (R2) from the maximum to minimum setting. |

| POSSIBLE CAUSES | VERIFICATION PROCEDURE |
|---|---|
| **27. Voltage Droop Control Setting Too High (R1)** | Correct voltage at no load but low voltage under load at 0.8 power factor, is an indication that voltage droop control (R1) setting is too high. To make an adjustment, see Operation and Maintenance Instructions. Check for good contact between the moving brush and the turns of wire on voltage droop control potentiometer (R1). Paint or other material can prevent good electrical contact between these components. Bad contact will result in low voltage from the generator under load at 0.8 power factor. You will not get an adjustment in the voltage as the droop control is moved from maximum to minimum setting. |
| **28. Regulator Gain Control Setting Too Low (R3)** | Correct voltage at no load but too low at rated load is an indication that regulator gain control (R3) setting is too low. See Operation and Maintenance Instructions for adjustment procedures |
| **29. Engine RPM Too High** | Check engine rpm with a tachometer of high accuracy or with a frequency meter. Make adjustments as needed to get correct engine rpm. |
| **30. Voltage Level Adjustment Too High (R2)** | Turn the voltage level rheostat (R2) toward minimum setting. See Operation and Maintenance Instructions for adjustment. |
| **31. Reverse Polarity on Voltage Droop Transformer (T1)** | Correct voltage at no-load but too high under load at 0.8 power factor is an indication that the connections on voltage droop transformer (T1) is wrong. Stop the engine and change the connections of voltage droop transformer (T1) at terminals (5) and (6). If this gives a correct high voltage under load, change the numbers on wires from the transformer (T1). |
| **32. Regulator Gain Control Setting Too High (R3)** | Correct voltage at no load but too high at rated load is an indication that the voltage gain control (R3) setting is too high. See Operation and Maintenance Instructions for adjustment. Check for good contact between the moving brush and the turns of wire on voltage gain control rheostat (R3). Paint or other material can prevent good electrical contact between these components. Bad contact will result in high voltage at rated load and it will not be possible to get an adjustment when the control is moved from maximum to minimum setting. |
| **33. Open Regulator Gain Rheostat (R3)** | Disconnect regulator gain rheostat (R3) by removing wire (lb) at spade terminal (8) of regulator module (A1). Check resistance from wire (18) to spade terminal (7) on regulator module (Al). With the regulator gain rheostat setting on maximum gain, the resistance will be approximately 5000 ohms (500 ohms in units with Al module that is black in color). When the gain control is turned to minimum position the resistance will become less and will read a short at the minimum position. |
| **34. Open Field Rectifier (CR10)** | Disconnect field rectifier (CR10) circuit by removing wire (8) from terminal (F1). Use an ohmmeter or continuity checker (8S4627). To check forward resistance of (CR10) put the positive cable on terminal (F2) and the negative cable on wire (8). A low resistance (10 ohms or less) on ohmmeter scale (RX1) or a light with the continuity tester must be seen. If an open circuit (infinity) or no light is seen field rectifier (CR10) is open. Remove and install a new rectifier. For more information, see TESTING POWER RECTIFIERS AND CONTROLLED RECTIFIERS. |

| POSSIBLE CAUSES | VERIFICATION PROCEDURE |
|---|---|
| **35. Load Not Balanced** | When the load on the generator cables (phases) is not the same the load is not in balance and this can cause high voltage. Sensing of the load on the generator is done from phase 1 to phase 2 and from phase 3 to phase 2. If the lowest load is connected from phase 1 to phase 3, the indicated generator voltage will be high. |
| **36. Regenerative Load Power Too High** | In some applications the load on the generator will come from al induction motor, used in lifting equipment. When a weight is lowered with lifting equipment, the motor will work as generator. The result of this condition is regenerative power going to the electric set. The regenerative power will cause the electric set to turn at too high rpm when:<br><br>1. There is no other load, or only a small other load on the set<br><br>2. When the lifting equipment has no dynamic brake.<br><br>With the electric set at too high rpm the output voltage will also be too high. |
| **37. Open Regulator Power Resistor (R4)** | If regulator power resistor (R4) is open, a temporary high voltage will be the result. This will cause fuse (F1) to open. To check (R4) disconnect wire (3) from spade terminal (3) on regulator module (A1). Check resistance from wire (3) to terminal (26). Typical resistance is approximately 1500 ohms. |
| **38. Open Voltage Reference Circuit** | If the voltage reference circuit is open, a temporary high voltage will be the result. This will cause fuse (F1) to open. Disconnect the voltage reference circuit by removing wires (20) and (22) from terminals (20) and (22). Check resistance from wire (20) to wire (22). Typical resistance is approximately 95,000 ohms. Check resistance from wire (20) to terminal (24) and from wire (22) to terminal (24). Typical resistance is approximately 65,000 ohm for each circuit. For more information, see REGULATOR MODULE. |
| **39. Lack of Load Stability** | Constant changes in load can cause a condition of variable speed and voltage. Check load changes that vary at the same time. |
| **40. Too Much Vibration of Suppression Reactor (L1)** | Too much vibration of suppression reactor (L1) can loosen the coil-core assembly. A loose core can prevent stability of the voltage. |
| **41. Lack of Engine RPM Stability**<br><br>**(Continued on next page)** | When the voltage and engine rpm have no stability, the cause can be either the voltage regulator assembly or the engine (governor) To find the cause, disconnect the voltage regulator assembly from the engine. A separate source of DC excitation is needed. The separate DC source can not be over 24 volts (batteries can be used and must have a manually controlled rheostat in series with the negative lead of the source. The rheostat is needed to give protection to the exciter field from too much current. Stop the engine and disconnect wires (F1) and (F2) from terminals (F1 and (F2). Connect the positive cable "+" from the DC source to wire (F1). Turn the series rheostat to maximum resistance less than five volts). Connect the negative cable "-" to wire (F2). Start the engine and run at rated rpm. Look at the AC voltmeter and turn the rheostat to add to the excitation voltage from the batteries until the AC voltmeter gives an indication of rate, |

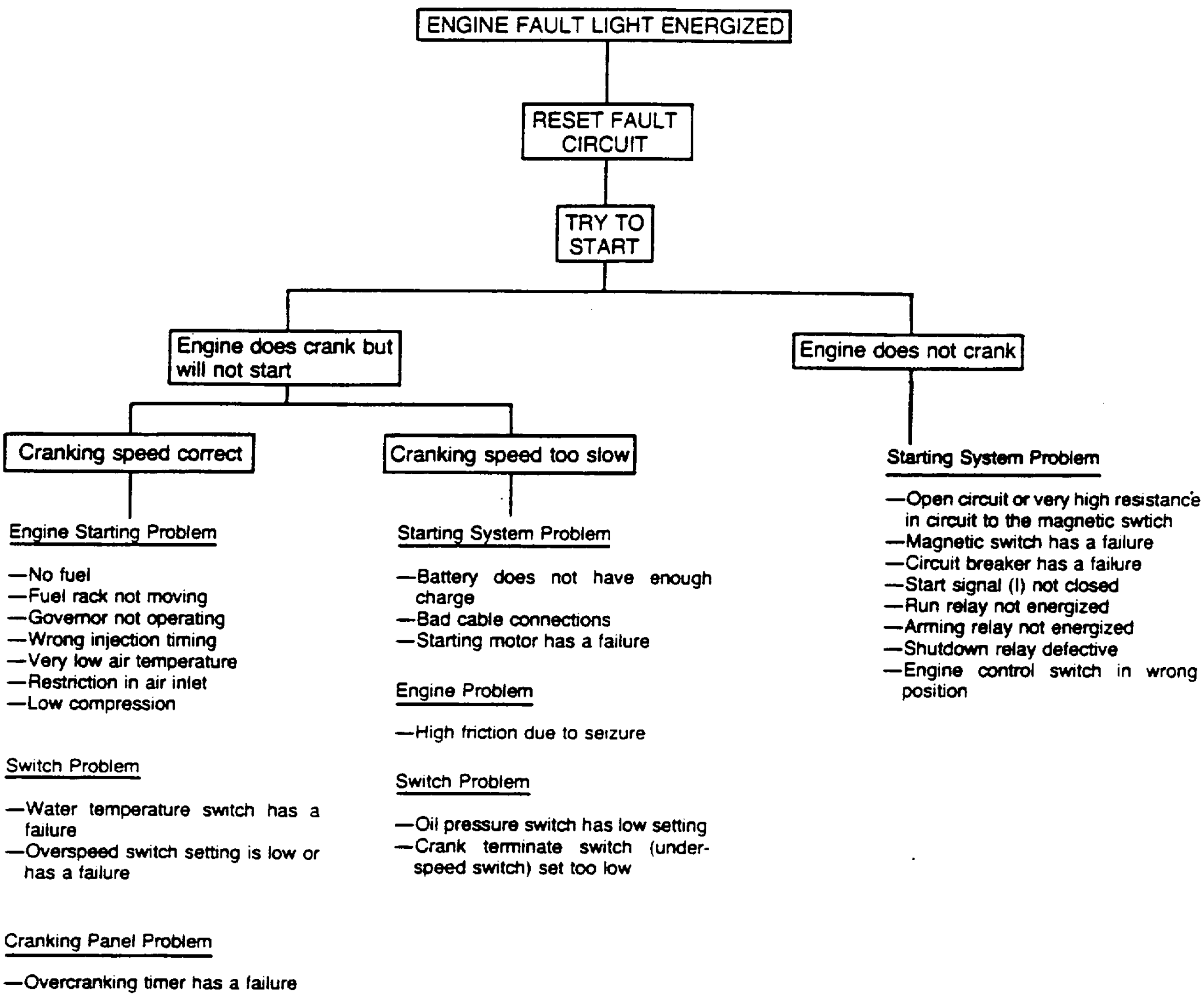
| POSSIBLE CAUSES | VERIFICATION PROCEDURE |
|---|---|
| | (Continued)<br><br>voltage. If the stability of the voltage and rpm are the same as before, the problem is in the engine (governor).<br><br>**NOTE: The generator name plate shows the maximum excitation voltage for full load. At no load, the correct excitation voltage is approximately 25% of the number on the generator nameplate.** |
| **42. Damping Resistor Open (R5)** | Disconnect damping resistor (R5) by removing wire (12) between damping resistor (R5) and suppression capacitor (C2). Check resistance of (R5) from wire (12) to terminal (26). Typical resistance is approximately 10 ohms. |
| **43. Temporary Short Circuit in RFI Suppression Capacitor (C1)** | Disconnect the RFI suppression capacitor (C1) by removing the spade terminal connection of wire (6). Start the engine and look for voltage stability. If voltage is not correct, remove (C1) and install a new capacitor. |
| **44. Temporary Short Circuit in Suppression Capacitor (C2)** | Disconnect suppression capacitor (C2) by removing spade terminal connection of wire (6). Start the engine and look for voltage stability. If voltage is not correct, remove (C2) and install a new capacitor.<br>To check suppression capacitor (C2), measure the resistance. A resistance measurement of anything but infinity shows that the suppression capacitor (C2) is defective. If the resistance is infinity connect 120V AC, 60 Hz, across the terminals. Current must be approximately one amp.<br><br>**NOTE: Install a 10 amp fuse in the 120V AC, 60 Hz, circuit. This is to be a safety limit if the capacitor is defective.** |
| **45. Current in Exciter Field (L3) is not Stable** | With the engine stopped, disconnect wire F1 from terminal F1. Connect the positive cable from a DC ammeter to terminal Fl. Connect the negative cable to wire F1.<br><br>**NOTE: The DC ammeter must have a capacity of 15 amps or more. Start the engine. The DC current in the exciter field (L3) must increase to a value less than 15 amps and remain constant.** |
| **46. Defect in Voltage Level Rheostat (R2)** | With engine stopped, disconnect wire (7) from spade terminal (4) of module (A1). Measure the resistance between wire (7) and spade terminal (6) of module (A1). This is the resistance of the voltage level rheostat (R2). The resistance with the voltage level rheostat (R2) fully clockwise is 0 ohms. The resistance is 500 ohms at fully counterclockwise. The resistance must change smoothly as the adjustment of the voltage level rheostat (R2) is changed between these points. |
| **47. Defect in Voltage Droop Potentiometer (R1)** | With the engine stopped, disconnect wire (5) from terminal (5) on module (A1). Measure the resistance between wire (5)and terminal (6) on the module (A1). Resistance with the voltage droop potentiometer (R1) fully counterclockwise is 0 ohms. The resistance is 8 ohms at fully clockwise. The resistance must change smoothly as the adjustment of the voltage droop potentiometer (R1) is changed between these points. |

| POSSIBLE CAUSES | VERIFICATION PROCEDURE |
|---|---|
| **48. Rotor Winding (L5) Defect** | If generator voltage goes low again and again. or only when generator gets to normal temperature for operation. rotor field (L5 ) could be the cause.<br><br>If exciter field (L3) current at no load, rated voltage and frequency is more than rated no load current by 60c, the exciter field ( L3). exciter armature (L4). or the rotor field (L5) windings could be defective. If Verification Procedure ,=5 shows no defect. the main rotor winding (L5) is defective.<br><br>If the exciter field current is within the limit at no load. check it a, close to rated condition (.8 power factor. rated volt and current) as possible.<br><br>**NOTE: For rated specifications make reference to ELECTRICAL MECHANICAL CHARACTERISTICS.**<br><br>**NOTE: A small change in power factor will change the field current necessary to give rated voltage. An increase in the power factor of the load will decrease the necessary field current.**<br><br>If it is not possible to operate the generator at rated load condition,. operate the generator 4 hours at a known load condition. Measure the field current. To find acceptable field current for load conditions other than rated, contact CATERPILLAR TRACTOR CO. |

## AUTOMATIC START/STOP SYSTEM (GENERATOR MOUNTED CONTROL PANEL)

The charts that follow give some of the problems and probable causes for trouble with automatic start/stop systems.

### NO SUPPLY OF STANDBY CURRENT



## NO SUPPLY OF STANDBY CURRENT

ENGINE FAULT LIGHT NOT ENERGIZED

- Engine does not crank
- Engine does operate
  - Generator does give Voltage
  - No voltage from Generator

**Engine does not crank**

Transfer Switch Problem

—Initiating contact (I) not closed (make reference to Transfer Switch Troubleshooting Guide).

Control Panel Problem

—ACS Switch wrong position
—IR or RR & AR relay open circuit

**Generator does give Voltage**

Generator Problem

—See "No AC Voltage" in Troubleshooting section.

**No voltage from Generator**

Transfer Switch Problem

—See Transfer Switch Troubleshooting Guide

Switchgear Problem

—See Switchgear Service Manual

## STANDBY CURRENT SUPPLY STOPS BEFORE NORMAL CURRENT RETURNS

**ENGINE FAULT LIGHT ENERGIZED**

Engine Problem

—High water temperature
—Low oil pressure
—Overspeed
—No fuel
—Overload
—Mechanical failure

**ENGINE FAULT LIGHT NOT ENERGIZED**

Generator Problem

—Malfunction developed during operation—see "No AC Voltage" in Troubleshooting section

## OPERATION OF STANDBY SYSTEM WHEN STANDBY CURRENT IS NO LONGER NEEDED

### Standby System still gives power

Transfer Switch Problem

- See Transfer Switch Troubleshooting Guide

### Standby System does not give power, but engine keeps operating

Cranking Panel Problem

- IR relay has a failure
- RR relay has a failure (if so equipped)
- TD/CDTR relay has a failure

Problem on Engine

- Pressure switch has a failure
- Rack stop solenoid has a failure or open in its circuit
- Fuel rack seizure in the open position (overspeed possible)

Transfer Switch Problem

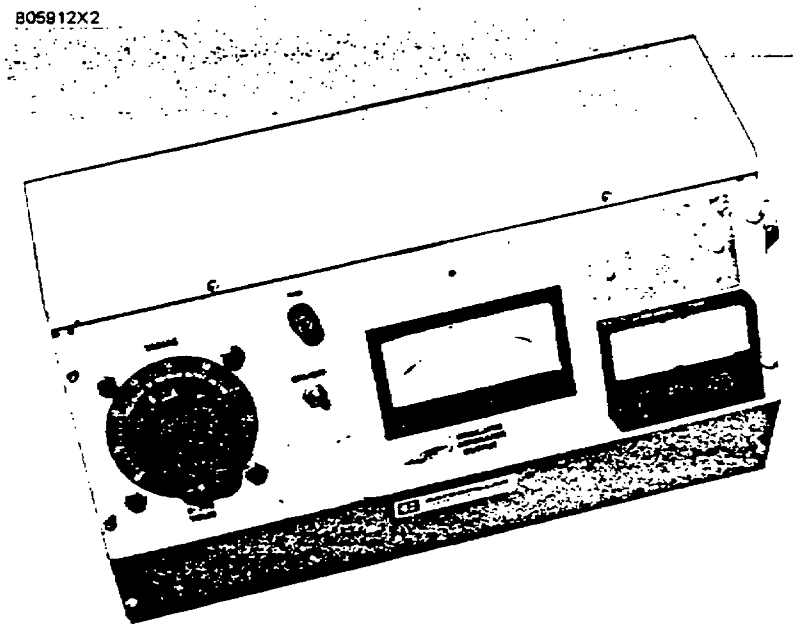
- See Transfer Switch Troubleshooting Guide

### No current to the load, standby system stopped

Transfer Switch Problem

- See Transfer Switch Troubleshooting Guide

## TEST OF REGULATOR EXCITER ASSEMBLIES
### (Regulator Removed From Generator)




**FABRICATED TOOLING - FT1488**

The special fabricated tooling ( FT1488) provides a way to test the power generator regulator - exciter assemblies. It allows testing after repairs without connecting to the generator set.

**TEST PROCEDURE**

1. Preparation
   A. Connect regulator-exciter to the FT tester as directed by connection chart.

| CONNECTION CHART | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Tester Terminal** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
| **SR-4 Terminal** | **5** | **6** | **24** | **26** | **22** | **20** | **F1** | **F2** |

   B. Set voltage, droop and gain controls full CCW.
   C. Set tester variac control CCW.
   D. Turn power switch on.
2. Relay Test
   A. Turn the variac slowly CW. at 90 ± 20 volts, there should be slight drop in the field voltage as the relay energizes.
3. Level control test
   A. Set voltage level control to mid-range position.
   B. Increase the variac position, raise general. voltage, until the field voltage starts to decrease and the load lamp starts to dim. This condition should occur between 200 and 260 volts on the generator voltmeter.
   C. Turn the voltage level control CW. the field voltage should increase and the load lamp should brighten.
   D. Turn the voltage level control CCW. the field voltage should decrease and the load lamp should dim.
4. Gain control test
   A. Set variac, generator voltmeter. to '240 volts.
   B. Adjust level control till load lamp is dim.
   C. Turn gain control CW. load lamp brightness should increase, field voltage should Increase.
5. Droop control test
   A. Set gain control CCW.
   B. Set variac, generator voltmeter, to 240.
   C. Adjust level control till load lamp is dim.
   D. Turn droop control CW, load lamp should go out, field voltage should decrease.

**NOTE: If the load lamp gets brighter and field voltage increases, reverse the secondary leads of transformer T3. This should only occur the first time the tester is used.**

## TESTING POWER RECTIFIERS AND CONTROLLED RECTIFIERS

The power rectifiers and controlled rectifiers, used in the SR 4 Generator Sets, are of the stud mounted type. You must be extra careful during the installation, testing and replacement of these components.

Failure of these units can be caused by:

1. Too much current.
2. Too much voltage.
3. Too much heat.
4. Wrong torque during installation.

The type of failure normally found in a rectifier or controlled rectifier is a short circuit from anode to cathode. An open circuit failure will not be seen with any frequency. Controlled rectifiers can have a failure with either a short or an open from gate to cathode. The performance of the excitation and regulation circuits can be less than desired as a result of a change in the characteristics of these components. This type of failure can not be found with an ohmmeter or continuity tester.

Rotating rectifiers (CR1, CR2 and CR3) and field rectifier (CR10) are of the normal polarity type: that is the terminal end is the anode and the stud end is the cathode. Rotating rectifiers (CR4, CR5 and CR6) are of the reverse polarity type: that is the stud end is the - anode and the terminal end is the cathode.

Controlled rectifier (CR9) is made with the stud end as the anode, the longest terminal end is the cathode and the shorter terminal end is the gate.

Ohmmeter or continuity tester (8S4627) checks can be made on these rectifiers but only to find short or open circuit conditions. To do these tests, the positive cable is connected to the anode and the negative cable to the cathode, then reverse the cables.

A shorted rectifier will have an indication of zero or very low resistance with an ohmmeter, or the light will be on with the circuit tester in both directions. An open rectifier will have an indication of infinity (maximum) on an ohmmeter or no light indication with the continuity tester in both directions. A "good" rectifier will have a much greater reverse resistance (cathode positive; anode negative) than forward resistance (cathode negative; anode positive). Typical reverse resistance is 30,000 ohms to 300,000 ohms. Typical forward resistance is less than 10 ohms.

The values you get can change with different meters.

A "good" controlled rectifier will have both forward and reverse resistance from anode to cathode of 30,000 ohms to 300,000 ohms but they must be approximately the same.

To make a test of the gate circuit of a controlled rectifier, connect the positive and negative cables of an ohmmeter to the gate and cathode terminals. Read the value of resistance. Reverse the cables and read the value again. A shorted gate will have an indication of zero resistance in both directions. An open gate will have an indication of an infinite (maximum) resistance in both directions. A "good" controlled rectifier will have a forward (gate to cathode) and reverse (cathode to gate) resistance that are about the same and approximately 10 to 200 ohms.

To make a test of the "turn-on" characteristic of the controlled rectifier use the continuity tester (8S4627). Put the positive cable of the tester on the stud end (anode) and the negative cable on the cathode terminal. Temporarily put a wire between the terminals of the gate and anode. The tester light will come on and be on until one of the cables is removed. If the light does not come on, the rectifier is bad. Install a new rectifier.

The stud used to install these rectifiers has two purposes: to give an electrical connection and a method of taking the heat away from the rectifier through the heat sink.

Be careful during the installation of a power rectifier or controlled rectifier on the aluminum heat sink. The threads on the rectifier and the contact surfaces on both the rectifier and the heat sink must be clean. Apply a small amount of 5P8937 or 5P92 10 Thermal Joint Compound to the contact surfaces.

**NOTE: A pound-inch (N·m) torque wrench check accuracy in the respective torque range) must be used for installation of power rectifiers and controlled rectifiers.**

The replacement of rotating rectifiers (CR1 through CR6) can be done more easily by removing the heat sink assemblies from the cooling fan. Positive heat sink (E1) has a mark "POS'" and the edge has a red paint mark. Negative heat sink (E2) has a mark "NEG" and the edge has a black paint mark.

| RECTIFIER TIGHTENING CHART | | |
|---|---|---|
| Rectifier Pat No. | Rectifier Base Stud Size | Tightening Torque Pound-Inches (N-m) |
| 3N1482 | No. 10 - 32 | 12 to 15 (1.3 to 1.7) |
| 3N1483 | 1/4 - 28 | 20 to 25 (2.3 to 2.8) |
| 3N1484 | 1/4 - 28 | 20 to 25 (2.3 to 2.8) |
| Controlled Rectifier 3N1481 | 1/4 - 28 | 20 to 25 (2.3 to 2.8) |

To remove the heat sink assemblies, each of the electrical connections must be opened. The assembly is fastened to the fan with two 5/ 16 in. tap-tite bolts. When these bolts are installed again, after removal, they must be tightened to a torque of 144 to 216 pound-inch ( 16.3 to 28.1 N•m). When you install the rotating rectifiers, put the terminal so that it is parallel to the long edge of the heat sink. This makes it easier when you are ready to connect the wires from the exciter armature (L4).

The replacement of controlled rectifier (CR9) and field rectifier (CR10) can be easily done by removing the rectifier module (A2) from the regulator chassis. To remove the module, each of the connections to spade terminals (6, 8, 10, 11 and 19) must be disconnected. The module can then be easily removed. The solder connections on controlled rectifier (CR9) and field rectifier (CR10) can be safely opened with a soldering gun and needle-nose pliers. When you install either of these units use a resin-core solder of the typically 60/40% (tin/lead) type. Use extra care to be sure that too much heat does not destroy the rectifiers.

## VOLTAGE REGULATOR MODULE (A1)

One of the components used in the voltage regulator assembly on the SR 4 Generator is the regulator module (A1). It is a completely sealed unit. Failure of the regulator is usually. caused by failure of other components in the circuits of the voltage regulator assembly.

A regulator module (A1) with a defect can cause any of the following conditions:

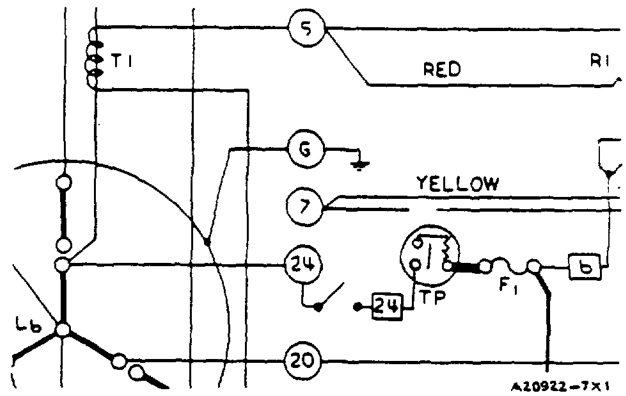
- No AC voltage
- AC voltage too low
- AC voltage too high
- Lack of AC voltage stability

**NOTE: Do not install a new regulator module (A1) until you have thoroughly tested all of the other components and circuits in the voltage regulator assembly.**

Tests can be made on the regulator module when the engine is running or is stopped. To test the regulator when the engine is running, install a single-pole, single-throw (SPST) switch in series with wire (24). This switch must have the ability to automatically turn off when it is released. Screw terminals must be on the switch.

**NOTE: Remove wire (24) from terminal (24). Connect switch to wire (24). Install another wire between the other side of the switch and terminal (24).**

Start the engine and run it at 1200 to 1250 rpm. Close the switch for a moment and read the value of the line voltage. If the generated voltage is approximately the same percent of rated voltage as the low idle rpm is of rated rpm, the regulator is working correctly.




*SPTS SWITCH INSTALLED IN SERIES IN WIRE (24).*

Example: If an electric set is rated for 240 volts at 1800 rpm (60 hertz), it will generate 160 volts at 1200 rpm (40 hertz).

Run the engine at high idle rpm and close the switch for a moment. Read the line voltage while the switch is closed. If the line voltage is approximately the same as rated voltage, the regulator module is working correctly. If the failure condition does not change, the regulator module can have a defect.

## PROCEDURE FOR FIRST OPERATION AFTER REPAIR

Do not run the electric set at rated rpm immediately after repair. The following procedure can prevent new failures if the CAUSE of the first failure condition was not correctly found.

1. Disconnect wires (10 and 19) from regulator assembly (A1). Cover the terminal of wires (10 and 19) with insulation tape.

2. Start the engine and run it at 1200 to 1250 rpm. The residual magnetism in the exciter field (L3) and the rotating field (L5) will give approximately 3 to 4 volts as measured at terminals (20) and (22). If the controlled rectifier has a short circuit, the generator will give a higher output voltage. Install a new controlled rectifier (CR9).

3. Stop the engine and connect wires (10 and 19) to spade terminals (10 and 9) of regulator assembly (A1).

4. Start the engine and run it at 1200 to 1250 rpm. The output voltage will be approximately 67 to 70 percent of the generator rated voltage. If the output voltage is too high (much higher than 70 percent of rated voltage), the failure is probably in the regulator module (A1).

5. With the engine running at a low idle rpm and the generator giving a constant voltage (approximately 60 to 70 percent of rated voltage), move the governor control to let the engine come up gradually to rated rpm. Make an adjustment to the voltage level control (R2) until the generator is at rated voltage. The generator is now ready to use.

## FLASHING THE FIELD

If the generator rotating field (L5) or the exciter field (L3) have a loss of residual magnetism. the magnetism can be put back by "flashing" the exciter field winding with a direct current 6 volt source. This source can be a 6 volt battery or a stationary battery charger.

### DYNAMIC FLASHING (ENGINE RUNNING)

With the engine stopped, connect a voltmeter (one with a high degree of accuracy) to terminals (20 and 22). Connect the positive "+" cable of the six volt source to terminal (F1). Start the engine and run at low idle rpm. Put the negative cable of the six volt source on terminal (F2) while reading the voltmeter. As soon as the voltmeter has an indication, remove the negative cable from terminal (F2).

**NOTE: If the negative cable of the DC source is held on terminal (F2) too long, the generator voltage can become too high and cause fuse (F1) to open. An ON-OFF switch in the DC source makes the work safer and easier. If a battery is the 6 volt source, a blocking diode in series with the battery decreases the chance of blowing (opening) the fuse (F1).**

### FLASHING WITH ENGINE STOPPED (STATIC FLASHING)

With the engine stopped, disconnect exciter filed (L3) wires; (F1) from terminal (F1) and (F2) from terminal (F2). Connect the positive “+” cable of the six volt source to wire (F1). Put the negative “-“ cable from the source and wire (F2) together for a moment, (two or three times). DO NOT HOLD THEM TOGETHER FOR MORE THAN ONE OR TWO SECONDS.

NOTE: According to theory, this method has the effect of putting residual magnetism back in the exciter field.

A more practical method is to flash the field with the engine running. This is dynamic flashing.

**INDUSTRIAL DIVISION ENGINE DATA SHEET**

EDS 70.0.1

DATE January 1976

SUBJECT: Caterpillar SR 4 Generators - Electrical/Mechanical Characteristic
BUSINESSES: Building Services, Material Handling, Marine, Agriculture
PRODUCT: Generator Sets

General Description

Construction
The SR 4 brushless generator is a single bearing, salient pole, revolving field alternator of drip-proof construction built to U.S. NEMA (National Electrical Manufacturers Association) specifications. The stator frame is bolted to the engine flywheel housing and the rotor is connected by a flexible plate type coupling to the engine flywheel. The generator shaft has an extension into the flywheel pilot bore to assure optimum alignment. The pilot also assures positive rotor support in the unlikely event of coupling looseness or fracture. The stator core is constructed of laminated electrical steel with semiclosed skewed slots.

The rotor consists of an integral pole laminated steel assembly keyed directly to the shaft. The pole faces contain complete amortisseur windings. Rotating speed is either 1500 rpm for 50 Hz, or 1800 rpm for 60 Hz.

Windings and Insulation
All SR 4 generators use Class F insulation on both rotor and stator.

NEMA allows, for Class F insulation, a 1050C temperature rise (measured by resistance) over a 40°C inlet air temperature for continuous full load, 24 hour per day operation. A 130°C temperature rise (above 400C) is allowed for standby operations. At prime power and standby kW ratings, SR 4 Generators will not exceed allowable NEMA temperature rises. Actual operating temperatures are lower than allowable NEMA temperature rises.

Stator, rotor and exciter windings are impregnated with 100% epoxy varnish, and the rotor and stator have an epoxy-asphalt overcoat which resists abrasion and fungus growth. Windings are 10-wire wye, connectable for high or low voltage. Multiple line leads, (parallel wires) assure maximum line lead flexibility.

Cooling
The SR 4 Generator is self-ventilated with air entry through louvers at the rear end of the generator and discharge through screened openings at the drive coupling end. Air is directed by two axial flow shaft mounted fans and a centrifugal fan which is mounted to the flywheel. The centrifugal fan also serves as a pressure ring for the coupling plates.

Regulator Assembly and Terminal Box
The louver ventilated steel cabinet houses the regulator assembly and the generator line leads.

SR 4 Generators have solidly mounted cabinet with an independently shock mounted regulator assembly. This construction provides vibration isolation for the regulation unit as well as a solid cabinet to which flexible electrical conduit may be attached.

Leads may be brought out of the cabinet from either the top or side of the upper right-hand quadrant of the cabinet (facing the rear of the generator set). An optional extension terminal box is available on all SR 4 Generators for improved ease of connections of load leads to generator leads, or for mounting a circuit breaker or link board.

Rotating Brushless Exciter
The rotating brushless exciter is mounted within the generator stator frame. The stationary exciter field is a 6 pole distributed winding on a core that is integral with the generator end bracket. The three-

phase rotating armature is mounted on an extension of the rotor shaft. Six rotating diodes mounted on the rear fan convert this three-phase AC current to DC for excitation of the main revolving field.

Voltage Regulation

The static voltage regulator is compact. It has only one moving part - a hermetically sealed voltage build-up relay which operates once each time the generator starts up and shuts down. The relay is integral with the solid-state epoxy encapsulated module.

The regulating system continually monitors generator output voltage (as well as line current and operating power factor) and corrects differences between the preset voltage level and the actual voltage level. Differences are sensed by the regulator which raises or lowers the field excitation of the brushless exciter. In turn, the brushless exciter raises or lowers generator field excitation to maintain the desired preset voltage level. This regulating and control system functions at low voltage and current levels within the exciter field circuit. Direct current output from the brushless exciter is continuous. The resulting voltage and current variations in the generator field are smooth. The result is voltage regulation within ± 2% from no load to full load with 3% speed droop. At isochronous speeds, regulation is ± 1% from no load to full load. At steady state conditions (no change in load on generator), voltage level is maintained within ± 0.2% of preset voltage level.

All SR 4 Generators use "volts-per-hertz" type regulation, which provides the best possible response by matching generator output to engine capability. This type of regulation prevents engine stalling under heavy load application (See engine data sheet 71.3). Over the normal load range, the voltage gain control maintains a nearly constant voltage even if the governed engine speed droops as much as 5% on an 0.8 P.F. load.

Radio Noise Suppression

Although the voltage regulating and exciting system generate a very minimum of radio frequency noise, the SR 4 Generator does include noise suppression as standard equipment. Radio frequency noise level of SR 4 Generators is well within commercially acceptable limits.

Telephone Influence Factor (TIF)

Caterpillar SR 4 Generator performance falls well within accepted standards for minimum telephone interference. A factor of 250 to 350 is commercially acceptable, in accordance with NEMA. All SR 4 Generators have a TIF of less than 50.

Thermal Protection

A thermal protective circuit breaker is used in the exciter field circuit in addition to a protective fuse. These two devices provide protection against overheating due to prolonged operation at low power factor loads. The circuit breaker is resettable, and the fuse must be replaced in event it opens.

These protection devices do not replace the normal load line circuit breaker or line fuses and disconnect switch.

Manual Adjustments

There are three controls on the exciter panel:

Voltage Level - provides a minimum adjustment of generator output voltage 5% above or below the standard nameplate voltage on all generators, except the 50 Hertz 240-480 volt generators which have an adjustment 10% above and 5% below nameplate voltage.

Voltage Gain - an adjustment to compensate for voltage drop caused by generator load and governor speed droop. It is used to optimize voltage regulation with either an isochronous or speed droop governor.

Voltage Droop - Standard on all SR 4 Generators. This adjustment provides for equal division of reactive KVA when two or more generators are operated in parallel. It is set at zero for single unit operation.

SERVICE INFORMATION

Complete service information on SR 4 Generators, including detail of automatic start-stop systems in the Package Generator Sets, is found in Service Department Form No. REG01106-02, "SR 4 Generator Service Manual."

Notes Relating to Charts

1. All SR 4 Generators have 10 line leads and are Wye (Y, star) connected. Line leads are connectable to either the higher or lower listed rated voltage.

2. Stator resistance is the line-to-line ohmic value when the coils are connected in parallel for the lower voltage. For line-to-neutral stator resistance, divide the value by 2. For line-to-line resistance when the coils are connected in series for high voltage, multiply the value by 4. For line-to-neutral resistance with the coils in series for high voltage, multiply the figure by 2.

3. Reactances are line-to-neutral per unit values at the listed kW rating. To convert to ohmic values, multiply listed value by the factor:

$$\frac{\text{Rated Volts}}{\sqrt{3} \times \text{Rated Amperes}}$$

4. To find the per unit reactance value at any kW, multiply the listed per unit value by the factor:

$$\frac{\text{kW}}{\text{Rated kW}}$$

**NOTE: For the latest electrical/mechanical information, make reference to the TECHNICAL INFORMATION FILE (T.I.F.).**

ELECTRICAL/MECHANICAL CHARACTERISTICS

| Generator Part Number (Frequency) | 5N1 (50 Hz) | 5N1 (60 Hz) | 5N2 (50 Hz) | 5N2 (60 Hz) | 5N3 (50 Hz) | 5N3 (60 Hz) |
|---|---|---|---|---|---|---|
| Frame Number | 365 | 365 | 444 | 444 | 445 | 445 |
| kW/KVA Rating Prime Power | 50/63 | 55/69 | 85/106 | 90/112 | 110/138 | 135/169 |
| Rated Volts | 200-400 | 240-480 | 200-400 | 240-480 | 200-400 | 240-480 |
| Rated Amperes | 180-90 | 166-83 | 306-153 | 270-135 | 397-198 | 406-203 |
| Nº Poles/Sync Speed | 4/1500 | 4/1800 | 4/1500 | 4/1800 | 4/1500 | 4/1800 |
| Overspeed Capacity, % | 150 | 125 | 150 | 125 | 150 | 125 |
| *Stator Resistance, Ohms, @ 25°C | .0367 | .0367 | .0250 | .0250 | .0120 | .0120 |
| *Transient Reactance | 0.1872 | 0.1716 | 0.3401 | 0.3001 | 0.2139 | 0.2188 |
| *Sub Transient Reactance | 0.0944 | 0.0866 | 0.1806 | 0.1594 | 0.1046 | 0.1070 |
| *Synchronous Reactance | 2.2052 | 2.0215 | 2.9617 | 2.6132 | 2.1038 | 2.1516 |
| *Negative Sequence Reactance | 0.1363 | 0.1250 | 0.2150 | 0.1897 | 0.1372 | 0.1404 |
| *Zero Sequence Reactance | 0.0420 | 0.0385 | 0.0548 | 0.0483 | 0.0391 | 0.0400 |
| Open Circuit Time Constant, Seconds | 0.9496 | 0.9496 | 1.2759 | 1.2759 | 1.4660 | 1.4660 |
| Exciter Field Res. Ohms, @ 25°C | 2.07 | 2.07 | 2.40 | 2.40 | 2.40 | 2.40 |
| Excitation Volts NL/FL | 7.5/25 | 7.5/19 | 7.5/22 | 7.5/20 | 9.0/21 | 9.0/21 |
| Excitation Amps NL/FL | 2.3/10.3 | 3.0/8.2 | 2.3/8.4 | 2.3/7.8 | 3.6/8.8 | 3.6/8.8 |
| Derate Altitude, Meters | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 |
| Derate Temperature °C | 50 | 50 | 50 | 50 | 50 | 50 |
| Efficiency at 0.8 Power Factor @0.50 FL | 89.3 | 89.8 | 90.8 | 91.2 | 90.3 | 91.0 |
| @0.75 FL | 89.9 | 90.7 | 90.5 | 91.5 | 90.8 | 91.7 |
| @1.00 FL | 89.3 | 90.6 | 89.4 | 91.0 | 90.4 | 91.4 |
| @1.25 FL | 88.4 | 90.0 | 88.0 | 90.1 | 89.6 | 90.8 |
| Temp Rise °C, Stator/Rotor | 90/90 | 90/90 | 90/90 | 90/90 | 90/90 | 90/90 |
| Heat Dissipated kCal/min | 86 | 82 | 145 | 128 | 168 | 182 |
| Air Flow Req'd, $M^3$/min | 25 | 24 | 43 | 38 | 50 | 54 |
| Rotor Weight, kg/LBS | 132/291 | 132/291 | 180/397 | 180/397 | 213/469 | 213/469 |
| $WR^2$ $Nmsec^2$ (LB in $sec^2$) | 1.021(9.04) | 1.021(9.04) | 2.100(18.58) | 2.100(18.58) | 2.525(22.34) | 2.525(22.34) |
| Stator Weight kg/LBS | 249/550 | 249/550 | 368/812 | 368/812 | 411/908 | 411/908 |
| Total Weight, kg/LBS | 381/841 | 381/841 | 548/1209 | 548/1209 | 624/1377 | 624/1377 |
| SAE Mounting Flange Number | No. 1 | No. 1 | No.1 | No. 1 | No. 1 | No. 1 |

*See Notes

ELECTRICAL/MECHANICAL CHARACTERISTICS

| Generator Part Number (Frequency) | 5N4 (50 Hz) | 5N4 (60 Hz) | 5N5 (50 Hz) | 5N5 (60 Hz) | 5N6 (50 Hz) | 5N6 (60 Hz) |
|---|---|---|---|---|---|---|
| Frame Number | 447 | 447 | 449 | 449 | 448 | 448 |
| kW/KVA Rating, Prime Power | 125/156 | 175/219 | 210/262 | 250/313 | 170/213 | 210/263 |
| Rated Volts | 200-400 | 240-480 | 200-400 | 240-480 | 200-400 | 240-480 |
| Rated Amperes | 450-225 | 526-263 | 758-379 | 752-376 | 613-306 | 632-316 |
| Nº Poles/Sync Speed | 4/1500 | 4/1800 | 4/1500 | 4/1800 | 4/1500 | 4/1800 |
| Overspeed Capacity, % | 50 | 125 | 150 | 125 | 150 | 125 |
| *Stator Resistance, Ohms, @ 25°C | .0077 | .0077 | .0048 | .0048 | .0059 | .0059 |
| *Transient Reactance | 0.2134 | 0.2490 | 0.2665 | 0.2644 | 0.2614 | 0.2691 |
| *Sub Transient Reactance | 0.1030 | 0.1201 | 0.1254 | 0.1244 | 0.1225 | 0.1261 |
| *Synchronous Reactance | 2.0727 | 2.4181 | 2.6539 | 2.6328 | 2.5415 | 2.6163 |
| *Negative Sequence Reactance | 0.1323 | 0.1543 | 0.1647 | 0.1634 | 0.1590 | 0.1636 |
| *Zero Sequence Reactance | 0.0386 | 0.0450 | 0.1257 | 0.1247 | 0.0857 | 0.0882 |
| Open Circuit Time Constant, Seconds | 1.6804 | 1.6804 | 1.9219 | 1.9219 | 1.8541 | 1.8541 |
| Exciter Field Res. Ohms, @ 25°C | 2.75 | 2.75 | 2.75 | 2.75 | 2.75 | 2.75 |
| Excitation Volts NL/FL | 7.3/18 | 7.3 | 9.0/27 | 9.0/27 | 7.9/28 | 7.9/26.5 |
| Excitation Amps NL/FL | 2.7/9.3 | 2.7 | 3.0/8.8 | 3.0/8.8 | 2.7/9.3 | 2.7/9.0 |
| Derate Altitude, Meters | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 |
| Derate Temperature °C | 50 | 50 | 50 | 50 | 50 | 50 |
| Efficiency at 0.8 Power Factor @0.50 FL | 90.9 | 92.6 | 92.9 | 93.3 | 92.8 | 93.1 |
| @0.75 FL | 92.0 | 93.3 | 93.4 | 93.9 | 93.3 | 93.8 |
| @1.00 FL | 92.2 | 93.2 | 93.1 | 93.8 | 93.1 | 93.7 |
| @1.25 FL | 91.9 | 92.8 | 92.6 | 93.4 | 92.5 | 93.3 |
| Temp Rise °C, Stator/Rotor | 90/90 | 90/90 | 90/90 | 90/90 | 90/90 | 90/90 |
| Heat Dissipated kCal/min | 152 | 184 | 224 | 237 | 181 | 202 |
| Air Flow Req'd, $M^3$/min | 45 | 54 | 66 | 70 | 53 | 60 |
| Rotor Weight, kg/LBS | 260/574 | 260/574 | 322/711 | 322/711 | 282/622 | 282/622 |
| $WR^2$ $Nmsec^2$ (LB In $Sec^2$) | 3.129(27.70) | 3.129(27.70) | 4.224(37.39) | 4.224(37.39) | 3.426(30.33) | 3.426(30.33) |
| Stator Weight kg/LBS | 494/1088 | 494/1088 | 601/1325 | 601/1325 | 537/1183 | 537/1183 |
| Total Weight, kg/LBS | 754/1622 | 754/1662 | 923/2036 | 923/2036 | 819/1805 | 819/1805 |
| SAE Mounting Flange Number | No. 1 | No. 1 | No. 1 | No. 0 | No. 1 | No. 1 |

| Generator Part Number (Frequency) | 5N7 (60 Hz) | 5N13(60 Hz) | 5N14(60 Hz) | 5N14(60 Hz) | 5N15(50 Hz) | 5N15(50 Hz) |
|---|---|---|---|---|---|---|
| Frame Number | 447 | 449A | 444 | 444 | 444 | 444 |
| kW/KVA Rating, Prime Power | 185/231 | 235/294 | 90/112 | 110/138 | 85/106 | 105/131 |
| Rated Volts | 240-480 | 240-480 | 208-416 | 208-416 | 200-400 | 200-400 |
| Rated Amperes | 556-278 | 707-353 | 314-157 | 382-191 | 306-153 | 379-190 |
| Nº Poles/Sync Speed | 4/1800 | 4/1800 | 4/1800 | 4/1800 | 4/1500 | 4/1500 |
| Overspeed Capacity, % | 125 | 125 | 125 | 125 | 150 | 150 |
| *Stator Resistance, Ohms, @ 25°C | .0077 | .0048 | .0195 | .0195 | .0250 | .0250 |
| *Transient Reactance | 0.2632 | 0.2485 | 0.3185 | 0.3893 | 0.3401 | 0.4201 |
| *Sub Transient Reactance | 0.1270 | 0.1170 | 0.1692 | 0.2068 | 0.1806 | 0.2232 |
| *Synchronous Reactance | 2.5563 | 2.4749 | 2.7736 | 3.3899 | 2.9617 | 3.6585 |
| *Negative Sequence Reactance | 0.1631 | 0.1536 | 0.2013 | 0.2461 | 0.2150 | 0.2655 |
| *Zero Sequence Reactance | 0.0476 | 0.1173 | 0.0513 | 0.0627 | 0.0548 | 0.0677 |
| Open Circuit Time Constant | 1.6804 | 1.9219 | 1.2759 | 1.2759 | 1.2759 | 1.2759 |
| Exciter Field Res. Ohms, @ 25°C | 2.75 | 2.75 | 1.95 | 1.95 | 2.40 | 2.40 |
| Excitation Volts NL/FL | 7.0/22.5 | 9.0/24 | 7.0/20 | 7.0/24 | 7.5/22 | 7.5/29 |
| Excitation Amps NL/FL | 3.2/8.0 | 3.0/8.0 | 3.0/7.8 | 3.0/9.3 | 2.3/8.4 | 2.3/11 |
| Derate Altitude, Meters | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 |
| Derate Temperature °C | 50 | 50 | 40 | 40 | 40 | 40 |
| Efficiency at 0.8 Power Factor @0.50 FL | 92.8 | 93.3 | 91.2 | 91.6 | 90.8 | 90.8 |
| @0.75 FL | 93.3 | 94.0 | 91.5 | 91.3 | 90.5 | 89.8 |
| @1.00 FL | 93.2 | 94.0 | 91.0 | 90.3 | 89.4 | 88.2 |
| @1.25 FL | 92.7 | 93.6 | 90.1 | 89.1 | 88.0 | 86.3 |
| Temp Rise °C, Stator/Rotor | 90/90 | 90/90 | 105/105 | 105/105 | 105/105 | 105/105 |
| Heat Dissipated kCal/min | 194 | 215 | 128 | 169 | 145 | 201 |
| Air Flow Req'd, $M^3$/min | 57 | 64 | 38 | 50 | 43 | 59 |
| Rotor Weight, kg/LBS | 260/574 | 322/711 | 180/397 | 180/397 | 180/397 | 180/397 |
| $WR^2$ $Nmsec^2$ (LB In $Sec^2$) | 3.129(27.70) | 3.766(33.34) | 2.100(18.58) | 2.100(18.58) | 2.100(18.58) | 2.100(18.58) |
| Stator Weight kg/LBS | 502/1107 | 583/1284 | 368/812 | 368/812 | 368/812 | 368/812 |
| Total Weight, kg/LBS | 762/1681 | 905/1995 | 548/1209 | 548/1209 | 548/1209 | 548/1209 |
| SAE Mounting Flange Number | No. 1 | No. 1 | No. 1 | No. 1 | No. 1 | No. 1 |

*See Notes

ELECTRICAL/MECHANICAL CHARACTERISTICS

| Generator Part Number (Frequency) | 5N15(60 Hz) | 5N15(60 Hz) | 5N16(50 Hz) | 5N16(50 Hz) | 5N16(60 Hz) | 5N16(60 Hz |
|---|---|---|---|---|---|---|
| Frame Number | 444 | 444 | 444 | 444 | 444 | 444 |
| kW/KVA Rating, Prime Power | 90/112 | 110/138 | 85/106 | 105/131 | 90/112 | 110/138 |
| Rated Volts | 240-480 | 240-480 | 240-480 | 240-480 | 300-600 | 300-600 |
| Rated Amperes | 270-135 | 331-166 | 256-128 | 316-158 | 216-108 | 264-132 |
| N° Poles/Sync Speed | 4/1800 | 4/1800 | 4/1500 | 4/1500 | 4/1800 | 4/1800 |
| Overspeed Capacity, % | 125 | 125 | 150 | 150 | 125 | 125 |
| *Stator Resistance, Ohms, @ 25°C | .0250 | .0250 | .0366 | .0366 | .0366 | .0366 |
| *Transient Reactance | 0.3001 | 0.3668 | 0.3690 | 0.4559 | 0.3001 | 0.3668 |
| *Sub Transient Reactance | 0.1594 | 0.1948 | 0.1960 | 0.2421 | 0.1594 | 0.1948 |
| *Synchronous Reactance | 2.6132 | 3.1939 | 3.2136 | 3.9697 | 2.6132 | 3.1939 |
| *Negative Sequence Reactance | 0.1897 | 0.2318 | 0.2333 | 0.2881 | 0.1897 | 0.2318 |
| *Zero Sequence Reactance | 0.0483 | 0.0591 | 0.0595 | 0.0734 | 0.0483 | 0.0591 |
| Open Circuit Time Constant | 1.2759 | 1.2759 | 1.2759 | 1.2759 | 1.2759 | 1.2759 |
| Exciter Field Res. Ohms, @ 25°C | 2.40 | 2.40 | 2.40 | 2.40 | 2.40 | 2.40 |
| Excitation Volts NL/FL | 7.5/20 | 7.5/24 | 7.5/22 | 7.5/29 | 7.5/20 | 7.5/24 |
| Excitation Amps NL/FL | 2.3/7.8 | 2.3/9.3 | 2.3/8.4 | 2.3/11 | 2.3/7.8 | 2.3/9.3 |
| Derate Altitude, Meters | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 |
| Derate Temperature °C | 40 | 40 | 40 | 40 | 40 | 40 |
| Efficiency at 0.8 Power Factor @0.50 FL | 91.2 | 91.6 | 90.8 | 90.8 | 91.2 | 91.6 |
| @0.75 FL | 91.5 | 91.3 | 90.5 | 89.8 | 91.5 | 91.3 |
| @1.00 FL | 91.0 | 90.3 | 89.4 | 88.2 | 91.0 | 90.3 |
| @1.25 FL | 90.1 | 89.1 | 88.0 | 86.3 | 90.1 | 89.1 |
| Temp Rise °C, Stator/Rotor | 105/105 | 105/105 | 105/105 | 105/105 | 105/105 | 105/105 |
| Heat Dissipated kÇal/min | 128 | 169 | 145 | 201 | 128 | 169 |
| Air Flow Req'd, $M^3$/min | 38 | 50 | 43 | 59 | 38 | 50 |
| Rotor Weight, kg/LBS | 180/397 | 180/397 | 180/397 | 180/397 | 180/397 | 180/397 |
| $WR^2$ $Nmsec^2$ (LB In $Sec^2$) | 2.100(18.58) | 2.100(18.58) | 2.100(18.58) | 2.100(18.58) | 2.100(18.58) | 2.100(18.58) |
| Stator Weight kg/LBS | 368/812 | 368/812 | 368/812 | 368/812 | 368/812 | 368/812 |
| Total Weight, kg/LBS | 548/1209 | 548/1209 | 548/1209 | 548/1209 | 548/1209 | 548/1209 |
| SAE Mounting Flange Number | No. 1 | No. 1 | No. 1 | No. 1 | No. 1 | No. 1 |

| Generator Part Number (Frequency) | 5N17(60 Hz) | 5N18(50 Hz) | 5N18(60 Hz) | 5N19(50 Hz) | 5N19(60 Hz) | 5N20(60 Hz |
|---|---|---|---|---|---|---|
| Frame Number | 445 | 445 | 445 | 445 | 445 | 447 |
| kW/KVA Rating, Prime Power | 135/169 | 110/138 | 135/169 | 110/138 | 135/169 | 175/219 |
| Rated Volts | 208-416 | 200-400 | 240-480 | 240-480 | 300-600 | 208-416 |
| Rated Amperes | 468-234 | 397-198 | 406-203 | 331-165 | 325-162 | 607-304 |
| N° Poles.Sync Speed | 4/1800 | 4/1500 | 4/1800 | 4/1500 | 4/1800 | 4/1800 |
| Overspeed Capacity, % | 125 | 150 | 125 | 150 | 125 | 125 |
| *Stator Resistance, Ohms, @ 25°C | .0100 | .0120 | .0120 | .0192 | .0192 | .0056 |
| *Transient Reactance | 0.3009 | 0.2139 | 0.2188 | 0.2425 | 0.2286 | 0.2436 |
| *Sub Transient Reactance | 0.1491 | 0.1046 | 0.1070 | 0.1186 | 0.1118 | 0.1175 |
| *Synchronous Reactance | 2.9327 | 2.1038 | 2.1516 | 2.3854 | 2.2483 | 2.3653 |
| *Negative Sequence Reactance | 0.1945 | 0.1372 | 0.1404 | 0.1556 | 0.1467 | 0.1509 |
| *Zero Sequence Reactance | 0.1382 | 0.0391 | 0.0400 | 0.0443 | 0.0418 | 0.0441 |
| Open Circuit Time Constant | 1.4660 | 1.4660 | 1.4660 | 1.4660 | 1.4660 | 1.6804 |
| Exciter Field Res. Ohms, @ 25°C | 1.95 | 2.40 | 2.40 | 2.40 | 2.40 | 2.17 |
| Excitation Volts NL/FL | 8.0/21 | 9.0/21 | 9.0/21 | 8.6/21 | 8.6/21 | 7.0/21 |
| Excitation Amps NL/FL | 2.6/8.8 | 3.6/8.8 | 3.6/8.8 | 3.4/8.8 | 3.4/8.8 | 3.2/7.5 |
| Derate Altitude, Meters | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 |
| Derate Temperature °C | 40 | 40 | 40 | 40 | 40 | 40 |
| Efficiency At 0.8 Power Factor @0.50 FL | 91.0 | 90.3 | 91.0 | 90.3 | 91.0 | 92.6 |
| @0.75 FL | 91.7 | 90.8 | 91.7 | 90.8 | 91.7 | 93.3 |
| @1.00 FL | 91.4 | 90.4 | 91.4 | 90.4 | 91.4 | 93.2 |
| @1.25 FL | 90.8 | 89.6 | 90.8 | 89.6 | 90.8 | 92.8 |
| Temp Rise °C, Stator/Rotor | 105/105 | 105/105 | 105/105 | 105/105 | 105/105 | 105/105 |
| Heat Dissipated kÇal/min | 182 | 168 | 182 | 168 | 182 | 184 |
| Air Flow Req'd, $M^3$/min | 54 | 50 | 54 | 50 | 54 | 54 |
| Rotor Weight, kg/LBS | 213/469 | 213/469 | 213/469 | 213/469 | 213/469 | 260/574 |
| $WR^2$ $Nmsec^2$ (LB In $Sec^2$) | 2.525(22.34) | 2.525(22.34) | 2.525(22.34) | 2.525(22.34) | 2.525(22.34) | 3.129(27.70) |
| Stator Weight kg/LBS | 411/908 | 411/908 | 411/908 | 411/908 | 411/908 | 494/1088 |
| Total Weight, kg/LBS | 624/1377 | 624/1377 | 624/1377 | 624/1377 | 624/1377 | 754/1662 |
| SAE Mounting Flange Number | No. 1 | No. 1 | No. 1 | No. 1 | No. 1 | No. 1 |

*See Notes

## ELECTRICAL/MECHANICAL CHARACTERISTICS

| Generator Part Number (Frequency) | 5N21(50 Hz) | 5N21(50 Hz) | 5N21(60 Hz) | 5N22(50 Hz) | 5N22(50 Hz) | 5N22(60 Hz) |
|---|---|---|---|---|---|---|
| Frame Number | 447 | 447 | 447 | 447 | 447 | 447 |
| kW/KVA Rating, Prime Power | 125/156 | 150/188 | 175/219 | 125/156 | 150/188 | 175/219 |
| Rated Volts | 200-400 | 200-400 | 240-480 | 240-480 | 240-480 | 300-600 |
| Rated Amperes | 450-225 | 541-271 | 526-263 | 376-188 | 451-225 | 421-210 |
| Nº Poles/Sync Speed | 4/1500 | 4/1500 | 4/1800 | 4/1500 | 4/1500 | 4/1800 |
| Overspeed Capacity, % | 150 | 150 | 125 | 150 | 150 | 125 |
| *Stator Resistance, Ohms, @ 25°C | .0077 | .0077 | .0077 | .0118 | .0118 | .0118 |
| *Transient Reactance | 0.2134 | 0.2561 | 0.2490 | 0.2186 | 0.2623 | 0.2350 |
| *Sub Transient Reactance | 0.1030 | 0.1236 | 0.1201 | 0.1054 | 0.1265 | 0.1134 |
| *Synchronous Reactance | 2.0727 | 2.4872 | 2.4181 | 2.1223 | 2.5468 | 2.2819 |
| *Negative Sequence Reactance | 0.1323 | 0.1587 | 0.1543 | 0.1354 | 0.1625 | 0.1456 |
| *Zero Sequence Reactance | 0.0386 | 0.0463 | 0.0450 | 0.0395 | 0.0474 | 0.0425 |
| Open Circuit Time Constant | 1.6804 | 1.6804 | 1.6804 | 1.6804 | 1.6804 | 1.6804 |
| Exciter Field Res. Ohms, @ 25°C | 2.75 | 2.75 | 2.75 | 2.75 | 2.75 | 2.75 |
| Exciation Volts NL/FL | 7.3/18 | 7.3/21 | 7.3/21 | 7.3/18 | 7.3/21 | 7.3/21 |
| Excitation Amps NL/FL | 2.7/6.3 | 2.7/7.5 | 2.7/7.5 | 2.7/6.3 | 2.7/7.5 | 2.7/7.5 |
| Derate Altitude, Meters | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 |
| Derate Temperature °C | 40 | 40 | 40 | 40 | 40 | 40 |
| Efficiency at 0.8 Power Factor @0.50 FL | 90.9 | 92.3 | 92.6 | 90.9 | 92.3 | 92.6 |
| Efficiency at 0.8 Power Factor @0.75 FL | 92.0 | 92.8 | 93.3 | 92.0 | 92.8 | 93.3 |
| Efficiency at 0.8 Power Factor @1.00 FL | 92.2 | 92.5 | 93.2 | 92.2 | 92.5 | 93.2 |
| Efficiency at 0.8 Power Factor @1.25 FL | 91.9 | 91.8 | 92.8 | 91.9 | 91.8 | 92.8 |
| Temp Rise °C, Stator/Rotor | 105/105 | 105/105 | 105/105 | 105/105 | 105/105 | 105/105 |
| Heat Dissipated kCal/min | 152 | 175 | 184 | 152 | 175 | 184 |
| Air Flow Req'd, M$^3$/min | 45 | 52 | 54 | 45 | 52 | 54 |
| Rotor Weight, kg/LBS | 260/574 | 260/574 | 260/574 | 260/574 | 260/574 | 260/574 |
| $WR^2$ Nmsec$^2$ (Lb In Sec$^2$) | 3.129(27.70) | 3.129(27.70) | 3.129(27.70) | 3.129(27.70) | 3.129(27.70) | 3.129(27.70) |
| Stator Weight kg/LBS | 494/1088 | 494/1088 | 494/1088 | 494/1088 | 494/1088 | 494/1088 |
| Total Weight, kg/LBS | 754/1662 | 754/1662 | 754/1662 | 754/1662 | 754/1662 | 754/1662 |
| SAE Mounting Flange Number | No. 1 | No. 1 | No. 1 | No. 1 | No. 1 | No. 1 |

| Generator Part Number (Frequency) | 5N23(60 Hz) | 5N24(50 Hz) | 5N24(60 Hz) | 5N25(50 Hz) | 5N25(60 Hz) | 5N27(60 Hz) |
|---|---|---|---|---|---|---|
| Frame Number | 449 | 449 | 449 | 449 | 449 | 446 |
| kW/KVA Rating, Prime Power | 250/312 | 210/262 | 250/312 | 210/262 | 250/312 | 155/194 |
| Rated Volts | 208-416 | 200-400 | 240-480 | 240-480 | 300-600 | 208-416 |
| Rated Amperes | 867-434 | 758-379 | 752-376 | 631-316 | 601-301 | 538-269 |
| N°Poles/Sync Speed | 4/1800 | 4/1500 | 4/1800 | 4/1500 | 4/1800 | 4/1800 |
| Overspeed Capacity, % | 125 | 150 | 125 | 150 | 125 | 125 |
| *Stator Resistance, Ohms, @ 25°C | .0038 | .0048 | .0048 | .0081 | .0081 | .0099 |
| *Transient Reactance | 0.2686 | 0.2665 | 0.2644 | 0.2946 | 0.2694 | 0.2931 |
| *Sub Transient Reactance | 0.1257 | 0.1254 | 0.1244 | 0.1379 | 0.1261 | 0.1448 |
| *Synchronous Reactance | 2.6830 | 2.6539 | 2.6328 | 2.9433 | 2.6910 | 2.7794 |
| *Negative Sequence Reactance | 0.1655 | 0.1647 | 0.1634 | 0.1815 | 0.1660 | 0.1826 |
| *Zero Sequence Reactance | 0.0907 | 0.1257 | 0.1247 | 0.0995 | 0.0910 | 0.0517 |
| Open Circuit Time Constant | 1.9219 | 1.9219 | 1.9219 | 1.9219 | 1.9219 | 1.6045 |
| Exciter Field Res. Ohms, @ 25°C | 2.17 | 2.75 | 2.75 | 2.75 | 2.75 | 1.95 |
| Excitation Volts NL/FL | 8.5/27 | 9.0/27 | 9.0/27 | 9.0/27 | 9.0/27 | 5.5/24 |
| Excitation Amps NL/FL | 3.5/8.8 | 3.0/8.8 | 3.0/8.8 | 3.0/8.8 | 3.0/8.8 | 3.1/8.8 |
| Derate Altitude, Meters | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 |
| Derate Temperature °C | 40 | 40 | 40 | 40 | 40 | 40 |
| Efficiency at 0.8 Power Factor @0.50 FL | 93.3 | 92.9 | 93.3 | 92.9 | 93.2 | 92.5 |
| Efficiency at 0.8 Power Factor @0.75 FL | 93.9 | 93.4 | 93.9 | 93.4 | 93.9 | 93.0 |
| Efficiency at 0.8 Power Factor @1.00 FL | 93.8 | 93.1 | 93.8 | 93.1 | 93.8 | 92.7 |
| Efficiency at 0.8 Power Factor @1.25 FL | 93.4 | 92.6 | 93.4 | 92.6 | 93.4 | 92.1 |
| Temp Rise °C, Stator/Rotor | 105/105 | 105/105 | 105/105 | 105/105 | 105/105 | 105/105 |
| Heat Dissipated kCal/min | 237 | 224 | 237 | 224 | 237 | 175 |
| Air Flow Req'd, M$^3$/min | 70 | 66 | 70 | 66 | 70 | 52 |
| Rotor Weight, kg/LBS | 322/711 | 322/711 | 322/711 | 322/711 | 322/711 | 232/511 |
| $WR^2$ Nmsec$^2$ (LB In Sec$^2$) | 4.224(37.39) | 4.224(37.39) | 4.224(37.39) | 4.224(37.39) | 4.224(37.39) | 2.847(25.19) |
| Stator Weight kg/LBS | 601/1325 | 601/1325 | 601/1325 | 601/1325 | 601/1325 | 434/958 |
| Total Weight, kg/LBS | 923/2036 | 923/2036 | 923/2036 | 923/2036 | 923/2036 | 666/1469 |
| SAE Mounting Flange Number | No. 0 | No. 0 | No. 0 | No. 0 | No. 0 | No. 1 |

*See Notes

ELECTRICAL/MECHANICAL CHARACTERISTICS

| Generator Part Number (Frequency) | 5N28(60 Hz) | 5N29(60 Hz) | 5N30(60 Hz) | 5N31(50 Hz) | 5N31(60 Hz) | 5N32(50 H |
|---|---|---|---|---|---|---|
| Frame Number | 446 | 446 | 447 | 447 | 447 | 447 |
| kW/KVA Rating, Prime Power | 155/194 | 155/194 | 185/231 | 155/194 | 185/231 | 155/194 |
| Rated Volts | 240-480 | 300-600 | 208-416 | 200-400 | 240-480 | 240-480 |
| Rated Amperes | 467-233 | 372-186 | 642-321 | 560-280 | 556-278 | 467-233 |
| N° Poles/Sync Speed | 4/1800 | 4/1800 | 4/1800 | 4/1500 | 4/1800 | 4/1500 |
| Overspeed Capacity, % | 125 | 125 | 125 | 150 | 125 | 150 |
| *Stator Resistance, Ohms, @ 25°C | .0119 | .0159 | .0056 | .0077 | .0077 | .0118 |
| *Transient Reactance | 0.2827 | 0.2761 | 0.2575 | 0.2646 | 0.2632 | 0.2710 |
| *Sub Transient Reactance | 0.1397 | 0.1364 | 0.1242 | 0.1277 | 0.1270 | 0.1307 |
| *Synchronous Reactance | 2.6815 | 2.6187 | 2.5004 | 2.5700 | 2.5563 | 2.6316 |
| *Negative Sequence Reactance | 0.1762 | 0.1721 | 0.1596 | 0.1640 | 0.1631 | 0.1679 |
| *Zero Sequence Reactance | 0.0499 | 0.0487 | 0.0466 | 0.0478 | 0.0476 | 0.0490 |
| Open Circuit Time Constant | 1.6045 | 1.6045 | 1.6804 | 1.6804 | 1.6804 | 1.6804 |
| Exciter Field Res. Ohms, @ 25°C | 2.40 | 2.40 | 2.17 | 2.75 | 2.75 | 2.75 |
| Excitation Volts NL/FL | 6.8/24 | 6.8/24 | 7.0/22.5 | 7.3/22.5 | 7.3/22.5 | 7.3/22.5 |
| Exciation Amps NL/FL | 2.6/8.8 | 2.6/8.8 | 3.2/8.0 | 2.7/8.0 | 2.7/8.0 | 2.7/8.0 |
| Derate Altitude, Meters | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 |
| Derate Temperature °C | 40 | 40 | 40 | 40 | 40 | 40 |
| Efficiency at 0.8 Power Factor @0.50 FL | 92.5 | 92.5 | 92.8 | 92.3 | 92.8 | 92.3 |
| @0.75 FL | 93.0 | 93.0 | 93.3 | 92.8 | 93.3 | 92.8 |
| @1.00 FL | 92.7 | 92.7 | 93.2 | 92.4 | 93.2 | 92.4 |
| @1.25 FL | 92.1 | 92.1 | 92.7 | 91.7 | 92.7 | 91.7 |
| Temp Rise °C, Stator/Rotor | 105/105 | 105/105 | 105/105 | 105/105 | 105/105 | 105/105 |
| Heat Dissipated kCal/min | 175 | 175 | 194 | 182 | 194 | 182 |
| Air Flow Req'd, $M^3$/min | 52 | 52 | 57 | 54 | 57 | 54 |
| Rotor Weight, kg/LBS | 232/511 | 232/511 | 260/574 | 260/574 | 260/574 | 260/574 |
| $WR^2$ $Nmsec^2$ (Lb In $Sec^2$) | 2.847(25.9) | 2.847(25.19) | 3.129(27.70) | 3.129(27.70) | 3.129(27.70) | 3.129(27.7 |
| Stator Weight kg/LBS | 434/958 | 434/958 | 502/1107 | 502/1107 | 502/1107 | 502/1107 |
| Total Weight, kg/LBS | 666/1469 | 666/1469 | 762/1681 | 762/1681 | 762/1681 | 762/1681 |
| SAE Mounting Flange Number | No. 1 | No. 1 | No. 1 | No. 1 | No. 1 | No. 1 |

| Generator Part Number (Frequency) | 5N32(60 Hz) | 5N33(60 Hz) | 5N34(50 Hz) | 5N34(60 Hz) | 5N35(50 Hz) | 5N35(60 H |
|---|---|---|---|---|---|---|
| Frame Number | 447 | 448 | 448 | 448 | 448 | 448 |
| kW/KVA Rating, Prime Power | 185/231 | 210/263 | 180/225 | 210/263 | 180/225 | 210/263 |
| Rated Volts | 300-600 | 208-416 | 200-400 | 240-480 | 240-480 | 300-600 |
| Rated Amperes | 445-223 | 728-364 | 650-325 | 631-316 | 542-271 | 505-253 |
| N° Poles/Sync Speed | 4/1800 | 4/1800 | 4/1500 | 4/1800 | 4/1500 | 4/1800 |
| Overspeed Capacity, % | 125 | 125 | 150 | 125 | 150 | 125 |
| *Stator Resistance, Ohms, @ 25°C | .0118 | .0044 | .0059 | .0059 | .0092 | .0092 |
| *Transient Reactance | 0.2484 | 0.2643 | 0.2768 | 0.2691 | 0.3004 | 0.2691 |
| *Sub Transient Reactance | 0.1198 | 0.1246 | 0.1297 | 0.1261 | 0.1407 | 0.1261 |
| *Synchronous Reactance | 2.4123 | 2.5599 | 2.6909 | 2.6163 | 2.9199 | 2.6163 |
| *Negative Sequence Reactance | 0.1540 | 0.1613 | 0.1683 | 0.1636 | 0.1826 | 0.1636 |
| *Zero Sequence Reactance | 0.0449 | 0.1209 | 0.0907 | 0.0882 | 0.0985 | 0.0882 |
| Open Circuit Time Constant | 1.6804 | 1.8541 | 1.8541 | 1.8541 | 1.8541 | 1.8541 |
| Exciter Field Res. Ohms, @ 25°C | 2.75 | 2.17 | 2.75 | 2.75 | 2.75 | 2.75 |
| Excitation Volts NL/FL | 7.3/22.5 | 8.5/26.5 | 7.9/31 | 7.9/26.5 | 9.0/31 | 9.0/26.5 |
| Excitation Amps NL/FL | 2.7/8.0 | 3.5/9.0 | 2.7/9.8 | 2.7/9.0 | 3.0/9.8 | 3.0/9.0 |
| Derate Altitude, Meters | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 |
| Derate Temperature °C | 40 | 40 | 40 | 40 | 40 | 40 |
| Efficiency at 0.8 Power Factor @0.50 FL | 92.8 | 93.1 | 92.7 | 93.1 | 92.7 | 93.1 |
| @0.75 FL | 93.3 | 93.8 | 93.3 | 93.8 | 93.3 | 93.8 |
| @1.00 FL | 93.2 | 93.7 | 93.0 | 93.7 | 93.0 | 93.7 |
| @1.25 FL | 92.7 | 93.3 | 92.4 | 93.3 | 92.4 | 93.3 |
| Temp Rise °C, Stator/Rotor | 105/105 | 105/105 | 105/105 | 105/105 | 105/105 | 105/105 |
| Head Dissipated kCal/min | 194 | 202 | 194 | 202 | 194 | 202 |
| Air Flow Req'd, $M^3$/min | 54 | 60 | 57 | 60 | 57 | 60 |
| Rotor Weight, kg/LBS | 260/574 | 282/622 | 282/622 | 282/622 | 282/622 | 282/622 |
| $WR^2$ $Nmsec^2$ (Lb In $Sec^2$) | 3.129(27.70) | 3.426(30.33) | 3.426(30.33) | 3.426(30.33) | 3.426(30.33) | 3.426(30.33 |
| Stator Weight kg/LBS | 502/1107 | 537/1183 | 537/1183 | 537/1183 | 537/1183 | 537/1183 |
| Total Weight, kg/LBS | 762/1681 | 819/1805 | 819/1805 | 819/1805 | 819/1805 | 819/1805 |
| SAE Mounting Flange Number | No. 1 | No. 1 | No. 1 | No. 1 | No. 1 | No. 1 |

*See Notes

ELECTRICAL/MECHANICAL CHARACTERISTICS

| Generator Part Number (Frequency) | 5N36(60 Hz) | 5N37(50 Hz) | 5N37(60 Hz) | 5N38(50 Hz) | 5N38(60 Hz) | 5N39(60 Hz) |
|---|---|---|---|---|---|---|
| Frame Number | 449A | 449A | 449A | 449A | 449A | 449 |
| kW/KVA Rating, Prime Power | 235/294 | 205/256 | 235/294 | 205/256 | 235/294 | 260/325 |
| Rated Volts | 208-416 | 200-400 | 240-480 | 240-480 | 300-600 | 208-416 |
| Rated Amperes | 816-408 | 740-370 | 707-353 | 617-309 | 566-283 | 903-452 |
| N° Poles/Sync Speed | 4/1800 | 4/1500 | 4/1800 | 4/1500 | 4/1800 | 4/1800 |
| Overspeed Capacity, % | 125 | 150 | 125 | 150 | 125 | 125 |
| *Stator Resistance, Ohms, @ 25°C | .0038 | .0048 | .0048 | .0081 | .0081 | .0038 |
| *Transient Reactance | 0.2525 | 0.2602 | 0.2485 | 0.2876 | 0.2532 | 0.2793 |
| *Sub Transient Reactance | 0.1182 | 0.1225 | 0.1170 | 0.1346 | 0.1185 | 0.1307 |
| *Synchronous Reactance | 2.5220 | 2.5907 | 2.4749 | 2.8732 | 2.5295 | 2.7903 |
| *Negative Sequence Reactance | 0.1555 | 0.1608 | 0.1536 | 0.1772 | 0.1560 | 0.1721 |
| *Zero Sequence Reactance | 0.0853 | 0.1227 | 0.1173 | 0.0971 | 0.0855 | 0.0944 |
| Open Circuit Time Constant | 1.9219 | 1.9219 | 1.9219 | 1.9219 | 1.9219 | 1.9219 |
| Exciter Field Res. Ohms, @ 25°C | 2.17 | 2.75 | 2.75 | 2.75 | 2.75 | 2.17 |
| Excitation Volts NL/FL | 8.5/20 | 9.0/24.7 | 9.0/20 | 9.0/24.7 | 9.0/20 | 8.5/22 |
| Excitation Amps NL/FL | 3.5/7.2 | 3.0/8.5 | 3.0/7.2 | 3.0/8.5 | 3.0/7.2 | 3.5/8.0 |
| Derate Altitude, Meters | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 |
| Derate Temperature °C | 40 | 40 | 40 | 40 | 40 | 40 |
| Efficiency at 0.8 Power Factor @0.50 FL | 93.3 | 93.0 | 93.3 | 93.0 | 93.3 | 93.4 |
| @0.75 FL | 94.0 | 93.5 | 94.0 | 93.5 | 94.0 | 94.0 |
| @1.00 FL | 94.0 | 93.2 | 94.0 | 93.2 | 94.0 | 93.8 |
| @1.25 FL | 93.6 | 92.7 | 93.6 | 92.7 | 93.6 | 93.3 |
| Temp Rise °C, Stator/Rotor | 105/105 | 105/105 | 105/105 | 105/105 | 105/105 | 105/105 |
| Heat Dissipated kCal/min | 215 | 215 | 215 | 215 | 215 | 247 |
| Air Flow Req'd, $M^3$/min | 64 | 64 | 64 | 64 | 64 | 73 |
| Rotor Weight, kg/LBS | 322/711 | 322/711 | 322/711 | 322/711 | 322/711 | 322/711 |
| $WR^2$ $Nmsec^2$ (Lb In $Sec^2$) | 3.766(33.34) | 3.766(33.34) | 3.766(33.34) | 3.766(33.34) | 3.766(33.34) | 4.224(37.39) |
| Stator Weight kg/LBS | 583/1284 | 583/1284 | 583/1284 | 583/1284 | 583/1284 | 610/1344 |
| Total Weight, kg/LBS | 905/1995 | 905/1995 | 905/1995 | 905/1995 | 905/1995 | 932/2055 |
| SAE Mounting Flange Number | No. 1 | No. 1 | No. 1 | No. 1 | No. 1 | No. 0 |

| Generator Part Number (Frequency) | 5N40(50 Hz) | 5N40(60 Hz) | 5N41(50 Hz) | 5N41(60 Hz) | 5N42(50 Hz) | 5N42(60 Hz) |
|---|---|---|---|---|---|---|
| Frame Number | 449 | 449 | 449 | 449 | 449 | 449 |
| kW/KVA Rating, Prime Power | 230/288 | 260/325 | 230/288 | 260/325 | 220/275 | 260/325 |
| Rated Volts | 200-400 | 240-480 | 240-480 | 300-600 | 200-400 | 240-480 |
| Rated Amperes | 830-415 | 783-391 | 692-346 | 626-313 | 794-397 | 783-391 |
| N° Poles/Sync Speed | 4/1500 | 4/1800 | 4/1500 | 4/1800 | 4/1500 | 4/1800 |
| Overspeed Capacity, % | 150 | 125 | 150 | 125 | 150 | 125 |
| *Stator Resistance, Ohms, @ 25°C | .0048 | .0048 | .0081 | .0081 | .0048 | .0048 |
| *Transient Reactance | 0.2919 | 0.2750 | 0.3226 | 0.2801 | 0.2792 | 0.2750 |
| *Sub Transient Reactance | 0.1373 | 0.1294 | 0.1510 | 0.1311 | 0.1314 | 0.1294 |
| *Synchronous Reactance | 2.9066 | 2.7381 | 3.2235 | 2.7986 | 2.7802 | 2.7381 |
| *Negative Sequence Reactance | 0.1804 | 0.1700 | 0.1988 | 0.1726 | 0.1725 | 0.1700 |
| *Zero Sequence Reactance | 0.1377 | 0.1297 | 0.1090 | 0.0947 | 0.1317 | 0.1297 |
| Open Circuit Time Constant | 1.9219 | 1.9219 | 1.9219 | 1.9219 | 1.9219 | 1.9219 |
| Exciter Field Res. Ohms, @ 25°C | 2.75 | 2.75 | 2.75 | 2.75 | 2.75 | 2.75 |
| Excitation Volts NL/FL | 9.0/27 | 9.0/22 | 9.0/27 | 9.0/22 | 9.0/27 | 9.0/28 |
| Excitation Amps NL/FL | 3.0/9.6 | 3.0/8.0 | 3.0/9.6 | 3.0/8.0 | 3.0/9.2 | 3.0/9.5 |
| Derate Altitude, Meters | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 |
| Derate Temperature °C | 40 | 40 | 40 | 40 | 50 | 50 |
| Efficiency at 0.8 Power Factor @0.50 FL | 92.5 | 93.4 | 92.5 | 93.4 | 92.7 | 93.4 |
| @0.75 FL | 92.9 | 94.0 | 92.9 | 94.0 | 93.2 | 94.0 |
| @1.00 FL | 92.6 | 93.8 | 92.6 | 93.8 | 92.9 | 93.8 |
| @1.25 FL | 92.0 | 93.3 | 92.0 | 93.3 | 92.3 | 93.3 |
| Temp Rise °C, Stator/Rotor | 105/105 | 105/105 | 105/105 | 105/105 | 90/90 | 90/90 |
| Heat Dissipated kCal/min | 264 | 247 | 264 | 247 | 241 | 247 |
| Air Flow Req'd, $M^3$/min | 78 | 73 | 78 | 73 | 71 | 73 |
| Rotor Weight, kg/LBS | 322/711 | 322/711 | 322/711 | 322/711 | 322/711 | 322/711 |
| $WR^2$ $Nmsec^2$ (Lb In $Sec^2$) | 4.224(37.39) | 4.224(37.39) | 4.224(37.39) | 4.224(37.39) | 4.224(37.39) | 4.224(37.39) |
| Stator Weight kg/LBS | 610/1344 | 610/1344 | 610/1344 | 610/1344 | 610/1344 | 610/1344 |
| Total Weight, kg/LBS | 932/2055 | 932/2055 | 932/2055 | 932/2055 | 932/2055 | 932/2055 |
| SAE Mounting Flange Number | No. 0 | No. 0 | No. 0 | No. 0 | No. 0 | No. 0 |

*See Notes

ELECTRICAL/MECHANICAL CHARACTERISTICS

| Generator Part Number (Frequency) | 5N43(50 Hz) | 5N43(50 Hz) | 5N43(60 Hz) | 5N43(60 Hz) | 5N43(60 Hz) | 5N43(60 H |
|---|---|---|---|---|---|---|
| Frame Number | 584 | 584 | 584 | 584 | 584 | 584 |
| kW/KVA Rating, Prime Power | 265/331 | 290/363 | 295/369 | 295/369 | 320/400 | 320/400 |
| Rated Volts | 200-400 | 200-400 | 240-480 | 208-416 | 208-416 | 240-480 |
| Rated Amperes | 957/478 | 1047/523 | 888-444 | 1024-512 | 1110-555 | 963-482 |
| N° Poles/Sync Speed | 4/1500 | 4/1500 | 4/1800 | 4/1800 | 4/1800 | 4/1800 |
| Overspeed Capacity, % | 150 | 150 | 125 | 125 | 125 | 125 |
| *Stator Resistance, Ohms, @ 25°C | .0054 | .0054 | .0054 | .0054 | .0054 | .0054 |
| *Transient Reactance | 0.2163 | 0.2367 | 0.2006 | 0.2671 | 0.2898 | 0.2176 |
| *Sub Transient Reactance | 0.1239 | 0.1356 | 0.1149 | 0.1530 | 0.1660 | 0.1247 |
| *Synchronous Reactance | 2.6319 | 2.8801 | 2.4416 | 3.2506 | 3.5261 | 2.6485 |
| *Negative Sequence Reactance | 0.1289 | 0.1411 | 0.1196 | 0.1592 | 0.1727 | 0.1297 |
| *Zero Sequence Reactance | 0.0237 | 0.0259 | 0.0220 | 0.0293 | 0.0317 | 0.0239 |
| Open Circuit Time Constant | 2.1133 | 2.1133 | 2.1133 | 2.1133 | 2.1133 | 2.1133 |
| Exciter Field Res. Ohms, @ 25°C | 4.77 | 4.77 | 4.77 | 4.77 | 4.77 | 4.77 |
| Excitation Volts NL/FL | 12.0/45 | 12.0/51 | 12.0/38 | 10.0/38 | 10.0/41 | 12.0/41 |
| Excitation Amps NL/FL | 2.5/9.0 | 2.5/10 | 2.5/7.5 | 2.1/7.5 | 2.1/8.0 | 2.5/8.0 |
| Derate Altitude, Meters | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 |
| Derate Temperature °C | 40 | 40 | 40 | 40 | 40 | 40 |
| Efficiency at 0.8 Power Factor @0.50 FL | 92.1 | 92.2 | 92.1 | 92.1 | 92.4 | 92.4 |
| Efficiency at 0.8 Power Factor @0.75 FL | 92.5 | 92.4 | 93.0 | 93.0 | 93.0 | 93.0 |
| Efficiency at 0.8 Power Factor @1.00 FL | 92.2 | 91.9 | 93.0 | 93.0 | 92.9 | 92.9 |
| Efficiency at 0.8 Power Factor @1.25 FL | 91.5 | 91.2 | 92.6 | 92.6 | 92.4 | 92.4 |
| Temp Rise °C, Stator/Rotor | 105/105 | 105/105 | 105/105 | 105/105 | 105/105 | 105/105 |
| Heat Dissipated kCal/min | 321 | 367 | 318 | 318 | 351 | 351 |
| Air Flow Req'd, $M^3$/min | 95 | 109 | 94 | 94 | 104 | 104 |
| Rotor Weight, kg/LBS | 396/873 | 396/873 | 396/873 | 396/873 | 396/873 | 396/873 |
| $WR^2$ $Nmsec^2$ (Lb In $Sec^2$) | 8.389(74.25) | 8.389(74.25) | 8.389(74.25) | 8.389(74.25) | 8.389(74.25) | 8.389(74.25 |
| Stator Weight kg/LBS | 748/1649 | 748/1649 | 748/1649 | 748/1649 | 748/1649 | 748/1649 |
| Total Weight, kg/LBS | 1144/2522 | 1144/2522 | 1144/2522 | 1144/2522 | 1144/2522 | 1144/2522 |
| SAE Mounting Flange Number | No. 0 | No. 0 | No. 0 | No. 0 | No. 0 | No. 0 |

| Generator Part Number (Frequency) | 5N44(50 Hz) | 5N44(50 Hz) | 5N44(60 Hz) | 5N44(60 Hz) | 5N45(60 Hz) | 5N46(50 Hz |
|---|---|---|---|---|---|---|
| Frame Number | 584 | 584 | 584 | 584 | 586 | 588 |
| kW/KVA Rating, Prime Power | 265/331 | 290/363 | 295/369 | 320/400 | 335/419 | 315/394 |
| Rated Volts | 240-480 | 240-480 | 300-600 | 300-600 | 240-480 | 200-400 |
| Rated Amperes | 798-399 | 873-476 | 708-354 | 768-384 | 1009-504 | 1137-569 |
| N° Poles/Sync Speed | 4/1500 | 4/1500 | 4/1800 | 4/1800 | 4/1800 | 4/1500 |
| Overspeed Capacity, % | 150 | 150 | 125 | 125 | 125 | 150 |
| *Stator Resistance, Ohms, @ 25°C | .0079 | .0079 | .0079 | .0079 | .0048 | .0037 |
| *Transient Reactance | 0.2347 | 0.2568 | 0.2006 | 0.2176 | 0.2059 | 0.1987 |
| *Sub Transient Reactance | 0.1344 | 0.1471 | 0.1149 | 0.1247 | 0.1181 | 0.1575 |
| *Synchronous Reactance | 2.8558 | 3.1251 | 2.4416 | 2.6485 | 2.5189 | 2.4105 |
| *Negative Sequence Reactance | 0.1398 | 0.1530 | 0.1196 | 0.1297 | 0.1234 | 0.1224 |
| *Zero Sequence Reactance | 0.0257 | 0.0281 | 0.0220 | 0.0239 | 0.0257 | 0.0215 |
| Open Circuit Time Constant | 2.1133 | 2.1133 | 2.1133 | 2.1133 | 2.1664 | 2.3741 |
| Exciter Field Res. Ohms, @ 25°C | 4.77 | 4.77 | 4.77 | 4.77 | 4.77 | 4.77 |
| Excitation Volts NL/FL | 12.0/45 | 12.0/51 | 12.0/38 | 12.0/41 | 12.6/35 | 12.6/38 |
| Excitation Amps NL/FL | 2.6/9.0 | 2.6/10 | 2.6/7.5 | 2.6/8.0 | 2.6/7.8 | 2.6/8.0 |
| Derate Altitude, Meters | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 |
| Derate Temperature °C | 40 | 40 | 40 | 40 | 50 | 40 |
| Efficiency at 0.8 Power Factor @0.50 FL | 92.1 | 92.2 | 92.1 | 92.4 | 92.2 | 91.6 |
| Efficiency at 0.8 Power Factor @0.75 FL | 92.5 | 92.4 | 93.0 | 93.0 | 93.1 | 92.8 |
| Efficiency at 0.8 Power Factor @1.00 FL | 92.2 | 91.9 | 93.0 | 92.9 | 93.2 | 93.0 |
| Efficiency at 0.8 Power Factor @1.25 FL | 91.5 | 91.2 | 92.6 | 92.4 | 92.9 | 92.7 |
| Temp Rise °C, Stator/Rotor | 105/105 | 105/105 | 105/105 | 105/105 | 90/90 | 105/105 |
| Heat Dissipated kCal/min | 321 | 367 | 318 | 351 | 350 | 340 |
| Air Flow Req'd, $M^3$/min | 95 | 109 | 94 | 104 | 104 | 101 |
| Rotor Weight, kg/LBS | 396/873 | 396/873 | 396/873 | 396/873 | 420/927 | 476/1050 |
| $WT^2$ $Nmsec^2$ (Lb In $Sec^2$) | 8.389(74.25) | 8.389(74.25) | 8.389(74.25) | 8.389(74.25) | 8.887(78.65) | 10.099(89.38) |
| Stator Weight kg/LBS | 748/1649 | 748/1649 | 748/1649 | 748/1649 | 799/1758 | 875/1930 |
| Total Weitht, kg/LBS | 1144/2522 | 1144/2522 | 1144/2522 | 1144/2522 | 1219/2685 | 1351/2980 |
| SAE Mounting Flange Number | No. 0 | No. 0 | No. 0 | No. 0 | No. 0 | No. 0 |

*See Notes

## ELECTRICAL/MECHANICAL CHARACTERISTICS

| Generator Part Number (Frequency) | 5N46(60 Hz) | 5N46(60 Hz) | 5N47(50 Hz) | 5N47(60 Hz) | 5N48(50 Hz) | 5N48(60 Hz) |
|---|---|---|---|---|---|---|
| Frame Number | 588 | 588 | 588 | 588 | 584 | 584 |
| kW/KVA Rating, Prime Power | 395/494 | 395/494 | 315/394 | 395/494 | 225/281 | 275/344 |
| Rated Volts | 208-416 | 240-480 | 240-480 | 300-600 | 200-400 | 208-416 |
| Rated Amperes | 1371-685 | 1189-595 | 948-474 | 948-474 | 812-406 | 954-477 |
| Nº Poles/Sync Speed | 4/1800 | 4/1800 | 4/1500 | 4/1800 | 4/1500 | 4/1800 |
| Overspeed Capacity, % | 125 | 125 | 150 | 125 | 150 | 125 |
| *Stator Resistance, Ohms, @ 25°C | .0037 | .0037 | .0045 | .0045 | .0054 | .0054 |
| *Transient Reactance | 0.2765 | 0.2077 | 0.1896 | 0.1826 | 0.1836 | 0.2490 |
| *Sub Transient Reactance | 0.2191 | 0.1646 | 0.1466 | 0.1412 | 0.1052 | 0.1426 |
| *Synchronous Reactance | 3.3537 | 2.5190 | 2.4189 | 2.3296 | 2.2347 | 3.0302 |
| *Negative Sequence Reactance | 0.1702 | 0.1279 | 0.1109 | 0.1068 | 0.1094 | 0.1464 |
| *Zero Sequence Reactance | 0.0299 | 0.0224 | 0.0148 | 0.0142 | 0.0201 | 0.0273 |
| Open Circuit Time Constant | 2.3741 | 2.3741 | 2.3566 | 2.3566 | 2.1133 | 2.1133 |
| Exciter Field Res. Ohms, @ 25°C | 4.77 | 4.77 | 4.77 | 4.77 | 4.77 | 4.77 |
| Excitation Volts NL/FL | 12.6/37 | 12.6/37 | 12.6/38 | 12.6/37 | 12.0/37 | 12.0/37 |
| Excitation Amps NL/FL | 2.6/7.6 | 2.6/7.6 | 2.6/8.0 | 2.6/7.6 | 2.5/7.5 | 2.5/7.2 |
| Derate Altitude, Meters | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 |
| Derate Temperature °C | 40 | 40 | 40 | 40 | 40 | 40 |
| Efficiency at 0.8 Power Factor @0.50 FL | 92.7 | 92.7 | 91.6 | 92.7 | 91.6 | 91.5 |
| Efficiency at 0.8 Power Factor @0.75 FL | 93.6 | 93.6 | 92.8 | 93.6 | 92.5 | 92.8 |
| Efficiency at 0.8 Power Factor @1.00 FL | 93.7 | 93.7 | 93.0 | 93.7 | 92.4 | 93.0 |
| Efficiency at 0.8 Power Factor @1.25 FL | 93.5 | 93.5 | 92.7 | 93.5 | 92.0 | 92.7 |
| Temp Rise °C, Stator/Rotor | 105/105 | 105/105 | 105/105 | 105/105 | 105/105 | 105/105 |
| Heat Dissipated kCal/min | 381 | 381 | 340 | 381 | 265 | 297 |
| Air Flow Req'd, $M^3$/min | 113 | 113 | 101 | 113 | 79 | 88 |
| Rotor Weight, kg/LBS | 476/1050 | 476/1050 | 476/1050 | 476/1050 | 396/873 | 396/873 |
| $WR^2$ $Nmsec^2$ (Lb In $Sec^2$) | 10.099(89.38) | 10.099(89.38) | 10.099(89.38) | 10.099(89.38) | 8.389(74.25) | 8.389(74.25) |
| Stator Weight kg/LBS | 875/1930 | 875/1930 | 875/1930 | 875/1930 | 733/1617 | 733/1617 |
| Total Weight, kg/LBS | 1351/2980 | 1351/2980 | 1351/2980 | 1351/2980 | 1129/2490 | 1129/2490 |
| SAE Mounting Flange Number | No. 0 | No. 0 | No. 0 | No. 0 | No. 0 | No.0 |

| Generator Part Number (Frequency) | 5N48(60 Hz) | 5N49(50 Hz) | 5N49(60 Hz) | 5N50(60 Hz) | 5N51(50 Hz) | 5N51(60 Hz) |
|---|---|---|---|---|---|---|
| Frame Number | 584 | 584 | 584 | 365 | 365 | 365 |
| kW/KVA Rating, Prime Power | 275/344 | 225/281 | 275/344 | 55/69 | 52/65 | 55/69 |
| Rated Volts | 240-480 | 240-480 | 300-600 | 208-416 | 200-400 | 240-480 |
| Rated Amperes | 828-414 | 677-339 | 660-330 | 191-95 | 188-94 | 166-83 |
| Nº Poles/Sync Speed | 4/1800 | 4/1500 | 4/1800 | 4/1800 | 4/1500 | 4/1800 |
| Overspeed Capacity, % | 125 | 150 | 125 | 125 | 150 | 125 |
| *Stator Resistance, Ohms, @ 25°C | .0054 | .0079 | .0079 | .0248 | .0367 | .0367 |
| *Transient Reactance | 0.1870 | 0.1992 | 0.1870 | 0.1658 | 0.1947 | 0.1716 |
| *Sub Transient Reactance | 0.1071 | 0.1141 | 0.1071 | 0.0836 | 0.0982 | 0.0866 |
| *Synchronous Reactance | 2.2761 | 2.4248 | 2.2761 | 1.9530 | 2.2935 | 2.0215 |
| *Negative Sequence Reactance | 0.1115 | 0.1187 | 0.1115 | 0.1207 | 0.1418 | 0.1250 |
| *Zero Sequence Reactance | 0.0205 | 0.0218 | 0.0205 | 0.0372 | 0.0437 | 0.0385 |
| Open Circuit Time Constant | 2.1133 | 2.1133 | 2.1133 | 0.9496 | 0.9496 | 0.9496 |
| Exciter Field Res. Ohms, @ 25°C | 4.77 | 4.77 | 4.77 | 1.66 | 2.07 | 2.07 |
| Excitation Volts NL/FL | 12.0/37 | 12.0/37 | 12.0/37 | 7.0/19 | 7.5/26.5 | 7.5/19 |
| Excitation Amps NL/FL | 2.5/7.2 | 2.6/7.5 | 2.6/7.2 | 3.0/8.2 | 3.0/10.4 | 3.0/8.2 |
| Derate Altitude, Meters | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 |
| Derate Temperature °C | 40 | 40 | 40 | 40 | 40 | 40 |
| Efficiency at 0.8 Power Factor @0.50 FL | 91.5 | 91.6 | 91.5 | 89.8 | 89.6 | 89.8 |
| Efficiency at 0.8 Power Factor @0.75 FL | 92.8 | 92.5 | 92.8 | 90.7 | 89.9 | 90.7 |
| Efficiency at 0.8 Power Factor @1.00 FL | 93.0 | 92.4 | 93.0 | 90.6 | 89.2 | 90.6 |
| Efficiency at 0.8 Power Factor @1.25 FL | 92.7 | 92.0 | 92.7 | 90.0 | 88.2 | 90.0 |
| Temp Rise °C, Stator/Rotor | 105/105 | 105/105 | 105/105 | 105/105 | 105/105 | 105/105 |
| Heat Dissipated kCal/min | 297 | 265 | 297 | 82 | 90 | 82 |
| Air Flow Req'd, $M^3$/min | 88 | 79 | 88 | 24 | 27 | 24 |
| Rotor Weight, kg/LBS | 396/873 | 396/873 | 396/873 | 132/291 | 132/291 | 132/291 |
| $WR^2$ $Nmsec^2$ (Lb In $Sec^2$) | 8.389(74.25) | 8.389(74.25) | 8.389(74.25) | 1.021(9.04) | 1.021(9.04) | 1.021([illegible].04) |
| Stator Weight kg/LBS | 733/1617 | 733/1617 | 733/1617 | 249/550 | 249/550 | 249/550 |
| Total Weight, kg/LBS | 1129/2490 | 1129/2490 | 1129/2490 | 381/841 | 381/841 | 381/841 |
| SAE Mounting Flange Number | No. 0 | No. 0 | No. 0 | No. 1 | No. 1 | No. 1 |

*See Notes

## ELECTRICAL/MECHANICAL CHARACTERISTICS

| Generator Part Number (Frequency) | 5N52(50 Hz) | 5N52(60 Hz) | 5N53(60 Hz) | 5N54(50 Hz) | 5N54(60 Hz) | 5N55(50 H |
|---|---|---|---|---|---|---|
| Frame Number | 365 | 365 | 366 | 366 | 366 | 366 |
| kW/KVA Rating, Prime Power | 52/65 | 55/69 | 65/81 | 62/78 | 65/81 | 62/78 |
| Rated Volts | 240-480 | 300-600 | 208-416 | 200-400 | 240-480 | 240-480 |
| Rated Amperes | 157-78 | 132-66 | 226-113 | 224-112 | 196-98 | 187-94 |
| Nº Poles.Sync Speed | 4/1500 | 4/1800 | 4/1800 | 4/1500 | 4/1800 | 4/1500 |
| Overspeed Capacity, % | 150 | 125 | 125 | 150 | 125 | 150 |
| *Stator Resistance, Ohms, @ 25°C | .0543 | .0543 | .0214 | .0324 | .0324 | .0480 |
| *Transient Reactance | 0.2144 | 0.1741 | 0.1822 | 0.2046 | 0.1787 | 0.2220 |
| *Sub Transient Reactance | 0.1081 | 0.0878 | 0.0902 | 0.1012 | 0.0885 | 0.1099 |
| *Synchronous Reactance | 2.5256 | 2.0516 | 2.1965 | 2.4664 | 2.1548 | 2.6763 |
| *Negative Sequence Reactance | 0.1561 | 0.1268 | 0.1327 | 0.1490 | 0.1302 | 0.1617 |
| *Zero Sequence Reactanc e | 0.0481 | 0.0391 | 0.0419 | 0.0470 | 0.0411 | 0.0510 |
| Open Circuit Time Constant | 0.9496 | 0.9496 | 1.0150 | 1.0150 | 1.0150 | 1.0150 |
| Exciter Field Res. Ohms, @ 25°C | 2.07 | 2.07 | 1.66 | 2.07 | 2.07 | 2.07 |
| Excitation Volts NL/FL | 7.5/26.5 | 7.5/19 | 7.0/20 | 7.5/31 | 7.5/20 | 7.5/31 |
| Excitation Amps NL/FL | 2.3/10.4 | 2.3/8.2 | 3.0/8.2 | 3.0/12 | 3.0/8.2 | 2.3/12 |
| Derate Altitude, Meters | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 |
| Derate Temperature °C | 40 | 40 | 40 | 40 | 40 | 40 |
| Efficiency at 0.8 Power Factor @0.50 FL | 89.6 | 89.8 | 90.6 | 90.3 | 90.6 | 90.3 |
| @0.75 FL | 89.9 | 90.7 | 91.2 | 90.3 | 91.2 | 90.3 |
| @1.00 FL | 89.2 | 90.6 | 91.0 | 89.5 | 91.0 | 89.5 |
| @1.25 FL | 88.2 | 90.0 | 90.3 | 88.4 | 90.3 | 88.4 |
| Temp Rise °C, Stator/Rotor | 105/105 | 105/105 | 105/105 | 105/105 | 105/105 | 105/105 |
| Heat Dissipated kCal/min | 90 | 82 | 92 | 105 | 92 | 105 |
| Air Flow Req'd, $M^3$/min | 27 | 24 | 27 | 31 | 27 | 31 |
| Rotor Weight, kg/LBS | 132/291 | 132/291 | 141/312 | 141/312 | 141/312 | 141/312 |
| $WR^2$ $Nmsec^2$ (Lb In $Sec^2$) | 1.021(9.04) | 1.021(9.04) | 1.091(9.66) | 1.091(9.66) | 1.091(9.66) | 1.091(9.6 |
| Stator Weight kg/LBS | 249/550 | 249/550 | 264/581 | 264/581 | 264/581 | 264/581 |
| Total Weight, kg/LBS | 381/841 | 381/841 | 405/893 | 405/893 | 405/893 | 405/893 |
| SAE Mounting Flange Number | No. 1 | No. 1 | No. 1 | No. 1 | No. 1 | No. 1 |

| Generator Part Number (Frequency) | 5N55(60 Hz) | 5N56(50 Hz) | 5N56(60 Hz) | 5N56(60 Hz) | 5N57(50 Hz) | 5N57(60 Hz |
|---|---|---|---|---|---|---|
| Frame Number | 366 | 586 | 586 | 586 | 586 | 586 |
| kW/KVA Rating, Prime Power | 65/81 | 280/350 | 335/419 | 335/419 | 280/350 | 335/419 |
| Rated Volts | 300-600 | 200-400 | 208-416 | 240-480 | 240-480 | 300-600 |
| Rated Amperes | 156-78 | 1011-505 | 1162-581 | 1009-504 | 842-421 | 807-408 |
| Nº Poles/Sync Speed | 4/1800 | 4/1500 | 4/1800 | 4/1800 | 4/1500 | 4/1800 |
| Overspeed Capacity, % | 125 | 150 | 125 | 125 | 150 | 125 |
| *Stator Resistance, Ohms, @ 25°C | .0480 | .0048 | .0048 | .0048 | .0072 | .0072 |
| *Transient Reactance | 0.1787 | 0.2065 | 0.2741 | 0.2059 | 0.2340 | 0.2150 |
| *Sub Transient Reactance | 0.0885 | 0.1184 | 0.1572 | 0.1181 | 0.1320 | 0.1213 |
| *Synchronous Reactance | 2.1548 | 2.5265 | 3.3536 | 2.5189 | 2.8852 | 2.6511 |
| *Negative Sequence Reactance | 0.1302 | 0.1238 | 0.1644 | 0.1234 | 0.1384 | 0.1272 |
| *Zero Sequence Reactance | 0.0411 | 0.0258 | 0.0343 | 0.0257 | 0.0395 | 0.0363 |
| Open Circuit Time Constant | 1.0150 | 2.1664 | 2.1664 | 2.1664 | 2.1079 | 2.1079 |
| Exciter Field Res. Ohms, @ 25°C | 2.07 | 4.77 | 4.77 | 4.77 | 4.77 | 4.77 |
| Excitation Volts NL/FL | 7.5/20 | 12.6/35 | 12.6/35 | 12.6/35 | 12.6/35 | 12.6/35 |
| Excitation Amps NL/FL | 2.3/8.2 | 2.6/7.9 | 2.6/7.8 | 2.6/7.8 | 2.6/7.9 | 2.5/7.8 |
| Derate Altitude, Meters | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 |
| Derate Temperature °C | 40 | 40 | 40 | 40 | 40 | 40 |
| Efficiency at 0.8 Power Factor @0.50 FL | 90.6 | 91.9 | 92.2 | 92.2 | 91.9 | 92.2 |
| @0.75 FL | 91.2 | 92.6 | 93.1 | 93.1 | 92.6 | 93.1 |
| @1.00 FL | 91.0 | 92.5 | 93.2 | 93.2 | 92.5 | 93.2 |
| @1.25 FL | 90.3 | 92.0 | 92.9 | 92.9 | 92.2 | 92.9 |
| Temp Rise °C, Stator/Rotor | 105/105 | 105/105 | 105/105 | 105/105 | 105/105 | 105/105 |
| Heat Dissipated kCal/min | 92 | 326 | 350 | 350 | 326 | 350 |
| Air Flow Req'd, $M^3$/min | 27 | 96 | 104 | 104 | 96 | 104 |
| Rotor Weight, kg/LBS | 141/312 | 420/927 | 420/927 | 420/927 | 420/927 | 420/927 |
| $WR^2$ $Nmsec^2$ (Lb In $Sec^2$) | 1.091(9.66) | 8.887(78.65) | 8.887(78.65) | 8.887(78.65) | 8.887(78.65) | 8.887(78.65) |
| Stator Weight, kg/LBS | 264/581 | 799/1758 | 799/1758 | 799/1758 | 799/1758 | 799/1758 |
| Total Weight, kg/LBS | 405/893 | 1219/2685 | 1219/2685 | 1219/2685 | 1219/2685 | 1219/2685 |
| SAE Mounting Flange Number | No. 1 | No. 0 | No. 0 | No. 0 | No. 0 | No. 0 |

*See Notes

ELECTRICAL/MECHANICAL CHARACTERISTICS

| Generator Part Number (Frequency) | 5N58(50 Hz) | 5N58(60 Hz) | 5N58(60 Hz) | 5N59(50 Hz) | 5N59(60 Hz) | 5N60(50 Hz) |
|---|---|---|---|---|---|---|
| Frame Number | 589 | 589 | 589 | 589 | 589 | 584 |
| kW/KVA Rating, Prime Power | 420/525 | 500/625 | 500/625 | 420/525 | 500/625 | 290/363 |
| Rated Volts | 200-400 | 208-416 | 240-480 | 240-480 | 300-600 | 200-400 |
| Rated Amperes | 1517-759 | 1735-868 | 1505-753 | 1264-632 | 1204-602 | 1047-523 |
| Nº Poles/Sync Speed | 4/1500 | 4/1800 | 4/1800 | 4/1500 | 4/1800 | 4/1500 |
| Overspeed Capacity, % | 150 | 125 | 125 | 150 | 125 | 150 |
| *Stator Resistance, Ohms, @ 25°C | .0023 | .0023 | .0023 | .0033 | .0033 | .0054 |
| *Transient Reactance | 0.1944 | 0.2568 | 0.1929 | 0.2343 | 0.2142 | 0.2367 |
| *Sub Transient Reactance | 0.1021 | 0.1349 | 0.1013 | 0.1365 | 0.1248 | 0.1356 |
| *Synchronous Reactance | 2.6397 | 3.4866 | 2.6188 | 2.8932 | 2.6452 | 2.8801 |
| *Negative Sequence Reactance | 0.1090 | 0.1439 | 0.1081 | 0.1441 | 0.1318 | 0.1411 |
| *Zero Sequence Reactance | 0.0633 | 0.0836 | 0.0628 | 0.0714 | 0.0652 | 0.0259 |
| Open Circuit Time Constant | 2.6079 | 2.6079 | 2.6079 | 2.5517 | 2.5517 | 2.1133 |
| Exciter Field Res. Ohms, @ 25°C | 4.03 | 4.03 | 4.03 | 4.03 | 4.03 | 4.77 |
| Excitation Volts NL/FL | 11.5/45 | 11.5/37 | 11.5/37 | 11.5/45 | 11.5/37 | 12.0/51 |
| Excitation Amps NL/FL | 2.8/9.8 | 2.8/8.2 | 2.8/8.2 | 2.8/9.8 | 2.8/8.2 | 2.5/10 |
| Derate Altitude, Meters | 1000 | 1000 | 1000 | 1000 | 1000 | 1000 |
| Derate Temperature °C | 40 | 40 | 40 | 40 | 40 | 50 |
| Efficiency at 0.8 Power Factor @0.50 FL | 92.8 | 93.5 | 93.5 | 92.8 | 93.5 | 92.2 |
| @0.75 FL | 93.6 | 94.3 | 94.3 | 93.6 | 94.3 | 92.4 |
| @1.00 FL | 93.5 | 94.3 | 94.3 | 93.5 | 94.3 | 91.9 |
| @1.25 FL | 93.1 | 94.0 | 94.0 | 93.1 | 94.0 | 91.2 |
| Temp Rise °C, Stator/Rotor | 105/105 | 105/105 | 105/105 | 105/105 | 105/105 | 90/90 |
| Heat Dissipated kCal/min | 419 | 433 | 433 | 419 | 433 | 367 |
| Air Flow Req'd, $M^3$/min | 124 | 128 | 128 | 124 | 128 | 109 |
| Rotor Weight, kg/LBS | 545/1202 | 545/1202 | 545/1202 | 545/1202 | 545/1202 | 396/873 |
| $WR^2$ $Nmsec^2$ (Lb In $Sec^2$) | 11.422(101.10) | 11.422(101.10) | 11.422(101.10) | 11.422(101.10) | 11.422(101.10) | 8.389(74.25) |
| Stator Weight, kg/LBS | 968/2135 | 968/2135 | 968/2135 | 968/2135 | 968/2135 | 748/1649 |
| Total Weight, kg/LBS | 1513/3337 | 1513/3337 | 1513/3337 | 1513/3337 | 1513/3337 | 1144/2522 |
| SAE Mounting Flange Number | No. 0 | No. 0 | No. 0 | No. 0 | No. 0 | No. 0 |

| Generator Part Number (Frequency) | 5N60(60 Hz) | 5N61(50 Hz) | 5N61(60 Hz) | 5N62(60 Hz) | 5N63(60Hz) |
|---|---|---|---|---|---|
| Frame Number | 584 | 588 | 588 | 589 | 446 |
| kW/KVA Rating, Prime Power | 320/400 | 315/394 | 395/494 | 500/625 | 155/194 |
| Rated Volts | 240-480 | 200-400 | 240-480 | 240-480 | 240-480 |
| Rated Amperes | 963-482 | 1137-569 | 1189-595 | 1505-753 | 467-233 |
| N° Poles/Sync Speed | 4/1800 | 4/1500 | 4/1800 | 4/1800 | 4/1800 |
| Overspeed Capacity, % | 125 | 150 | 125 | 125 | 125 |
| *Stator Resistance, Ohms, @ 25°C | .0054 | .0037 | .0037 | .0023 | .0119 |
| *Transient Reactance | 0.2176 | 0.1987 | 0.2077 | 0.1929 | 0.2827 |
| *Sub Transient Reactance | 0.1247 | 0.1575 | 0.1646 | 0.1013 | 0.1397 |
| *Synchronous Reactance | 2.6485 | 2.4105 | 2.5190 | 2.6188 | 2.6815 |
| *Negative Sequence Reactance | 0.1297 | 0.1224 | 0.1279 | 0.1081 | 0.1762 |
| *Zero Sequence Reactance | 0.0239 | 0.0215 | 0.0224 | 0.0628 | 0.0499 |
| Open Circuit Time Constant | 2.1133 | 2.3741 | 2.3741 | 2.6079 | 1.6045 |
| Exciter Field Res. Ohms, @ 25°C | 4.77 | 4.77 | 4.77 | 4.03 | 2.40 |
| Excitation Volts NL/FL | 12.0/41 | 12.6/38 | 12.6/37 | 11.5/37 | 6.8/24 |
| Excitation Amps NL/FL | 2.5/8.0 | 2.6/8.0 | 2.6/7.6 | 2.8/8.2 | 2.6/8.8 |
| Derate Altitude, Meters | 1000 | 1000 | 1000 | 1000 | 1000 |
| Derate Temperature °C | 50 | 50 | 50 | 50 | 50 |
| Efificency at 0.8 Power Factor @0.50 FL | 92.4 | 91.6 | 92.7 | 93.5 | 92.5 |
| @0.75 FL | 93.0 | 92.8 | 93.6 | 94.3 | 93.0 |
| @1.00 FL | 92.9 | 93.0 | 93.7 | 94.3 | 92.7 |
| @1.25 FL | 92.4 | 92.7 | 93.5 | 94.0 | 92.1 |
| Temp Rise °C, Stator/Rotor | 90/90 | 90/90 | 90/90 | 90/90 | 90/90 |
| Heat Dissipated kCal/min | 351 | 340 | 381 | 433 | 175 |
| Air Flow Req'd, $M^3$/min | 104 | 101 | 113 | 128 | 52 |
| Rotor Weight, kg/LS | 396/873 | 476/1050 | 476/1050 | 545/1202 | 232/511 |
| $WR^2$ $Nmsec^2$ (Lb In $Sec^2$) | 8.389(74.25) | 10.099(89.38) | 10.099(89.38) | 11.422(101.10) | 2.847(25.9) |
| Stator Weight, kg/LBS | 748/1649 | 875/1930 | 875/1930 | 968/2135 | 434/958 |
| Total Weight, kg/LBS | 1144/2522 | 1351/2980 | 1351/2980 | 1513/3337 | 666/1469 |
| SAE Mounting Flange Number | No. 0 | No. 0 | No. 0 | No. 0 | No. 1 |

*See Notes

**INDUSTRIAL DIVISION ENGINE DATA SHEET**

EDS 71.2.1

DATE February 1977

SUBJECT/TITLE: AC Voltages Available from Caterpillar SR 4 Generators
BUSINESS: Building Services, Material Handling, Marine, Agriculture
PRODUCT: Generator Sets

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Most generator set applications require that the electrical output match one of several existing commercial voltages and one of two frequencies. Where the generator set is replacing, or supplementing commercial power, the existing frequency and voltage characteristics will determine generator selection. Where the generator set is to be totally isolated from commercial power, the proposed load (particularly motors) will determine generated voltage and frequency. Practically all electric motors above 5 hp are three-phase, and motors of lesser horsepower can be single- or three-phase.

The more common commercial nominal voltages and frequencies are:

60 Hz - Single-Phase/Three-Phase
120/208Y, 125/216Y, 127/220Y, 277/480Y, 120/240

60 Hz - Three-Phase Only
220, 240, 480, 575, 600

60 Hz - 3-Wire, Single-Phase Only
110/220, 115/230, 220/440

50 Hz - Single-Phase/Three-Phase
220/380Y, 230/400Y, 240/415Y

50 Hz - Three-Phase Only
460

**Note: The slant (/) line indicates both voltages are available at the same time. With the exception of the 60 Hz 3-wire single-phase 110/220 and 220/440 systems, all other dual voltage systems consist of a single-phase lower voltage, and a three-phase higher voltage.**

Generally, voltages above about 220 volts originate from a three-phase source. Commercial distribution is more commonly three-phase which also permits use of single-phase loads. Some distribution is single-phase. This system is limited to single-phase loads only, unless special transformer-capacitor equipment is used to simulate or approach a three-phase voltage.

Larger industrial loads are usually three-phase, with single-phase loads supplied from one or more of the phases. The following diagrams show how commercial distribution transformer secondary windings are connected to obtain one of the above listed common three-phase and single-phase voltages.

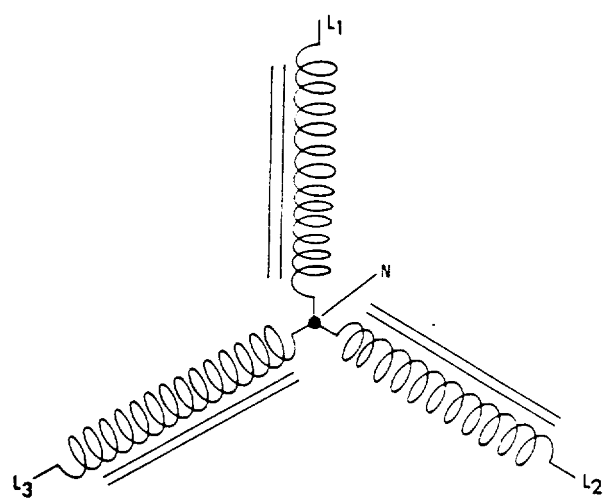



*Figure 1*
*3-Phase Y, Wye, Star Common Voltages:*
*120/208Y; 125/216Y; 127/220Y;*
*230/380Y; 230/400Y; 240/415Y; 277/480Y*

The listed lower voltages of this dual voltage system are single-phase and can be obtained from any one Line (L1, L2, L3) and the Neutra (N). The higher voltages are three-phase and are obtained from L1, L2, L3.

Note in this Y, Wye, or Star arrangement that a single-phase voltage is always equal to the higher voltage divided by 1.732.

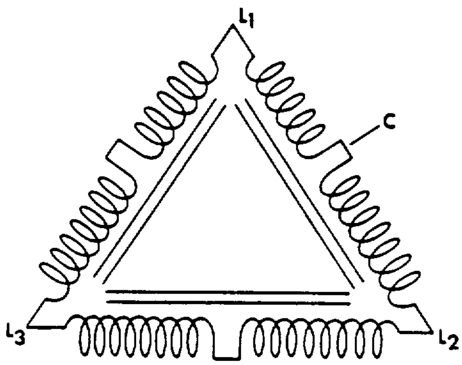



*Figure 2*
*3-Phase Delta Common Voltages:*
*110/220; 120/240; 208; 440; 460; 480*

The lower voltage of this delta, dual voltage system is obtained from one Line (L1 or L2) and the center tap (C) of one transformer coil. That center tap is usually connected to an earth ground. Note that these lower single-phase voltages are equal to one-half of the higher voltage. The higher listed voltage can be single-phase obtained from any two Lines: L1 to L2, L2 to L3 or L3 to L1. A three-phase voltage can also be obtained from a connection to L1, L2 and L3. Some industrial plants may also require 208 volts single-phase in addition to 120/240 volts single-phase, and 240 volts three-phase. The 208 volts can be obtained by connection to L3 and C.

Commercial power sources often identify their secondary (user) distribution by voltage and phase. (Example, 240-1o, 460-30.)

## FREQUENCY/VOLTAGE AVAILABLE FROM SR 4 GENERATORS

All SR 4 Generators can readily operate at either 50 Hz or 60 Hz. Regulated voltage output is proportional to generator speed. As an example, the 480 volt 60 Hz (1800 rpm) generator will produce a 400 volt 50 Hz supply at 1500 rpm.

SR 4 Generators are offered in three basic voltage levels. The nominal voltage available from one of these basic voltage levels, plus reconnectable line leads, and a wide voltage level adjustment range, permit the SR 4 to match the commercial frequencies, and most of the commercial voltages.

SR 4 Generators are "Y" (Star) connected three-phase machines and have 10 line leads, as shown in Figure 3. These leads can be field connected, as illustrated in Figures 4 and 5, to produce the following voltages at the frequency shown:

| Frequency (1) | Nominal Voltage | Nominal Adjustment Up | Range Down |
|---|---|---|---|
| Hz | (Volts) (2) | (Volts) | (Volts) |
| 60 | 120/208Y | 6/11 | 6/11 (3) |
| | or | | |
| | 240/416Y | 12/21 | 12/21 (4) |
| 60 | 139/240Y | 7/12 | 7/12 (3) (5) |
| | or | | |
| | 277/480Y | 14/24 | 14/24 (4) (5) |
| 50 | 115/200Y | 6/10 | 6/10 (3) |
| | or | | |
| | 230/400Y | 12/20 | 12/20 (4) (6) |
| 60 | 173/300Y | 9/15 | 9/15 (3) |
| | or | | |
| | 346/600Y | 17/30 | 17/30 (4) |
| 50 | 139/240Y | 14/24 | 7/12 (3) |
| | or | | |
| | 277/480Y | 28/48 | 14/24 (4) |

NOTES:

1. SR 4 Generators are designed for 50 or 60 Hz operation. Nominal voltage is proportional to speed.
2. The slant line indicates a line-to-neutral single phase' voltage and a line-to-line three-phase voltage. Both voltages are available at the same time.
3. Generator coils are parallel connected.
4. Generator coils are series connected.
5. The 139/240Y or 277/480Y volt 5N43, 5N46, 5N48, 5N56, and 5N58 Generators have a broad range voltage regulator capable of adjustment down to 120/208 or 240/416 volts.
6. 400 volt, 50 Hz SR 4 Generators will develop up to 420 volts, no load.

### Application

Larger 50 Hz industrial loads require three-phase power in the range of 380 to 420 volts. Additionally, these systems often require single-phase voltages in the range of 220 to 240 volts. The 400 volt 50 Hz

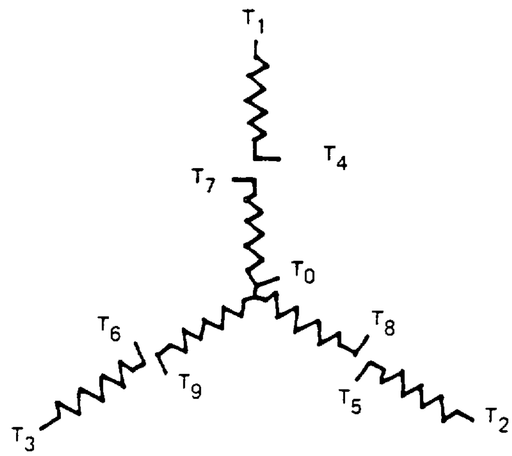



*Figure 3*
*10 LEAD GENERATOR*

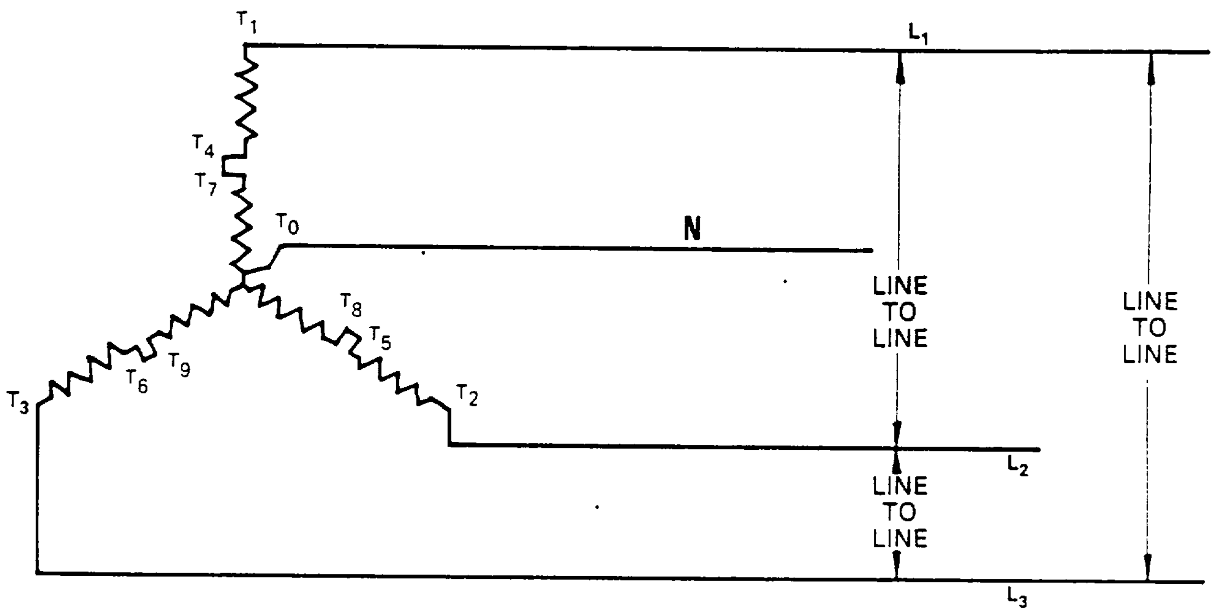



*Figure 4*
*HIGH VOLTAGE CONNECTION*

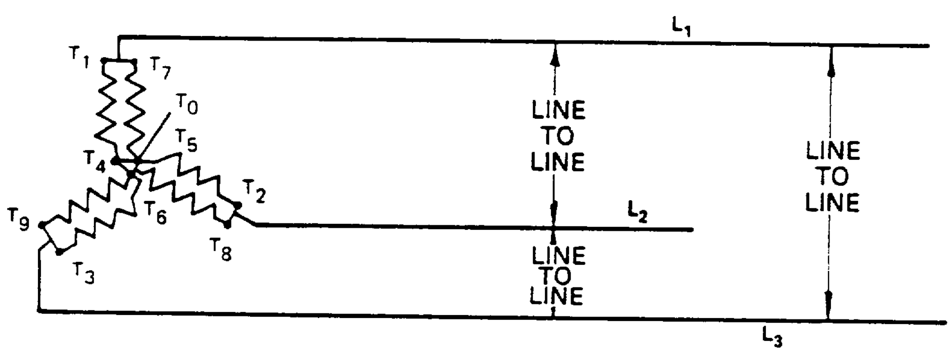



*Figure 5*
*LOW VOLTAGE CONNECTION 95*

SR 4 Generators directly meet these requirements. Single-phase loads should be distributed equally from the three lines to the neutral giving 230 volts single-phase (at 400 volts, three-phase). Industrial 50 Hz three-phase loads in the range of 480 volts can be directly supplied by the 480 volt 50 Hz generators. However, if single-phase voltage in the range of 220 volts is also required from a 480 volt three-phase system, single-phase step down transformers will be required.

Larger 60 Hz industrial loads are generally three-phase in the range of 460 to 480 volts. Single-phase 120 volt, 120-240 volt or 240 volt loads are almost always supplied from transformer banks, operating from the 460 to 480 volt three-phase service. The 480 volt 60 Hz SR 4 Generators match this requirement directly. With the stator coils parallel connected, this range of generators will directly match large industrial three-phase, 230-240 volt loads.

Other 60 Hz commercial service supplies power in the range of 120/208Y to 125/216Y volts in a 4-wire "Y" connected single-phase/three-phase system. The nominal 120/208Y 60 Hz generator is directly applicable. Motor starting ability compares to the nominal 240 volt generator operating at 240 volts. The broad voltage range 5N43, 5N46, 5N48, 5N56, and 5N58 Generators connected for low voltage will also directly meet these application, as the voltage level control has adequate range.

When these broad range generators are operated in the 208-416 volt range, motor starting ability is good, but of course, less than when operating at the 240-480 volt range. The expected voltage dip at the 208-416 setting will approximate 35% when starting 0.5 hp of motor per kW of generator prime power rating.

Another common 60 Hz commercial power service distribution comes from Delta connected transformers, which will simultaneously supply 240 and 120 volt single-phase. Such systems can be quite satisfactorily supplied from the 60 Hz, 120/208Y volt SR 4 Generator, since connected equipment readily accepts a ±10% voltage tolerance. When the prospective installation demands voltages exactly equal to the original, transformers will be necessary, as 120 and 240 volts can not be obtained simultaneously from a "Y" connected generator.

In any installation, single-phase loads should be distributed as equally as possible around the three-phases to avoid generator derating or excessive heating. Single-phase loads, balanced within 10%, are considered acceptable within present engineering practices. In any combination of single-and three-phase loads, individual line current should not exceed the generator nameplate ampere rating.

## Voltage Modifications

There are areas where existing commercial 50 Hz power systems will eventually be converted to 60 Hz. These areas require a generator which will presently produce a given voltage at 50 Hz and later be capable of producing the same voltage at 60 Hz. Suitable generator application depends on present voltage.

If the present required 50 Hz three-phase voltage is 240 or 480, and the future system will be 60 Hz, 240 or 480 volts, the 50 Hz 240-480 volt generator is suggested. This generator will produce 300-600 volts at 60 Hz. However, the exciter-regulator system can easily be reconnected to lower generated voltage to 240-480 at 60 Hz when the change in commercial frequency occurs.

As originally constructed, this 50 Hz, 240-480 volt generator has the voltage regulator and exciter field tapped into the three generator coils forming the center "Y". These coil taps terminate at terminals 20, 22, and 24 of the regulator terminal board. Remove the wires from the terminal board, and carefully insulate each wire to avoid any possible connection or ground. Install new No. 14 gauge, 600 volt insulated flexible wires from the terminal board to the generator line leads as follows:

| From Terminal Board | To Line Lead |
|---|---|
| No. 20 | T-9 |
| No. 22 | T-7 |
| No. 24 | T-8 |

The generator will now produce 240 or 480 volts at 60 Hz. The modified generator has the same kVA rating at 60 Hz as it did originally at 50 Hz. Parallel operation is not affected. Since the modified excitation system is running at a reduced excitation level, the ability to start very large motors will be reduced. The range of voltage level control is also slightly reduced.

If the application presently requires three-phase 50 Hz voltage at 400 volts, and the future 60 Hz three-phase voltage will <u>also</u> be 400 volts, the 200-400 volt 50 Hz generator is a good choice. Without modification, this generator would produce 240 or 480 volts at 60 Hz. A special connection of the line leads, called "Zig-Zag" will lower the nominal 60 Hz voltage about 13%, making it usable as a 400 volt unit. Voltage level adjustment range remains about +5%. With a zig-zag connection, the excitation level at 60 Hz, 400 volts is essentially the same as it was at 50 Hz, 400 volts. The zig-zag connected generator therefore will retain its excellent motor starting ability. The final connections are shown in Figure 6.

Connect T1 to T8
T2 to T9
T3 to T7
Line Leads are T4, T5, T6
Neutral is TO

If the zig-zag connected generators are to be operated in parallel or with other generator sets, additional line leads must be run through the window of the droop transformer (3N1964). This is necessary to retain the correct droop transformer voltage relationship when a zig-zag connected generator is paralleled.

Observe the direction and the number of T-8 line leads coming out of the generator and passing through the transformer window. Also observe the number of times the T-8 lead (or leads) pass through the transformer window. An equal number of T-2 leads, must pass through the window the same number of times, and in the same direction as the existing T8 leads. The end of T2 is then connected to T9 as shown in Figure 6.

On some generators the droop transformer will not accommodate the additional line leads through the window. Instructions for the necessary conversion are shown in Figures 7 and 8.

Correctly connected zig-zig generators will operate in parallel. In single or parallel operation, the 50 Hz kVA ratings would generally apply to a zig-zag connected generator operating at 60 Hz.

Zig-zag connections (with proper droop transformer modification if parallel operation is expected) may also be applied to a 480 volt 50 Hz generator to cause it to produce 420 volts at 50 Hz. The original line ampere rating of a 480 volt 50 Hz generator would apply to the unit when operated at 420 volts. kVA capacity is reduced 13%. Modified units will operate in parallel.

There are other areas of the world where 60 Hz generator sets are now used as prime power, but these may eventually be required to serve in a standby system when commercial 50 Hz power becomes available, or is required by governmental decree. In these instances the oncoming or future power system will probably be one of the above listed common 50 Hz three-phase voltages (i.e., 380, 400, or 415). As noted previously, a 60 Hz 480 volt generator will produce 400 volts at 50 Hz. Normal voltage level adjustment range of the SR 4 Generator is adequate to meet the lower and upper limits of the probable future voltages.

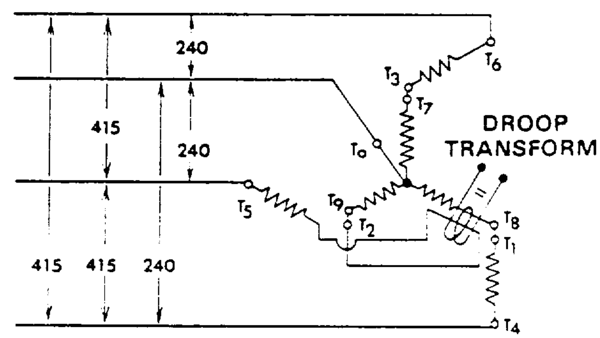



*Figure 6*

Zig-zag connection to obtain 420 volts from a 480 volt generator or 87% of normal volt from any SR 4 Generator. For parallel operation, the droop transformer must enclose 1-leads as shown. Note the direction of T2 through transformer and the connection to See Figure 7 for detail when droop transform will not accommodate additional line leads.

The following generators require installation of a second 3N1964 Droop Transformer to provide space for additional line leads necessary for operation of zig-zag connects SR 4 Generators in a parallel system.

| | | | | |
|---|---|---|---|---|
| 5N2 | 5N24 | 5N36 | 5N146 | 5N6 |
| 5N5 | 5N28 | 5N37 | 5N57 | 5N6 |
| 5N6 | 5N29 | 5N39 | 5N58 | |
| 5N13 | 5N33 | 5N40 | 5N59 | |
| 5N23 | 5N34 | 5N42 | 5N61 | |

1. Mount the second transformer on the generator frame in line with the existing 3N1964 Transformer and approximately 3 cm (1.2 inch) to the left.

   Drill and tap 4 holes in the generator frame. Put cloth under the area of drilling. Use a circular magnet around the holes to catch any drill chips. Extreme caution is necessary to avoid any metallic chips from falling onto the stator winding.

2. Remove the wire marked 6 from the terminal board. Install the wire marked 6 from the new transformer. Connect the original wire 6 to the wire 5 coming from the new transformer. Use a bolt, nut, and washer. Carefully insulate this connection. Secure the wires.

   The transformers are now connected in series additive.

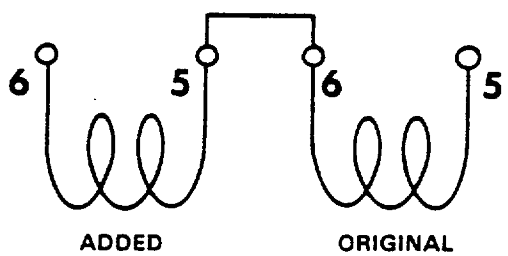



*Figure 7*

3. Follow the instructions given above to put the correct number of T2 line leads correctly through the new droop transformer. Secure the leads to prevent vibration.

4. Adjust the generator droop as outlined in the Operation and Maintenance Guide.

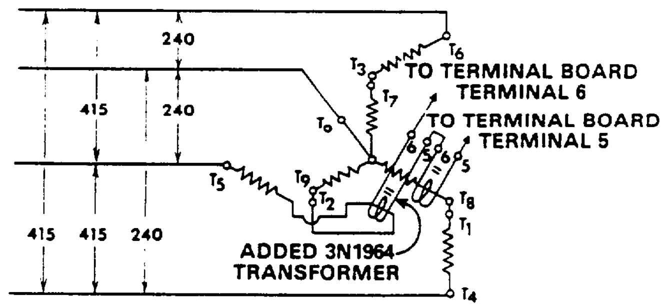



*Figure 8*

Zig-zag connection showing installation of second droop transformer in generators listed on chart.

# INDUSTRIAL DIVISION ENGINE DATA SHEET

EDS 71.4

DATE July 1978

SUBJECT: Effect of Temperature on Voltage Regulation
BUSINESS: Building Services, Marine/Petroleum, Material Handling
PRODUCT/APPLICATION: Generator Sets, SRCR or SR 4 Generators

The operating voltage of a cold (just started) generator will be slightly higher than the operating voltage when the generator has been under load and warm. Assume an SRCR or SR 4 Generator is started when the temperature has stabilized at 25ºC. The full load voltage of the SRCR Generator would decrease a maximum of 3% when the generator temperature stabilized at 100ºC. The full load voltage of an SR 4 Generator would decrease a maximum of 1% when this generator stabilized at 100°C. Most of the voltage decrease occurs in about 30 minutes. Generally, temperatures of generators stabilize within two hours.

The effect of cold-to-hot resistance change on generated voltage is rarely observed in a single SRCR or SR 4 Generator. A correctly adjusted voltage regulator compensates for most of the voltage differences due to resistance changes and due to speed changes which result from increases or decreases in load. The recommended adjustment procedure is printed in operators' books and on the inside of a generator side panel.

The effect of the small voltage change, cold-to-hot, is observable when paralleling a correctly adjusted cold generator with a correctly adjusted generator that has been carrying load for an hour or more. The resulting voltage difference, although small, causes a circulating current between generators. There is no cause for concern as the circulating current will diminish as the oncoming unit increases in temperature.

The recommended adjustment for parallel operation makes each generator set voltage the same at operating temperature. This assures the most stable operation with lowest circulating currents in unsupervised systems. However, if a supervised system includes power factor meters, an operator can at any time adjust the individual generator set voltage level controls as needed to minimize circulating currents.

You may want to retain the January 1973 issue of this Engine Data Sheet for reference on early equipment.

# INDUSTRIAL DIVISION ENGINE DATA SHEET

EDS 71.5

DATE September 1975

SUBJECT: Remote Voltage Level Control For Caterpillar Generators
BUSINESS: Building Services, Material Handling, Marine, Petroleum, Agriculture
PRODUCT/APPLICATION: Generator Sets, SRCR and SR 4

It is sometimes desirable to control the voltage level of a generator at a remote-mounted control panel rather than at the generator. These instructions cover the selection and installation of a remote potentiometer to provide the same full range of voltage level control as the original generator mounted control. These instructions move the point of control from the generator to the remote location.

Selection of Potentiometer Control
If screw driver slot adjustment with locking feature is acceptable, the original generator mounted control can be moved to the remote location. A parts service control (duplicate of original) could also be used. If a knob adjustment and indicator dial is desired, select a 25 watt wire wound potentiometer of suitable shaft length to accommodate the knob and dial. SRCR Generators require a 25 ohm, 25 watt potentiometer. SR4 generators require a 500 ohm, 25 watt potentiometer.

Wiring the Remote Voltage Level Control:

1. Prepare three lengths of No. 14 600 volt insulated wire. Use one yellow wire, one red wire, and one white wire. Cable these wires to avoid damage. Connect the potentiometer to the three wires as follows:

   Yellow Wire - Solder to the clockwise end of the potentiometer.

   Red Wire - Solder to the counter-clockwise end of the potentiometer.

   White Wire - Solder to the sliding arm contact of the potentiometer and to the counterclockwise end of the potentiometer along with the red wire.

2. Disconnect the existing generator mounted voltage level control at the terminals noted below. Insulate each of the removed wires and secure these to avoid any vibration damage. Connect the wires to the terminals designated:
   A. SRCR Generators With Panel Mounted Two Phase Half Wave Exciter (Serial Numbers below 1500)

      1. Remove existing white wire at terminal 17, red wire at terminal 20, and yellow wire at terminal 16.

      2. Connect new white wire to terminal 17, red wire to terminal 20, and yellow wire to terminal 16.

   B. SRCR Generators With Tray Mounted Two-Phase Half Wave Exciter (Serial Numbers 1500-2000)

      1. Remove existing white wire from terminal TB1-3, red wire from terminal TB1-5, and yellow wire from terminal TB1-4.

      2. Connect new white wire to terminal TB1-3, red wire to terminal TB1-5, and yellow wire to terminal TB1-4.

   C. SRCR Generators With Tray Mounted Two-Phase Half Wave Exciter (Serial Numbers above 2000)

1. Remove existing white wire from terminal TB1-3, red wire from terminal TB1-5, and yellow wire from terminal TB1-4.
2. Connect new white wire to terminal TB1-3, red wire to terminal TB1-5, and yellow wire to terminal TB1-4.

D. SRCR Generators With Panel Mounted Single-Phase Full Wave Exciter (Serial Numbers below 1500)

1. Remove existing white wire from terminal TB2-4, red wire from terminal TB2-5, and yellow wire from terminal TB2-3.
2. Connect new white wire to terminal TB2-4, red wire to terminal TB2-5, and yellow wire to terminal TB2-3.

E. SRCR Generators With Tray Mounted Single-Phase Full Wave Exciter (Serial Numbers 1500-1999)

1. Remove existing white wire from terminal TB1-3, red wire from terminal 10 on noise filter (FL1), and yellow wire from terminal TB1-4.
2. Connect new white wire to terminal TB1-3, red wire to terminal 10 on noise filter (FL1), and yellow wire to terminal TB1-4.

F. SRCR Generators With Tray Mounted Single-Phase Full Wave Exciter (Serial Numbers above 2000)

1. Remove existing white wire from terminal TB1-3, red wire from terminal TB2-5, and yellow wire from terminal TB1-4.
2. Connect new white wire to terminal TB1-3, red wire to terminal TB2-5, and yellow wire to terminal TB1-4.

G. SR 4 Generators (Single Phase Half Wave Excitation and Regulation)

1. From terminal 7, remove yellow wire that extends to the clockwise end of voltage level control.
2. Connect new yellow wire to terminal 7, new red wire to terminal 6.

# ENGINE DIVISION
# ENGINE DATA SHEET

EDS 73.1

DATE April 1979

SUBJECT: Linear Vibration
BUSINESS: All
PRODUCT/APPLICATION: Generator Sets

The purpose of this Engine Data Sheet is to:

1. Review the basic theory and nomenclature of vibration. A knowledge of the language of this discipline will encourage a fundamental understanding. Such terms as linear, period, displacement, velocity, and acceleration will be defined and compared.

2. Identify causes of engine-related vibration. Major contributors to engine vibration are described, as well as procedures to isolate and measure vibrations.

3. Provide possible corrective action. Excessive vibratory motion may be encountered in the engine, generator, related components, or any part of the mounting system. If left unresolved this motion may cause personnel discomfort and/or equipment damage. Balance techniques are discussed, and limits or vibratory forces are defined.

## FUNDAMENTALS

Any mechanical system which possesses mass and elasticity is capable of relative motion. If this motion repeats itself after a given time period, it is known as vibration. A simple illustration of vibration is to suspend a weight (mass) on the end of a spring (elasticity).

As long as no external force is imposed on the system, the weight remains at rest -- there is no vibration. But when the weight is moved or displaced and then released, vibration occurs. The weight will continue to travel up and down through its original

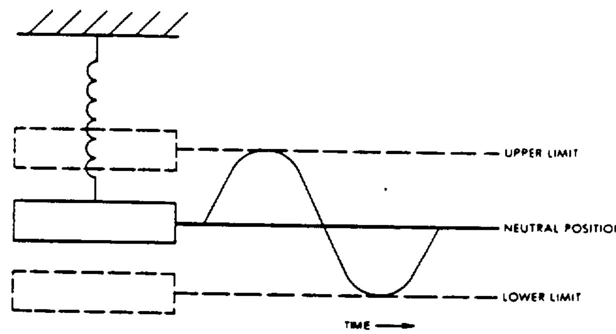



*Figure 1*

position until frictional forces again cause it to rest. This specific illustration is an example of free vibration. If an external force continues to affect the system while it is vibrating, it is termed "forced vibration."

The illustration is also an example of linear vibration. Linear vibration is an "in-line" motion and occurs as an object moves and returns along a repeatable path. Linear vibration must not be confused with the torsional (twisting) vibration motion of the crankshaft and driven rotating shafts (refer to EDS 202.1 for the subject of torsional vibration).

The time required for the weight to complete one complete cycle is called a period.

If the weight needed one second to complete a full cycle, the vibration frequency of this system would be one cycle per second. A system that completed its full motion 20 times in one minute would have a frequency of 20 cycles per minute, or 20 cpm.

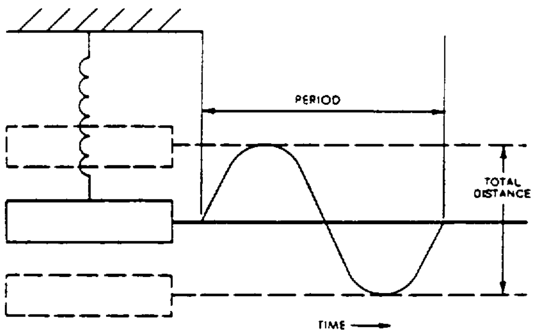



*Figure 2*

The total distance traveled by the weight, that is, from one peak to the opposite peak, is referred to as the peak-to-peak displacement.

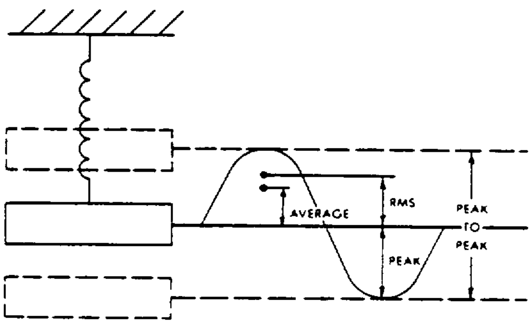



*Figure 3*

This measurement is usually expressed in mils, where one mil equals one thousandth of an inch (0.001 in). It can be used as a guide in judging vibration severity.

Both average or root-mean-square (rms) are sometimes used to measure vibration. rms = 0.707 times peak of vibration. These readings are meaningful in theoretical discussions, but are of limited practical value.

Another popular method used to determine the magnitude of vibration is to measure the vibration velocity. Note that the example is not only moving, but also changing direction. This means that the speed of the weight is also constantly changing. At its limit of motion, the speed of the weight is "0." As it passes through the neutral position, its speed or velocity is greatest.

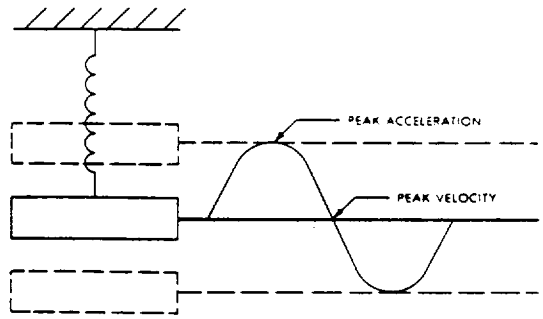



*Figure 4*

The velocity is an extremely important characteristic of vibration but, because of its changing nature, a single point has been chosen for measurement. This is the peak velocity and is normally expressed in inches per second peak.

Vibration acceleration is another important characteristic of vibration. It is the rate of change of velocity. In the example, not that peak acceleration is at the extreme limit of travel where velocity is "0." As the velocity increases, the acceleration decreases until it reaches "0" at the neutral point.

Acceleration is normally referred to in units of "g" (peak) where one "g" equals the force of gravity at the earth's surface. (980.665 cm/se, 386.09 in/s2, 32.174 ft/s2

Displacement, velocity, and acceleration a all used by vibration experts to diagnose particular problems. Displacement measurements tend to be a better indication of vibration under condition of dynamic stress and are, therefore, most commonly used. Caterpillar has standardized on displacement measurement.

Velocity is a direct measure of vibration and, as such, provides the best overall indicator of machinery condition. It does not, however, reflect the affect of vibration on brittle material.

The relationship between peak velocity and peak-to-peak displacement can be found by the following formula:

$$V\ Peak = 52.36\ D \times F \times 10^{-6}$$

Where V Peak = Vibration velocity in inches per second peak.

D = Peak-to-peak displacement in mils (1 mil = 0.001 in).

F = Frequency in cycles per minute (cpm).

Acceleration measurements or "gs" are commonly used where relatively large forces are applied. At very high frequencies (60,000 cpm) it is perhaps the best indicator of vibration.

The vibration acceleration can be calculated as:

$$g\ Peak = 1.42\ D \times F2 \times 10^{-8}$$

Measurement

The exact nature of linear vibration is difficult to define without instrumentation. The human senses are not adequate to detect relationships between the magnitude of displacement of a vibration and its period of occurrence. For instance, a first order (1 x rpm) vibration of 0.010 in (0.254 mm) displacement may feel about the same as a third order measurement of 0.001 in (0.026 mm). However, the severity of vibration does correlate reasonably well with levels of perception and annoyance.

Establishing the vibration frequency is necessary when analyzing this type of problem. It allows identification of the engine component or mass system which is causing the vibration. In discussions of vibration, the frequency of the motion is commonly referred to in terms of "order" of vibration. In an engine, the order of vibration is the number of vibratory cycles exhibited by a component during one revolution of the crankshaft.

$$Order = \frac{Vibration\ Frequency\ (cpm)}{Engine\ Speed\ (rpm)}$$

Overall vibration motion is the vector sum of the motion of all the orders. In other words, individual order motions will add or subtract to produce the overall. This measurement is not used to identify problems or establish limits, but rather as an indication of the total linear vibration motion.

A vibration analyzer is a prerequisite to troubleshooting a problem of this nature. A unit that measures frequencies and amplitude is suggested. Further, the analyzer should be rugged and easily understood. Good results have been obtained with the IRD Mechanalysis Model 320. It is offered by:

IRD Mechanalysis, Inc.
6150 Huntley Road
Columbus, Ohio 43229

All measurements must be made on the main rigid structural members of the engine and generator. The instrument pickup must be positioned on the crankshaft centerline at the locations shown on the sample form. Measurements (except torque reaction and some misalignment) can be made at no-load operation. If measurements are taken while the generator is loaded, the magnetic field of the generator leads must be avoided.

If excessive linear vibration motion is present or suspected, an initial measurement should be made to identify the source prior to starting corrective action. These measurements are to be checked against the applicable limits shown in the graph on Page 107. A sample form is described in this data sheet for convenient recording of raw data at various engine speeds (generator frequencies). This form can be used for the basic engine, single-bearing generators, and two-bearing generators.

Identification

Experience has shown that in order of decreasing importance, the primary sources of linear vibration motion problems are:

1. Misalignment of engine and driven equipment.

2. Unbalance of rotating parts.

3. Resonance from structural mass (weight) and stiffness (rigidity) combinations.

4. Torque reaction.

5. Cylinder misfiring.

6. Combustion forces.

7. Unbalance of reciprocating parts.

As test data is reviewed, if excessive vibration motion exists, it will be due to one of the following causes:

Misalignment or Unbalance

Most linear vibrations of generator sets are caused by misalignment or unbalance of the rotating members. This results in first order vibration which can be corrected in the field.

The vibration motion is relatively constant over the speed range but exceeds accepted limits. For generator set applications this may be determined by operating between 45 Hz to 65 Hz. Load does not change vibration motion caused by unbalance.

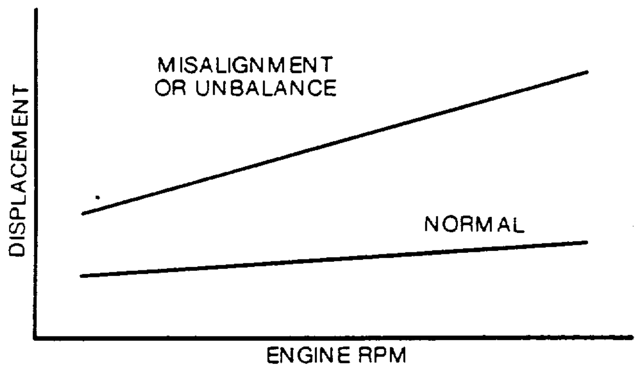



*Figure 5*

Resonance

Large vibration motion (amplitude) occurs within a narrow speed range. This can occur on the generator set and/or the attached equipment, such as piping, air cleaners, etc. When vibrations "peak out" in a narrow speed range, the vibrating component is in resonance. Resonance occurs when the disturbing force in the engine has the same frequency as the natural frequency of the part which is vibrating. The force of the vibration is, therefore, added to each cycle of the vibration part causing magnification of the original vibration.

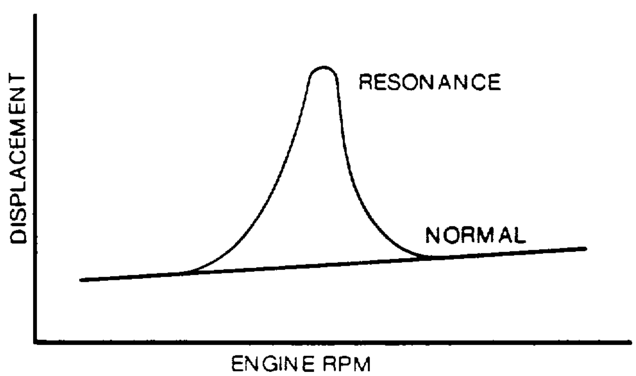



*Figure 6*

Torque Reaction

The vibration motion increases as load is applied. With a two-bearing generator, it can be caused by insecure mounting of the engine or generator to its base and/or by a base not sufficiently rigid to withstand the associated forces.

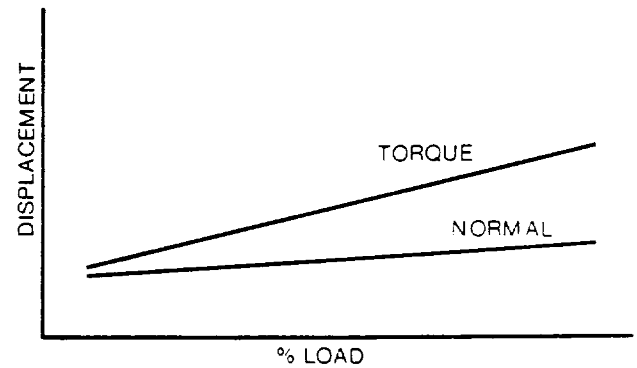



*Figure 7*

Torque reaction problems are not found with close-coupled two-bearing or single-bearing generators. The rigid joint between the flywheel housing and the generator body is generally adequate to withstand torque.

Assuming that a two-bearing generator is mounted on a weak base, first order motion and orders related to the number of cylinders firing with one crankshaft revolution are due to torque reaction which, in turn, causes misalignment. In this case, the first order motion would be most prevalent. A few engines do not follow the cylinder firing rule. These are the D346 and 0379 with second order and the D349 and 0399 with fourth order, in addition to the first order motion.

Certain specific causes of linear vibration can be further identified:

| Vibration Frequency | Correctable Causes |
|---|---|
| 1/2 x Engine rpm (1/2 Order) | Misfiring of One or More Cylinders |
| 1 x Engine rpm (1st Order) | Unbalance, Misalignment Out of Time Balance Weights (3408), Crank-case Overfill |
| 2 x Engine rpm (2nd Order) | Unbalance, Out of Time Balance Weights, Rotating Twice Engine Speed (3304, D346, D379 |
| 1-1/2, 2-1/2, 3rd and Higher Orders | Normal Cylinder Combus-tion (Not Correctable) |

CORRECTIVE ACTION

General

If a component is the only item with excessive motion, the component mounting will have to be altered until the motion is reduced to an acceptable level at operating rpm.

When the vibration motion measurements show that 1/2 order is causing the problem, the engine fuel and governing system must be serviced to eliminate engine misfiring. No other work should be attempted until engine misfiring is eliminated.

When excessive 2nd order vibration occurs on 4-cylinder and V8 engines, the timing of the 2nd order force balancers should be checked. Other high order vibration levels cannot be corrected with flywheel balance weights or balancer timing. Usually these orders involve the structural characteristics of the generator and base which would have to be altered.

If the vibration motion involves nonengine-mounted structures and the engine vibration motion is acceptable, either the off engine components must have their mounting altered or proper vibration isolators would have to be installed between the generator set and the structure.

If the entire unit has excessive motion, the following steps are required to remedy the various types of vibration. However, if the vibration motion for 1st and 2nd orders only still remain excessive after these procedures, the engine should be removed from the set and placed on suitable isolators. If the engine is within limits, a vibration specialist should be consulted. If the bare engine exceeds the limits, engine components rotating at engine speed (1st order) or twice engine speed (2nd order) should be inspected.

Misalignment and Unbalance

1. Check alignment of the unit. Refer-to Caterpillar Special Instructions for single- and two-bearing generator installations instructions. These are indexed under Section 4450 in the Caterpillar Service Department Master Index microfiche system. The Special Instructions are also in the microfiche system.
2. If vibration is still excessive, refer to Balance Procedure on Page 6.
3. Should this procedure fail, the unit should be mounted on isolators and the Balance Procedure repeated until a satisfactory level of vibration is obtained.

Resonance

With resonant conditions there are two ways of reducing the vibration level. These are: reduction of the exciting force and changing the natural frequency of the unit. If the following checks show that the structure the generator set is mounted on is the cause of the problem, a vibration specialist or mounting system specialist should be consulted.

1. Check alignment of the unit.
2. If vibration is still excessive, refer to Balance Procedure on Page 107.
3. Should this procedure fail, the unit should be mounted on isolators and rechecked. If the unit is satisfactory, the problem is an improper mounting system which requires changing. Consult the proper specialist.

   Should the balance procedure fail and the set has excessive linear vibration motion when installed on the proper isolators, the balance procedure should be repeated until the linear vibration motion level is satisfactory.

Torque Reaction

1. This condition is generally encountered when the engine is driving a conventional two-bearing generator which is not close coupled. Check alignment of the unit.
2. If the two-bearing generator set utilizes a structural steel base which is point mounted, i.e., pads, isolators, etc., torque reaction can deflect the weak base. This deflection can cause severe misalignment and resulting vibration. Assuming the unit continues to exhibit vibration after alignment, the base is not strong enough to hold the torque reaction and needs strengthening. One method of strengthening is to weld plates on the top and bottom of the base across the width of the base from 6 in. forward of the rear engine supports to 6 in. behind the generator feet closest to the engine.

Balance Procedure

The following correction procedure applied to 1st order vibration motion.

1. The crankshaft must assume the same position each time a balance adjustment is made. To assure this identical location is assumed, position flywheel to top dead center (TDC) of Number 1 cylinder. A chalk mark or scribe across flywheel and coupling plates will provide an easy reference during the balancing operation.
2. Remove bolts holding generator coupling plates to flywheel. Rotate generator rotor with plates attached 90° clockwise while flywheel remains at Number 1 TDC. Replace coupling plate bolts and retest for vibration.
3. If vibration remains, again position flywheel at TDC Number 1 cylinder, index generator rotor another 90° clockwise (total 1800), and retest.
4. If necessary, repeat Step 3 by rotating another 90° clockwise.
5. Position coupling assembly relative to flywheel where least amount of vibration occurred. If magnitude of vibration remains unacceptable, add weight of 2 oz (56.70 g) under any single coupling plate to flywheel bolt. Flat washers can be used for this purpose. Bolt must be sufficiently long to maintain at least 1 1/4 times the bolt diameter of thread engagement.
6. Observe vibration level and relocate weight 90° quadrant to identify where minimum vibration occurs.
7. Add additional weight at point of minimum vibration identified in Step 6 until vibration level is no longer diminished. In no case should more than 5 oz (141.75 g) be added under any one bolt.
8. If vibration levels are still unacceptable, a local vibration control specialist should be consulted.

LINEAR VIBRATION GUIDELINES

The following graph is for use with analyzed linear vibration motion. The graph tables apply to measurements made an the basic engine structure and generator frame. It is not for component vibration.

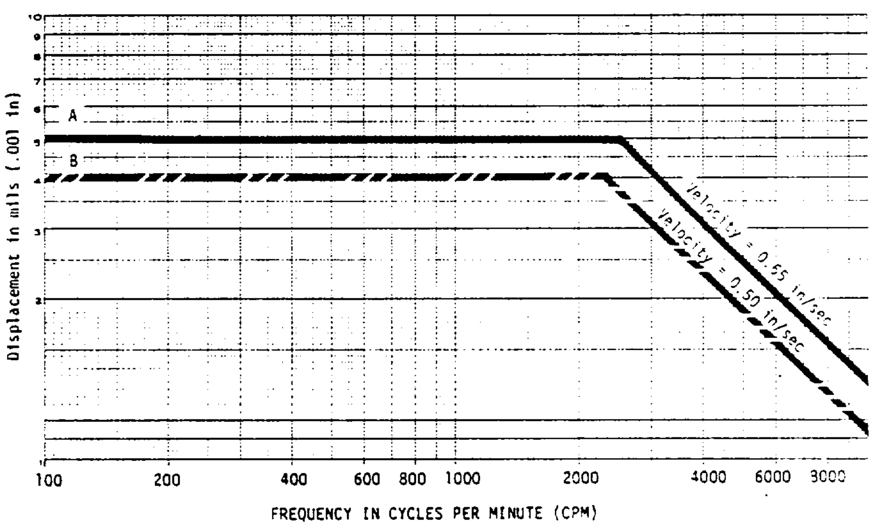



*Figure 8*

Line A is to be as a guideline for units as installed, either with or without mounting isolators. If the linear vibration motion is at higher levels, vibration complaints may occur from personnel discomfort and perhaps some premature parts service.

Line B is the vibration motion limit expected on a bare engine, i.e., with all crankshaft-driven equipment removed, and the engine mounted on isolating mounts where the mounted engine natural frequency is less than one-half the exciting frequency.

# LINEAR VIBRATION TEST

Date: ______________________

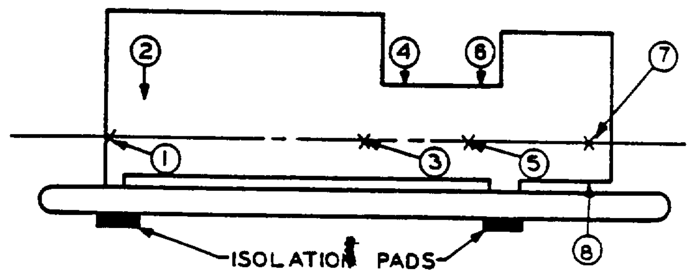
Tested by: ______________________

Engine:

RPM ______________________
S/N ______________________

Generator:

Manufacturer ______________________
Model ______________________
S/N ______________________




Run No.: ______________________

Description of Correction: ______________________

| | | ORDER (VIBRATION FREQUENCY / ENGINE RPM) | | | | | |
|---|---|---|---|---|---|---|---|
| TEST LOCATION | OVER ALL | 1/2 | 1 | 1-1/2 | 2 | 2-1/2 | 3 |
| 1 | | | | | | | |
| 2 | | | | | | | |
| 3 | | | | | | | |
| 4 | | | | | | | |
| 5 | | | | | | | |
| 6 | | | | | | | |
| 7 | | | | | | | |
| 8 | | | | | | | |

Run No.: ______________________

Description of Correction: ______________________

| | | ORDER (VIBRATION FREQUENCY / ENGINE RPM) | | | | | |
|---|---|---|---|---|---|---|---|
| TEST LOCATION | OVER ALL | 1/2 | 1 | 1-1/2 | 2 | 2-1/2 | 3 |
| 1 | | | | | | | |
| 2 | | | | | | | |
| 3 | | | | | | | |
| 4 | | | | | | | |
| 5 | | | | | | | |
| 6 | | | | | | | |
| 7 | | | | | | | |
| 8 | | | | | | | |

# ENGINE DIVISION ENGINE DATA SHEET

EDS 73.1.1

DATE April 1979

SUBJECT: Flywheel Balance Weights On D348, 0349 And 3412 Engines With Single-Bearing Generators
BUSINESS: Building Services, Marine/Petroleum, Material Handling
PRODUCT/APPLICATION: Engines With Single-Bearing Generators, Generator Sets

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On D348 and D349 Engines, a flywheel balance weight must always be installed when making a single-bearing generator installation. On 3412 Engines a flywheel balance weight is required if the single-bearing generator rotor weight supported by the flywheel exceeds 800 lb (363 kg). The purpose of this balance weight is to minimize linear, first order vibration.

Generator manufacturer's normally balance a rotor within very small deviation limits. Assuming the rotor is balanced, there are two other requirements which must be met before the exact amount and location of the balance weight can be determined.

1. The rotor must be accurately aligned on center with the crankshaft.
2. The flywheel supported weight must be known.

Two different methods are used with single-bearing generators to center the rotor with the crankshaft.

1. Stamped, close tolerance, drive plates center the rotor into one of the outer flywheel drive pilot bores.
2. An extension of the rotor shaft with a machined pilot diameter centers the rotor directly into the flywheel pilot bearing bore.

Rotor alignment, with drive plates establishing the pilot into the flywheel, is subject to toleranced variations of several parts. The accuracy of alignment with this method is not adequate to allow the predetermination of balance weight to compensate for the effect of rotor weight. A trial and error method is required to reduce linear, first order vibration to an acceptable level. The procedure is discussed in EDS 73.1 under Correction Action.

An extended piloted rotor shaft inherently centers and aligns the rotor directly into the flywheel pilot-bearing bore. The drive plates then retain the rotor in this centered position when secured to the flywheel. This accurate initial alignment allows predetermining selection and location for adding a flywheel balance weight.

The balance weight should be added at the proper location prior to installing the generator with extended rotor shaft pilot. The amount of balance weight required depends upon rotor weight supported by the flywheel. See Figure 1 for determining flywheel support weight or consult the generator manufacturer. Charts A, B, and C list the appropriate weight for ranges of rotor weight supported by the flywheel. Figure 2 shows flywheel locations for adding the required weight.

No operational function is performed by the extended shaft; however, it is recommended for applications where balance weight is required to counteract the effects of crankshaft supported weight. The major advantage being selecting and installing balance weight before assembly virtually eliminates trial and error balancing after assembly.

A generator manufactured with an extended rotor shaft pilot is preferred and can be supplied by the generator manufacturer. Generators without an extended rotor shaft may be converted with a bolt-on extension. Figure 3 has recommended dimensions.

A bolt on shaft extension introduces additional machining tolerances. However, if carefully made and assembled to the rotor, the expected total concentric runout can be held to 0.002 in (0.05 mm).

The extended shaft rotor should be dynamically balanced within the generator manufacturer's balance deviation limits while suspended by the rear bearing and extended shaft pilot diameter.

With an extended piloted rotor shaft, the coupling plates must have clearance between the outside diameter of the plates and the flywheel coupling plate bore. Clearance is necessary or serious vibration may result.

The coupling plates provided with a generator which does not have an extended shaft rotor pilot are usually of the close fitting piloting type. These cannot be used when the bolt-on shaft extension is used.

CATERPILLAR GENERATOR SETS

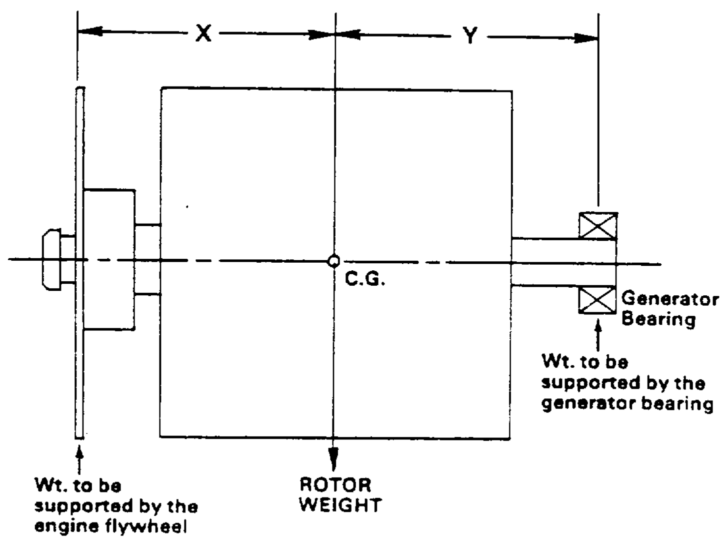
Caterpillar Generators are matched to the Caterpillar Engine for minimum vibration. The installation group includes proper coupling plates and, if necessary, balance weights correctly mounted on the engine. Current, price listed Caterpillar Generators should always be mounted with the price listed installation arrangement or coupling group for the engine.

TESTING GENERATOR SET ENGINES

Occasionally, a generator set engine is test run without the generator attached. If the engine is equipped with a balance weight on the flywheel (weight, bolt, washer or bolt and weight), the engine will vibrate. If an engine equipped with a flywheel balance weight is to be test run by itself (without the generator), the test should be performed without the flywheel balance weight assembly. Before the generator is mounted, be sure the proper weight assembly (bolt and weight or bolt, weight, and washer) is installed. Do not permit any substitution of balance weight parts (i.e., a longer or shorter bolt).

Generator sets having piloted shaft generators may exhibit wear on the pilot shaft, wear in the flywheel bore, or both after extensive service. When the total clearance between these points exceeds 0.005 in (0.127 mm), the assembly alignment function of the piloted shaft is lost. Shaft extension diameter and flywheel pilot bore dimensions should be checked. Bore and shaft should be round within 0.001 in (0.025 mm). Wear generally occurs on only a small segment of surface in the bore and/or on the shaft diameter. During assembly, original alignment can frequently be reestablished by rotating the engine and generator to positions where the flywheel bore will support the rotor shaft on previously not worn surfaces.

Finding the weight to be carried on engine flywheel when total rotor weight and location of center of gravity (C.G.) to points of support are known.




$$\text{Weight supported by flywheel} = \frac{(\text{Rotor Weight}) \cdot (\text{Length Y})}{(\text{Length X}) + (\text{Length Y})}$$

*Figure 1*

Chart A

D348 Flywheel Balance Weight

(For Use Only With Piloted Rotor Shaft)

| Range of Weight Supported by Flywheel | | Weight Part No. | Bolt Part No. |
|---|---|---|---|
| Pounds | Kilograms | | |
| 582- 652 | 265-296 | 5Z1180 | S1571 |
| 652- 714 | 296-325 | 3N9558 | S1571 |
| 714- 783 | 325-356 | 5N3140 | S1571 |
| 783- 864 | 356-393 | 2N7214 | S1571 |
| 864- 930 | 393-423 | 5Z905 | S1571 |
| 930- 995 | 423-452 | 5Z938 | S1571 |
| 1,027-1,109 | 467-504 | 5Z1098 | S1590 |
| 1,109-1,183 | 504-538 | 5Z1146 | S1571 |
| 1,183-1,254 | 538-570 | 5R2751 | S1571 |

384506 lock washer is used on all bolts.

Weight to be mounted at 3/8-16 tapped hole in flywheel. (See Figure 2A.)

Chart B

D349 Flywheel Balance Weight

(For Use Only With Piloted Rotor Shaft)

| Range of Weight Supported by Flywheel | | Weight Part No. | Bolt Part No. |
|---|---|---|---|
| Pounds | Kilograms | | |
| 663- 740 | 301-336 | 5Z2252 | S1587 |
| 740- 818 | 336-372 | 3N9556 | S1587 |
| 818- 890 | 372-405 | 5Z562 | S1587 |
| 890- 962 | 405-437 | 3N6598 | S1587 |
| 962-1,033 | 437-470 | 2N7215 | S1587 |
| 1,066-1,138 | 485-517 | 5N2521 | 1A1460 |
| 1,227-1,299 | 558-590 | 5R3408 | 9S1366 |
| 1,321-1,393 | 600-633 | 5R2868 | 9S1366 |
| 1,409-1,482 | 640-674 | 3N7001 | 2B947 |
| 1,482-1,555 | 674-707 | 3N8655 | 2B947 |
| 1,623-1,630* | 738-741* | 5R2995 | 9S1366 |

3B4508 lock washer is used on all bolts.

Weight to be mounted at 1/2-13 tapped hole in flywheel. (See Figure 2B.)

*Maximum permissible weight.

Chart C

3412 Flywheel Balance Weight

(For Use Only With Piloted Rotor Shaft)

| Range of Weight Supported by Flywheel | | Weight Part No. | Bolt Part No. |
|---|---|---|---|
| Pounds | Kilograms | | |
| 0- 800 | 0-363 | None | None |
| 800-1,416 | 363-642 | 1 - 5N1870 | 1 - 7B3235* |

Weight to be mounted at 1/2-13 tapped hole in flywheel. (See Figure 2C.)

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*Lock washer or flat washer not required.

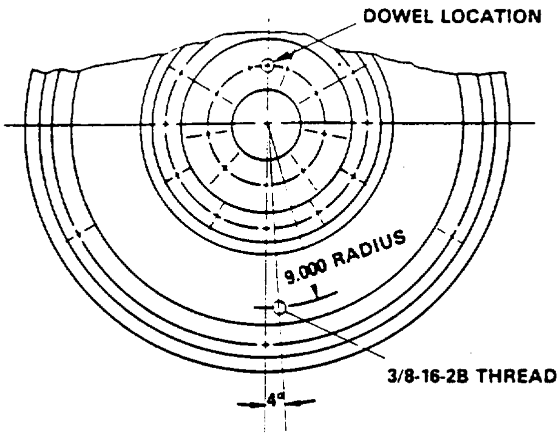



Figure 2A

D348 -- Threaded hole location in flywheel.
-- Balance weights are listed in Chart A.

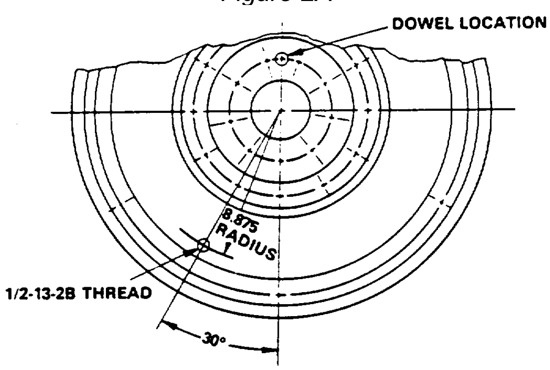



Figure 2B

D349 -- Threaded hole location in flywheel.
-- Balance weights are listed in Chart B.

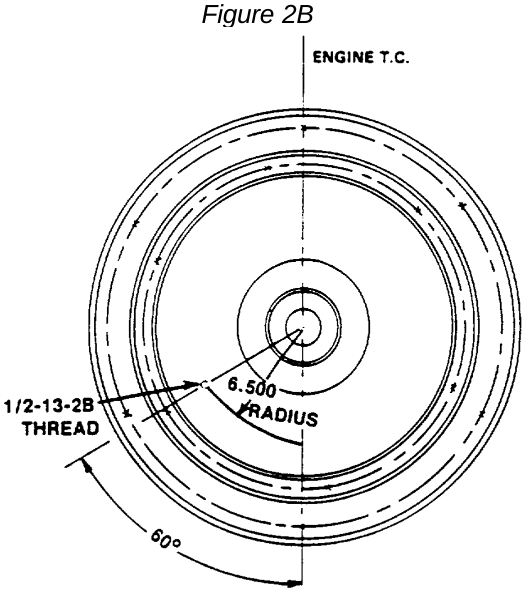
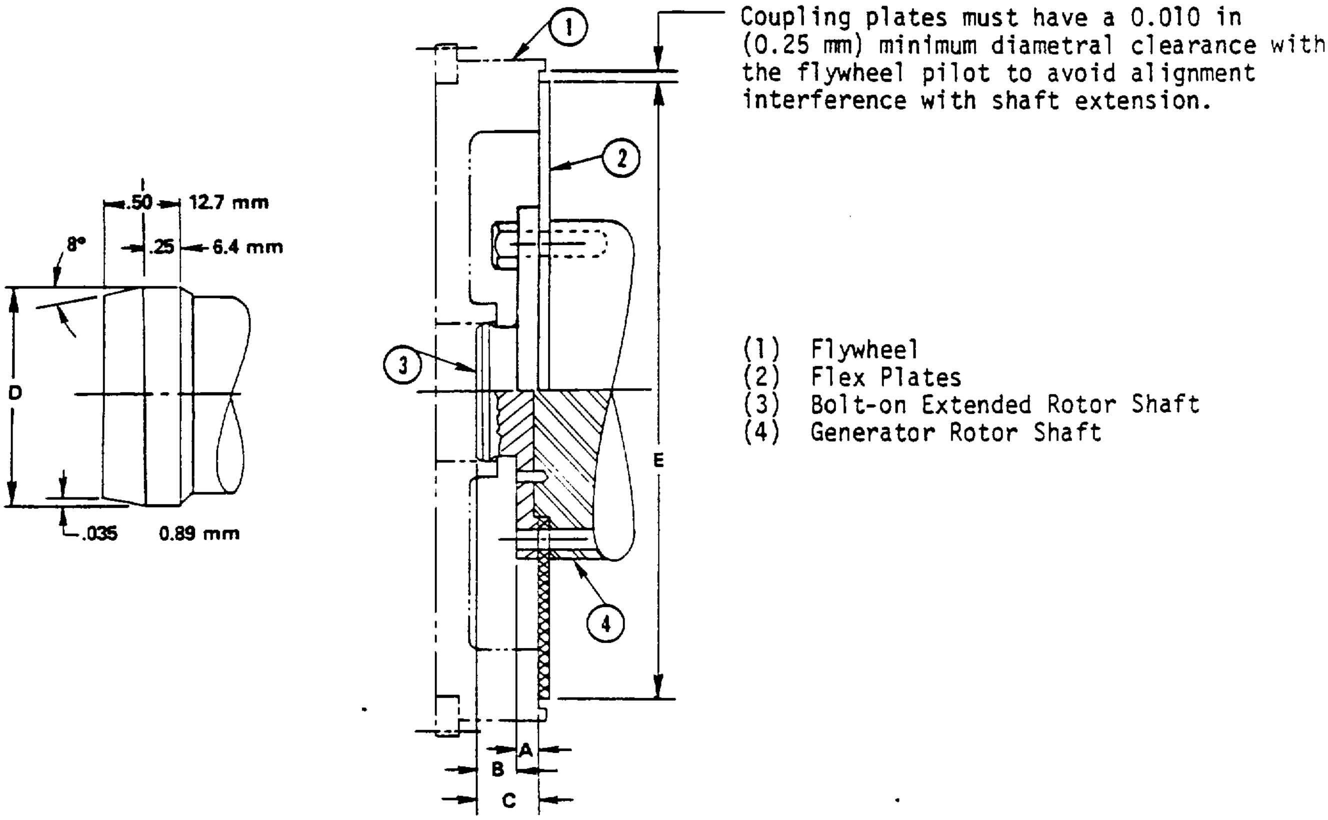



Figure 2C

D412 -- Threaded hole location in flywheel.
-- Drill hole and tap if threaded hole does not appear at location shown.
-- Balance weights are listed in Chart C.

Figure 2




- Bolt-on rotor shaft extension must be piloted on generator shaft with 0.001 in (0.03 mm) loose to 0.001 in (0.03 mm) tight fit and doweled to maintain alignment during reassembly.
- Completed assembly must be dynamically balanced within same limits as manufacturer prescribes for the rotor without the extension. Rotor should be suspended on the shaft extension and the rear bearing when balance is checked.

| Engine Model | SAE No. | A in mm | B in mm | C in mm | D in mm | E in mm | Maximum Weight To Be Supported On Flywheel lb kg |
|---|---|---|---|---|---|---|---|
| 3412 | 0 | 1.00<br>25.4 | 1.94<br>49.3 | 2.94<br>74.7 | 3.9355 $\pm$ 0.0005<br>99.96. $\pm$ 0.0127 | 22.490 $\pm$ 0.005<br>571.25 $\pm$ 0.13 | 1,416<br>642 |
| D349 | 0 | 0.75<br>19.1 | 1.75<br>44.5 | 2.50<br>63.5 | 4.7230 $\pm$ 0.0005<br>119.964 $\pm$ 0.0127 | 22.490 $\pm$ 0.005<br>571.25 $\pm$ 0.13 | 1,630<br>741 |
| D348 | 0 | 0.75<br>19.1 | 1.75<br>44.5 | 2.50<br>63.5 | 4.7230 + 0.0005<br>119.964 $\pm$ 0.0127 | 22.490 $\pm$ 0.005<br>571.25 $\pm$ 0.13 | 1,630<br>741 |

*Figure 3*

# INDUSTRIAL DIVISION ENGINE DATA SHEET

EDS: EDS 73.1.2

DATE: January 1978

| | |
|---|---|
| SUBJECT: | Linear Vibration Control -- Engines With Single-Bearing Generators |
| BUSINESS: | Building Services, Marine/Petroleum, Material Handling |
| PRODUCT/APPLICATION: | 3408 Engines With Single-Bearing Generators, Generator Sets |

This Engine Data Sheet supplements the information in EDS 73.1.1. Information that follows relates only to later 3408 PC-TA Engines driving single-bearing generators.

We no longer recommend the use of piloted shaft, single-bearing generators on 3408 PC-TA Generator Set Engines. Effective with the 3408 Generator Set Engine, Serial No. 67U1099, a 7N6395 flywheel assembly is installed which requires use of piloted drive plates. Although the close tolerance shaft pilot continues on the 5N39, 5N40, 5N41, and 5N42 generators, it is not used for alignment during assembly. Instead, the accurately machined drive (coupling) plates function as the initial alignment device. This drive arrangement can be applied to any 3408 PC-TA Generator Set Engine equipped with a 7N6395 flywheel assembly.

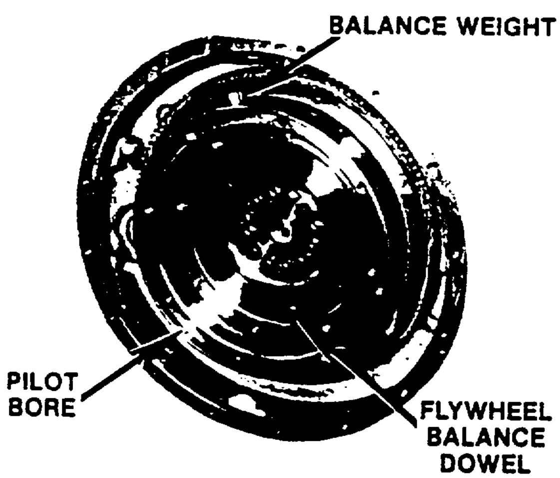



*FIGURE 1*
*7N6395 FLYWHEEL ASSEMBLY*

A 7N6395 flywheel assembly is readily identified by absence of the usual finished shaft pilot hole at the center and presence of the deep pilot bore (18.379 in. to 18.377 in. [466.83 mm to 466.78 mm]) at the outer diameter. See Figure 1. A 5N2030 coupling plate assembly from a 5N2021 coupling group properly aligns the generator rotor to the flywheel. The 5N2030 coupling plate assembly is machined to an outside diameter of 18.374 in. to 18.372 in. (466.69 mm to 466.65 mm). Do not attempt to use the 2N7025 coupling plate assembly from a 5N1628 coupling group. The 2N7025 plate assembly has an outside diameter of 18.365 in. (466.47 mm) and will not correctly align-a generator with the flywheel.

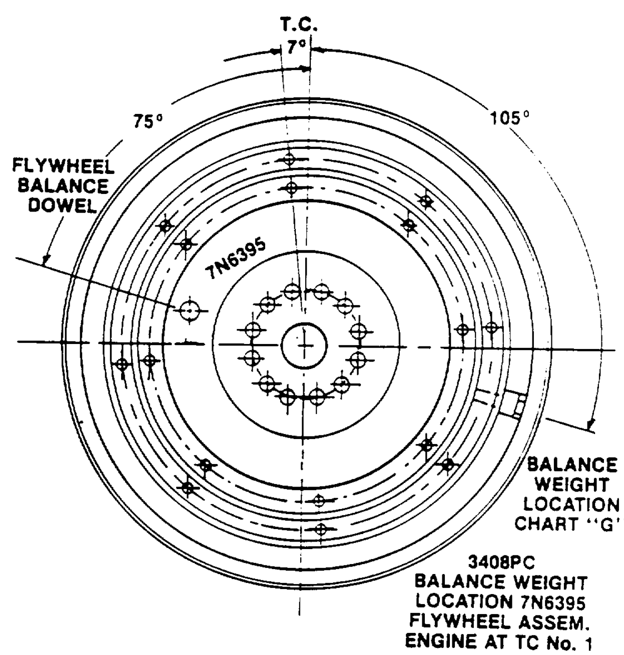



*FIGURE 4*

Figure 2 shows the assembly of a 5N39, 5N40, 5N41, or 5N42 generator to a 3408 PC-TA Engine having a 7N6395 flywheel assembly. Note that the fan of these later generators has a long pilot diameter fitted into the flywheel pilot bore. Balance weights are added to the flywheel when driving single-bearing generators.

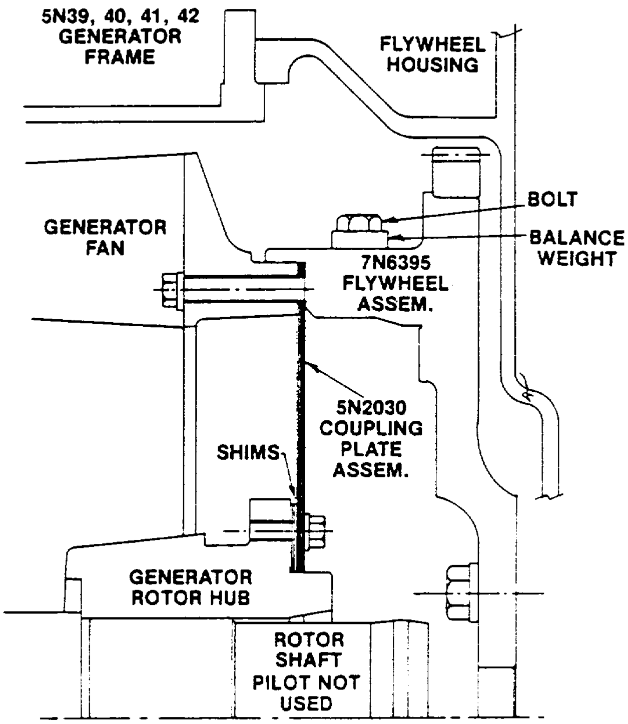



*FIGURE 2*

Necessary dimensions for coupling other manufacturers' generators are given in Figure 3. The required balance weight assembly for various generator rotors is in Chart G. Dimensions for local fabrication of the weights are Figure 5. Weights are assembled on the outer diameter of the flywheel directly opposite the flywheel balance weight (pressed-in dowel). See Figures 1 and 4.

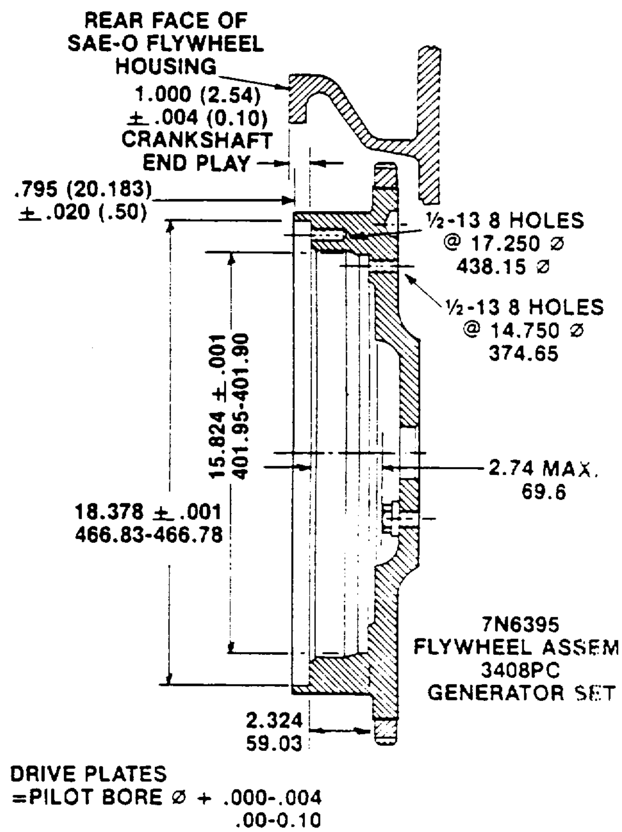


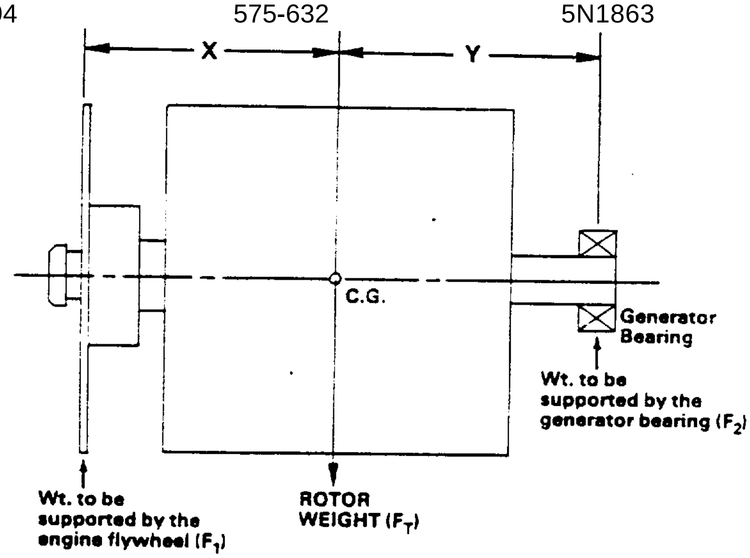

*FIGURE 3*

CHART G

3408 PC Balance Weights

Range of Weight Supported by Flywheel Assembly 7N6395

| Pounds | Kilograms | Weight Part No. | Bolt Part No. |
|---|---|---|---|
| 0- 210 | 0- 96 | No Weight | |
| 210- 334 | 96-151 | 5N1871 | S1620 |
| 334- 467 | 151-212 | 5N1870 | 7B3235 |
| 467- 601 | 212-272 | 5N1869 | S1587 |
| 601- 734 | 272-333 | 5N1868 | S1621 |
| 734- 868 | 333-393 | 5N1867 | 6H1717 |
| 868-1,001 | 393-454 | 5N1866 | S1595 |
| 1,001-1,134 | 454-515 | 5N1865 | S1595 |
| 1,134-1,268 | 515-575 | 5N1864 | S1585 |
| 1,268-1,394 | 575-632 | 5N1863 | S1585 |

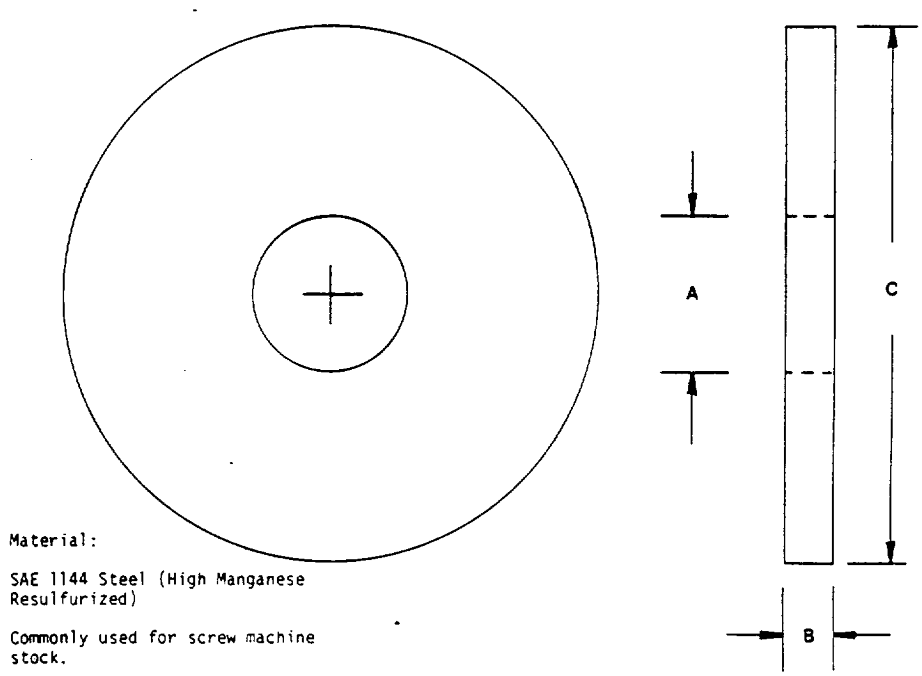



$$F_T = F_1 + F_2$$

$$F_1 = \frac{F_T \bullet Y}{X + Y}$$

Finding the weight to be carried on engine flywheel when total rotor weight, CG, and dimensions to points of support are known.

*FIGURE 6*




Balance Weight Dimensions

| Part No. | Weight | | A | | B | | C | |
|---|---|---|---|---|---|---|---|---|
| | oz | g | in | mm | in | mm | in | mm |
| 5N1863 | 8.34 | 236.3 | 0.53 | 13.49 | .650 | 16.51 | 1.968 | 50.00 |
| 5N1864 | 7.35 | 208.3 | 0.53 | 13.49 | .573 | 14.55 | 1.968 | 50.00 |
| 5N1865 | 6.49 | 183.9 | 0.53 | 13.49 | .506 | 12.85 | 1.968 | 50.00 |
| 5N1866 | 5.49 | 155.6 | 0.53 | 13.49 | .394 | 10.87 | 1.968 | 50.00 |
| 5N1867 | 4.61 | 130.5 | 0.53 | 13.49 | .360 | 9.12 | 1.968 | 50.00 |
| 5N1868 | 3.69 | 104.7 | 0.53 | 13.49 | .288 | 7.32 | 1.968 | 50.00 |
| 5N1869 | 1.91 | 54.2 | 0.53 | 13.49 | .780 | 19.81 | 0.984 | 25.00 |
| 5N1870 | 1.20 | 34.0 | 0.53 | 13.49 | .490 | 12.45 | 0.984 | 25.00 |
| 5N1871 | 0.67 | 19.1 | 0.53 | 13.49 | .274 | 6.98 | 0.984 | 25.00 |

Tolerance
Dimensions: ± .002 in (0.05 mm)

*FIGURE 5*

Calculate the supported weight as outlined in Figure 6. Maximum weight which can be carried on the flywheel is 1,394 lb (632 kg). Fasten the balance weight to the flywheel with the bolt listed in Chart G. Do not substitute bolts of different length or material. Do not add lock washers or other metal locks.

In event a generator set engine is to be tested without the generator, remove the flywheel weight assembly. Be sure this is reinstalled with the correct bolt before installing the generator. The dowel in the flywheel should not be disturbed when test engines.

# INDUSTRIAL DIVISION ENGINE DATA SHEET

EDS 75.0

DATE February 1976

SUBJECT: Grounding SRCR and SR 4 Generators
BUSINESS: Building Services, Marine, Material Handling
PRODUCT/APPLICATION: Generator Sets

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1. In any generator set installation, the frame of the generator must be positively connected to an earth ground or to the hull of a vessel. This connection is the first one made at installation, and the last one to be removed. If the generator set is on flexible or resilient pads, the ground connection must be flexible to avoid possible breakage in later operation. Ground connection cable or straps should have at least the current carrying capacity of the largest line lead to the connected load. Joints in cables or straps must be clean, free of electrical resistance, and protected from possible oxidation. Bolted ground connection joints eventually oxidize, and are frequent sources of radio frequency interference. Silver soldered, bolted joints are electrically and mechanically sound.

   a. The radio frequency noise suppressor in early SRCR generators (below S/N 2000) is connected to the generator frame. Inadequate frame grounding can result in interference to communication or audio equipment and improper operation of electronic governors.

   b. Where local codes permit, an effective ground connection can be made to an underground all metallic water piping system. The growing use of plastic and cement type water pipes makes water pipe connections hazardous as well as ineffective. One or more approved corrosion resistant ground rods, driven at least ten feet (three meters) into damp soil, are effective. In dry, sandy soil an extensive wire ground mat may be required.

2. "Y"-connected generators should have the neutral (and frame) grounded when the generator is installed unless definite measures are taken to prevent grounds on the load side. (NOTE: Noncurrent 2400-Volt generators are manufactured with the neutral wire connected to the generator frame.)

   a. If the neutral wire is not grounded and one of the load phase leads becomes grounded, the resulting voltage surge may damage the noise suppressor on SRCR Generators with serial numbers below 2000.

   b. If the neutral wire is grounded and one of the phase leads becomes grounded, the excessive current will open the load circuit breaker or collapse the generator voltage. The result depends on the particular generator electrical characteristics, type of fault, and circuit breaker trip rating. An under voltage device may be required to provide adequate short circuit protection.

   c. There are some instances in which it is undesirable to ground the neutral wire. In these applications where definite measures (ground fault protective circuits) have been taken to prevent grounds to the phase leads, an ungrounded generator neutral lead is acceptable. Ground fault protection requires that the entire group of distribution circuits be studied and treated as a system. The owner should engage a competent consultant if a new distribution system is being developed, or if an existing system is to be modified for ground fault protection.

3. There have been reports of excessive circulating neutral current occurring when two or more generators are operated in parallel. Generators should be installed with the assumption that no excessive circulating neutral current will occur with the generators paralleled at full load. The phase current should not exceed 100% of the generator nameplate ampere rating.

   In those cases where excessive neutral currents are encountered, either a neutral lead reactor or selective grounding of the neutrals may be used. If selective grounding of one generator neutral is used, a disconnect switch should be installed in each generator ground lead. The disconnect switch should have about 25% more current carrying capacity than the generator line ampere rating.

   **NOTE: Three phase, "Y"-connected generators can have a third harmonic voltage that does not cancel at the neutral. It is this voltage that causes the excessive circulating neutral current that can occur when operating in parallel.**

4. Instructions concerning excessive neutral current and grounding the generator neutral also apply to former model generators.

5. Most radio and audio frequency interference problems are corrected by proper grounding of the generator frame. In other instances, the cause is not the generator set, but equipment that may be related or unrelated to it. A small, hand-held battery-powered radio is a useful tool in locating the source of interference. Tune the radio receiver to the frequency of the interference and use the receiver as a probe around pipes, conduits, or other metal parts. Emitted noise will increase as the source is approached. Pipes rubbing together can cause radio frequency interference. Instances have been known where steel and galvanized pipe connections create interference even though the joint is mechanically sound and leak proof. In areas adjacent to high power radio frequency generators(transmitters, heating equipment, etc.), a partial or corroded joint or connection acts like a very poor rectifier, and can emit interference at frequencies different from the exciting frequency.

   The solution in all such instances has been physical bonding of the joint or conduit. A clean copper strap bridging the joint normally clears up the interference.

# INDUSTRIAL DIVISION ENGINE DATA SHEET

EDS 75.1

DATE September 1976

SUBJECT: Currents - Circulating in Paralleled Generators
BUSINESS: Building Services, Marine, Material Handling
PRODUCT/APPLICATION: Generator Sets

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When two or more generator sets are operated in parallel, a current may circulate between the generators. This current will exist when the internal voltage generated by each generator is slightly different, but the terminal or bus voltage is the same. In the most elementary form, current will flow out the line leads of one generator, through the paralleling bus and into the second generator. It does not flow into the load. This current, called "circulating current," is in addition to the normal line current supplied to the connected load. When more than two generators are in parallel, current could flow out of any generator and into one or more of the other generators. Circulating currents can take many paths into and out of the several generators.

We are concerned with these "wattless amperes" only when they interfere with normal generator set operation or when the normal on-line kVA capacity of the generators must be reduced because of excessive line currents. With no-load (zero kilowatts) on a generator in a parallel system, Caterpillar generators can readily tolerate a circulating current equal to 20%-25% of the line ampere rating shown on the generator name plate. At load conditions (100% kW load), Caterpillar generators will tolerate a circulating current of up to 10% of the rated line amperes.

Since circulating currents pass through the generator coils, these currents heat the coils the same as does the load current. Further, since circulating currents are superimposed on the load current passing through the circuit breaker, circulating currents can cause a breaker to trip as the breaker could "see" an actual ampere overload. More complex control systems include "reverse current" relays which sense counter flow currents. Currents in excess of the relay setting will actuate the circuit breaker trip mechanism.

Observed line current (as indicated by panel ammeters) in a parallel generator set system is a summation of two or three currents:

1. Load current -- that current which is supplied to the load. It may be in phase with the voltage (unity power factor) or somewhat out of phase with the voltage (power factor less than unity).
2. Harmonic current -- usually third harmonic current which flows through the entire system when "Y" connected paralleled generators have their neutral leads connected, either directly or through an earth or ground connection.
3. Circulating current -- that current which flows between generators for reasons explained below.

Each of the above currents contribute heat to the generator coils, the amount being equal to the square of the sum total current times the resistance of the coils. Thus, if the current doubles, the heat loss increases by a factor of four. Coil heating reflects in possible overheating and lowered efficiency. In very large generators, this is an important consideration. Significance of efficiency decreases with smaller generators. However, coil heat is always a factor, as it must be removed by ventilation or radiation to keep coil temperatures to an acceptable maximum.

The load alone determines the load current. Reactors or switches can be placed in neutral leads to reduce or eliminate third harmonic currents. Proper generator voltage adjustment can bring operating circulating currents to a minimum.

Circulating currents perform an important function: they account for misadjustment of the generator voltage control system as well as slight variations in the control systems.

The kilowatt (or horsepower) load on parallel alternators is entirely a function of the driving source. Thus, to increase the load demand on one generator set in a parallel system, the governor speed setting of that generator set must be increased.

Changing the voltage setting on one generator does not change the kilowatt load division between generators. This fact is often confusing, as observation of line ammeters after a voltage level adjustment will indicate a current increase, leading to the belief that one generator has picked up "load." It has not. Instead, currents circulating between generators have changed. The panel ammeters indicate this change.

Paralleled alternators must operate at the same terminal voltage since they are physically connected through the paralleling bus. If internally generated voltages are not exactly equal, one alternator will automatically supply an exciting or magnetizing current to the other alternator to raise its internally generated voltage. At the same time, the second alternator will supply a current to the first, which will lower the generated voltage of this unit. The net result of circulating or "cross" current is equal generated voltages.

This action is inherent and automatic. The amount of circulating current flow is entirely a function of the internal voltage generated by each of the several alternators in the parallel system.

The amount and type of connected load also affects internally generated voltage. Induction motors, for example, will tend to lower the generated voltage because the motors require magnetizing current in addition to power producing current. The generator which is trying to produce the higher generated voltage will supply a proportionately greater share of the magnetizing current not only to the motors but to other generators on the bus.

When generators are run in parallel, a current sensing system must be added to each voltage regulator. The current sensing system samples the generator line current not only in quantity but also in its phase (angular) relation to the voltage. The current sensing or droop system produces a voltage that adds to, or subtracts from, the voltage sensed by the voltage regulating system. (This accounts for the name often used: Voltage Droop System.) The resultant regulating voltage level (plus or minus droop voltage) causes the regulator to adjust the alternator exciting current downward for lowered generated voltage, or upward for increased generated voltage. Within limits, the complete regulator keeps individual generated voltages nearly equal and amperes balanced.

In any alternator power system -- single or multiple -- the system voltage level is established by the level of generator excitation. When the system is supplying a purely resistive load (unity power factor), generate excitation is normally expected to come from the individual generator exciters (static or rotary). If one generator exciter in a parallel system is somewhat deficient, the additional excitation will be supplied by circulating currents from other generators on the bus.

When the system is supplying induction motors, a higher exciting or magnetizing current is needed to provide the magnetic forces in the motors. This motor excitation subtracts from the total generator excitation driving the generated voltage downward. All of the voltage regulators in the system sense this decrease and individually raise the excitation level and the generated voltage of their respective generators.

If the voltage regulator action and resultant generator performance are precisely uniform, each generator would supply its exact proportion of additional magnetizing current. In practice this does not occur. Very small differences result in relatively large differences of current supplied. The voltage droop system senses these currents (in amount and in phase or power factor) and causes the voltage regulator to react in the correct direction, raising or lowering the individual excitation level. The result is controlled division of total line current.

Droop systems will function correctly only if the current sensing transformers of the several generators are all in the same phase or line lead. (T-2 in Caterpillar SRCR Generators, T-8 in SR 4 Generators.)

Droop systems are proportionate. This means that droop system reaction is proportionate to the ampere load on an individual generator set. Example: the total kW load on the system is 150 kW at 0.8 P.F. One generator is supplying 50 kW, and the other 100 kW. The total kVA (187.5) should be proportioned with 62.5 kVA on the 50 kW unit, and 125 kVA on the 100 kW unit. Indicated individual line amperes would also be proportionate, with one third of the total current coming from the 50 kW unit and two thirds of the load current coming from the 100 kW unit.

Operating conditions as just described are not always possible over the entire load range of the generators. Electrical and mechanical variations in generators cause a small difference in ampere or kVA division. Neither is exactly proportionate to kW load division. The difference shows up in the panel ammeter indications: the sum of individual generator line currents exceeds the load current.

Acceptable levels of circulating current result if the published procedures are followed for voltage level, regulator gain, and voltage droop on SRCR and SR 4 generators. These adjustments are always made with the generator at or near operating temperature. When a "cold" unit is paralleled to the bus, circulating currents may be noted. However, these will decrease as the incoming generator reaches its operating temperature. These currents are seldom cause for concern. Where excessive circulating currents do exist, the cause is generally found to be error in the adjustment procedure or in operating procedure.

When different sizes of generators are used, or where different types of voltage regulators are used, the best adjustment results from using the actual plant load. Voltage droop levels should be established from a reference voltage level, and at a reference frequency.

It is generally desirable to have the same voltage droop on all generators. This means that each generator should reduce its voltage an equal amount (3% to 5%X) between no-load and expected full load. Where different size generators are involved, it may be impractical to make the full load droop adjustment on the larger generators. A close approximation can be made by considering the droop system as a linear device. Select a plant load equal to at least three-fourths of the smaller generator capacity. Set the required droop on this smaller unit (example 5%). Transfer-parallel this same load to the larger generator and establish the reference frequency. Set the droop proportionate to the capacity. Example: 5% was set on the smaller unit with full load. That load is one-half the larger generator capacity. Set the droop on the larger generator at 2.5%. The resulting adjustment will be quite adequate.

Operating errors can cause very high circulating currents. These generally occur where indicating instruments are limited to voltmeters and ammeters. It is entirely possible to have one generator set absorbing power from the system, and have the ammeters showing "correct" currents. To avoid this, the operator should always have the incoming generator set running slightly fast, as shown by synchronizing light brilliance at 6 to 10 times per minute prior to closing the circuit breaker. This will assure that the incoming generator supplies power (kW) to the load at the time of breaker closure. Load is then added to the incoming generator set by increasing the setting of its governor control, or decreasing the setting of the on-line generator set governor controls.

Operating refinements to regulator adjustment are easily made on installations equipped with VAR meters, power factor meters, or wattmeters and line ammeters. (If the system includes only ammeters, regulator adjustments must be made with a single unit on the line.) Where power factor or VAR meters show equal indications, each generator is supplying its share of the load current reactive amperes, and circulating current between generators is at a minimum. Example: load power factor is 0.8. Generator No. 1 indicates 0.7 P.F. Generator No. 2 indicates 0.85 P.F. These meter readings tell the operator that Generator No. 1 is supplying too much magnetizing current to the load, and possibly to Generator No. 2. The magnetizing current of Generator No. 1 can be reduced simply by lowering its voltage level. Or, if desired, by raising the voltage level of Generator No. 2, the operating power factors can be equalized. Circulating current is then at a minimum.

Wattmeters and ammeters can provide the information necessary to accomplish operating or on-line voltage level adjustments.
Example:

Load kW 500, Load Line Amperes 750,
Voltage 480
Generator No. 1, Load kW 250,
Line Amperes 350
Generator No. 2, Load kW 250,
Line Amperes 450

These meter readings indicate that Generator No. 2 is supplying more than its share of magnetizing current. This is true because Generator No. 1 is operating at a power factor of 0.86 which is higher than the load power factor of 0.80, and generator No. 2 is operating at a power factor of 0.67 which is lower than the load power factor. Decreasing the voltage level setting of Generator No. 2 will reduce its magnetizing current and increase the power factor. At the same time the magnetizing current from Generator No. 1 will increase, and its power factor will decrease.

When loads are not equal, the calculated power factor of each generator can be used to correctly distribute magnetizing current and keep the circulating currents to a minimum. Example:

Load kW 700, Load Line Amperes 1,100,
Voltage 460
Generator No. 1, Load kW 250,
Line Amperes 500
Generator No. 2, Load kW 450,
Line Amperes 630

It should be obvious that the voltage level setting on Generator No. 2 is too low. Adjustments could be made to one or both until No. 1 shows a line ampere reading of about 390, and the line ampere reading of No. 2 shows about 700 amperes. At these conditions, both generators will be operating at the same load power factor of 0.8. Circulating current is at a minimum. Refinements as described above will assure highly satisfactory operation of paralleled generator sets.

Summary

Circulating currents exist in paralleled generators when the several generators are attempting to operate at different voltages although they are connected together through the common bus. These circulating currents reduce the effective excitation of one or more generators, and increase the effective excitation of others. Generator voltage is directly related to exciter output. Hence, an attempted generator voltage difference is the result of different exciter output. Exciter output is controlled by the voltage regulator, and ultimate control of circulating current is a function of the regulator.

### Effect of Circulating Currents On Load Sensing Electronic Governors

The Woodward 2301 load sensing governor can react to excessively large circulating currents. With correct adjustment of generator voltage regulators, the load sensing governor responds to true power or kW load on the generator set. However, when the value of circulating current between generators approaches the value of the actual load current, the governors may react to these excessive circulating currents and change the kW load division between generator sets. Load transfer may be slow, or it may be rapid. There is no predictable pattern since the observed action depends on the condition of the generator voltage regulators controlling the several generators.

Incorrectly adjusted voltage regulators are the most common cause of the "load shift" problem. It is generally found that initial generator regulator adjustments fail to include adequate voltage droop or cross-current compensation. This difficulty can also cause operating errors.

Some commercially available generator control panels for use with commercially avail-able generators include a switch that bypasses the voltage droop circuit in the voltage regulator. These switches have various names such as "Single-Parallel" or "Droop In Droop Out." Operators incorrectly position these switches during parallel operation, causing one or more generators to operate without voltage droop or cross-current compensation. Circulating currents can greatly increase under these conditions. Governors will generally react.

Switchboard wiring errors, such as reverse-connected current transformers (used as part of the droop or cross-current system), can also cause load shift problems. In these instances, the voltage droop system causes a rise in generated voltage as the line current increases. Circulating currents can increase rapidly, and possibly cause circuit breakers to open. Governor reaction may be noted just prior to circuit breaker opening.

INDUSTRIAL DIVISION
ENGINE DATA SHEET

EDS 76.3
DATE December 1975

SUBJECT: Brine Tank Load Test
BUSINESS: Building Services, Material Handling
PRODUCT: Generator Sets

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BRINE TANK LOAD TEST

The most popular and inexpensive method used to check generator set power output is the brine tank load test. This simple test uses a salt water solution for a resistive load between the terminals of a generator. The equipment required is relatively easy to acquire and assemble.

EQUIPMENT REQUIRED

Tank -- Preferable circular because electrodes should be equidistant from each other and the walls of the tank. It should be 3 to 5 feet (O.9-1.5m) deep with at least 2.5 gallons (9.4L) per kW capacity. A galvanized steel stock tank works well.

Electrodes -- 1/8" to 1/4" (3 to 6mm) thick sheet steel with surface area of 1.5 square inches (10cm2) per kW. The electrodes should be fitted into slotted wooden or steel frames that will hold them stationary in turbulent water. Insulation is required between each of the electrodes and between the electrodes and the frames to prevent an electrical short. The electrodes must be positioned equidistant from each other and the tank walls so that each generator phase has the same line current.

Salt -- About 0.1 pounds (45g) of very fine salt per gallon.

Electrical Meters -- Portable tong ammeter and voltmeter to check current and voltage in each phase. (Use generator control panel if possible).

Miscellaneous -- Lumber or steel for overhead framework and electrode frames. Sufficient cord or cable and pulleys to control electrodes. Rubber or plastic hose to run make-up water to tank and to direct overflow away from tank.

OPERATING PROCEDURES

Set up apparatus similar to example pictures.

Raise the electrodes out of the water.

Start the generator set and run it at high idle until it is warm.

Close the circuit breaker.

Slowly lower the electrodes into the water making sure each causes the same line current on each phase.

Operate the unit at one-half load for thirty minutes. This will warm up the unit and permit current flow to aid in dissolving the salt.

If the line current does not approach 0.8 of rated full load current when all electrodes are fully submerged, add salt to lessen the resistance of the water. The salt should be added slowly to allow time for complete dissolving. Watch the ammeter to ensure readings do not pass maximum allowable. (If the water is cool when the salt is added, the salt may dissolve suddenly when the water begins to boil. This will cause a rapid increase of line current). Additional water should be added to replace evaporation loss.

Brine tank load will remain reasonably constant if the water level is maintained, and the water does not boil. If the liquid is boiling or flashing into steam around the electrodes, the load will not be stable. Severe steam flashing around the electrodes can cause governor reactions that may appear to be governor "hunting." The best results are always obtained with minimum liquid conductivity (lowest amount of salt) and maximum electrode immersion. (Greatest possible electrode area in the liquid.)

For any current reading, the power output of a 3-phase generator can be calculated using the following formula:

$$kW = \frac{E \times I \times 1.73}{1.000} \times P.F.$$

Where: kW = Kilowatt output
E = Voltage (average of 3 lines)
I = Amperes (average of 3 lines)
PF = Power Factor

A brine tank is a 1.0 power factor load.

WARNING

Rated generator kW occurs at 0.8 PF. Therefore, to obtain generator rated kW the line current should be 80% of the nameplate ampere rating of the generator. Operation at full rated current would result in a 25% overload.

PORTABILITY

The brine tank can be made portable by placing it on a small steel trailer as seen in the picture. The trailer should be equipped with a trailer jack on each corner to enable the tank to be leveled.

SAFETY

The brine tank test should not be used for any generator above 480 volts. If the generator voltage is greater, use reduction transformers. Avoid any possible flash over between electrodes and tank.

Be sure the tank or any of its metallic support is connected to a good earth ground.

The tank should be equipped with overflow outlets to prevent the boiling water from spilling over the top of the tank.

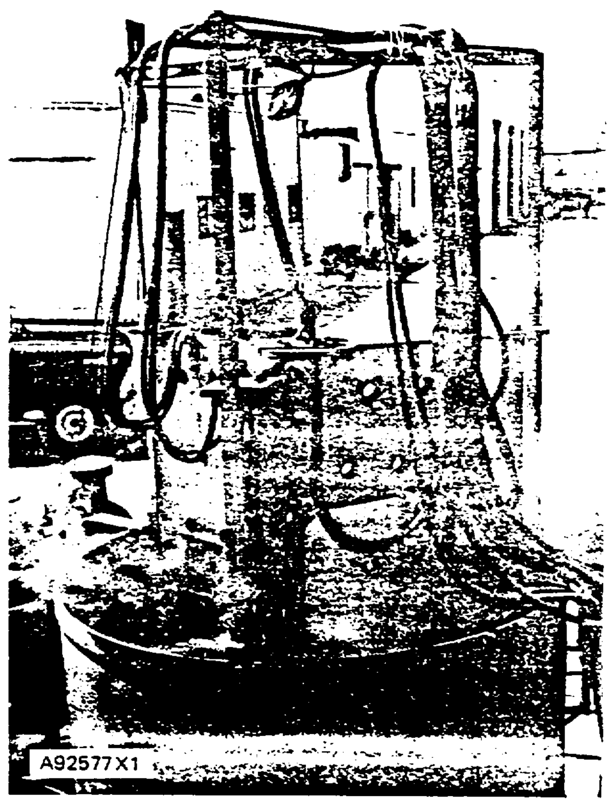
Each opening should be four to six inches (10 to 15 CM) from the top and have a hose to direct the water away from the tank and the operator.

EXPLANATION OF PICTURED BRINE TANK

This tank has three vee-shaped electrodes connected and insulated at the center and to the side frames. The large center hole and numerous small holes allow complete water circulation during the turbulence caused during load application.

This unit is very sophisticated and is only shown as an example for constructing a brine tank. Many applications do not require a load bank this elaborate. By following the basic construction guidelines listed earlier, a less expensive tank can be constructed.

For example, three oil barrels electrically connected will provide about a 150 kW load when using round electrodes about 3 inches (8cm) in diameter and 18 inches (45cm) long. Discarded pipe with random holes burned through the surface makes very good electrodes.



## ALPHABETICAL INDEX

The Alphabetical Index aids in quickly locating the page number of the operation to be performed and refers to the operation number as listed in the Service Index.

C

| COMPONENT OPERATION | Page No. | Oper. No. |
|---|---|---|
| Control Panel | 129 | 1 |
| Generator Bearing (Outside Bearing Type RFA) | 130 | 2a |
| Generator Bearing (Inside Bearing Type RFA) | 132 | 2b |
| Generator Removal | 138 | 3 |
| Generator Installation | 139 | 4 |
| Rotor Assembly (Vertical Method) | 143 | 5 |
| Rotor Assembly (Horizontal Method) | 145 | 6 |
| Stator Assembly | 147 | 7 |

## SERVICE INDEX

The Service Index lists all component operations covered in the Disassembly and Assembly section. Unless otherwise specified, all operations listed under the column "Component Operation" refer to the removal and installation of the component. The components are grouped within the Service Index with other components located in the same general area of the generator. The "Other Needed Operations" column indicates other operations that pertain to the operation being performed.

C

| OPERATION NO. | COMPONENT OPERATION | OTHER NEEDED OPERATIONS | PAGE NO. |
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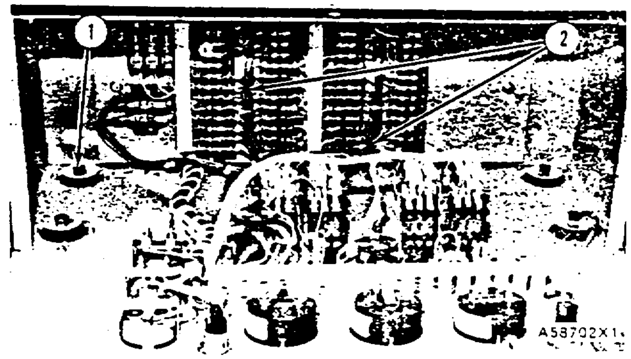
| 6 | Rotor Assembly (Horizontal Method) | 1,3 and 4 | 145 |
| 7 | Stator Assembly | 1, 3, 4 and 6 | 147 |

## CONTROL PANEL

### REMOVE CONTROL PANEL 4460-11

1. Disconnect wires (2) from the generator terminal strip.
2. Remove four bolts (1) from the shock mounts.
3. Remove control panel.



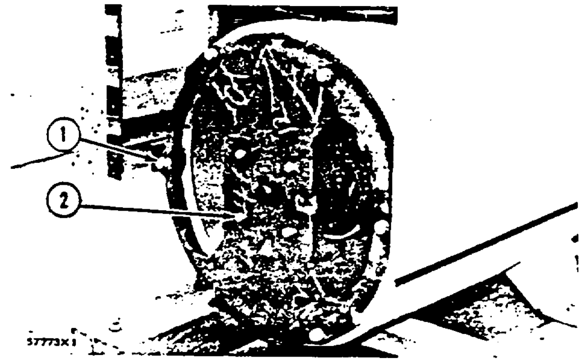

### INSTALL CONTROL PANEL 4460-12

1. Install control panel and four bolts (1).
2. Connect wires (2) to the generator terminal strip.

## GENERATOR BEARING
## (OUTSIDE BEARING TYPE RFA)

### REMOVE GENERATOR BEARING 7551-11

| | Tools Needed | A |
|---|---|---|
| 887551 | Bearing Puller Attachment | 1 |
| 887548 | Push Puller Assembly | 1 |
| 887560 | Step Plate | 1 |
| 887563 | Handle | 1 |
| 8H684 | Ratchet Box Wrench | 1 |

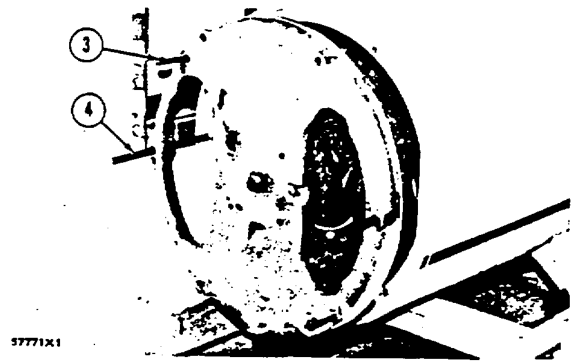



1. Remove the panel and louvers from the frame assembly.

2. Put two pieces of cardboard or sheet metal between the rotor assembly and the stator assembly. This will keep the rotor off of the stator when the cover assembly is removed.

3. Remove four bolts (2) and the retainers that hold the bearing.

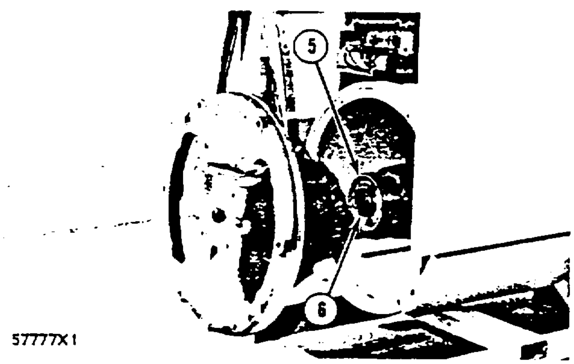
4. Remove six bolts (1) that hold the cover on the stator. Remove the wires F1 and F2 from the regulator assembly.




5. Install two guide bolts (4) with 1/2"-13 NC threads, 10 in. (250 mm) long.

6. Install two 3/8"-16 NC forcing bolts (3) in the threaded holes in cover. Push the cover from the bearing and remove the cover with a hoist.

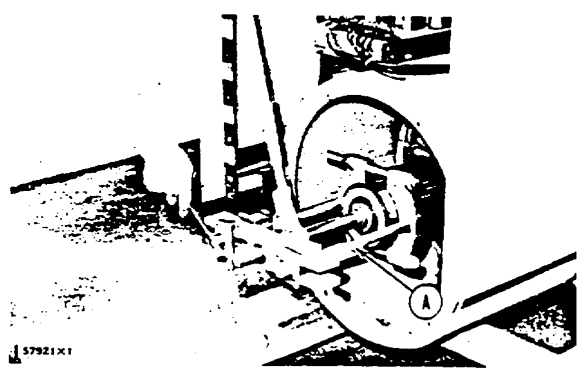
**NOTICE**
**Do not damage the stationary exciter field, which is part of the cover, when the cover is removed.**




7. Remove ring (6) that holds bearing (5) on the shaft.

8. Install tool group (A) and remove the bearing from shaft.

**NOTICE**
**Do not damage the armature of the exciter when the tool group is installed.**

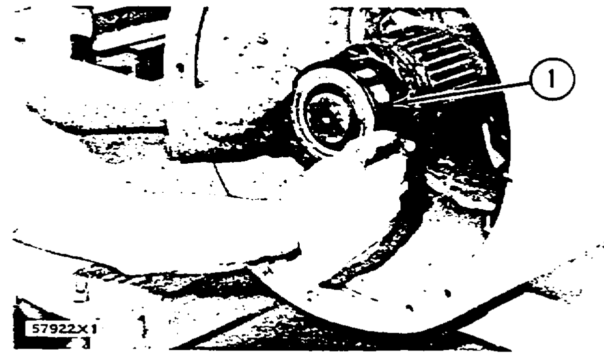



**NOTE: After the bearing has been removed, the armature of the exciter**
C **can be removed. The armature windings will be destroyed.**

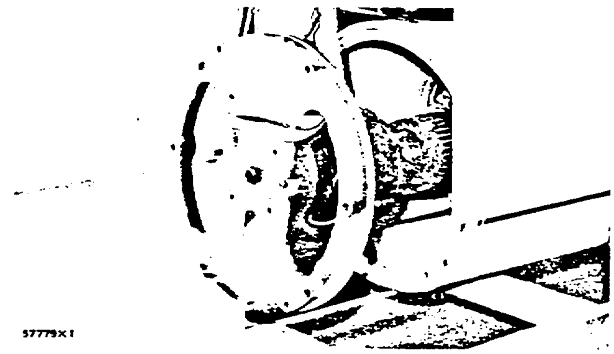
## GENERATOR BEARING
## (OUTSIDE BEARING TYPE RFA)

### INSTALL GENERATOR BEARING 7551-12

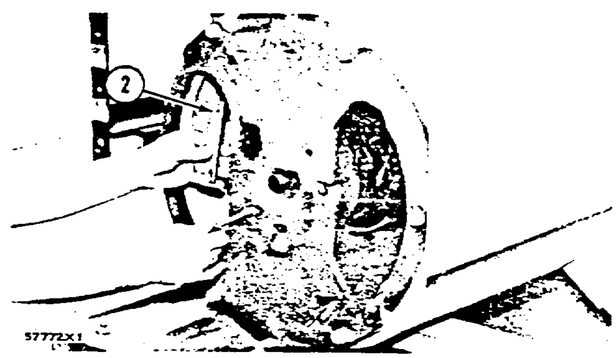
**NOTE: If the armature of the exciter has been removed, press the replacement armature on the rotor shaft using a pipe with approximately an I.D. and O.D. of the rotor shaft O.D. and armature winding I.D. respectively. The rotor shaft has a taper and keyway.**



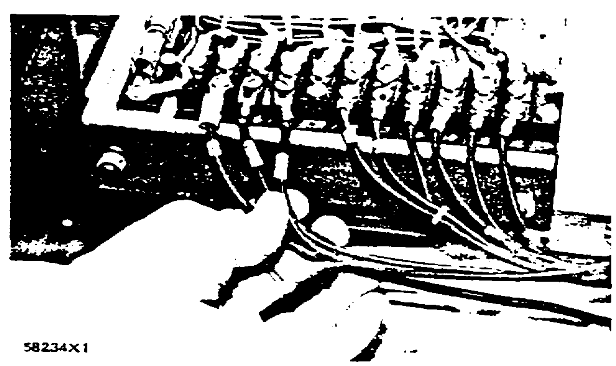

1. Heat the bearing in oven to a maximum temperature of 225° F (107° C).
2. Install bearing (1) on the shaft.
3. Install the ring that holds the bearing on the shaft.
4. Install two guide bolts with 1/2"-13 NC threads, 10 in. (250 mm) long, in the generator. Install the cover assembly on the two guide bolts. Slide the cover into position over the bearing.




**NOTICE**
**Do not damage the exciter fields and armature when cover is installed.**



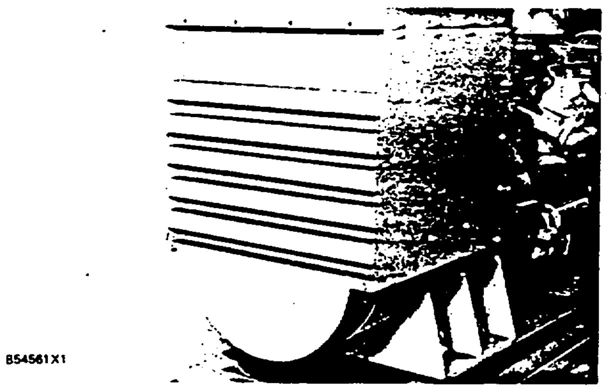

5. Install the bolts that hold the cover on the generator.
6. Install retainer's (2) and bolts that hold the bearing in the cover.
7. Connect the two field wires F1 and F2 to the regulator assembly terminal strip.
8. Remove the cardboard or sheet metal that was used to keep the rotor off of the stator.
9. Fill the bearing chamber with lubricant. See Lubrication and Maintenance Guide.
10. Install the louvers in the end of the generator frame. Install the panel in the frame.



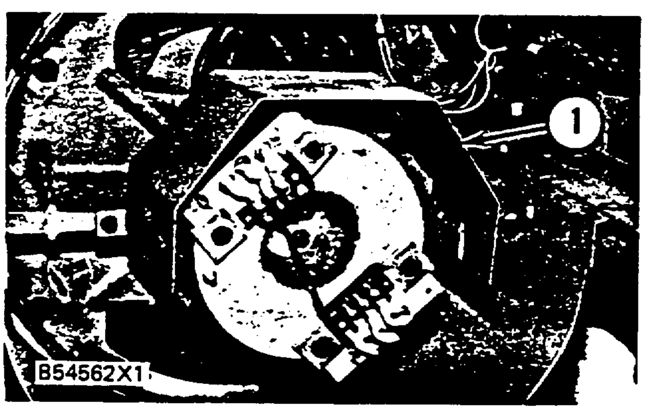
## Generator Bearing (Inside Bearing Type RFA)

### Remove Generator Bearing 7551-11

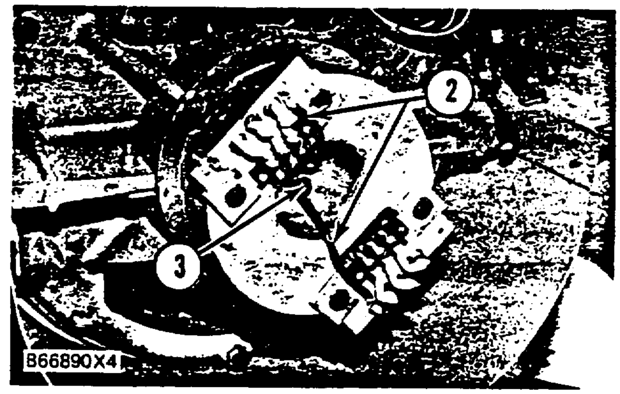
| Tools Needed | | A | B | C |
|---|---|---|---|---|
| 1P1863 | Pliers | 1 | | |
| 1H3107 | Puller Assembly | | 1 | |
| 1H3109 | Leg | | 2 | |
| 8H684 | Wrench | | 1 | |
| 5F7343 | Puller Assembly | | 1 | |
| 5P2958 | Step Plate | | | 1 |
| 1P520 Driver Group | | | | |




**1.** Remove panel, four louvers and cover assembly from frame assemblies.




**2**. Remove two bolts and the shield (1) from the generator.

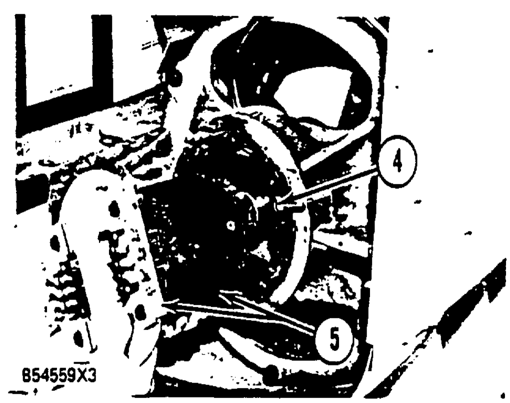



**3.** Disconnect two wires (2) from the rotor assembly.

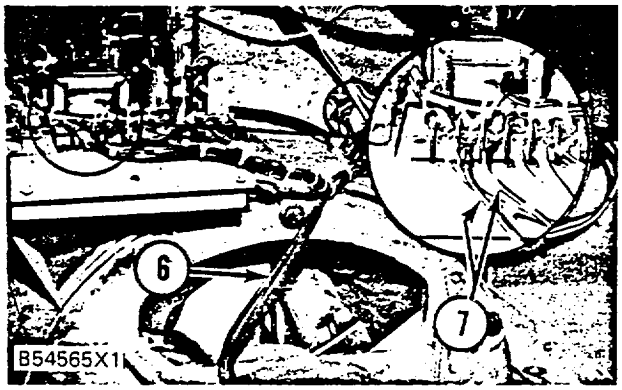
**4**. Remove two bolts (3) that hold the exciter and heat sink assembly to the shaft.

**NOTICE**

**Do not cause damage to the core assembly (exciter field) (4) when removing the exciter and heat sink assembly (5).**

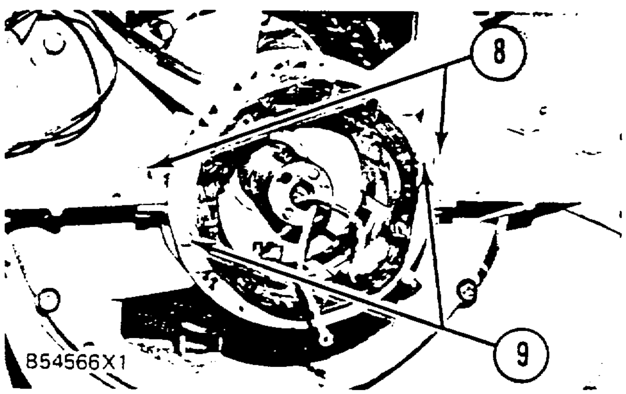



**5.** Remove the exciter and heat sink assembly (5) from the shaft.




**6**. Cut the plastic ties which hold the two wires (F1 and F2) (6) that go to the regulator from the core assembly (exciter field).

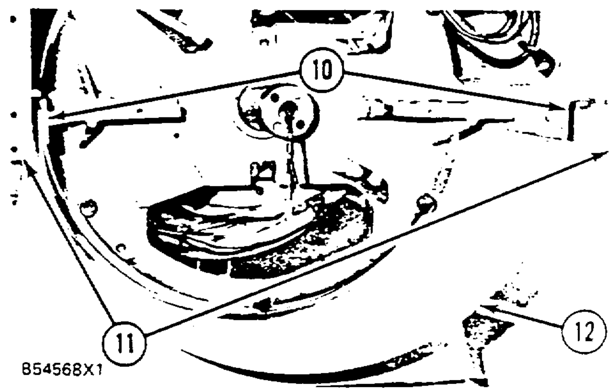
**7.** Disconnect the two wires (F1 and F2) (7) from the regulator terminal strip.




**8.** Remove two nuts and bolts (8) that help hold the core assembly to the bracket.

**9.** Remove two bolts (9) and the core assembly from the bracket.


**10.** Put cardboard between the rotor assembly and the stator assembly This will keep the rotor off the stator when the bracket is removed.

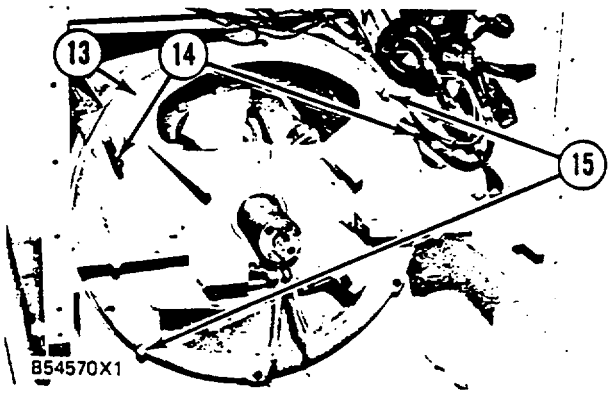



**11.** Support the frame assemblies (11).

**12.** Remove six bolts and the bottom cover (12) from the brackets (10).


**13.** Remove four bolts and two retainers that keep the bearing in position.

## Generator Bearing (Inside Bearing Type RFA)



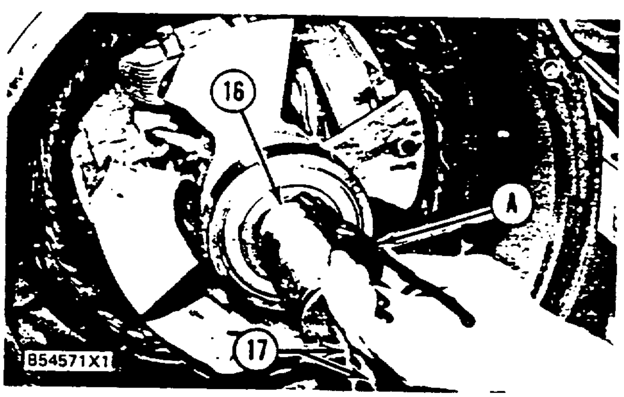

**14.** Remove two bolts from the bracket (13) and install two 1/2"-13 NC 10" long guide bolts (14).

**15.** Remove the remaining four bolts.

**16.** Install two 1/2"-13 NC forcing bolts (15) and remove the bracket. Weight of the bracket is approximately as follows:

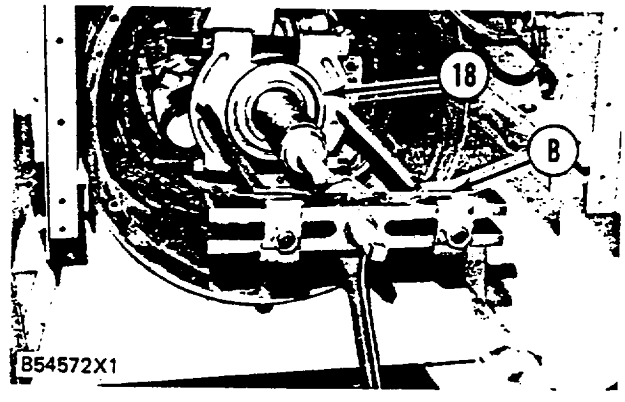
400 frame size 49.5 Kg (110 Ibs)

500 frame size 67 Kg (150 Ibs)

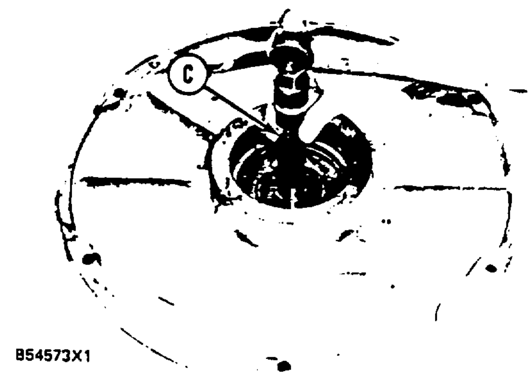



**17.** Use tool (A) and remove the ring (16) from the shaft.

Push the two wires (17) in until the end of the wires are even with the end of the rotor shaft.



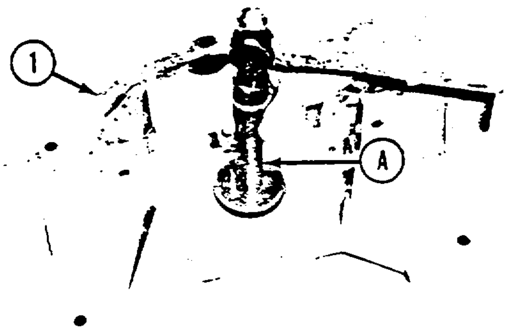

**18.** Install tooling (B) and remove the bearing (18) from the shaft.




**19.** Use tooling (C) and remove the seal from the bracket.

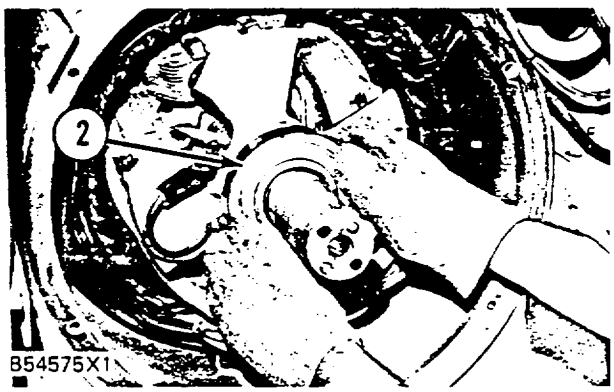
### Install Generator Bearing 7551-12

| Tools Needed | | A | B |
|---|---|---|---|
| 1P520 | Driver Group | 1 | |
| 1P1863 | Pliers | | 1 |




B54574X1

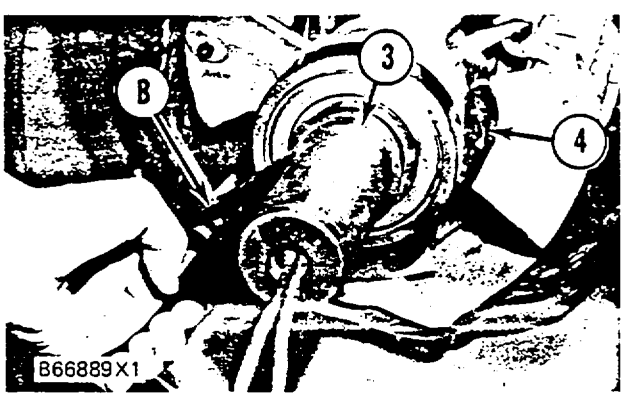
**1.** Use tooling (A) and install seal in bracket (1).




B54575X1

**2.** Heat bearing (2) to a maximum temperature of 107°C (225°F).

**3.** Install bearing on shaft.

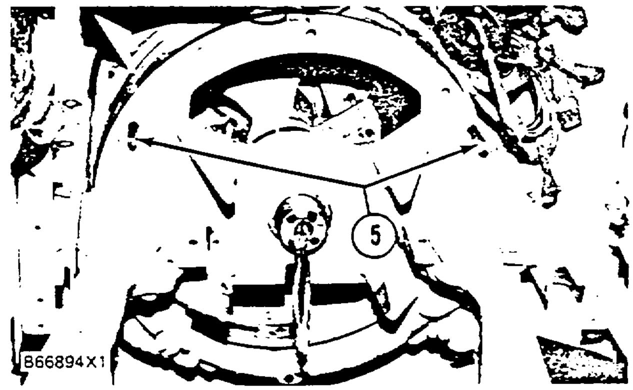



B66889X1

**4.** Use tool (B) and install the ring (3).

**NOTICE**

**Make sure the two wires are pulled through the rotor shaft. Also make sure that the wires have protection (4) where they enter the rotor shaft.**




B66894X1

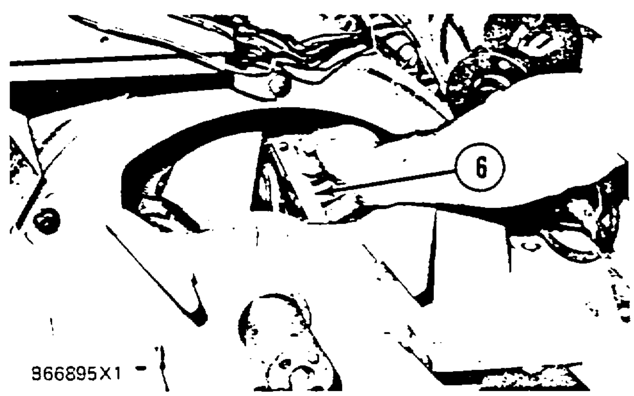
**5.** Install two 1/2"-13 NC 10 in. guide bolts (5).

**6.** Install bracket on shaft. Weight of bracket is approximately as follows:

420 frame size 49.5 Kg (110: lbs)

500 frame size 67 Kg (150 lbs)

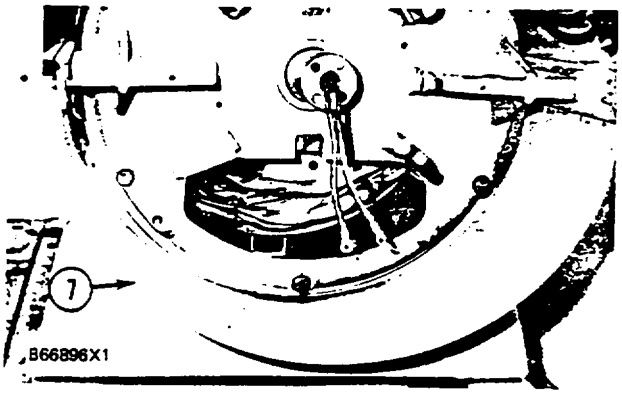
**7.** Install bolts that hold bracket in place




B66895X1

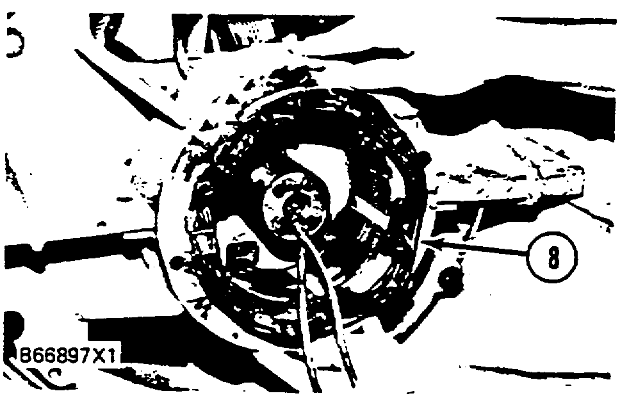
**8.** Install the two retainers (6) and four bolts that keep the bearing in place.

## Generator Bearing (Inside Bearing Type RFA)



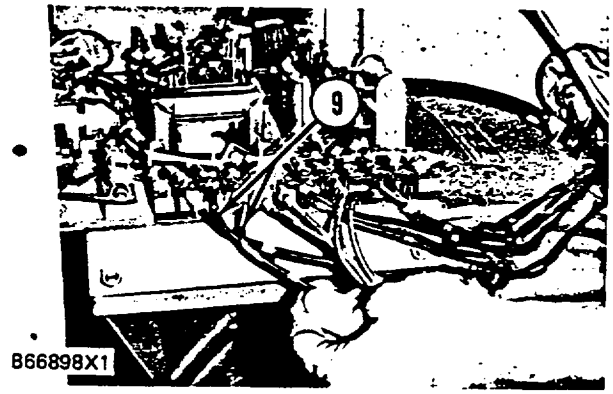

**9.** Put the bottom shield (7) in place and install six bolts.

**10.** Remove cardboard from between the stator and rotor assemblies.




**11.** Put the core assembly (exciter field) (8) in position on the bracket.

**12.** Install two long bolts. Install two bolts and nuts.

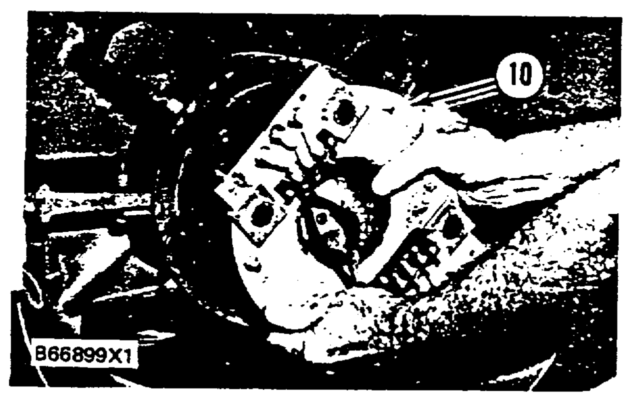



**13.** Connect two wires (F1 and F2) (9) to the regulator terminal strip.

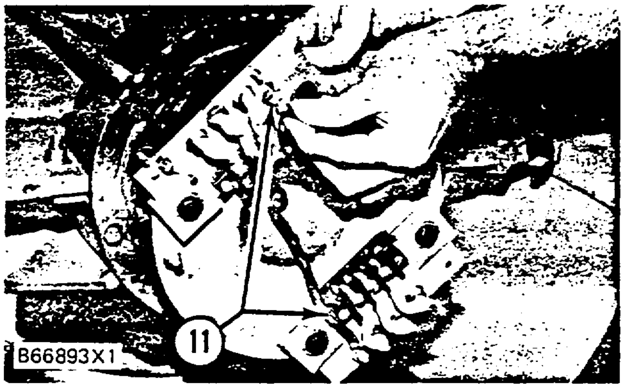
**14.** Tie the wires together with plastic ties.

**NOTICE**

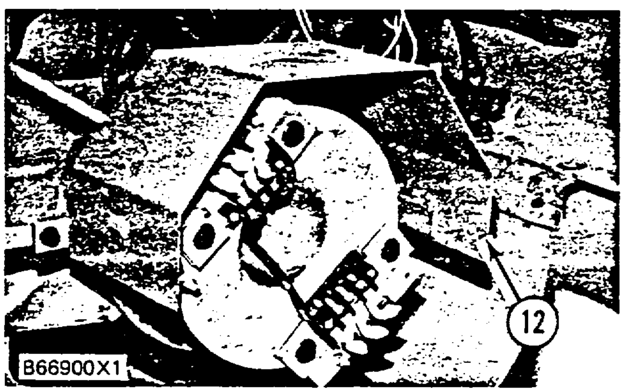
**Do not cause damage to the exciter field when installing the exciter and heat sink assembly.**




**15.** Position the exciter and heat sink assembly (10) on the rotor shaft and install two bolts.




**16.** Connect the two wires (11) to the exciter and heat sink assembly

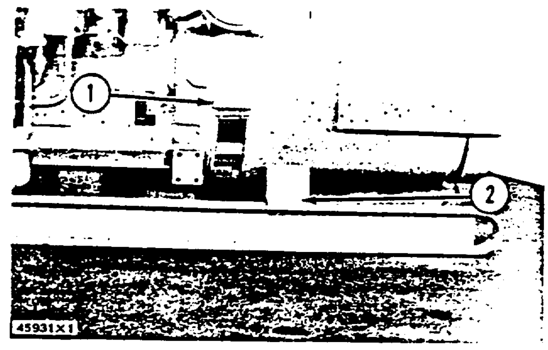



**17.** Put the shield (12) in position and install the bolts.

**18.** Install bottom cover assembly, louvers and panel to the frame assemblies.

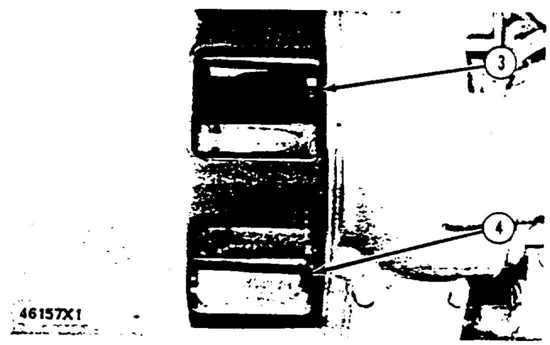
## GENERATOR REMOVAL

### REMOVE GENERATOR FROM ENGINE
**4450-11**




1. Remove the rear panel and louvers from the generator frame. Put pieces of cardboard or sheet metal between the rotor and the starter. See GENERATOR BEARING REMOVAL.

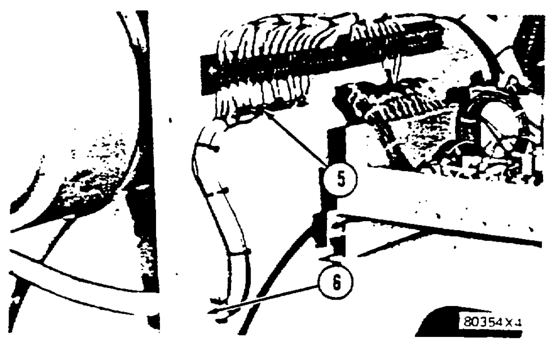
2. Remove cover (1) from the generator.




3. Remove bolts (4) that fasten the plates to the flywheel.

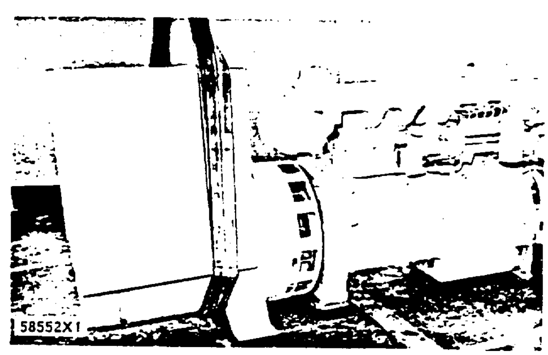
4. Remove bolts (3) that fasten the generator to the flywheel housing.

5. Fasten a hoist to the generator. Remove the four bolts (2) that hold the generator on the mount or rail.




6. If the generator is equipped with a control panel, disconnect wires (5) from the engine at the terminal strip.

7. Remove nut (6) and pull the conduit and wires (5) out of the generator housing.



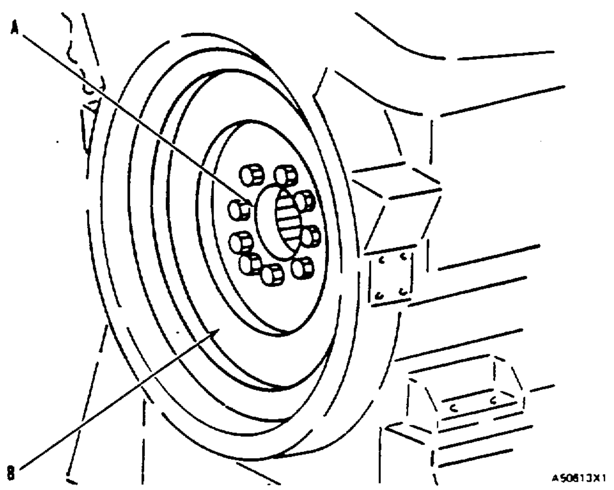

8. Remove the generator with a hoist.

**(ALIGNMENT OF SINGLE-BEARING GENERATORS TYPICAL)**

**NOTE: For information or alignment of two bearing generators makes reference to Form No. SEHS7073.**

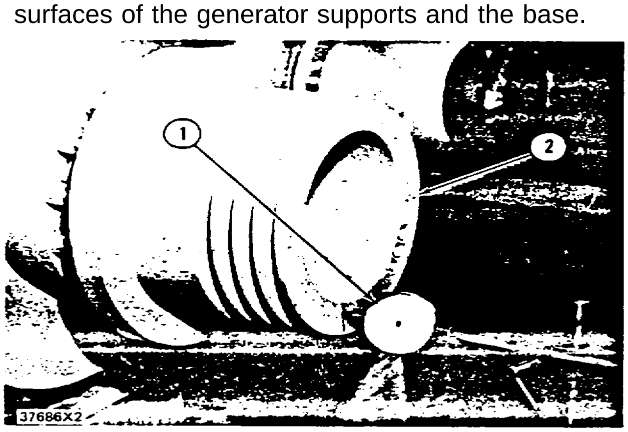
Typical installation and alignment procedure for electric sets with single-bearing generators. Do not start the alignment procedure until the electric set is permanently installed. If the electric set is moved to a different location, check the alignment and make any corrections necessary. The alignment between the generator and the engine must be correct to get maximum performance and long life from the electric set.

**INSTALLATION OF THE GENERATOR**




**REAR OF ENGINE**
**A. Pilot bore. B. Surface.**

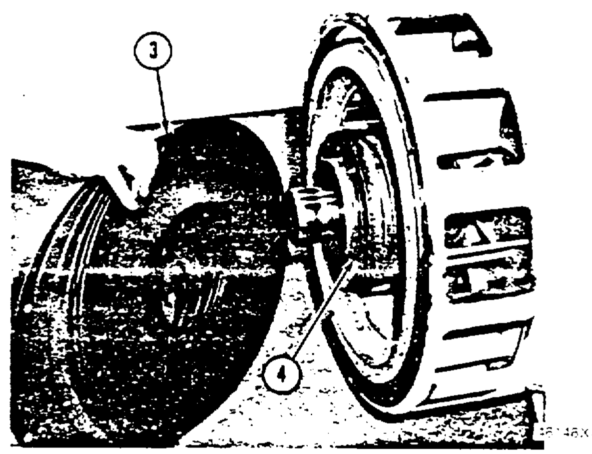
**1.** Remove all dirt, burrs and paint from the contact surfaces of the generator supports and the base.




**FRONT OF ENGINE**
**1. Indicator group. 2. Crankshaft pulley.**

Remove the protection material (compound) from the flywheel pilot bore (A) and from the surface (B) that makes contact with the coupling. All contact surfaces of the engine, coupling and generator must be completely clean.

2. Remove the timing pointer cover from the flywheel housing. Install indicator group (1 ) as shown on the front of the engine with the tip of the indicator on the face of crankshaft pulley ( 2). Use a bar between the flywheel and flywheel housing to push the crankshaft toward the flywheel to remove all end play. Put the dial indicator in the "zero" position. Move the crankshaft to its most forward position, and make a record of the Total Indicator Reading (TIR). The TIR is the end play of the crankshaft.

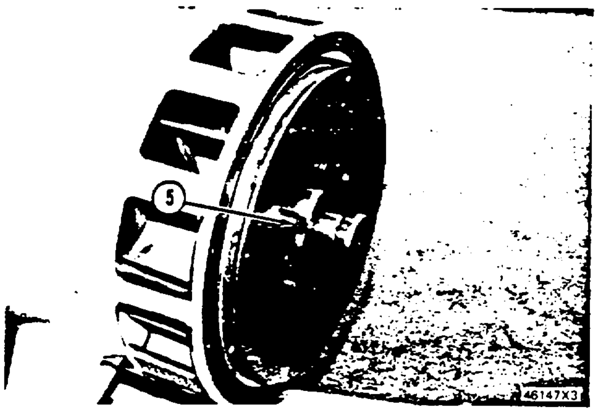



**FRONT OF GENERATOR**
**3. Plate assembly. 4. Shim pack.**

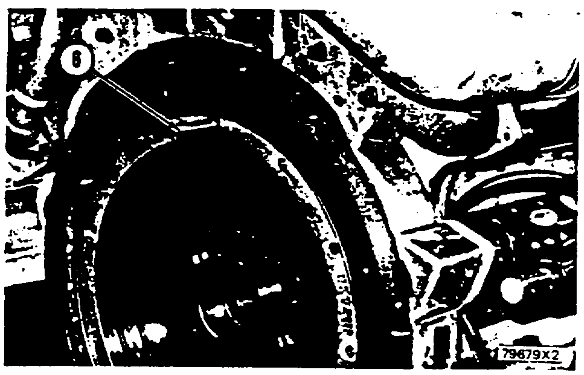
**3.** Put plate assembly (3) in position in the bore of the flywheel to check for clearance. There must be clearance between the outside diameter of the plate assembly (3) and the inside diameter of the bore in the flywheel.

**NOTICE**
**Damage to the engine and/or generator can be the result if the electric set is run with a plate assembly that does not have this clearance.**

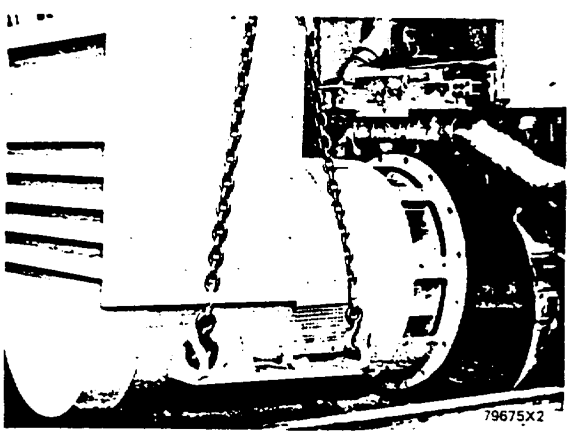
**4.** Install a full shim pack (4) and plate assembly (3) on the generator with bolts (5). On D379, G379, D398, G398, D399 and G399 engines, tighten bolts (5) to a torque of 370± 35 lb. ft. (505 ± 45 N•m). On all other engines, tighten bolts (5) to the standard torque.



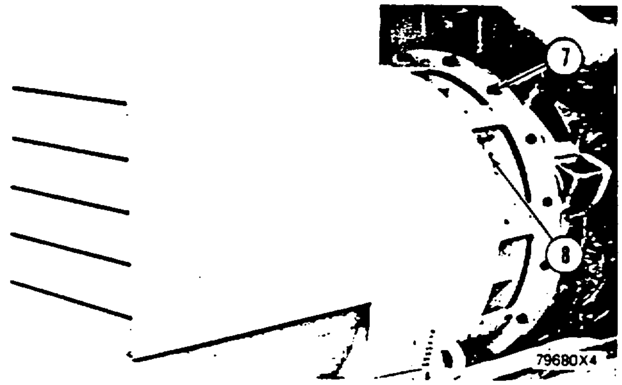

**INSTALL PLATE ASSEMBLY**
**5. Bolt.**




**ENGINE FLYWHEEL**
**5- Guide bolt**



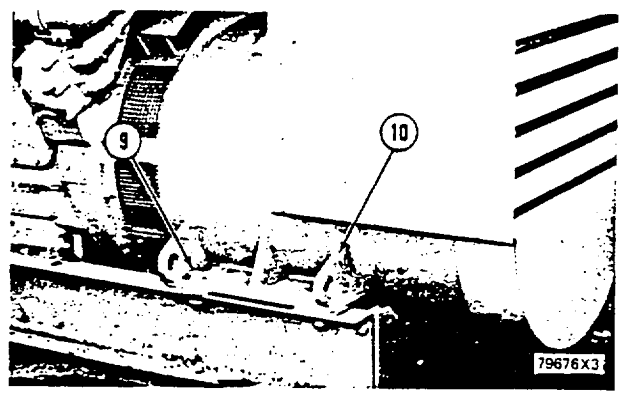

**PUT GENERATOR IN POSITION**




**INSTALL BOLTS**
**7. Bolt. 8. Bolt.**

**5.** Install guide bolt (6) in the flywheel. Put the generator in position on the engine, and Install bolts (7) and (8). Tighten bolts (7) and (8) but do not bend the locks under bolts (8) at this time.

**6.** Use a dial indicator (1) to check crankshaft end play (do not use force to hold the crankshaft in position). Remove the generator. Remove only enough shims to get the original amount of end play as shown in Step 2.

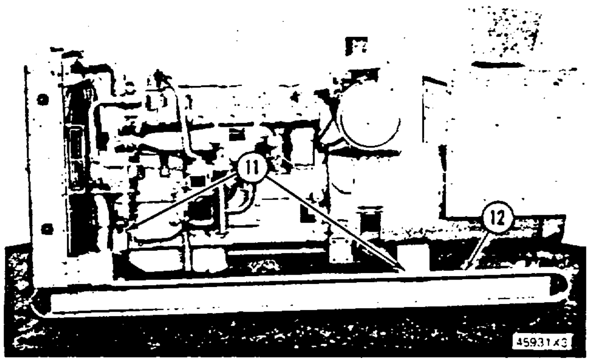



**PUT BOLTS IN POSITION**
**9. Bolt 10. Generator support.**

**7.** Install the generator and again check the crankshaft end play. After the correct amount of shims has been installed, bend the locks under bolts (8).

**8.** Install but do not tighten all bolts (9) that fasten generator supports (10) to the base. To align the generator to the engine, do the steps that follow:

**Electric Sets Without Supports at the Flywheel Housing**

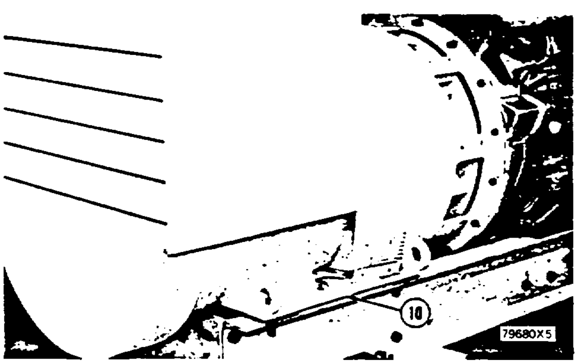



**GENERATOR SET**
**11. Bolts. 12. Base.**

a. If base (12) of the electric set is fastened to a foundation, loosen all base-to-foundation bolts. Loosen all bolts (11) that fasten the engine supports to base (12).

b. Check to be sure there is clearance between the bolts and the bolt holes in the base, engine supports and generator supports at all locations.

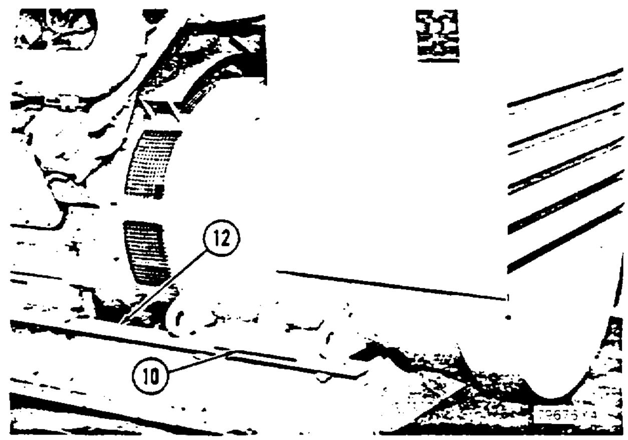
c. Check the clearance between the base and its foundation at all mounting locations. Use shims as necessary to prevent deflection of the base as the base-to-foundation bolts are tightened. When there is no deflection in the base tighten all base-to-foundation bolts to their final torque.




**CHECK CLEARANCE**
**10. Support.**

d. Check the clearance between the base and the engine and generator supports at all four location (11). Be sure to check the clearance over the entire length of the support. This is especially important on generators with long supports (10), since some surfaces may not be square or parallel. Use shims as necessary to prevent deflection of the supports as the bolts are tightened. After all the necessary shims have been installed, tighten all mounting bolts to their final torque.

**Electric Sets With Supports at the Flywheel Housing**



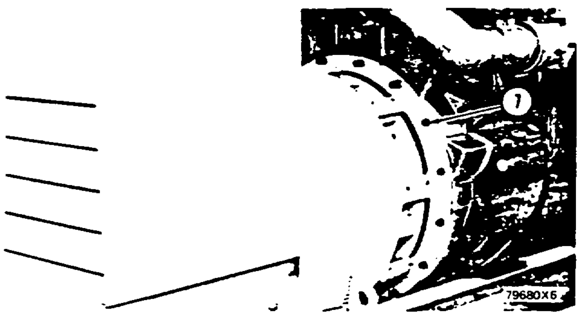

**GENERATOR SUPPORT**
**10. Support. 12. Base.**

a. If base (12) of the electric set is ,fastened to a foundation, loosen all base-to-foundation bolts. Loosen all bolts that fasten the engine and generator supports to the base.

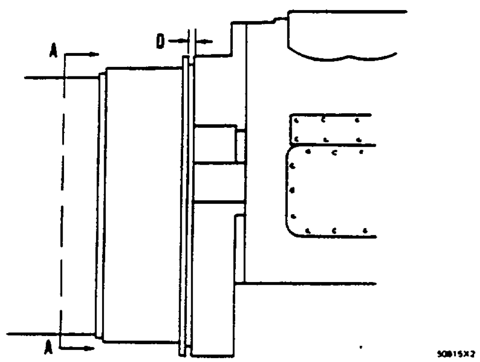
b. Check to be sure there is clearance between the bolts and the bolt holes in the base, engine supports and generator supports at all locations.

c. Check the clearance between the base and its foundation at all mounting locations. Use shims as necessary to prevent deflection of the base as the base-to-foundation bolts are tightened. When there is no deflection in the base, tighten all base-to-foundation bolts to their final torque.

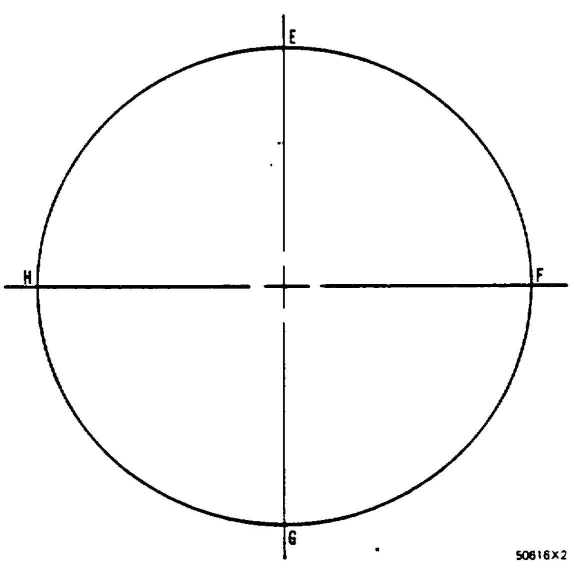
d. Loosen all bolts (7) that fasten the generator to the flywheel housing. Tighten every other bolt to its final torque. Check the clearance between the base and the engine and generator supports at all six locations. Be sure to check the clearance over the entire length of the supports. This is especially important on generators with long supports (10). Install shims as necessary until all of the mounting surfaces are fiat and parallel.




**CHECK CLEARANCE**
**7. Bolt.**




**CHECK GAP**
**D. Gap.**




**View A-A.**

e. Tighten all bolts that fasten the engine and generator supports to the base to one-half of their final torque. Loosen all bolts (7), and check the gap (D) between the generator and the flywheel housing at location (E), (F), (G) and (H). Location (E) must always be at the top. Make a record of each measurement.

f. If the gap at location (E) is larger than the gap at location (G) by more than .005 in. (0.13 mm), install an equal amount of shims under each generator support as necessary. If the gap at location (G) is larger than the gap at location (E) by more than .005 in. (0.13 mm), remove an equal amount of shims from under each generator support as necessary. After a correction has been made to shim thickness, tighten the generator support as necessary. After a correction has been made to shim thickness, tighten the generator support bolts to one-half of their final torque and again check the gap at location (E) and (G). Use this procedure again and again until the difference in gap measurements is .005 in. (0.13 mm) or less.

g. If the gap at location (F) is larger than the gap at location (H) by more than .005 in. (0.13 mm), loosen the bolts in the generator supports and move the rear of the generator to the right. If the gap at location (H) is larger than the gap at location (F) by more than .005 in. (0.13 mm). loosen the bolts in the generator supports and move the rear of the generator to the left. Do this procedure again and again until the difference in gap measurements is .005 in. (0.13 mm) or less. Tighten bolts (2) to their final torque.

h. Install a dial indicator on base (12) with the indicator tip next to a support mounting bolt. Tighten this bolt to its final torque, and at the same time check the indicator. If there is more than .005 in. (0.13 mm) of indicator movement, the shim thickness is incorrect under that bolt. Install shims as necessary. Do this procedure again and again until all engine and generator support-mounting bolts have been tightened to their final torque and support deflection is within specification.

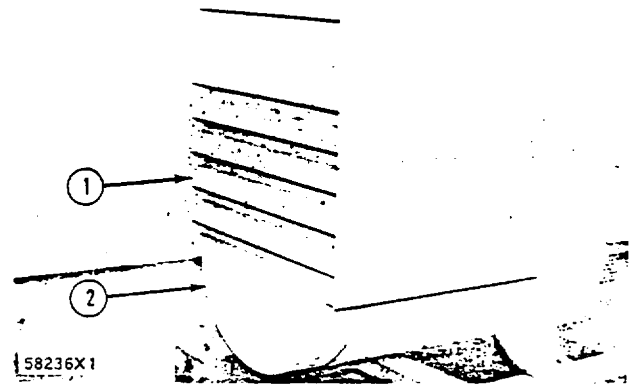
## ROTOR ASSEMBLY

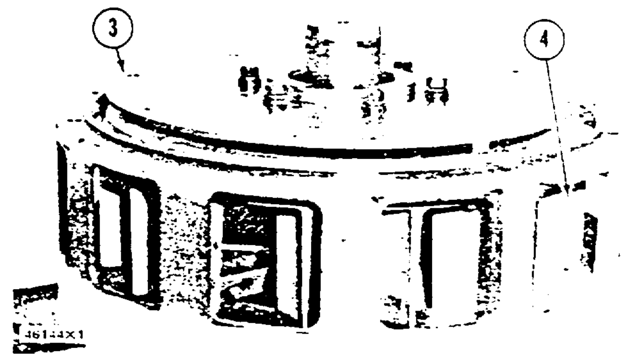
### REMOVE ROTOR ASSEMBLY (VERTICAL METHOD) 4457-11

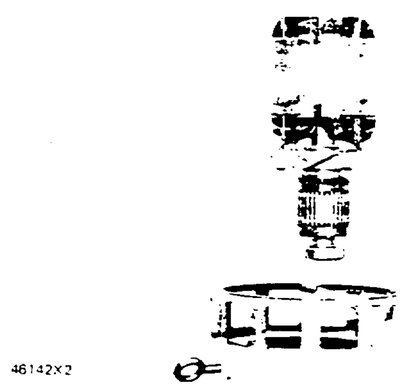
start by:
a) remove generator from engine
b) remove control panel

1. Remove the louvers (1) and panel (2) from back of generator frame.
2. Remove the side panels and frame on back of generator. Remove the retainers that hold the bearing in the cover.
3. Use a hoist to put the generator in a vertical position with the hub at the top.
4. Remove the plates (3), shims and the generator fan (4). Keep the plates and shims together for installation.
5. Remove the rotor assembly from the stator with a hoist.

**NOTICE**
**Do not let the rotor make a contact with the stator when it is removed.**

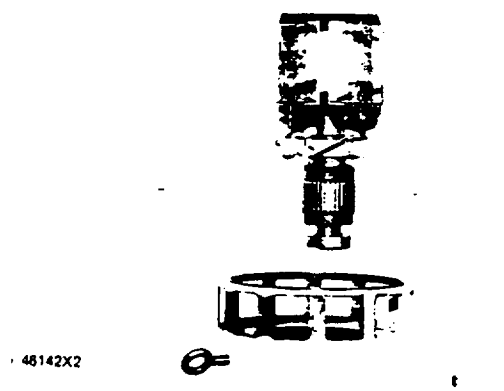


## ROTOR ASSEMBLY

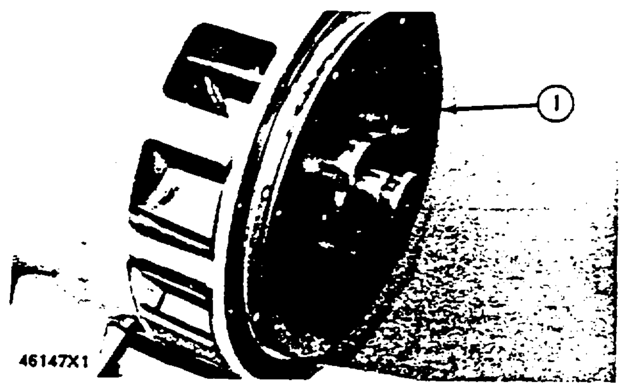
### INSTALL ROTOR ASSEMBLY (VERTICAL METHOD 4457-12



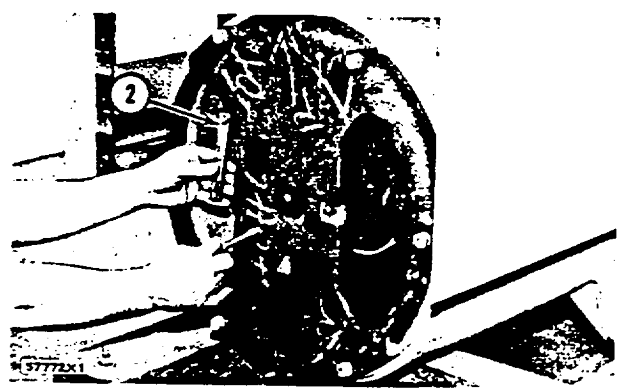

1. Be sure the stator assembly and rotor assembly are clean.
2. Lift the rotor into position over the stator with a hoist. Slowly lower the rotor into the stator. Be sure the bearing is in position in the cover.

**NOTICE**

**Do not let the rotor make a contact with the stator when it is lowered into the armature.**




3. Put the generator in a horizontal position with a hoist.
4. Put the generator fan over the hub. Install the original amount of shims and plates (1) on the hub.

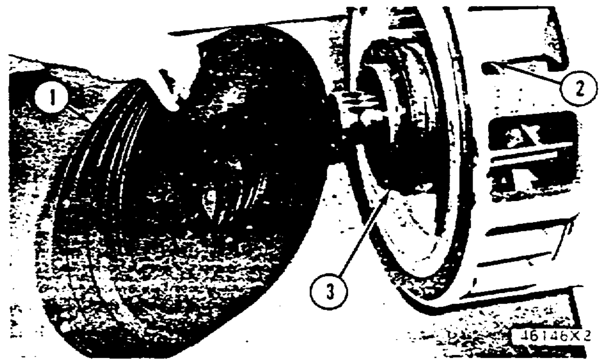


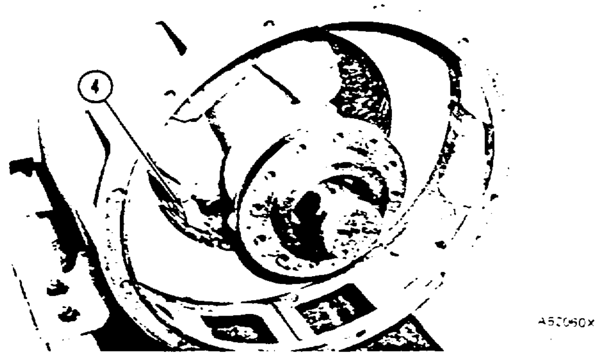

5. Install retainers (2) for the bearing.
6. Install the frames, covers, louvers, and panels on back of generator.

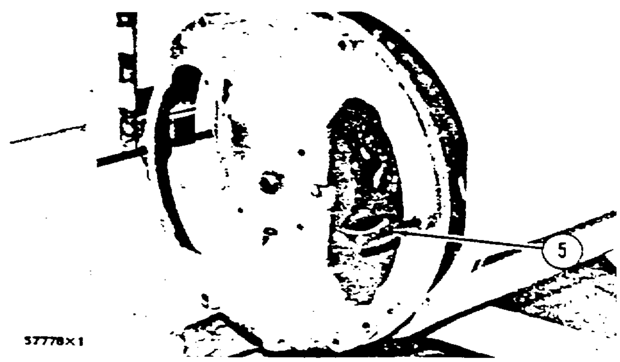
end by:
a. install generator on engine
b. install control panel

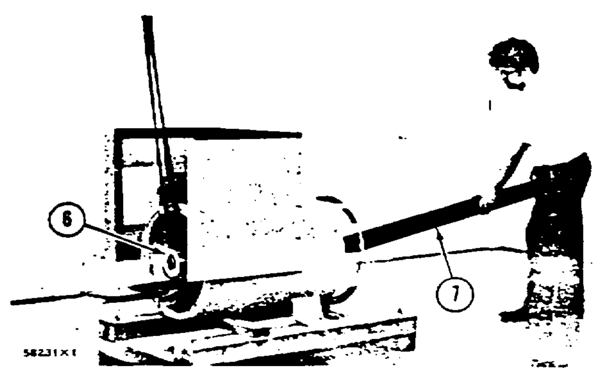
## ROTOR ASSEMBLY

### REMOVE ROTOR ASSEMBLY (HORIZONTAL METHOD) 4457-11




start by:

a) remove generator from engine
b) remove control panel

1. Remove plates (1), shims (3), and fan (2) from the front of generator.
2. Install pieces of cardboard or sheet metal (4) between the rotor assembly and the stator assembly. Be sure the pieces are as long as the rotor assembly.
3. Remove the louvers and panels from the back of generator. Remove the bolts that hold the retainers for the bearing. Disconnect wires F1 and F2 from the regulator assembly.
4. Remove the bolts for the cover. Install two guide bolts (5) with 1/2"-13 NC threads, approximately 10 in. (250 mm) long. Connect a hoist to the cover. Push the cover from the bearing with two 3/8"-16 NC forcing bolts. Remove the cover.

**NOTICE**

**Do not damage the stationary exciter field, which is part of the cover, when removing the cover.**

5. Fasten a hoist to the back of shaft.
6. Put a steel pipe (7) on the end of shaft, to the inside of hub.

**NOTE: Be sure the pipe is long enough to go through the generator.**

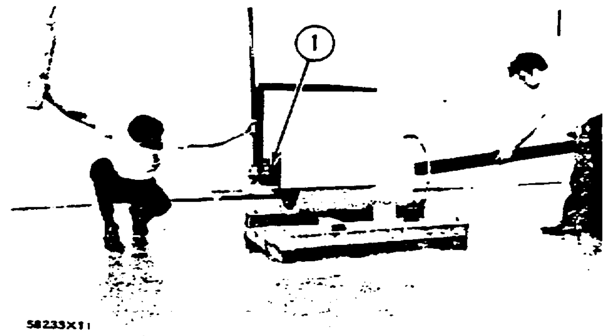
7. Remove rotor assembly (6) out the back of generator with a hoist.

**NOTICE**

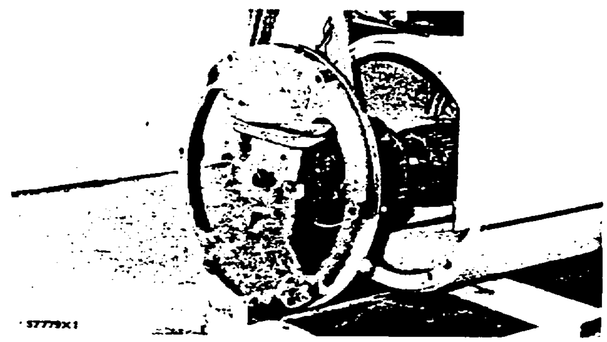
**Keep the rotor assembly level at all times during removal. This will prevent damage to the armature windings in the generator.**

## ROTOR ASSEMBLY

### INSTALL ROTOR ASSEMBLY (HORIZONTAL METHOD) 4457-12



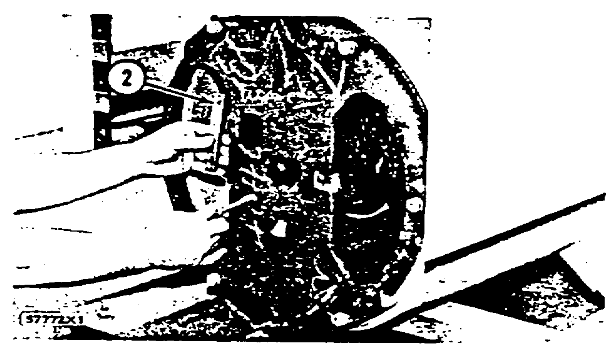

1. Be sure the stator assembly and the rotor assembly are clean.
2. Put a piece of cardboard or sheet metal on the inside of the stator.
3. Put the rotor in position for installation in back of the generator. Put a steel pipe through the stator and on to the front of the shaft, against the hub.
4. Fasten a hoist to the end of rotor (1). Install the rotor. Use the pipe as a support for the other end of the rotor.



**NOTICE**

**Keep the rotor level when it is installed and prevent damage to the stator wiring.**

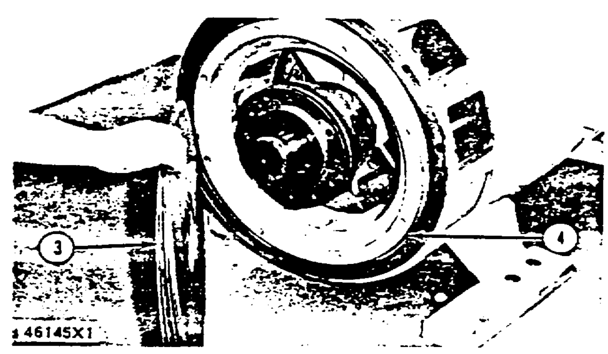
5. Remove the cardboard or sheet metal from between the rotor and the stator.
6. Install with two guide bolts 1/2"-13 NC threads, 10 in. (250 mm) long, in the back of generator. Install the cover assembly with a hoist. Connect the two field wires F1 and F2 to the regulator assembly.




**NOTICE**

**Do not damage the stationary exciter field which is part of the cover, when the cover is installed.**

7. Install the two retainers (2) for the bearing.' Install the louvers and panel in the back of the generator frame.
8. Install the generator fan (4). Install the original amount of shims (3), and plates on the generator hub.

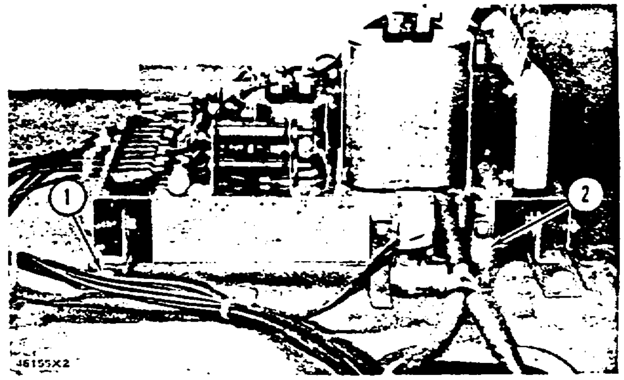



end by:
  a) install the generator on engine
  b) install control panel

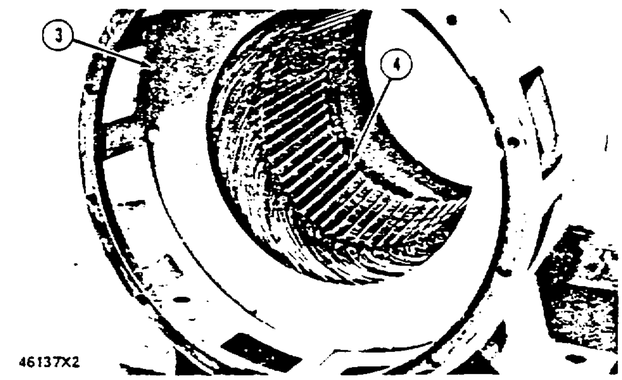
## STATOR ASSEMBLY

### REMOVE STATOR ASSEMBLY 4453-11

start by:
a) remove rotor assembly (Horizontal Method)

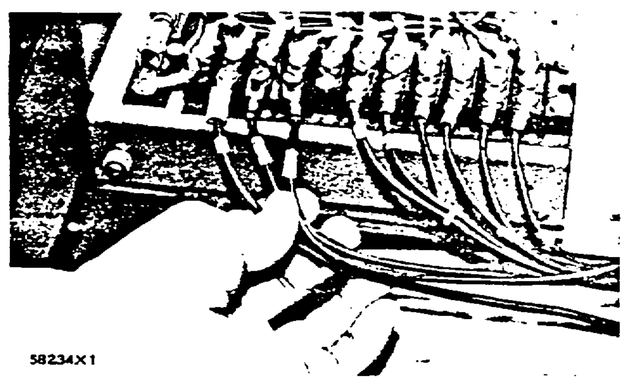



1. Remove the frame from the stator housing.
2. Disconnect the wires from the voltage regulator assembly. Put a mark on wires for identification.
3. Remove the voltage droop transformer (2).
4. Remove the bolts (1) that hold the voltage regulator on the stator housing. Remove voltage regulator.
5. Remove covers (3) from the housing.
6. The stator (4) is available to service if needed.



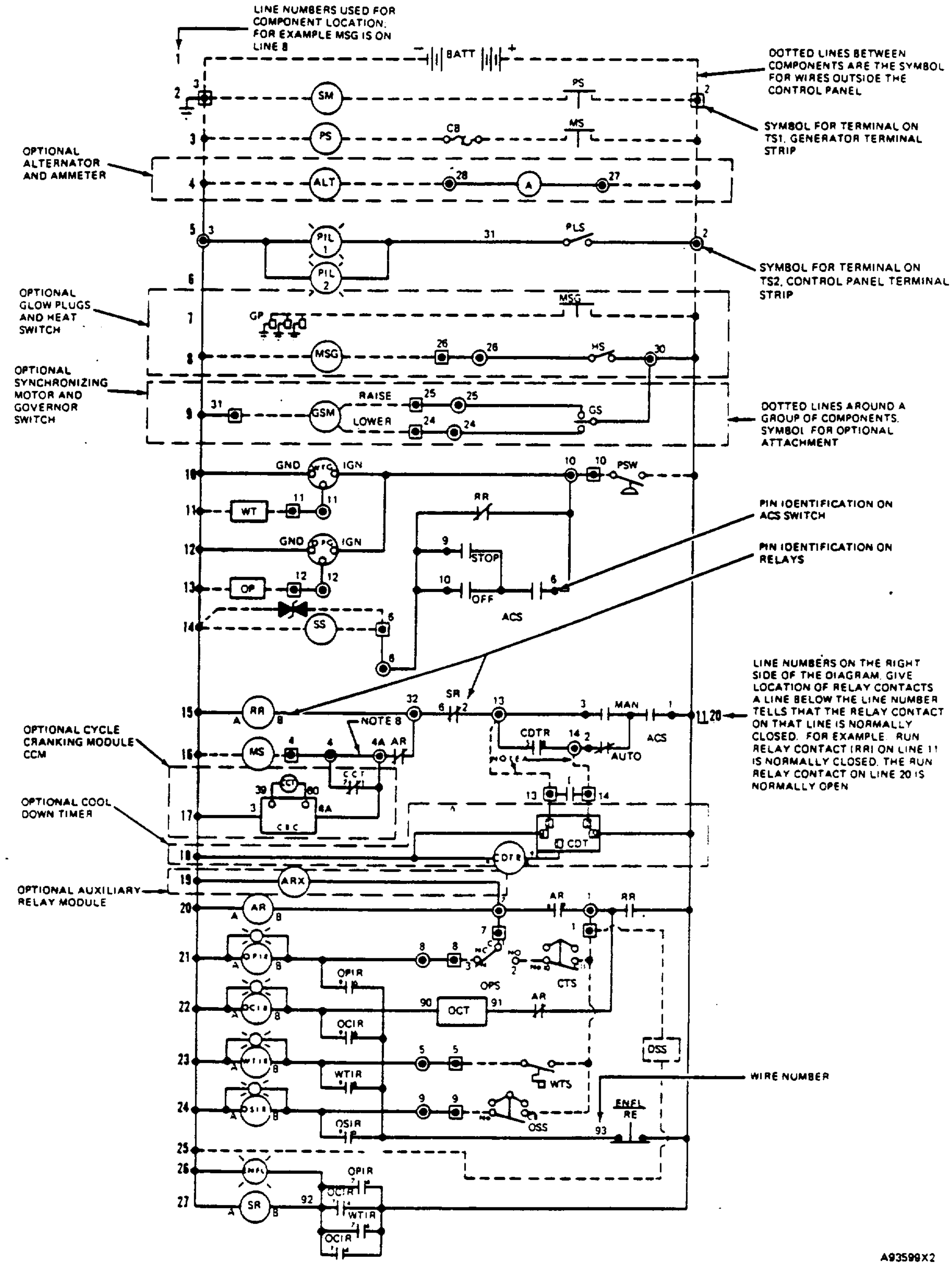

### INSTALL STATOR ASSEMBLY 4453-12

1. Install the covers on the housing.
2. Install the voltage regulator assembly on the housing.
3. Install the voltage droop transformer.
4. Connect the wires to the voltage regulator.
5. Install the frame on the stator housing.




end by:
a) install rotor assembly (Horizontal Method)

## HOW TO READ CONTROL PANEL DC SCHEMATICS




TYPICAL DC SCHEMATIC

## GENERATOR MOUNTED CONTROL PANEL
## (TYPE 1 - PRIOR TO CATERPILLAR PARTS SERVICE)

### INTRODUCTION

The uses of the generator mounted control panel are:

To help control the electric power made by the generator set

To monitor (check) the operation of the generator set.

To help protect the generator set from damage caused by low oil pressure, high coolant temperature, overspeed and overcrank.

To help with the transfer of electrical load to and from the generator set.

To help parallel two or more units onto the same bus.

### IDENTIFICATION

The location of the control panel is on the top of the regulator housing. Identification of some of the control panel components is given on black plastic plates. The position of control panel switches is also given on these plates. The control panel has an eleven place model number on the panel nameplate.

**NOTE: Parts for this control panel are not serviced by Caterpillar Tractor Company.**

### WIRING

Wiring diagram No. 1 shows wiring connections for control panels made before the remote Annunciator panel and Prealarm module were available through Caterpillar.

Wiring diagram No. 2 shows wiring connections for control panels made after remote Annunciator panel 3N7325 and Prealarm module 3N5569 were available through Caterpillar.

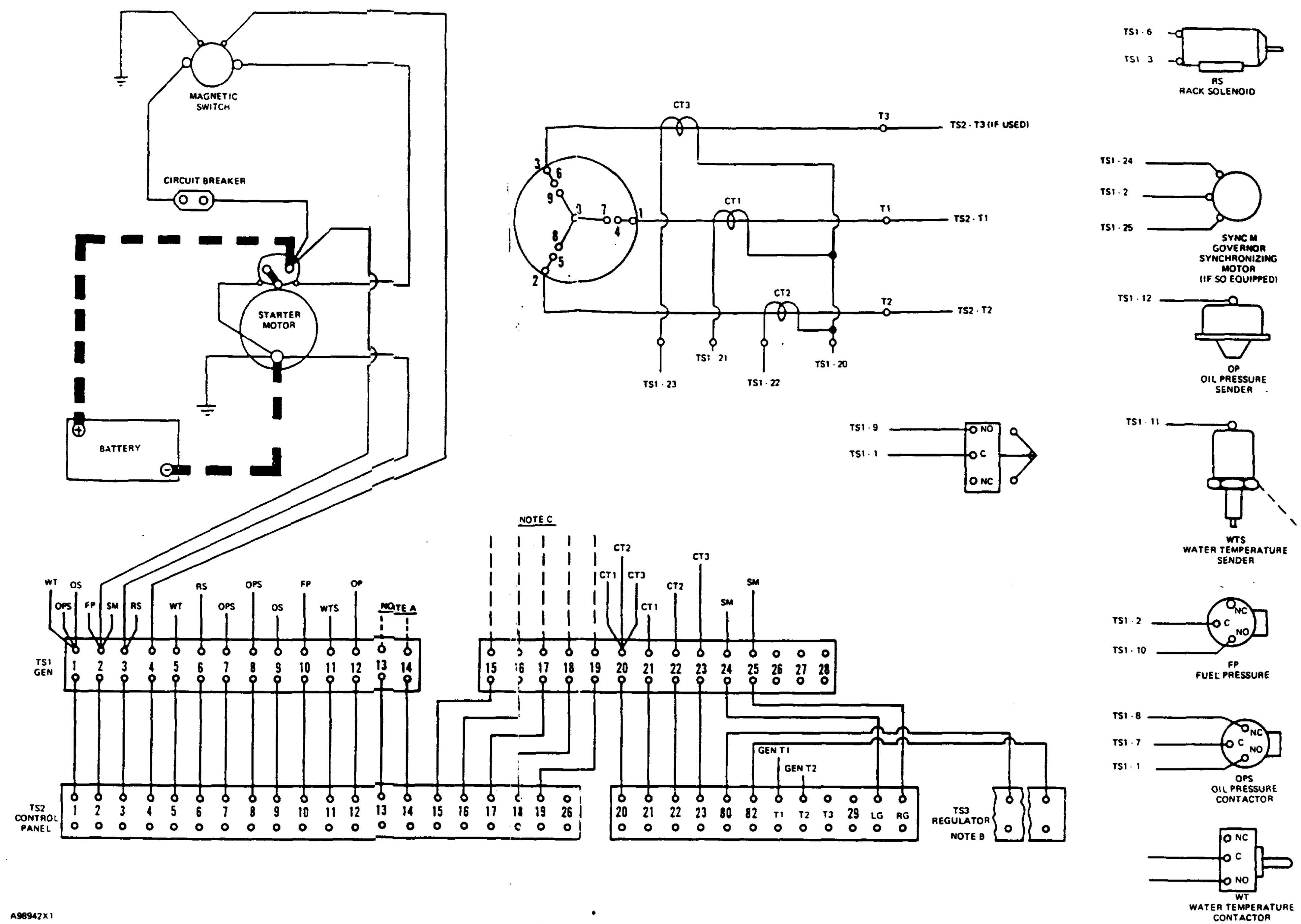
wiring diagram No. 3 is for packaged generator sets with a two element speed switch (OSS and USS) in place of overspeed switch (OS).

**NOTE: A photograph of the panel is shown after wiring diagram No. 2.**

| MAXIMUM RECOMMENDED TOTAL BATTERY CABLE LENGTH | | |
|---|---|---|
| CABLE SIZE | DIRECT ELECTRIC STARTING | |
| | 12 Volt | 24-32 Volt |
| 0 | 4 ft. (1.2 m) | 15 ft. (4.6 m) |
| 00 | 5 ft. (1.5 m) | 18ft. (5.5m) |
| 000 | 6 ft. (1.8 m) | 21 ft. (6.4 m) |
| 0000 | 7.5 ft. (2.3 m) | 27 ft. (8.2m) |

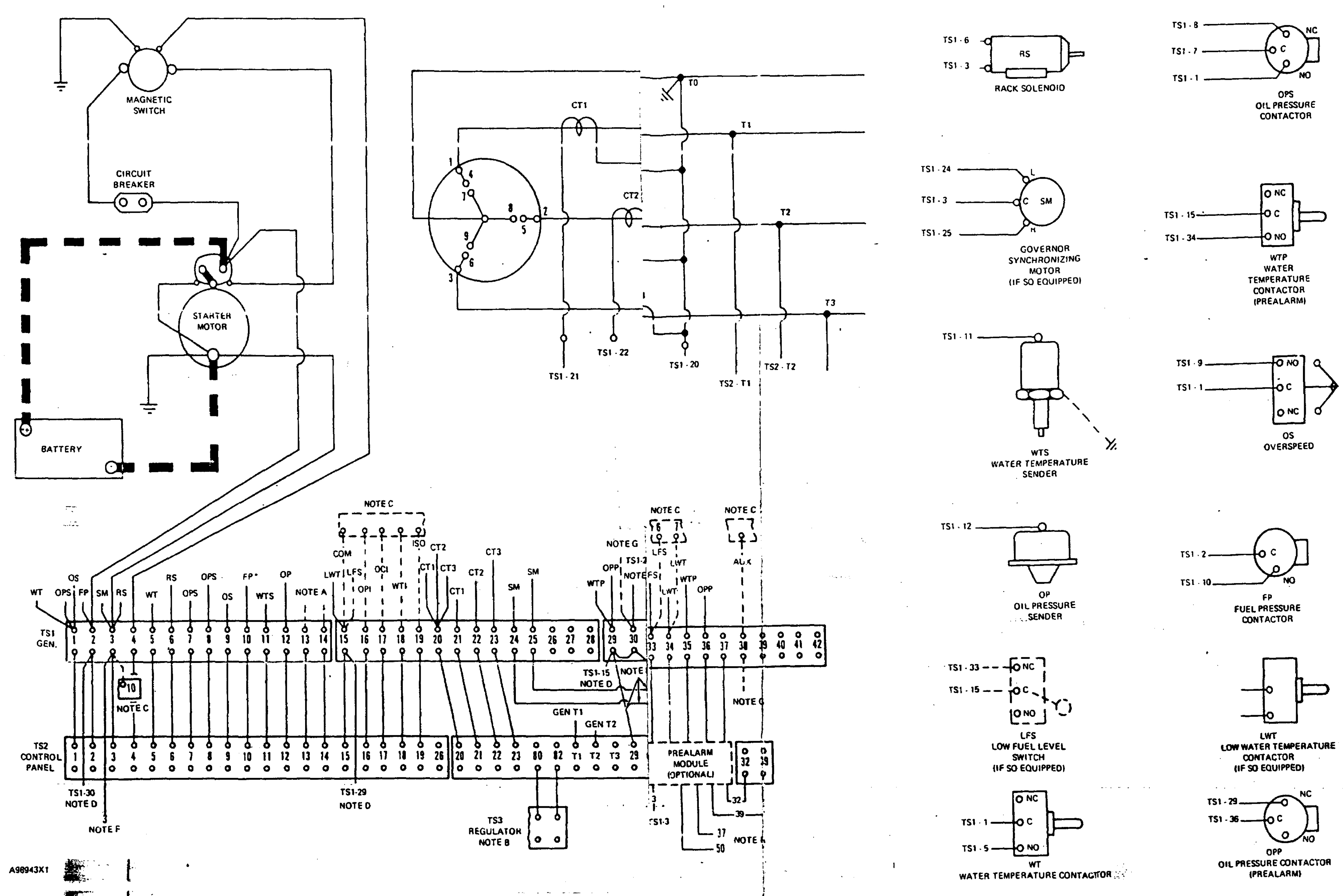
| COLOR CODE | | |
|---|---|---|
| B | - | black |
| W | - | white |
| R | - | red |
| PU | - | purple |
| W/B | - | white with black stripe |
| O | - | orange |
| BR | - | brown |
| BL | - | blue |
| LT GR | - | light green |

The number after the color is the recommended wire size




**WIRING DIAGRAM No. 1**

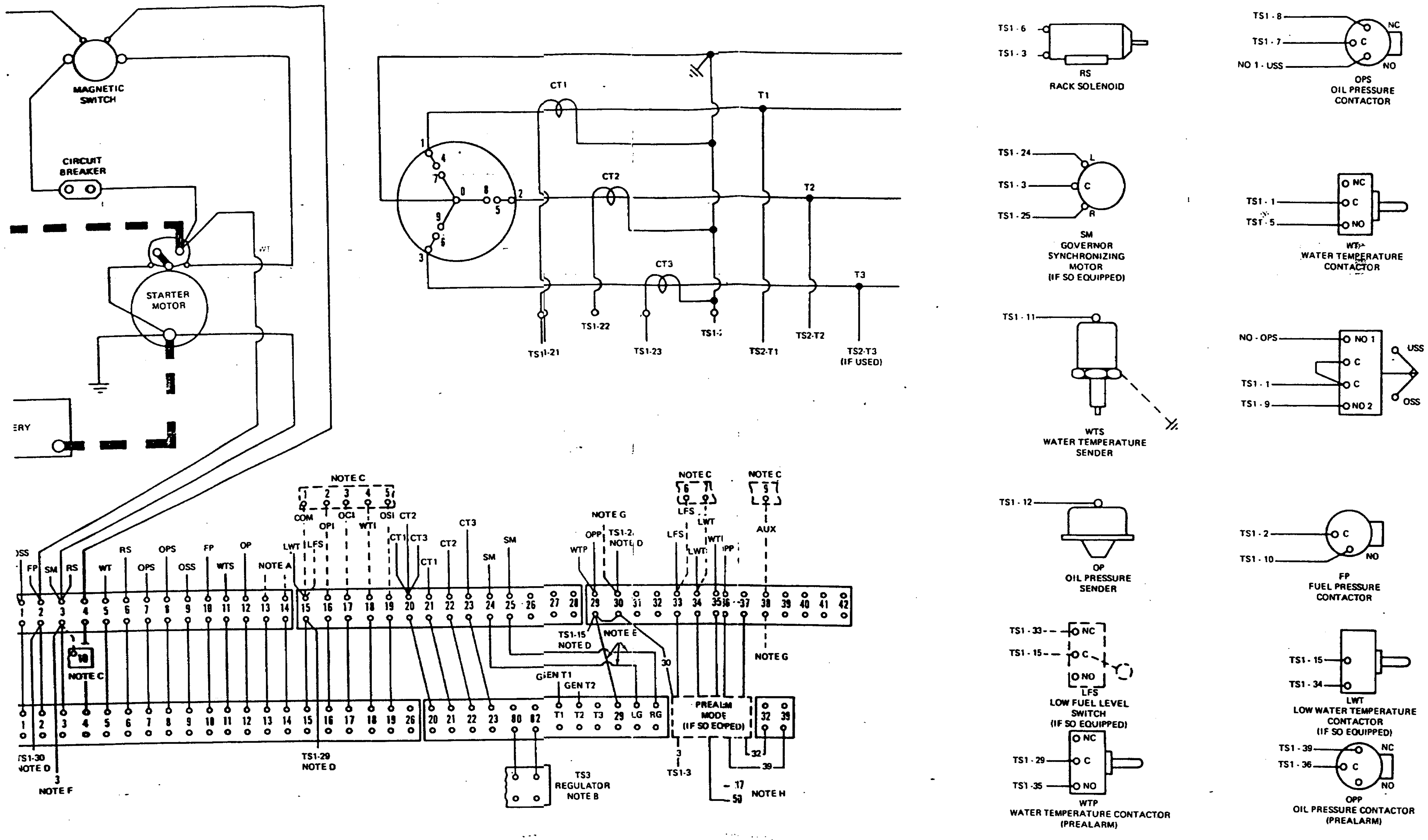
NOTE: Customer must supply wires shown dotted.
NOTE A: To initiating contactor at automatic transfer switch.
NOTE B: The yellow wire from voltage level rheostat (R2) to terminal (7) on the regulator terminal strip must be disconnected at terminal (7).
NOTE C: Terminals 15, 16, 17, 18 and 19 of TS2 available for remote annunciator panel.




WIRI GRAM No. 2

NOTE: Customer must supply wires shown dotted.
NOTE A: To initiating contactor at automatic transfer switch.
NOTE B: The yellow wire from voltage level rheostat (R2) to terminal (7) on the regulator terminal strip must be disconnected terminal (7).
NOTE C. Terminals in optional remote annunciator panel.
NOTE D: Used only with optional remote annunciator panel, prealarm module, or PSG governor. Jumper B+ from TS1-2 to TS1-; to TS1-29 to TS1-15 with R#14

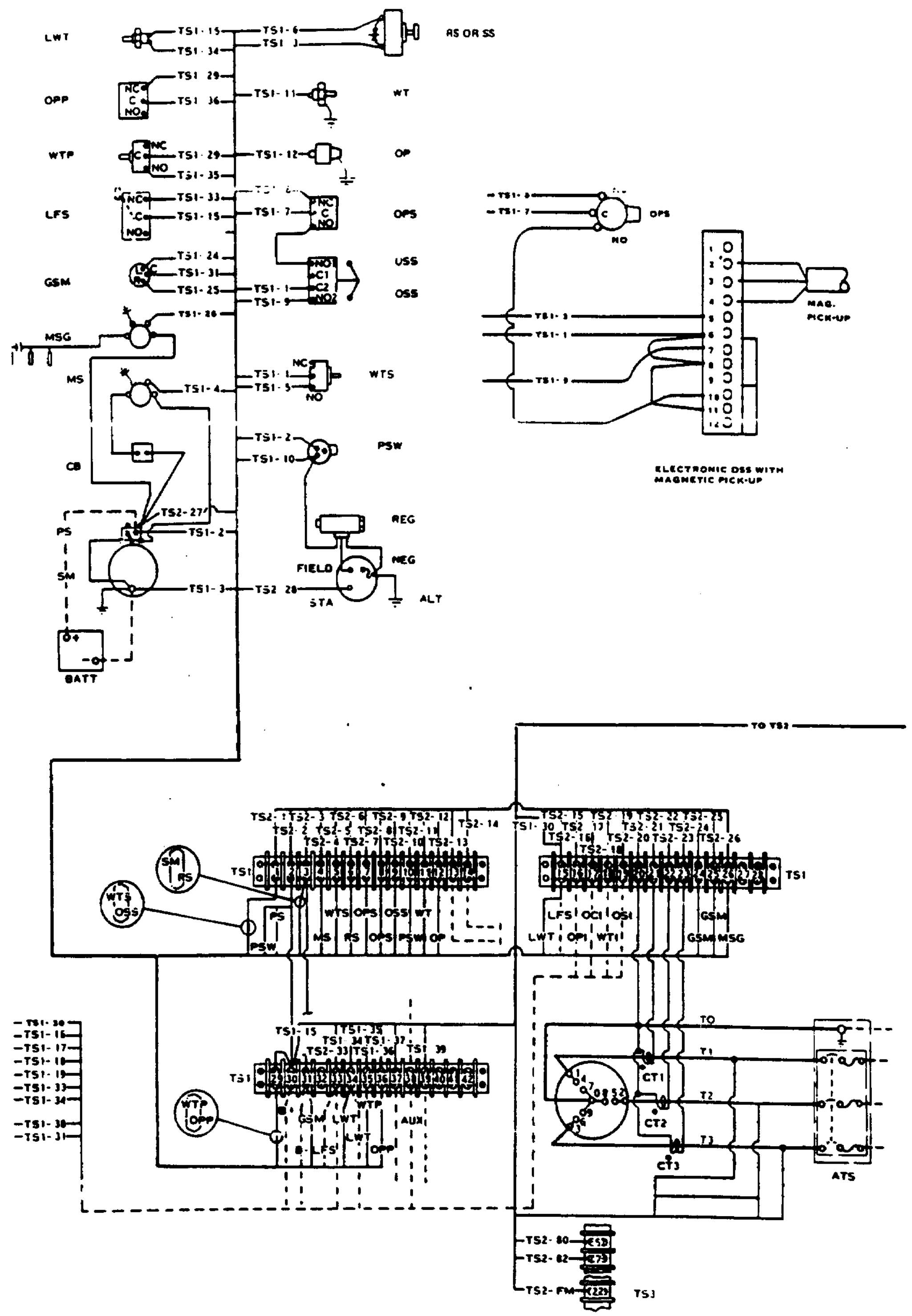
NOTE E: Used only with governor switch and PSG governor.
NOTE F: Connected to optional prealarm module.
NOTE G: Connected to auxiliary contact (N.O.) on emergency side of transfer switch. Used only with optional remote annunciator panel for generator indication.
NOTE H: To optional prealarm module. Connect wire 37 to terminal 1 on the low oil pressure indicator. Connect wire 50 to the normally open contact on the oil pressure timer.

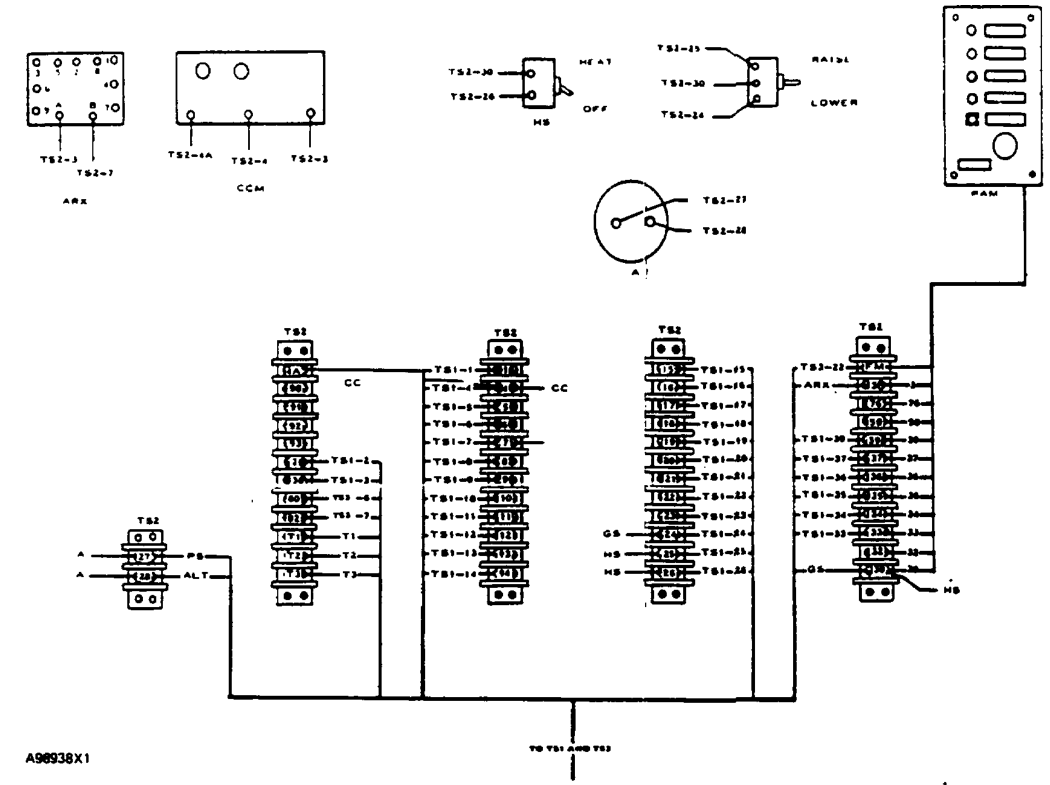



WIRING DIAGRANO. 3

tomer must supply wires shown dotted.
› initiating contactor at automatic transfer switch.
ıe yellow wire from voltage level rheostat (R2) to terminal (7) on the regulator terminal strip must be disconnected at
.
ırminals in optional remote annunciator panel.
ıed only with optional remote annunciator panel, prealarm module, or PSG governor. Jumper B+ from TS1-2 to TS1-30
› TS1-15 with R#14

NOTE E: Used only with governor switch and PSG governor.
NOTE F: Connected to optional prealarm module.
NOTE G: Connected to auxiliary contact (N.O.) on emergency side of transfer switch. Used only with optional remote annunciator panel for generator indication.
NOTE H: To optional prealarm module. Connect wire 37 to terminal 1 on the low oil pressure indicator. Connect wire 50 to the normally open contact on the oil pressure timer.





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**WIRING DIAGRAM**

A AMMETER
ALT ALTERNATOR
APR ANNUNCIATOR PANEL—REMOTE
ARX AUXILIARY RELAY MODULE
ATS AUTOMATIC TRANSFER SWITCH
AUX AUXILIARY CONTACT
B+ BATTERY POSITIVE
B− BATTERY NEGATIVE
BATT BATTERY
CB CIRCUIT BREAKER
CCM CYCLE CRANKING MODULE
CT CURRENT TRANSFORMER
GS GOVERNOR SWITCH
GSM GOVERNOR SYNCHRONIZING MOTOR
HS HEAT SWITCH
I INITIATING CONTACT (FOR CUSTOMER USE)
LFS LOW FUEL LEVEL SWITCH
LWT LOW WATER TEMPERATURE SWITCH
MS MAGNETIC SWITCH
MSG MAGNETIC SWITCH (GLOW PLUGS)
OCI OVERCRANK INDICATOR
OP OIL PRESSURE GAUGE SENDING UNIT
OPI LOW OIL PRESSURE INDICATOR
OPP OIL PRESSURE SWITCH (PRE-ALARM)
OPS OIL PRESSURE SWITCH (SHUTDOWN)
OSI OVERSPEED INDICATOR
OSS OVERSPEED SWITCH (SHUTD
PAM PRE-ALARM MODULE
PS PINION SOLENOID
PSW PRESSURE SWITCH
RS SHUTOFF SOLENOID
SM STARTING MOTOR
TS TERMINAL STRIP
USS UNDERSPEED SWITCH
WT WATER TEMPERATURE GAUG SENDING UNIT
WTI HIGH WATER TEMPERATURE INIDCATOR
WTP WATER TEMPERATURE SWITC (PRE-ALARM)
WTS WATER TEMPERATURE SWITC (SHUTDOWN)

Wire and Cable shown as dash lines (---) are to be put on by the customer.

TS2 Terminal numbers are shown on control panel schematics.

The wiring diagram shows the connections for all available attachments. The unit will have wiring only for the attachments which are installed.

TS3-6. Before connecting TS2-80 to TS3-6, remove yellow wire from TS3-7. Put insulation on the end of the yellow wire so it can not make electrical contact with TS3-7.

Jumper wires from B+ to TS1-2 to TS1-30 to TS1-29 to TS1-15 are for use with annunciator panel (remote) or pre-alarm module only.

TS1-38 is the terminal for connection of the indicator light on the annunciator panel (remote) which shows that the generator is working.

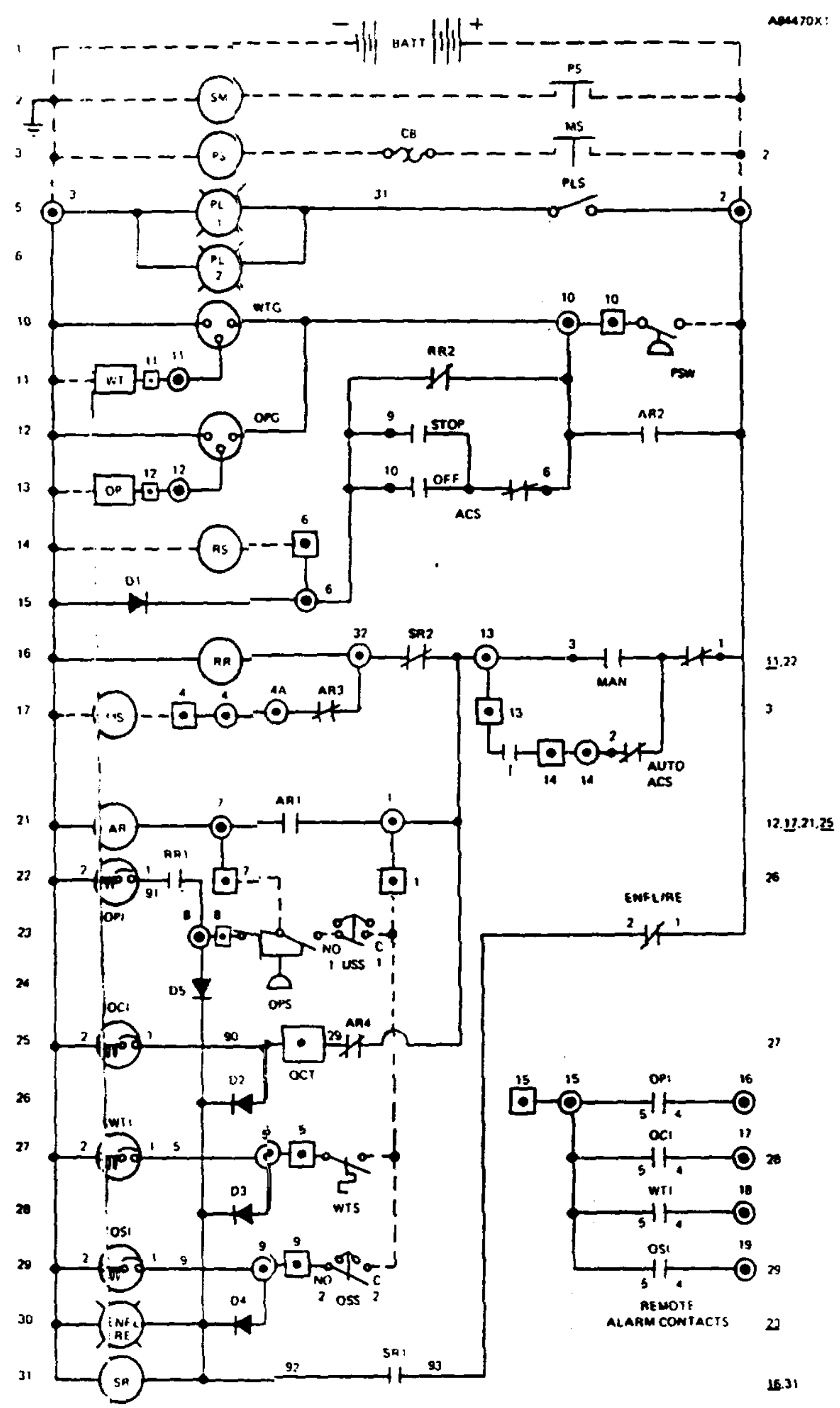
When cycle cranking module (CCM) is installed remove the jumper wire from TS2-4A to TS2-4.

Do not operate alternator (ALT) without a battery (BATT) connected in the circuit. Do not polarize the alternator. Do not try to charge a common battery (BATT) with the alternator (ALT) and a DC generator at the same time.

TS1-37 is the terminal for the connection of the low oil pressure indicator (OPP) in the pre-alarm module.

TS1-39 is the terminal for the connection of remote shutdown and pre-alarm indicators when the pre-alarm module is used.

*Some rack solenoids (RS) and shutoff solenoids (SS) do not have a zener diode across the terminals.

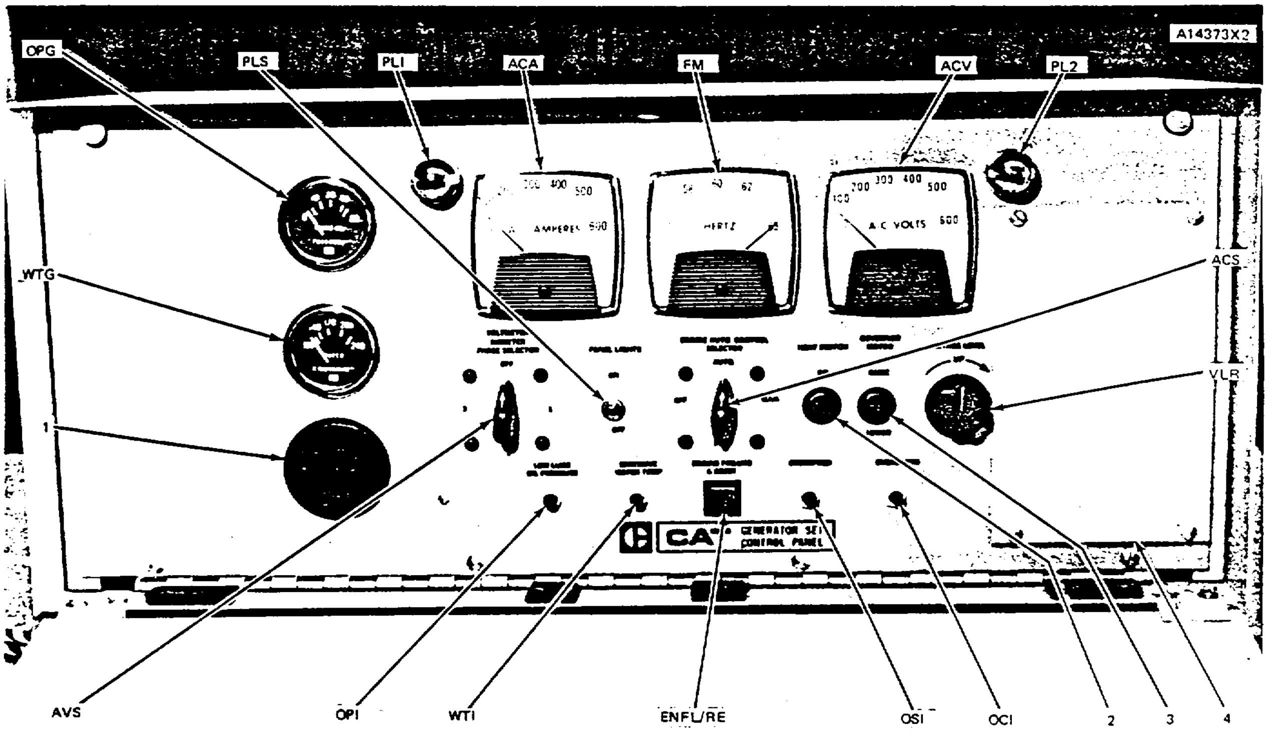



| | |
|---|---|
| **A** | **DC Ammeter** |
| **ACS** | **Engine Control Switch** |
| **ALT** | **Charging Alternator** |
| **AR** | **Arming Relay** |
| **ARX** | **Auxiliary Relay Module** |
| **BATT** | **Battery** |
| **CB** | **Circuit Breaker** |
| **CCM** | **Cycle Cranking Module** |
| **CCT** | **Cycle Crank Relay** |
| **CRC** | **Cycle Crank Logic Timer** |
| **D** | **Diode** |
| **DSS** | **Dual Speed Switch (Includes USS and OSS)** |
| **ENFL** | **Engine Fault Light With Fault Reset Function** |
| **GP** | **Glow Plugs** |
| **GS** | **Governor Switch** |
| **GSM** | **Governor Synchronizing Motor** |
| **HS** | **Glow Plug Heat Switch** |
| **I** | **Remote Start Initiating Contact** |
| **MS** | **Magnetic Switch (Crank Circuit)** |
| **MSG** | **Magnetic Switch (Glow Plug Circuit)** |
| **OCI** | **Overcrank Indicator** |
| **OCT** | **Overcrank Timer** |
| **OP** | **Oil Pressure Gauge Sender** |
| **OPG** | **Oil Pressure Gauge** |
| **OPI** | **Low Oil Pressure Indicator** |
| **OPS** | **Oil Pressure Switch** |
| **OSI** | **Overspeed Indication** |
| **OSS** | **Overspeed Switch** |
| **PIL** | **Panel Illumination Lamp** |
| **PLS** | **Panel Lamp Switch** |
| **PS** | **Pinion Solenoid** |
| **PSW** | **Pressure Switch** |
| **RE** | **Fault Reset Switch, Part of ENFL** |
| **RR** | **Run Relay** |
| **RS** | **Rack Solenoid** |
| **SM** | **Starting Motor** |
| **SR** | **Shutdown Relay** |
| **USS** | **Underspeed Switch** |
| **WT** | **Water Temperature Gauge Sender** |
| **WTG** | **Water Temperature Gauge** |
| **WTI** | **High Water Temperature Indicator** |
| **WTS** | **Water Temperature Switch** |
| ⊙ | **Terminal Strip Point (Control Panel)** |
| ⊡ | **Terminal Strip Point (Generator Terminal Box)** |

CONTROL PANEL WITH MECHANICAL SPEED SWITCH
AUTOMATIC POSITION

## COMPONENTS

**NOTE: For specifications on components located on the engine, make reference to the ENGINE SERVICE MANUAL.**



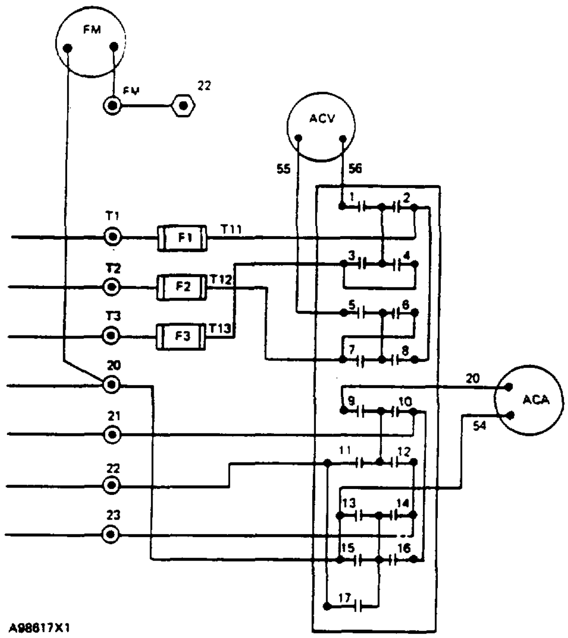

*CONTROL PANEL (TYPE 2 - CHANGE LEVEL 0 THRU 1)*

| | |
|---|---|
| ACA | Alternating current ammeter |
| ACS | Engine control switch |
| ACV | Alternating current voltmeter |
| AVS | Ammeter/voltmeter selector switch |
| ENFL/RE | Engine failure light/reset switch |
| FM | Frequency meter |
| PL1,2 | Panel lamps |
| PLS | Panel lamp switch |
| OCI | Overcrank indicator |
| OPG | Oil pressure gauge |
| OPI | Oil pressure indicator |
| OSI | Overspeed indicator |
| WTG | Water temperature gauge |
| WTI | Water temperature indicator |
| VLR | Voltage level rheostat |

1. Button (direct current ammeter DCA. it so equipped)
2. Button (heat switch HS. if so equipped)
3. Button (governor switch GS. if so equipped)
4. Panel (Prealarm module PAM. it so equipped)

### ACA Alternating Current Ammeter

AC ammeter (ACA) gives an indication, in amperes, of the current from each phase of the generator to the load. Ammeter/voltmeter selector switch (AVS) is used to connect the ammeter to the current transformer on phase T1, T2 or T3; see Contact Chart. Ammeters normally have an input range from 0 to 5 amperes. Current transformer (CT1, CT2 or CT3) causes a reduction of the actual line current, in its respective phase lead, to a level within the input range of the ammeter. The ammeter is calibrated (has marks) to give an indication of the actual current flow in one phase load of the generator.




**AMMETER/VOLTMETER SELECTOR SWITCH (AVS)**

**ACA** Alternating current ammeter
**ACV** Alternating current voltmeter
**F1,2,3** Fuses
**FM** Frequency meter
**⊙** Terminal point on TS2 in control panel
**⊙** Terminal Point on TS3 part of voltage regulator

| CONTACT CHART FOR AVS | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | OFF | | 1 | | 2 | | 3 | |
| 1 | | | | X | | X | | X | |
| 2 | | | | X | | | | | |
| 3 | | | | | | X | | | |
| 4 | | | | | | | | X | |
| 5 | | | | X | | X | | X | |
| 6 | | | | X | | | | | |
| 7 | | | | | | X | | | |
| 8 | | | | | | | | X | |
| 9 | | | X | X | X | X | X | X | X |
| 10 | | | X | X | X | | | | |
| 11 | | | | | X | X | X | | |
| 12 | | | | | | | X | X | X |
| 13 | X | X | X | | | | | | |
| 14 | X | X | X | X | X | X | X | | |
| 15 | | | X | X | X | X | X | X | X |
| 16 | X | X | X | | X | X | X | X | X |
| 17 | X | X | X | X | X | | X | X | X |

**NOTE: X gives an indication of a closed contact, X on the line gives an indication of "make before break"**

### ACS Engine Control Switch

Engine control switch (ACS) controls the engine start and stop systems. To start the engine move the switch to the manual position. To stop the engine. move the switch to the STOP or OFF position. For standby application (engine starts when remote initiating contact I closes) move the switch to the AUTO position. For more information on the operation of this switch, make reference to the AUTOMATIC START/STOP SYSTEM..

| CONTACT CHART FOR ACS | | | | |
|---|---|---|---|---|
| | AUTO | MAN | STOP | OFF |
| | 1 | 2 | 3 | 4 |
| 1 | X | X | X | X |
| 2 | X | | | |
| 3 | | X | | |
| 4 | | | X | |
| 5 | | | | X |
| 6 | X | X | X | X |
| 7 | X | | | |
| 8 | | X | | |
| 9 | | | X | |
| 10 | | | | X |

### ACV Alternating Current Voltmeter

AC voltmeter (ACV) shows the potential difference (voltage) between phase T1-T2, T2-T3 or T3-T1 at position 1, 2 or 3 respectively. Make reference to the ALTERNATING CURRENT AMMETER.

### DCA Direct Current Ammeter

Direct current ammeter (DCA) goes in place of plug (1). This ammeter shows the amount of DC current in amperes, that flows in the alternator circuit (if so equipped).

### ENFL/RE Engine Failure Light/Reset Switch

Engine failure light/reset switch (ENFL/RE) will activate when the engine has a failure. One or more of the shutdown indicators will also activate to give an indication of the problem. Shutdown relay (SR) will activate to start the shutdown sequence. Make reference to SHUTDOWN CAUSED BY ENGINE FAILURE and ENGINE DOES NOT START

**NOTICE**

**Turn engine control switch (ACS) to the STOP or OFF position immediately after engine shutdown caused by high water temperature, low oil pressure or overspeed. This will cause an open in the circuit to the arming relay (AR). Normally open contact of arming relay (AR2) will open and current fow to rack solenoid (RS) will stop. This will help prevent damage to the rack solenoid from too much current.**

**FM Frequency Meter**

Frequency meter (FM) shows the hertz (cycles per second) of the electricity made when the generator set is in operation. There is a direct relation between the frequency of the electricity and the rpm of the generator set; see formula.

$$\text{frequency (hertz)} = \frac{\text{number of poles x rpm}}{120}$$

**GS Governor Switch**

Governor switch (GS) is in place of button (3) when the engine is equipped with a remote control synchronizing motor for the governor. Engine speed is controlled with this switch.

**HS Heat Switch**

Heat switch (HS) is in place of button (2) when the engine is equipped with glow plugs. This switch is used to operate the glow plugs for cold weather starting.

**OPG Oil Pressure Gauge**

Oil pressure gauge (OPG) shows the pressure, in psi, of engine lubrication oil. When pressure switch (PSW) or normally open contact of the arming relay (AR2) is closed, oil pressure gauge (OPG) is connected across battery voltage. There is a relation between the current flow in this circuit and the engine oil pressure read on oil pressure gauge (OPG). Oil pressure sender (OP) controls the current flow by a change in resistance according to the change in engine oil pressure.

**PAM Prealarm Module**

Make reference to ATTACHMENTS.

**PL1,2 Panel Lamps**

Light for the control panel is given by panel lamps (PL1 and PL2). These lamps are controlled by panel light switch (PLS).

**VLR Voltage Level Rheostat**

Voltage level rheostat (VLR) takes the place of voltage level rheostat (R2) on the generator regulator assembly. It is used to adjust the voltage output of the generator.

**NOTE: Make reference to OPERATION OF GENERATOR; REGULATOR ADJUSTMENT. On generators equipped with a generator mounted control panel, the yellow wire from voltage level rheostat (R2) to terminal (7) on the regulator terminal strip is disconnected at terminal (7).**

**WTG Water Temperature Gauge**

Water temperature gauge (WTG) shows the temperature, in degrees fahrenheit, of engine coolant. When pressure switch (PSW) or normally open contact of the arming relay (AR2) is closed, water temperature gauge (WTG) is connected across battery voltage. There is a relation between the current flow in this circuit and the coolant temperature read on water temperature gauge (WTG). Water temperature sender (WT) controls the current flow by a change in resistance according to the change in coolant temperature.

## AUTOMATIC START/STOP SYSTEM

### Introduction

The automatic start/stop system is normally used for standby operation. That is, without an operator. The generator set must start, pick up the load, operate the load, and stop after the load is removed. An automatic transfer switch controls the transfer of load to and from the generator set. When normal (commercial) power has a failure, initiating contactor (I), part of the automatic transfer switch, closes. This will begin the automatic start sequence. When the engine starts, the control panel instruments will show voltage and frequency. The automatic transfer switch will transfer the load to the generator set when voltage and frequency reach approximately rated value. When normal power returns, the automatic transfer switch will transfer the load back to normal power. Initiating contactor (I) will open. This will begin the automatic stop sequence. The generator set will also stop automatically if the engine has a failure.

**NOTE: There are two types of automatic start/stop systems used with the earlier type generator mounted control panel. One uses a mechanically driven speed switch (USS and OSS) and an oil pressure switch (OPS) that is the shape of a cylinder. The other uses an electrical speed switch (DSS) and an oil pressure switch that is the shape of a box.**

### Automatic Start

With engine control switch (ACS) in the AUTO position, contacts 1, 2 and 6 are closed. When commercial (normal) power has a failure, initiating contactor (I) closes. This makes a complete circuit from battery (BATT) to energize run relay (RR), magnetic switch (MS). dual speed switch (DSS) (it so equipped) and overcrank timer (OCT).

When run relay (RR) is energized, contacts (RR2) open and contacts (RR1) close. (RR2) open prevents current flow to rack solenoid (RS) through pressure switch (PSW). (RR1) closed makes it possible to energize oil pressure indicator (OPI).

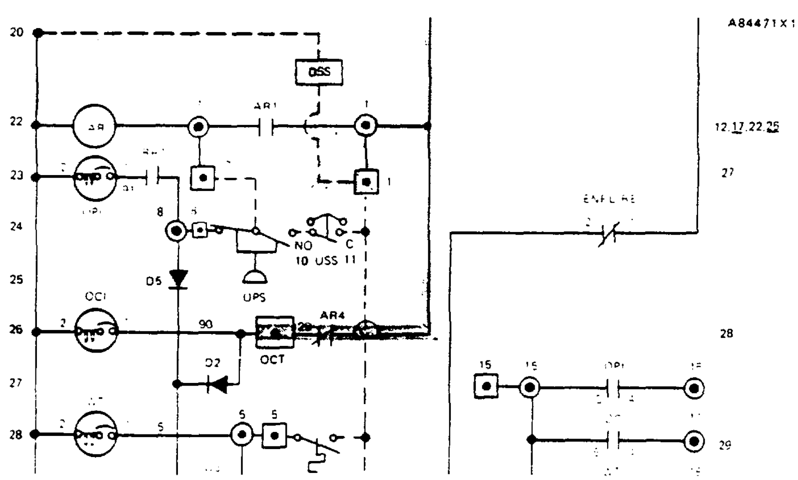
When magnetic switch (MS) is energized. (MS) contacts close and pinion solenoid (PS) is energized. This causes (PS) contacts to close, starting motor (SMJ) will crank the engine. (FPS) or (PSW) will close. This energizes water temperature gauge (WTG) and oil pressure gauge (OPG).

When overcrank timer (OCT) is energized. a timer will start. After the engine cranks for approximately 30 seconds, the timer will top. (OCT) contacts will close. Make reference to ENGINE DOES NOT START.

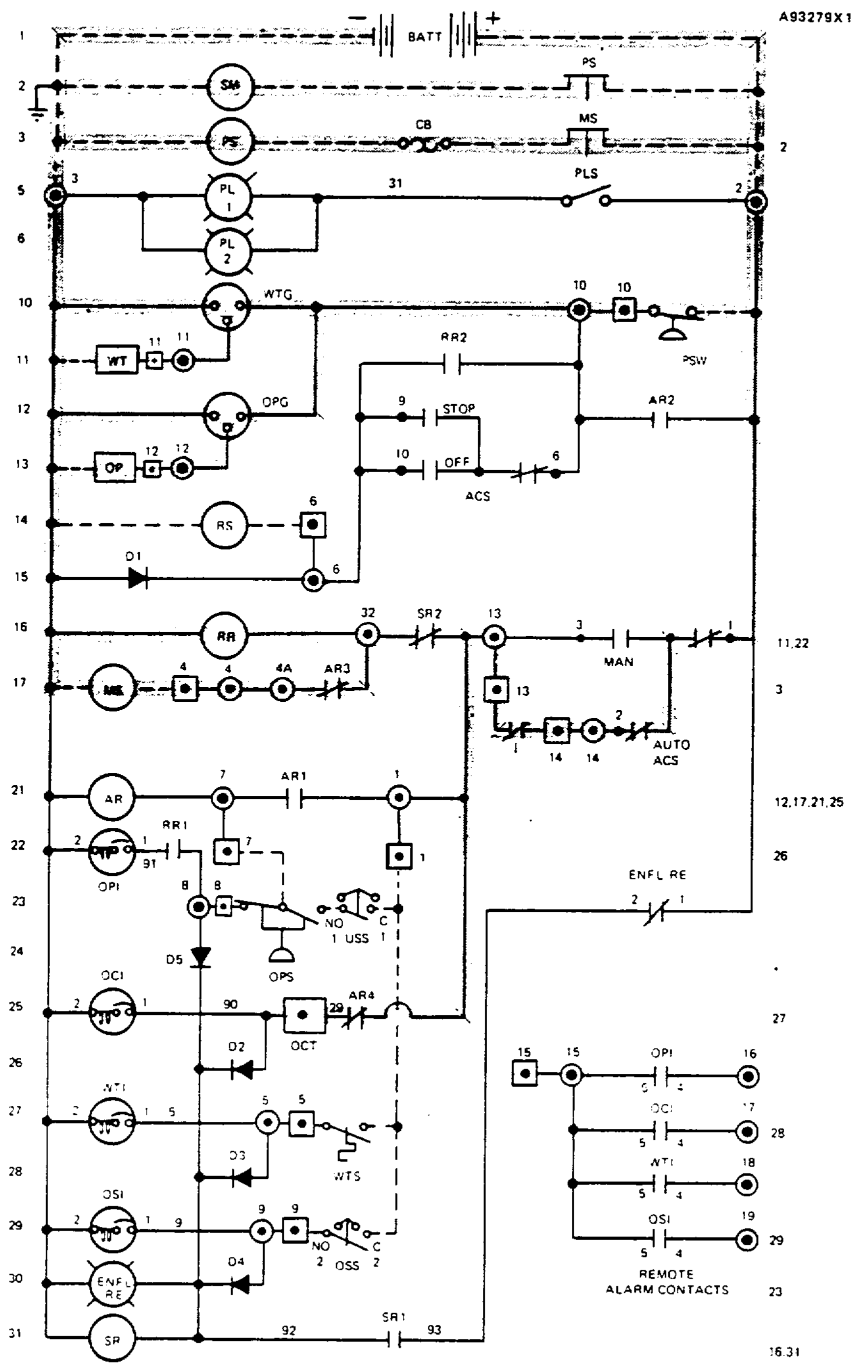
When dual speed switch (DSS) (if so equipped) is energized, the magnetic pickup relays the engine rpm to the switch. The dual speed switch has an underspeed (USS) circuit and an overspeed (OSS) circuit.

### Manual Start

The current flow for manual start is similar to automatic start except engine control switch (ACS) is turned to the MAN position. Contact (2) is open and contact (3) is closed. It is not necessary for initiating contactor (I) to close. Run relay (RR). magnetic switch (MS) and overcrank timer (OCT) will energize as soon as contact (3) is closed.




CONTROL PANEL WITH ELECTRONIC SPEED SWITCH
AUTOMATIC POSITION—ENGINE CRANKS

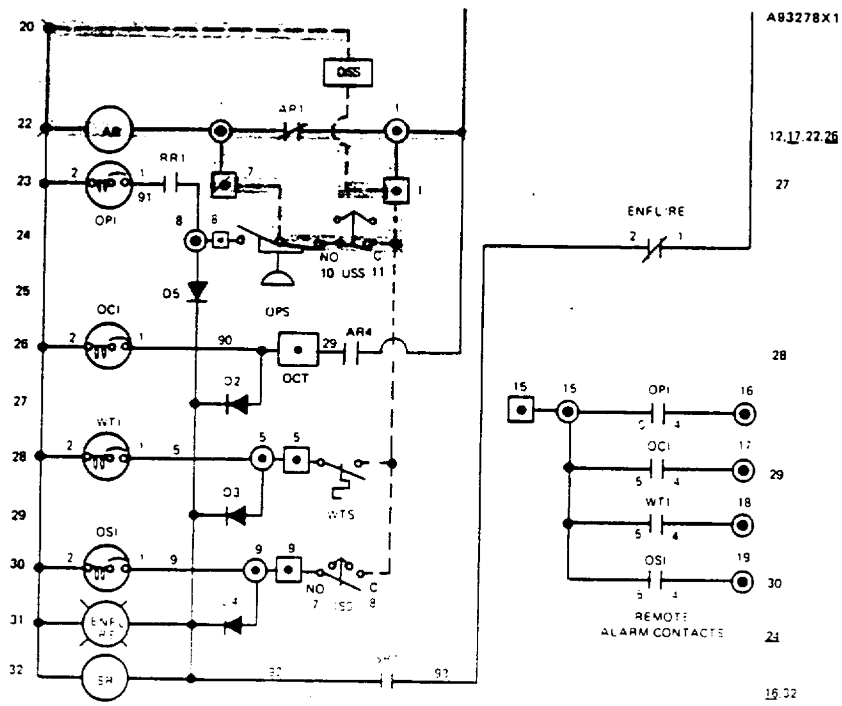


CONTROL PANEL WITH MECHANICAL SPEED SWITCH
AUTOMATIC POSITION—ENGINE CRANKS

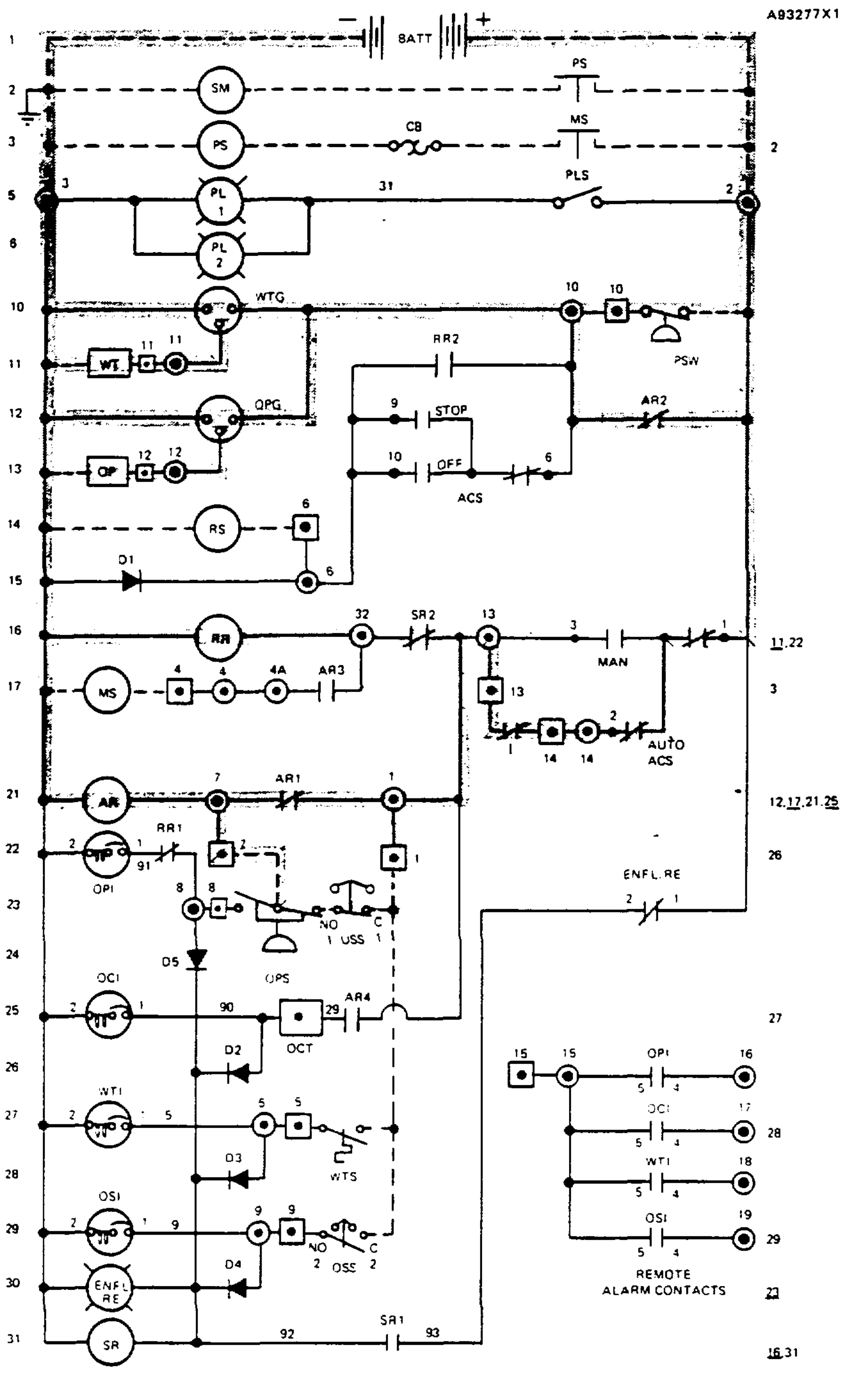
| | |
|---|---|
| ADC | AMMETER |
| ACS | ENGINE CONTROL SWITCH |
| ALT | CHARGING ALTERNATOR |
| AR | ARMING RELAY |
| ARX | AUXILIARY RELAY MODULE |
| BATT | BATTERY |
| CB | CIRCUIT BREAKER |
| CCM | CYCLE CRANKING MODULE |
| CCT | CYCLE CRANK RELAY |
| CRC | CYCLE CRANK LOGIC TIMER |
| D | DIODE |
| DSS | DUAL SPEED SWITCH (INCLUDES USS AND OSS) |
| ENFL | ENGINE FAULT LIGHT WITH FAULT RESET FUNCTION |
| GP | GLOW PLUGS |
| GS | GOVERNOR SWITCH |
| GSM | GOVERNOR SYNCHRONIZING MOTOR |
| HS | GLOW PLUG HEAT SWITCH |
| I | REMOTE START INITIATING CONTACT |
| MS | MAGNETIC SWITCH (CRANK CIRCUIT) |
| MSG | MAGNETIC SWITCH (GLOW PLUG CIRCUIT) |
| OCI | OVERCRANK INDICATOR |
| OCT | OVERCRANK TIMER |
| OP | OIL PRESSURE GAUGE SENDER |
| OPG | OIL PRESSURE GAUGE |
| OPI | LOW OIL PRESSURE INDICATOR |
| OPS | OIL PRESSURE SWITCH |
| OSI | OVERSPEED INDICATION |
| OSS | OVERSPEED SWITCH |
| PIL | PANEL ILLUMINATION LAMP |
| PLS | PANEL LAMP SWITCH |
| PS | PINION SOLENOID |
| PSW | PRESSURE SWITCH |
| RE | FAULT RESET SWITCH, PART OF ENFL |
| RR | RUN RELAY |
| RS | RACK SOLENOID |
| SM | STARTING MOTOR |
| SR | SHUTDOWN RELAY |
| USS | UNDERSPEED SWITCH |
| WT | WATER TEMPERATURE GAUGE SENDER |
| WTG | WATER TEMPERATURE GAUGE |
| WTI | HIGH WATER TEMPERATURE INDICATOR |
| WTS | WATER TEMPERATURE SWITCH |
| ⊙ | TERMINAL STRIP POINT (CONTROL PANEL) |
| ⊡ | TERMINAL STRIP POINT (GENERATOR TERMINAL BOX) |

### Engine Starts

At 600 rpm, underspeed switch (USS) closes. Oil pressure increases. This activates oil pressure switch (OPS). The normally closed contact opens and the normally open contact closes. The arming relay (AR) is now connected across battery voltage. Contacts (AR1) close and lock in the arming relay. Contacts (AR2) close to help complete a circuit to rack solenoid (RS) for shutdown. Contacts (AR3) open. This de-energizes magnetic switch (MS). (MS) contacts open to de-energize pinion solenoid (PS). (PS) contacts open to de-energize starting motor (SM). Contacts (AR4) open to de-energize overcrank timer (OCT).




**CONTROL PANEL WITH ELECTRONIC SPEED SWITCH AUTOMATIC POSITION-ENGINE STARTS**




**CONTROL PANEL WITH MECHANICAL SPEED SWITCH AUTOMATIC POSITION—ENGINE STARTS**

ADC AMMETER
ACS ENGINE CONTROL SWITCH
ALT CHARGING ALTERNATOR
AR ARMING RELAY
ARX AUXILIARY RELAY MODULE
BATT BATTERY
CB CIRCUIT BREAKER
CCM CYCLE CRANKING MODULE
CCT CYCLE CRANK RELAY
CRC CYCLE CRANK LOGIC TIMER
D DIODE
DSS DUAL SPEED SWITCH (INCLUDES USS AND OSS)
ENFL ENGINE FAULT LIGHT WITH FAULT RESET FUNCTION
GP GLOW PLUGS
GS GOVERNOR SWITCH
GSM GOVERNOR SYNCHRONIZING MOTOR
HS GLOW PLUG HEAT SWITCH
I REMOTE START INITIATING CONTACT
MS MAGNETIC SWITCH (CRANK CIRCUIT)
MSG MAGNETIC SWITCH (GLOW PLUG CIRCUIT)
OCI OVERCRANK INDICATOR
OCT OVERCRANK TIMER
OP OIL PRESSURE GAUGE SENDER
OPG OIL PRESSURE GAUGE
OPI LOW OIL PRESSURE INDICATOR
OPS OIL PRESSURE SWITCH
OSI OVERSPEED INDICATION
OSS OVERSPEED SWITCH
PIL PANEL ILLUMINATION LAMP
PLS PANEL LAMP SWITCH
PS PINION SOLENOID
PSW PRESSURE SWITCH
RE FAULT RESET SWITCH, PART OF ENFL
RR RUN RELAY
RS RACK SOLENOID
SM STARTING MOTOR
SR SHUTDOWN RELAY
USS UNDERSPEED SWITCH
WT WATER TEMPERATURE GAUGE SENDER
WTG WATER TEMPERATURE GAUGE
WTI HIGH WATER TEMPERATURE INDICATOR
WTS WATER TEMPERATURE SWITCH

⊙ TERMINAL STRIP POINT (CONTROL PANEL)
⊡ TERMINAL STRIP POINT (GENERATOR TERMINAL BOX)

**Engine Does Not Start**

If the engine does not start in approximately 30 seconds, overcrank timer (OCT) will let current flow to overcrank indicator (OCI), engine failure light/reset switch (ENFL/RE) and shutdown relay (SR).

(SR1) contacts close to lock in the shutdown relay. (SR2) contacts open. This de-energizes run relay (RR) and magnetic switch (MS). (MS) contacts open and de-energize pinion solenoid (PS). (PS) contacts open and de-energize starting motor (SM). Pressure switch (PSW) will open. This de-energizes water temperature gauge (WTG) and oil pressure gauge (OPG).

Overcrank indicator (OCI) will pop out (move out suddenly) and engine failure light/reset switch (ENFL/RE) will give light. To start the engine, do the steps that follow:

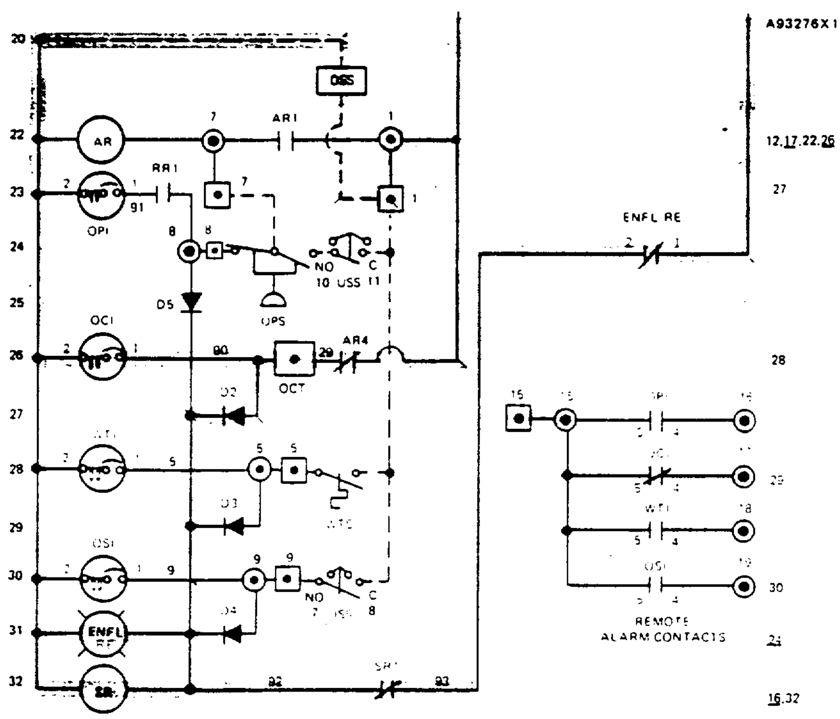
1. Turn engine control switch (ACS) to OFF or STOP. This will prevent the engine from starting if it is not desired. it will also de-energize overcrank timer (OCT) and overcrank indicator (OCI).

2. Push and release engine failure light reset switch (ENFL/RE). This will open (ENFL, RE) contacts for a moment and de-energize shutdown relay (SR) and engine failure light reset switch (ENFL/RE).

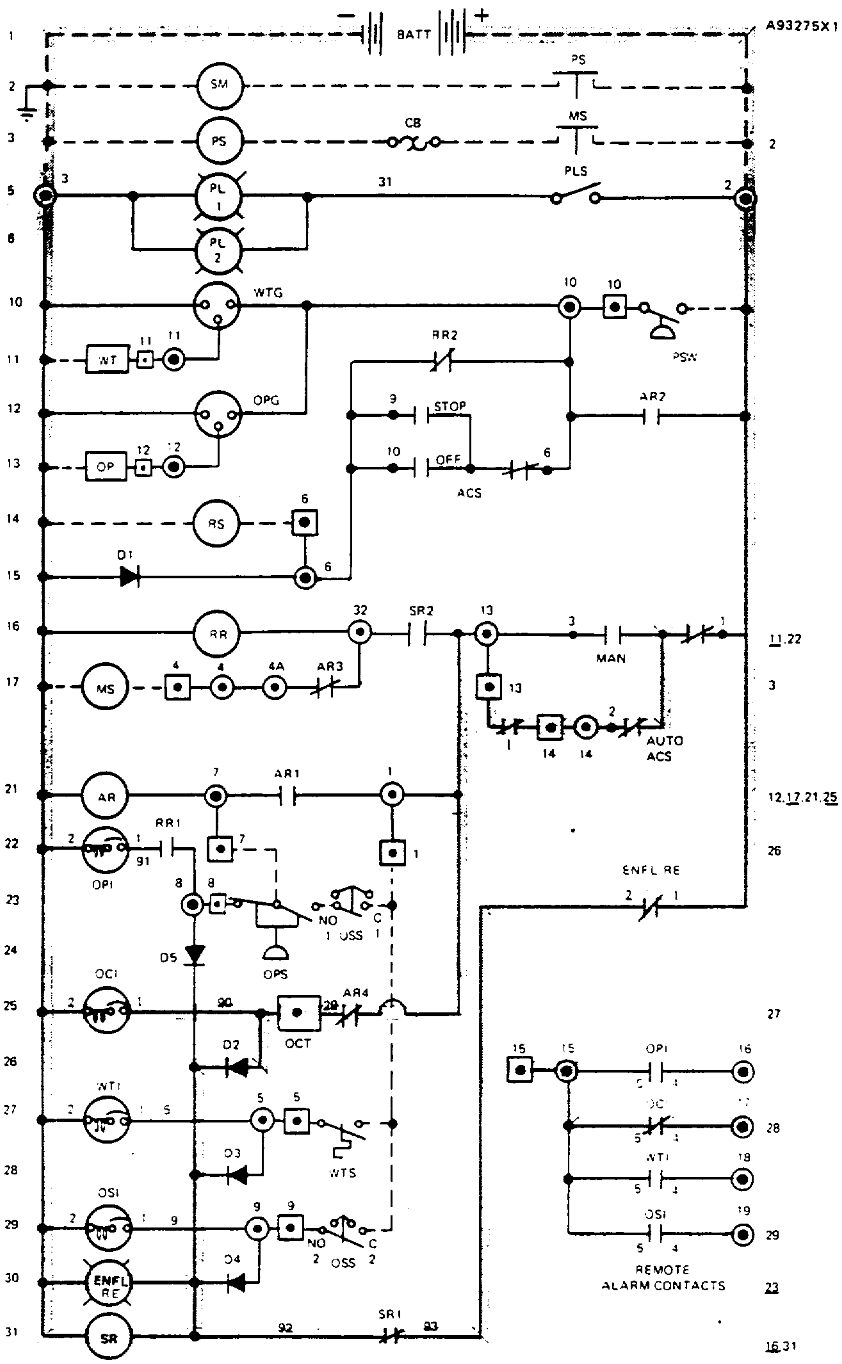
3. Push overcrank indicator button (OCI) back in.

4. Turn the engine controls switch to AUTO. If the engine does not start in approximately 30 seconds, the overcrank indicator will pop out and the engine failure light/reset switch will give light.

5. Turn engine control switch (ACS) to OFF or STOP. Correct the problem that caused the engine not to start. Make reference to TROUBLESHOOTING.




**CONTROL PANEL WITH ELECTRONIC SPEED SWITCH AUTOMATIC POSITION-ENGINE DOES NOT START**




**CONTROL PANEL WITH MECHANICAL SPEED SWITCH AUTOMATIC POSITION-ENGINE DOES NOT START**

| | |
|---|---|
| ADC | AMMETER |
| ACS | ENGINE CONTROL SWITCH |
| ALT | CHARGING ALTERNATOR |
| AR | ARMING RELAY |
| ARX | AUXILIARY RELAY MODULE |
| BATT | BATTERY |
| CB | CIRCUIT BREAKER |
| CCM | CYCLE CRANKING MODULE |
| CCT | CYCLE CRANK RELAY |
| CRC | CYCLE CRANK LOGIC TIMER |
| D | DIODE |
| DSS | DUAL SPEED SWITCH (INCLUDES USS AND OSS) |
| ENFL | ENGINE FAULT LIGHT WITH FAULT RESET FUNCTION |
| GP | GLOW PLUGS |
| GS | GOVERNOR SWITCH |
| GSM | GOVERNOR SYNCHRONIZING MOTOR |
| HS | GLOW PLUG HEAT SWITCH |
| I | REMOTE START INITIATING CONTACT |
| MS | MAGNETIC SWITCH (CRANK CIRCUIT) |
| MSG | MAGNETIC SWITCH (GLOW PLUG CIRCUIT) |
| OCI | OVERCRANK INDICATOR |
| OCT | OVERCRANK TIMER |
| OP | OIL PRESSURE GAUGE SENDER |
| OPG | OIL PRESSURE GAUGE |
| OPI | LOW OIL PRESSURE INDICATOR |
| OPS | OIL PRESSURE SWITCH |
| OSI | OVERSPEED INDICATION |
| OSS | OVERSPEED SWITCH |
| PIL | PANEL ILLUMINATION LAMP |
| PLS | PANEL LAMP SWITCH |
| PS | PINION SOLENOID |
| PSW | PRESSURE SWITCH |
| RE | FAULT RESET SWITCH, PART OF ENFL |
| RR | RUN RELAY |
| RS | RACK SOLENOID |
| SM | STARTING MOTOR |
| SR | SHUTDOWN RELAY |
| USS | UNDERSPEED SWITCH |
| WT | WATER TEMPERATURE GAUGE SENDER |
| WTG | WATER TEMPERATURE GAUGE |
| WTI | HIGH WATER TEMPERATURE INDICATOR |
| WTS | WATER TEMPERATURE SWITCH |

⊙ TERMINAL STRIP POINT (CONTROL PANEL)

⊡ TERMINAL STRIP POINT (GENERATOR TERMINAL BOX)

**Return of Commercial (Normal) Power**

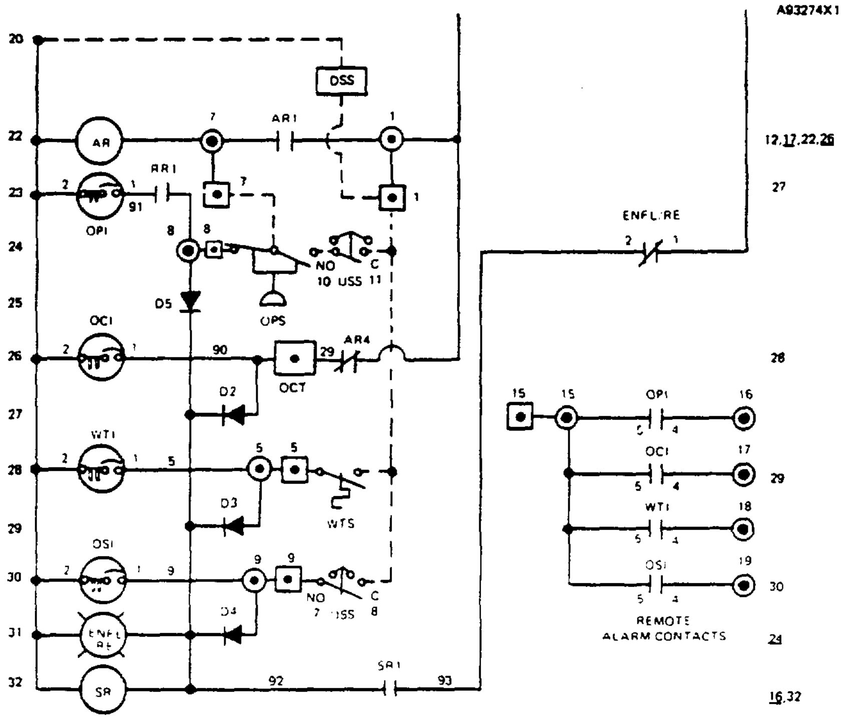
When commercial power returns, the automatic transfer switch transfers the load to commercial power. Initiating contacts (I) open. This de-energizes run relay (RR) and arming relay (AR).

When run relay (RR) is de-energized, contacts (RR2) close and contacts (RR1) open. (RR2) closed energizes rack solenoid (RS). The rack solenoid moves the rack to the FUEL OFF position. (RRI) open prevents an indication of low oil pressure with normal shutdown.

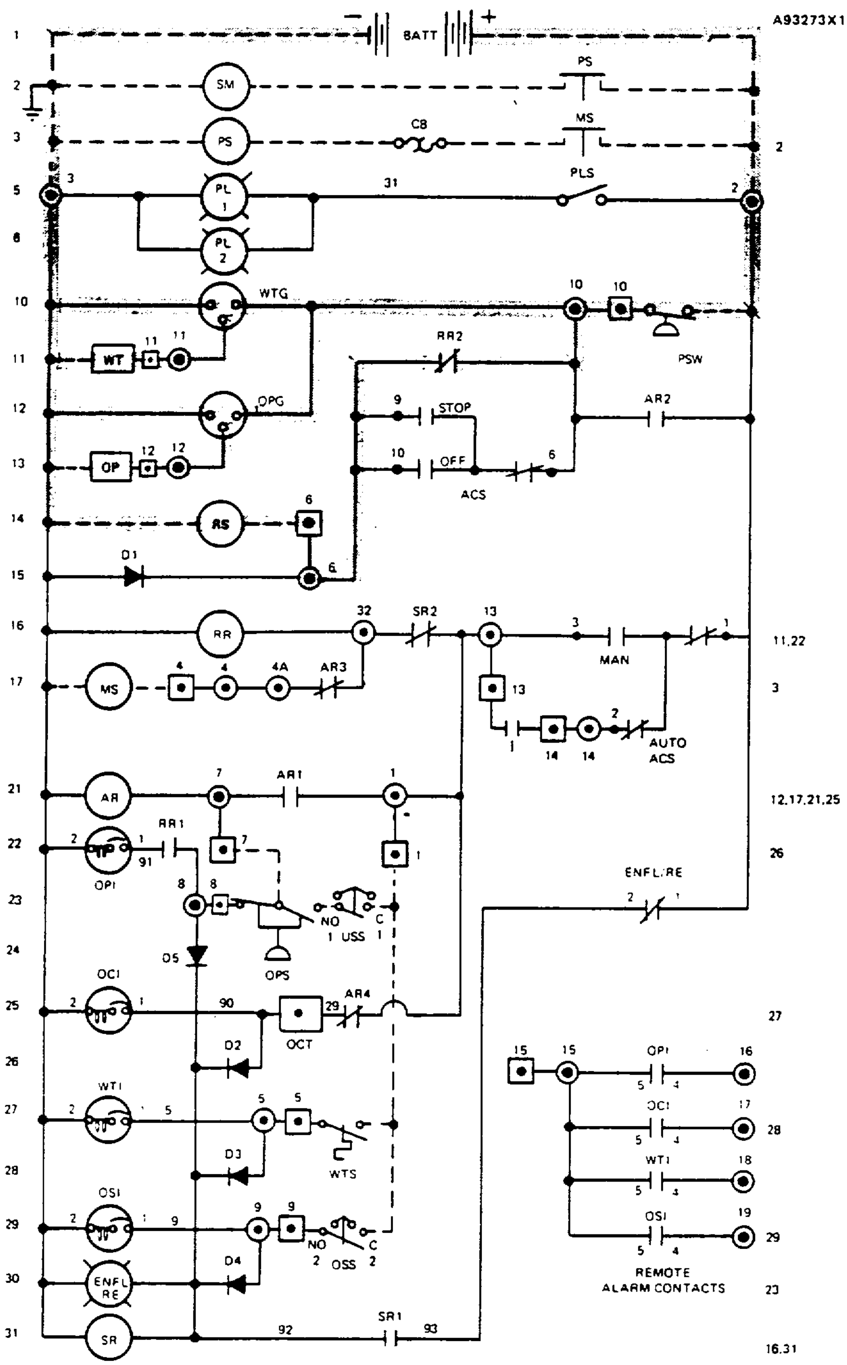
When arming relay (AR) is de-energized, contacts (AR1 and AR2) open and contacts (AR3 and AR4) close. (AR1) open prevents the arming relay from being energized before the engine starts. (AR2) open prevents current flow to rack solenoid (RS) when engine control switch (ACS) is in the OFF or STOP position. (AR3) closed helps complete the circuit to magnetic switch (MS). (AR4) closed helps complete the circuit to and overcrank timer (OCT).

When the engine stops, pressure switch (PSW) opens. This de-energizes water temperature gauge (WTG), oil pressure gauge (OPG) and rack solenoid (RS).

Diode (D1) releases any voltage in the coil of rack solenoid (RS) when it is de-energized.




**CONTROL PANEL WITH ELECTRONIC SPEED SWITCH AUTOMATIC POSITION-COMMERCIAL POWER RETURNS**




**CONTROL PANEL WITH MECHANICAL SPEED SWITCH AUTOMATIC POSITION-COMMERCIAL POWER RETURNS**

ADC AMMETER
ACS ENGINE CONTROL SWITCH
ALT CHARGING ALTERNATOR
AR ARMING RELAY
ARX AUXILIARY RELAY MODULE
BATT BATTERY
CB CIRCUIT BREAKER
CCM CYCLE CRANKING MODULE
CCT CYCLE CRANK RELAY
CRC CYCLE CRANK LOGIC TIMER
D DIODE
DSS DUAL SPEED SWITCH (INCLUDES USS AND OSS)
ENFL ENGINE FAULT LIGHT WITH FAULT RESET FUNCTION
GP GLOW PLUGS
GS GOVERNOR SWITCH
GSM GOVERNOR SYNCHRONIZING MOTOR
HS GLOW PLUG HEAT SWITCH
I REMOTE START INITIATING CONTACT
MS MAGNETIC SWITCH (CRANK CIRCUIT)
MSG MAGNETIC SWITCH (GLOW PLUG CIRCUIT)
OCI OVERCRANK INDICATOR
OCT OVERCRANK TIMER
OP OIL PRESSURE GAUGE SENDER
OPG OIL PRESSURE GAUGE
OPI LOW OIL PRESSURE INDICATOR
OPS OIL PRESSURE SWITCH
OSI OVERSPEED INDICATION
OSS OVERSPEED SWITCH
PIL· PANEL ILLUMINATION LAMP
PLS PANEL LAMP SWITCH
PS PINION SOLENOID
PSW PRESSURE SWITCH
RE FAULT RESET SWITCH, PART OF ENFL
RR RUN RELAY
RS RACK SOLENOID
SM STARTING MOTOR
SR SHUTDOWN RELAY
USS UNDERSPEED SWITCH
WT WATER TEMPERATURE GAUGE SENDER
WTG WATER TEMPERATURE GAUGE
WTI HIGH WATER TEMPERATURE INDICATOR
WTS WATER TEMPERATURE SWITCH

⊙ TERMINAL STRIP POINT (CONTROL PANEL)
⊡ TERMINAL STRIP POINT (GENERATOR TERMINAL BOX)

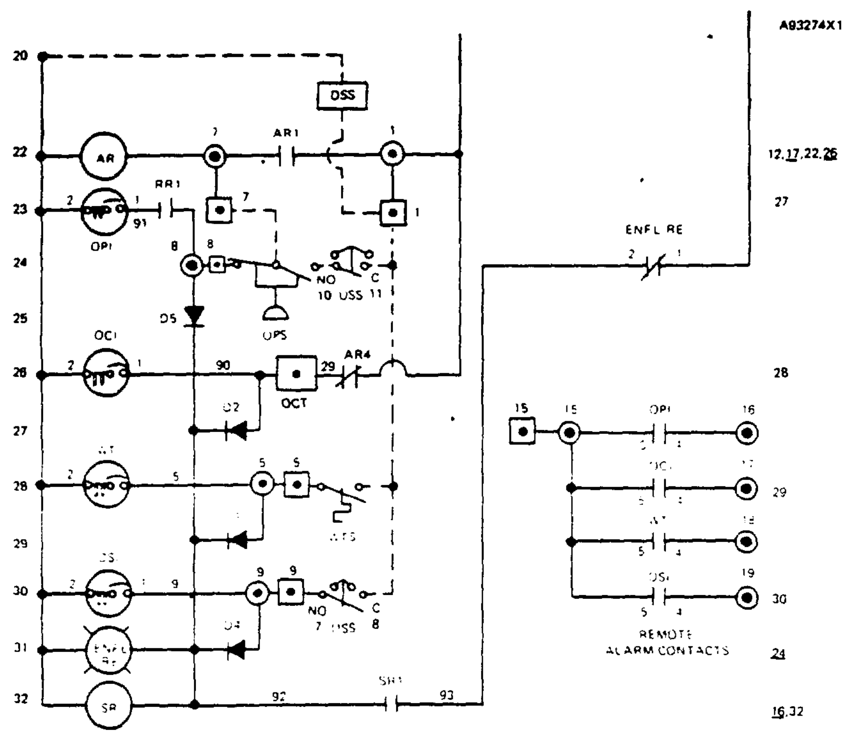
### Manual Shutdown

When engine control switch (ACS) is turned to the STOP or OFF position, contacts (9 or 10) close and contacts (2 and 3) are open. (9 or 10) closed completes a circuit to rack solenoid (RS). The rack solenoid moves the rack to the fuel OFF position. When contacts (2 and 3) are both open, no shutdown indicators can operate. This also de-energizes run relay (RR) and arming relay (AR). (RR2) opens, (RR1) closes. (AR1 and AR2) open, (AR3 and AR4) close.

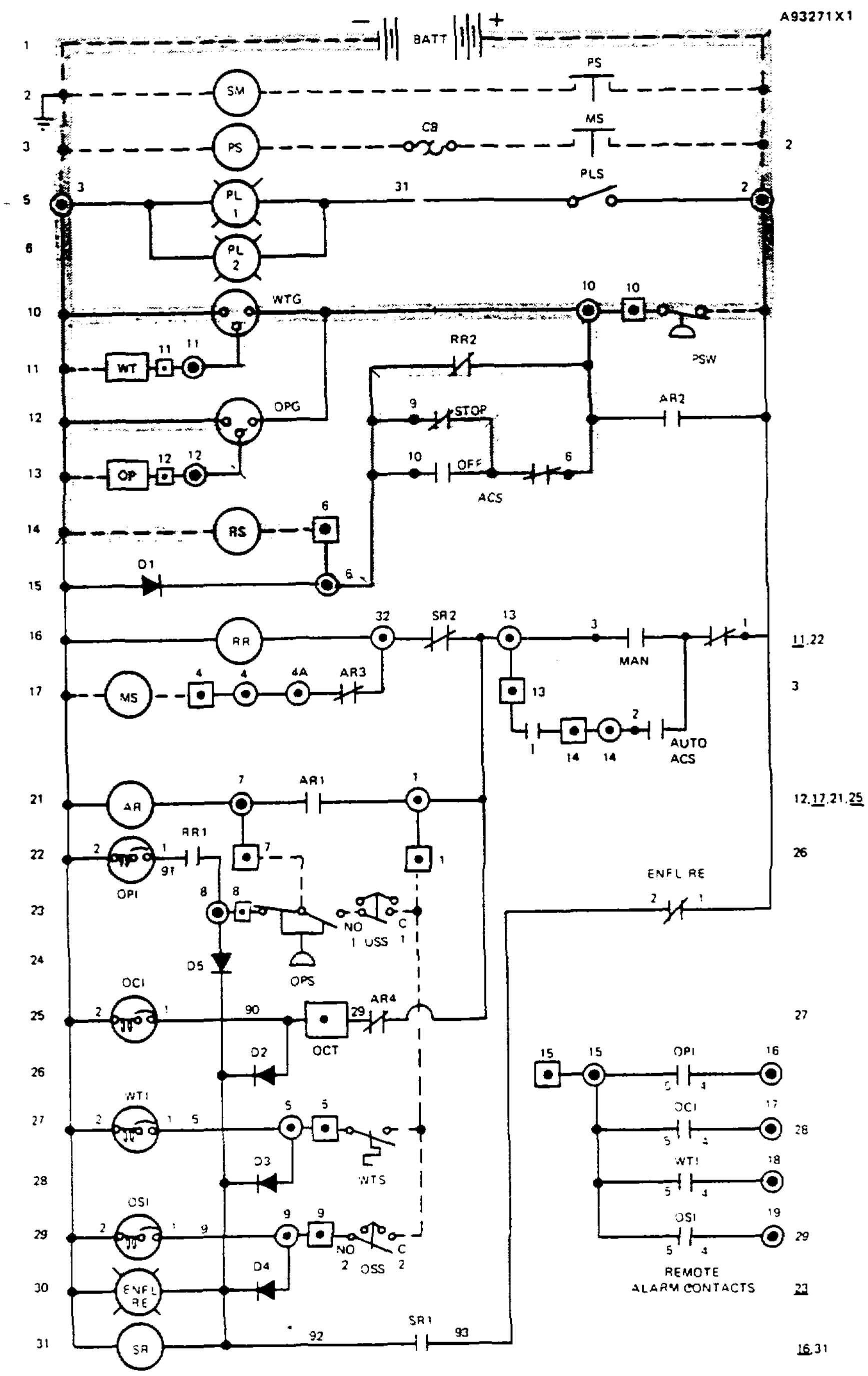
Pressure switch (PSW) will open when the engine stops. This de-energizes water temperature gauge (WTG), oil pressure gauge (OPG) and rack solenoid (RS).

Diode (D1) releases any voltage in the coil of rack solenoid (RS) when it is de-energized.

The system is ready to start if engine control switch (ACS) is turned to MAN or AUTO.




**CONTROL PANEL WITH ELECTRONIC SPEED SWITCH STOP POSITION-MANUAL SHUTDOWN**




**CONTROL PANEL WITH MECHANICAL SPEED SWITCH STOP POSITION—MANUAL SHUTDOWN**

| | |
|---|---|
| ADC | AMMETER |
| ACS | ENGINE CONTROL SWITCH |
| ALT | CHARGING ALTERNATOR |
| AR | ARMING RELAY |
| ARX | AUXILIARY RELAY MODULE |
| BATT | BATTERY |
| CB | CIRCUIT BREAKER |
| CCM | CYCLE CRANKING MODULE |
| CCT | CYCLE CRANK RELAY |
| CRC | CYCLE CRANK LOGIC TIMER |
| D | DIODE |
| DSS | DUAL SPEED SWITCH (INCLUDES USS AND OSS) |
| ENFL | ENGINE FAULT LIGHT WITH FAULT RESET FUNCTION |
| GP | GLOW PLUGS |
| GS | GOVERNOR SWITCH |
| GSM | GOVERNOR SYNCHRONIZING MOTOR |
| HS | GLOW PLUG HEAT SWITCH |
| I | REMOTE START INITIATING CONTACT |
| MS | MAGNETIC SWITCH (CRANK CIRCUIT) |
| MSG | MAGNETIC SWITCH (GLOW PLUG CIRCUIT) |
| OCI | OVERCRANK INDICATOR |
| OCT | OVERCRANK TIMER |
| OP | OIL PRESSURE GAUGE SENDER |
| OPG | OIL PRESSURE GAUGE |
| OPI | LOW OIL PRESSURE INDICATOR |
| OPS | OIL PRESSURE SWITCH |
| OSI | OVERSPEED INDICATION |
| OSS | OVERSPEED SWITCH |
| PIL | PANEL ILLUMINATION LAMP |
| PLS | PANEL LAMP SWITCH |
| PS | PINION SOLENOID |
| PSW | PRESSURE SWITCH |
| RE | FAULT RESET SWITCH, PART OF ENFL |
| RR | RUN RELAY |
| RS | RACK SOLENOID |
| SM | STARTING MOTOR |
| SR | SHUTDOWN RELAY |
| USS | UNDERSPEED SWITCH |
| WT | WATER TEMPERATURE GAUGE SENDER |
| WTG | WATER TEMPERATURE GAUGE |
| WTI | HIGH WATER TEMPERATURE INDICATOR |
| WTS | WATER TEMPERATURE SWITCH |
| ⊙ | TERMINAL STRIP POINT (CONTROL PANEL) |
| ⊡ | TERMINAL STRIP POINT (GENERATOR TERMINAL BOX) |

### Shutdown Caused by Engine Failure

The packaged generator set has shutdown sensors, shutdown indicators and a shutdown circuit for the conditions that follow:

1. Low oil pressure
2. High water temperature
3. Overspeed
4. Overcrank

For information about overcrank shutdown, make reference to ENGINE DOES NOT START.

Conditions (1, 2 or 3) will energize its respective indicator, engine failure light/reset switch (ENFL/RE) and shutdown relay (SR).

(SR1) contacts close to lock in the shutdown relay. (SR2) contacts open. This de-energizes run relay (RR). (RR2) closes and (RR1) opens. (RR2) closed energizes rack solenoid (RS). The rack solenoid moves the rack to the fuel OFF position. Pressure switch (PSW) will open when the engine stops. This de-energizes water temperature gauge (WTG), oil pressure gauge (OPG) and rack solenoid (RS). The correct indicator will pop out (move out suddenly) to show the cause of the shutdown. To start the engine, do the steps that follow:

1. Turn engine control switch (ACS) to OFF or STOP.

This will prevent the engine from starting if it is not desired.

**NOTICE**

**Do Step 1 immediately after shutdown. Step 1 will help prevent damage to rack solenoid (RS) from too much current. When engine control switch (ACS) is turned to STOP or OFF, (AR2) contacts will open and stop current flow to the rack solenoid.**

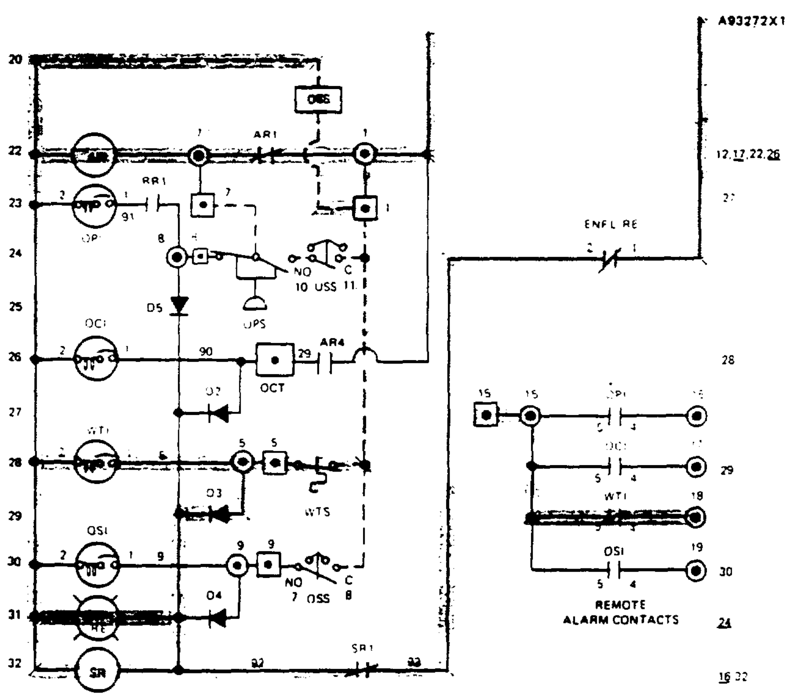
2. Identify and correct the problem that caused the shutdown.

3. Push engine failure light/reset switch (ENFL/RE). This will open (ENFL/RE) contacts and de-energize shutdown relay (SR).

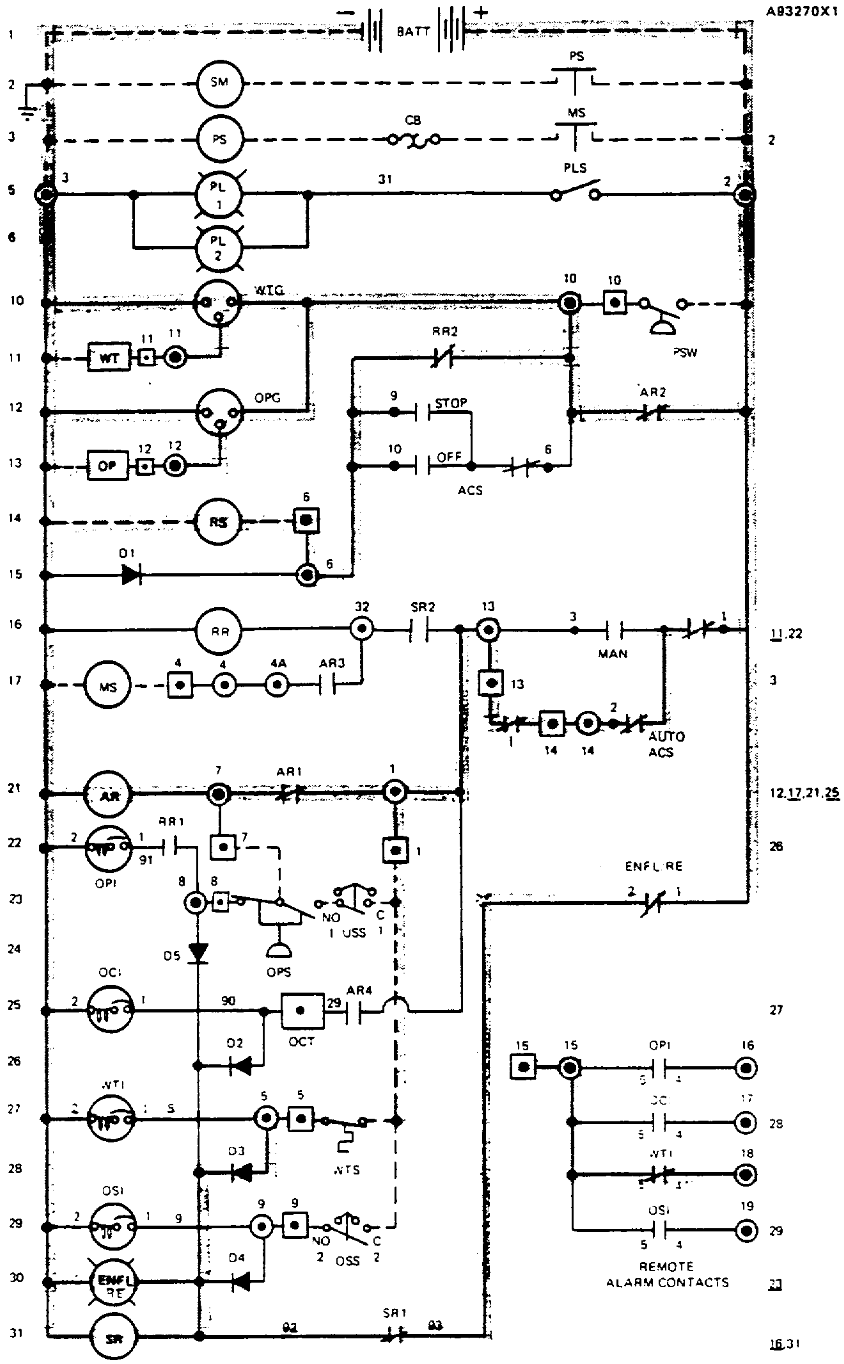
4. Push the indicator button that is out.

5. Reset oil pressure or overspeed switch if necessary.

The system is ready to start if engine control switch (ACS) is turned to MAN or AUTO.




**CONTROL PANEL WITH ELECTRONIC SPEED SWITCH AUTOMATIC POSITION-HIGH WATER TEMPERATURE SHUTDOWN**



CONTROL PANEL WITH MECHANICAL SPEED SWITCH
AUTOMATIC POSITION—HIGH WATER TEMPERATURE SHUTDOWN

ADC AMMETER
ACS ENGINE CONTROL SWITCH
ALT CHARGING ALTERNATOR
AR ARMING RELAY
ARX AUXILIARY RELAY MODULE
BATT BATTERY
CB CIRCUIT BREAKER
CCM CYCLE CRANKING MODULE
CCT CYCLE CRANK RELAY
CRC CYCLE CRANK LOGIC TIMER
D DIODE
DSS DUAL SPEED SWITCH (INCLUDES USS AND OSS)
ENFL ENGINE FAULT LIGHT WITH FAULT RESET FUNCTION
GP GLOW PLUGS
GS GOVERNOR SWITCH
GSM GOVERNOR SYNCHRONIZING MOTOR
HS GLOW PLUG HEAT SWITCH
I REMOTE START INITIATING CONTACT
MS MAGNETIC SWITCH (CRANK CIRCUIT)
MSG MAGNETIC SWITCH (GLOW PLUG CIRCUIT)
OCI OVERCRANK INDICATOR
OCT OVERCRANK TIMER
OP OIL PRESSURE GAUGE SENDER
OPG OIL PRESSURE GAUGE
OPI LOW OIL PRESSURE INDICATOR
OPS OIL PRESSURE SWITCH
OSI OVERSPEED INDICATION
OSS OVERSPEED SWITCH
PIL PANEL ILLUMINATION LAMP
PLS PANEL LAMP SWITCH
PS PINION SOLENOID
PSW PRESSURE SWITCH
RE FAULT RESET SWITCH, PART OF ENFL
RR RUN RELAY
RS RACK SOLENOID
SM STARTING MOTOR
SR SHUTDOWN RELAY
USS UNDERSPEED SWITCH
WT WATER TEMPERATURE GAUGE SENDER
WTG WATER TEMPERATURE GAUGE
WTI HIGH WATER TEMPERATURE INDICATOR
WTS WATER TEMPERATURE SWITCH

⊙ TERMINAL STRIP POINT (CONTROL PANEL)
⊡ TERMINAL STRIP POINT (GENERATOR TERMINAL BOX)

# GENERATOR MOUNTED CONTROL PANEL
# (TYPE 3 - CHANGE LEVEL 2 THRU 8)

## INTRODUCTION

The uses of the generator mounted control panel are:

To help control the electric power made by the generator set.

To monitor (check) the operation of' the generator set.

To help protect the generator set from damage caused by low oil pressure, high coolant temperature, overspeed and overcrank.

To help with the transfer of electrical load to and from the generator set.

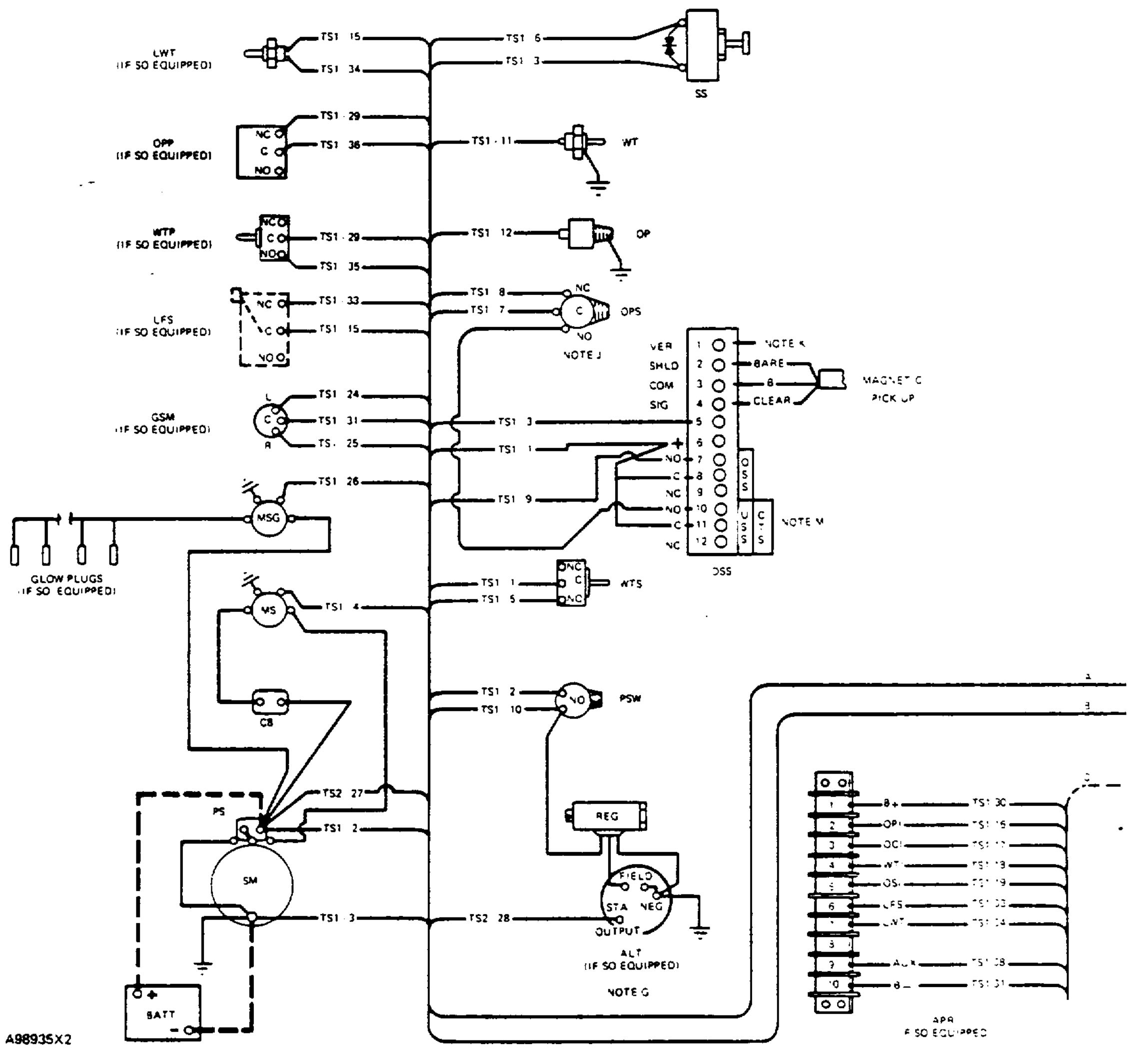
To help parallel two or more units onto the same bus.

## IDENTIFICATION

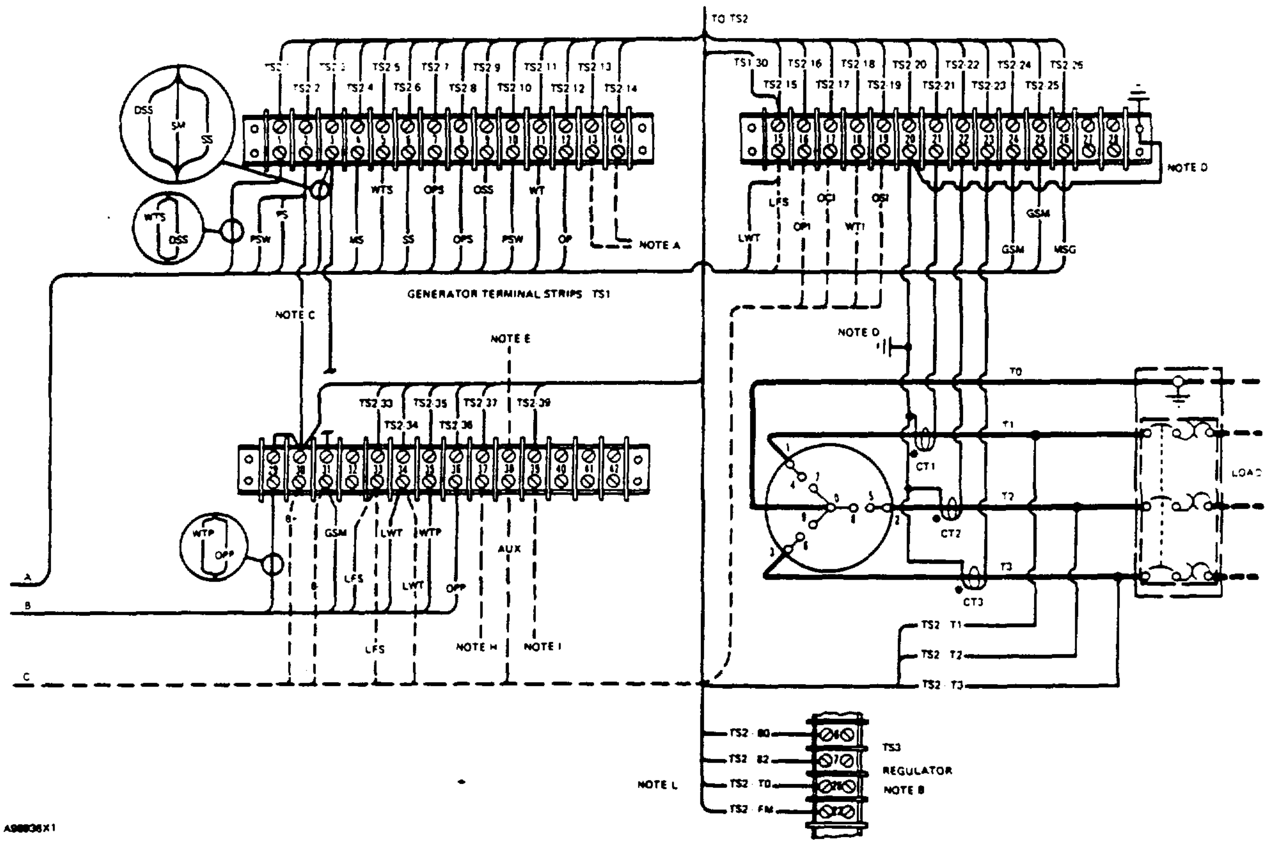
The location of the control panel is on the top of the regulator housing. This panel has a place for a heat switch and Prealarm module. The shutdown indicators are relay lamp type. The control panel has a 12 place model number on the panel nameplate. The model number gives an indication of the control panel component part numbers. Make reference to the Parts Book, GENERATOR MOUNTED CONTROL PANEL. Form No. SEBP1068. The last digit of the model number is the change level to which the panel was built.

## WIRING

See the pages that follow for wiring diagrams, schematics and photo illustrations for identification.

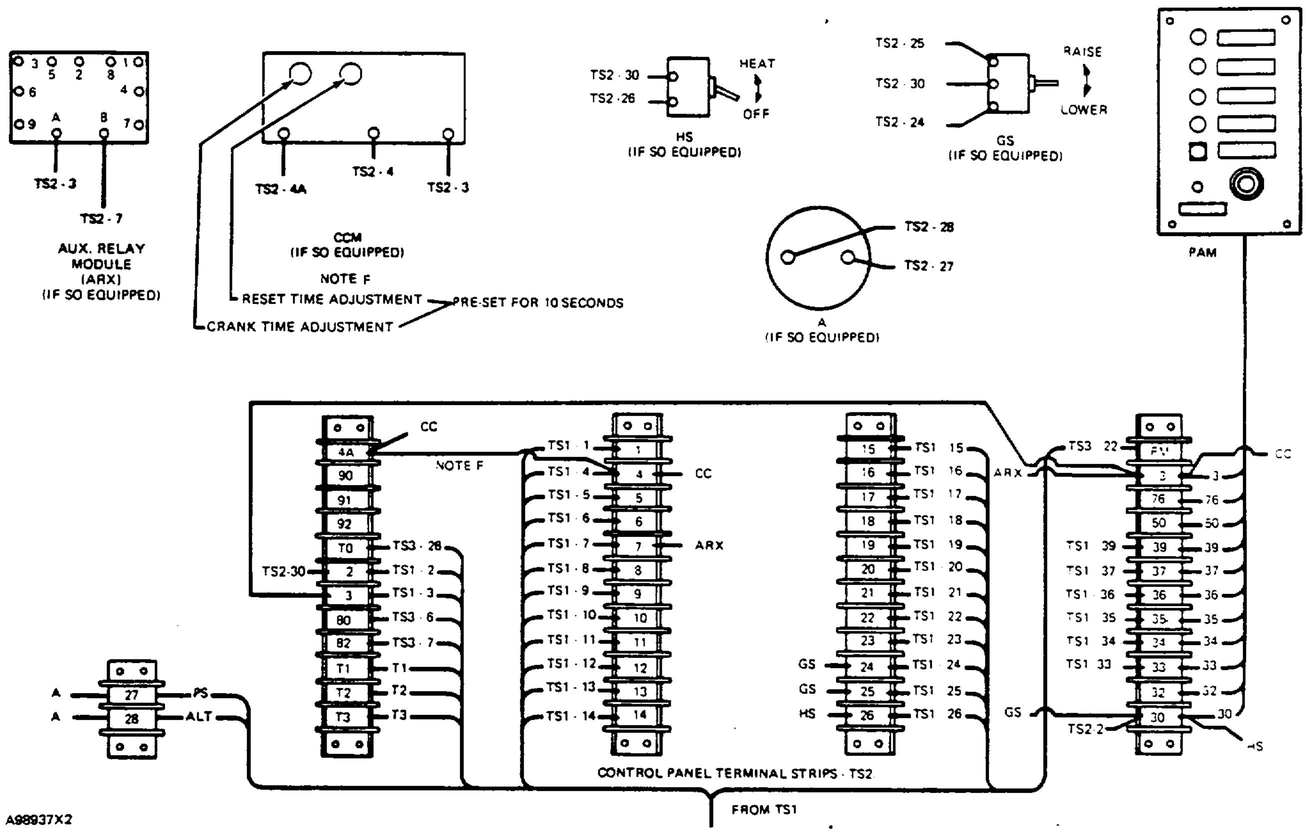



GENERATOR MOUNTED COMPONENTS AND ANNUNCIATOR PANEL (REMOTE)




**GENERATOR TERMINAL STRIP TS1, REGULATOR TERMINAL STRIP TS3. GENERATOR, CURRENT TRANSFORMERS AND CIRCUIT BREAKER**

| | |
|---|---|
| A | AMMETER (CONTROL PANEL MOUNTED) |
| ALT | CHARGING ALTERNATOR (NOTE H) |
| APR | ANNUNCIATOR PANEL-REMOTE |
| ARX | AUXILIARY RELAY MODULE (CONTROL PANEL MOUNTED) |
| AUX | AUXILIARY CONTACT (NOTE E) |
| B+ | BATTERY POSITIVE |
| B- | BATTERY NEGATIVE |
| BATT | BATTERY |
| CB | CIRCUIT BREAKER |
| CCM | CYCLE CRANKING MODULE (CONTROL PANEL MOUNTED) |
| CT | CURRENT TRANSFORMER |
| CTS | CRANK TERMINATE SWITCH |
| DSS | DUAL SPEED SWITCH |
| GS | GOVERNOR SWITCH (CONTROL PANEL MOUNTED) |
| GSM | GOVERNOR SYNC MOTOR |
| HS | HEAT SWITCH (CONTROL PANE MOUNTED) |
| LFS | LOW FUEL LEVEL SWITCH |
| LWT | LOW WATER TEMP SWITCH |
| MS | MAGNETIC SWITCH (CRANK CIRCUIT) |
| MSG | MAGNETIC SWITCH (GLOW PLUG CIRCUIT) |
| OCI | OVERCRANK INDICATOR |
| OP | OIL PRESSURE GAUGE SENDER |
| OPI | LOW OIL PRESSURE INDICATOR |
| OPP | OIL PRESSURE SWITCH (PRE-ALARM) |
| OPS | OIL PRESSURE SWITCH (SHUTDOWN) |
| OSI | OVERSPEED INDICATOR |
| OSS | OVERSPEED SWITCH (SHUTDOWN) |
| PAM | PREALARM MODULE (CONTROL PANEL MOUNTED) |
| PS | PINION SOLENOID |
| PSW | PRESSURE SWITCH |
| SS | SHUTOFF SOLENOID |
| SM | STARTING MOTOR |
| TS | TERMINAL STRIP |
| USS | UNDERSPEED SWITCH (CRANK TERMINATION) |
| WT | WATER TEMPERATURE GAGE SENDER |
| WTI | HIGH WATER TEMPERATURE INDICATOR |
| WTP | WATER TEMPERATURE SWITCH (PRE-ALARM) |
| WTS | WATER TEMPERATURE SWITCH (SHUTDOWN) |




## CONTROL PANEL COMPONENTS (PARTIAL) AND CONTROL PANEL TERMINAL STRIP TS2

NOTE: DOTTED WIRES BY CUSTOMER

NOTE A: To normally open initiating contacts I of automatic transfer switch.

NOTE B: The yellow wire from voltage level rheostat (R2)to terminal 7 on the regulator terminal strip is disconnected at terminal 7.

NOTE C: Some generator sets without an Annunciator panel (remote) or a Prealarm module are not equipped with B + connection from TS1-2 to TS1-30 to TS1-29 and TS1-15.

NOTE D: Some generator sets are grounded at the line from the current transformer's neutral. Some are grounded through a jumper between TS1-20 and a terminal strip support screw.

NOTE E: To normally open auxiliary contact on emergency side of transfer switch, if the generator set is equipped with an Annunciator panel (remote). Used to give generating indication.

NOTE F: Red jumper between TS2-4A and TS2-4 is not used with cycle cranking module.

NOTE G: Do not operate the alternator without a battery connected in the circuit. Do not polarize alternator. Do not charge a common battery with the alternator and a. DC generator at the same time.

NOTE H: To optional remote low lubrication oil pressure indicator installed by the customer.

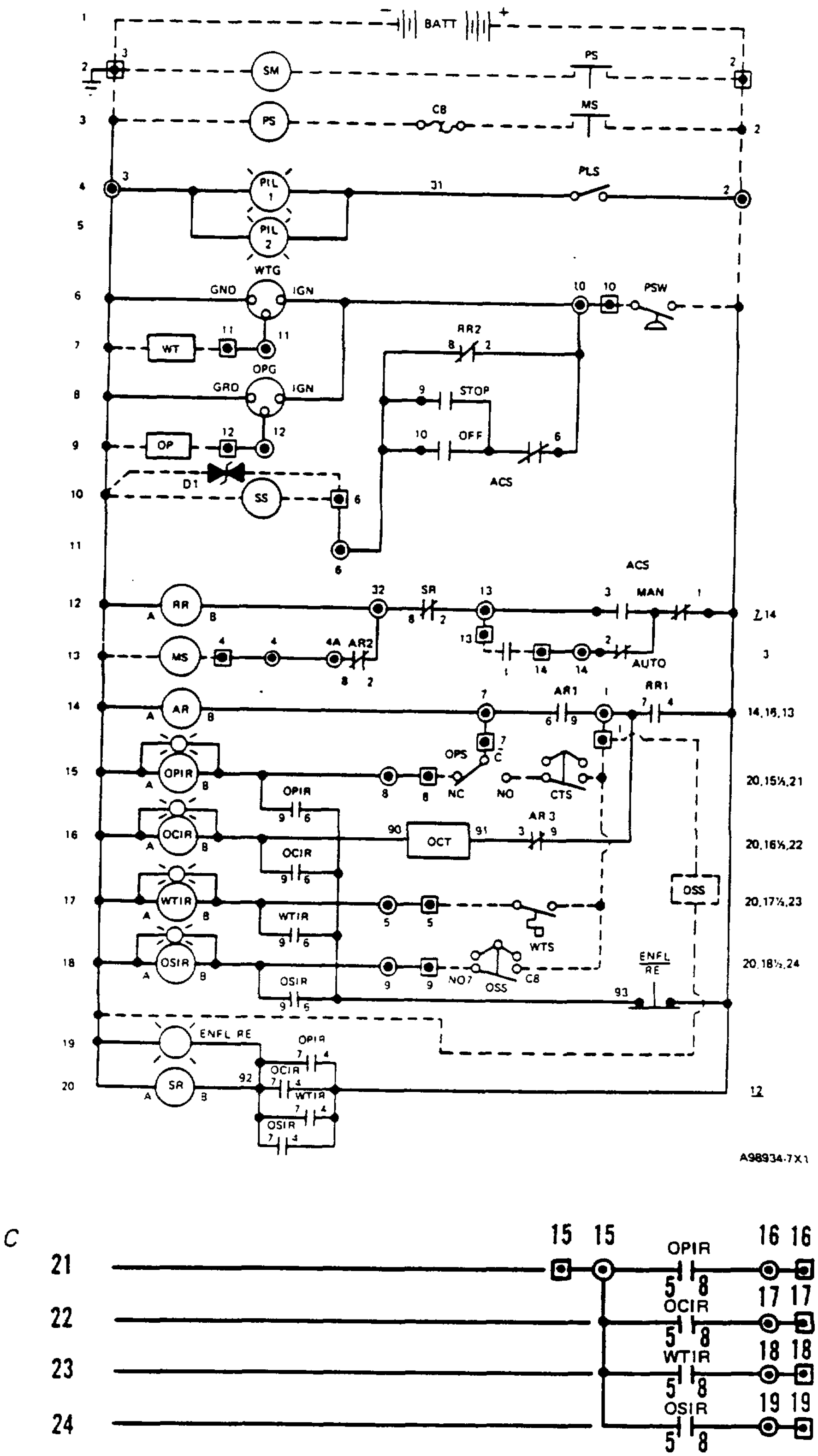
NOTE I: To optional remote shutdown indicator installed by the customer.

NOTE J: On some generator sets, underspeed switch (USS) is connected to the common terminal on oil pressure switch (OPS). Connect the wire to the normally open terminal on oil pressure switch (OPS) to help prevent low oil pressure shutdown when engine oil pressure does not increase as fast as engine speed during engine starting.

NOTE K: If terminal 1 is connected to terminal 2 speed switch will shutdown engine at 3/4 overspeed set point. Speed switches with a verify button do not have terminal 1. Push the verify button to shutdown the engine at 3/4 overspeed set point.

NOTE L: Some frequency meters are connected phase (TS2-FM to TS3-22 to stator T7) to neutral (TS2-TO to TS3-26 to stator TO). Others are connected phase (TS2-FM to TS3-22 to stator T7) to ground (control panel chassis). When the frequency meter is connected phase to ground, terminal TS2-TO has a mark 93 and is not connected to TS3-26.

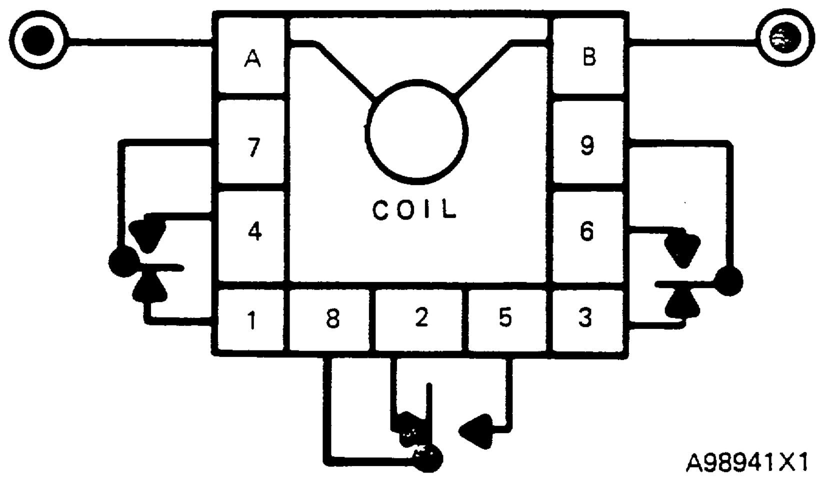
NOTE M: CTS is a replacement for USS. CTS, crank terminate switch, gives a better description of the actual purpose of the switch.



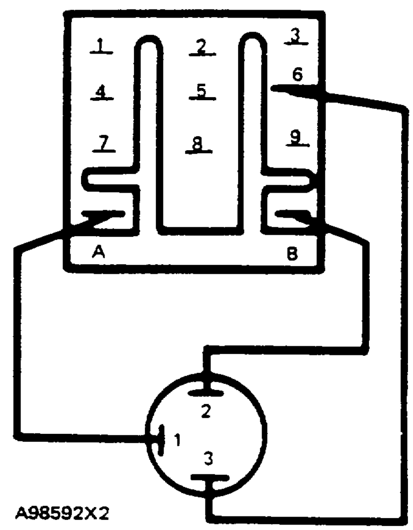

CONTROL PANEL
AUTOMATIC POSITION

ADC AMMETER
ACS ENGINE CONTROL SWITCH
ALT CHARGING ALTERNATOR
AR ARMING RELAY
ARX AUXILIARY RELAY MODULE
BATT BATTERY
CB CIRCUIT BREAKER
CCM CYCLE CRANKING MODULE
CCT CYCLE CRANK RELAY
CDT COOL DOWN TIMER
CDTR COOL DOWN TIMER RELAY
CRC CYCLE CRANK LOGIC TIMER
CTS CRANK TERMINATE SWITCH
D DIODE
DSS DUAL SPEED SWITCH (INCLUDES CTS AND DSS)
ENFL ENGINE FAULT LIGHT WITH FAULT RESET FUNCTION
GP GLOW PLUGS
GS GOVERNOR SWITCH
GSM GOVERNOR SYNCHRONIZING MOTOR
HS GLOW PLUG HEAT SWITCH
I REMOTE START INITIATING CONTACT
MS MAGNETIC SWITCH (CRANK CIRCUIT)
MSG MAGNETIC SWITCH (GLOW PLUG CIRCUIT)
OCIR OVERCRANK INDICATING RELAY
OCT OVERCRANK TIMER
OP OIL PRESSURE GAUGE SENDER
OPG OIL PRESSURE GAUGE
OPIR LOW OIL PRESSURE INDICATOR RELAY
OPS OIL PRESSURE SWITCH
OSIR OVERSPEED INDICATING RELAY
OSS OVERSPEED SWITCH
PIL PANEL ILLUMINATION LAMP
PLS PANEL LAMP SWITCH
PS PINION SOLENOID
PSW PRESSURE SWITCH
RE FAULT RESET SWITCH, PART OF ENFL
RR RUN RELAY
SS SHUT-OFF SOLENOID
SM STARTING MOTOR
SR SHUTDOWN RELAY
WT WATER TEMPERATURE GAUGE SENDER
WTG WATER TEMPERATURE GAUGE
WTIR HIGH WATER TEMPERATURE INDICATING RELAY
WTS WATER TEMPERATURE SWITCH

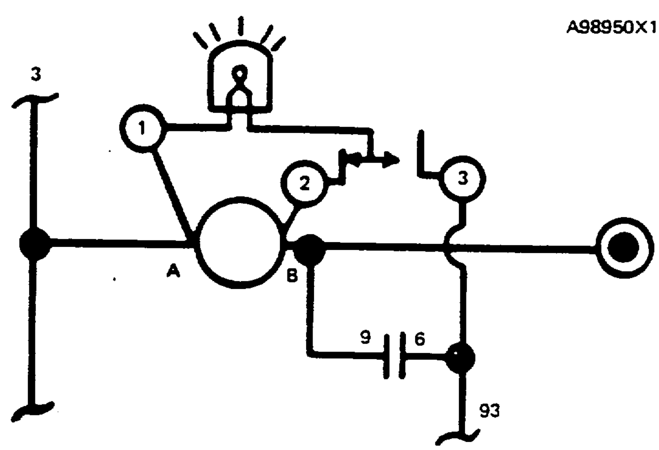
⊙ TERMINAL STRIP POINT (CONTROL PANEL)
⊡ TERMINAL STRIP POINT (GENERATOR TERMINAL BOX)




RELAY CONTACT SCHEMATIC



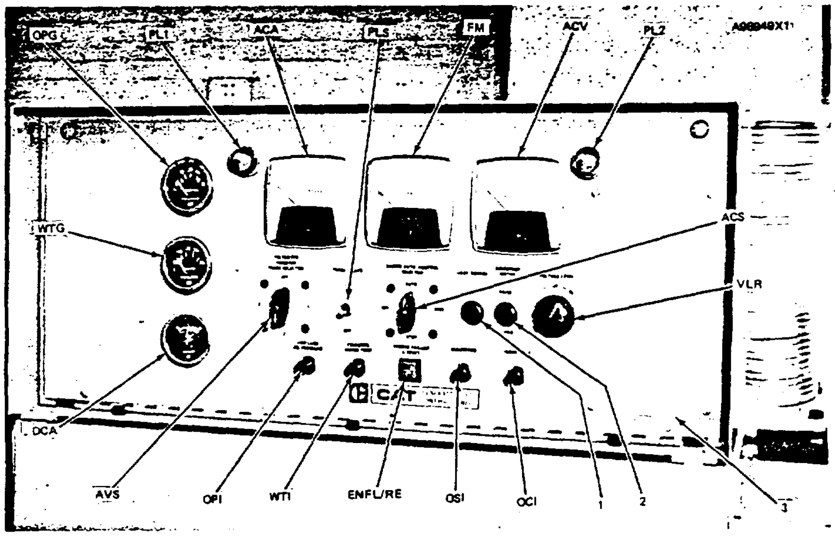

RELAY LAMP COMPONENT WIRING




RELAY LAMP SCHEMATIC

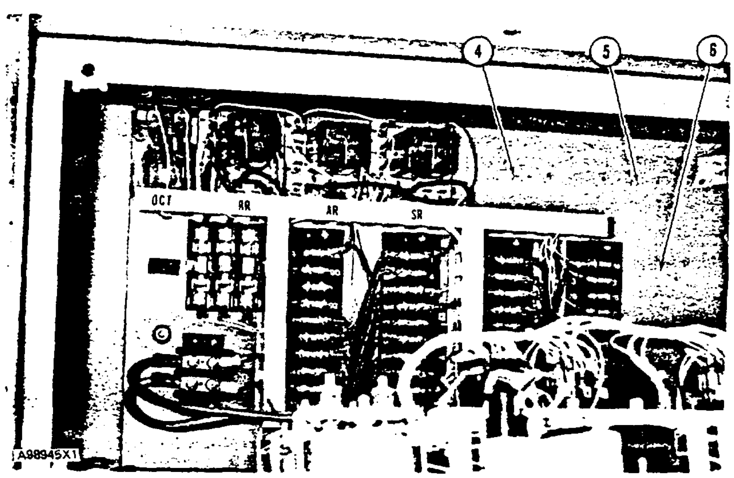
## COMPONENTS

**NOTE: For specifications on components located on the engine, make reference to the ENGINE SERVICE MANUAL.**




**CONTROL PANEL (TYPE 3 - CHANGE LEVEL 2 THRU 8)**

| | | | | | |
|---|---|---|---|---|---|
| ACA | Alternating current ammeter | FM | Frequency meter | VLR | Voltage level rheostat |
| ACS | Engine control switch | PL1,2 | Panel lamps | 1. | Button (heat switch HS, if so equipped) |
| ACV | Alternating current voltmeter | PLS | Panel lamp switch | 2. | Button (governor switch GS, if so equipped) |
| AVS | Ammeter/voltage selector switch | OCI | Overcrank indicator | 3. | Panel (Prealarm module PAM, If so equipped) |
| DCA | Direct current ammeter | OPG | Oil pressure gauge | | |
| ENFL/RE | Engine failure light/reset switch | OPI | Oil pressure indicator | | |
| | | OSI | Overspeed indicator | | |
| | | WTG | Water temperature gauge | | |
| | | WTI | Water temperature indicator | | |




**INSIDE CONTROL PANEL (TYPE 3 - CHANGE LEVEL 2 THRU 8)**

4. Location for CDT (cool down timer if so equipped). 5. Location for AUX (auxiliary relay, if so equipped). 6. Location for CCM (cycle crank module, If so equipped).

## ACA Alternating Current Ammeter

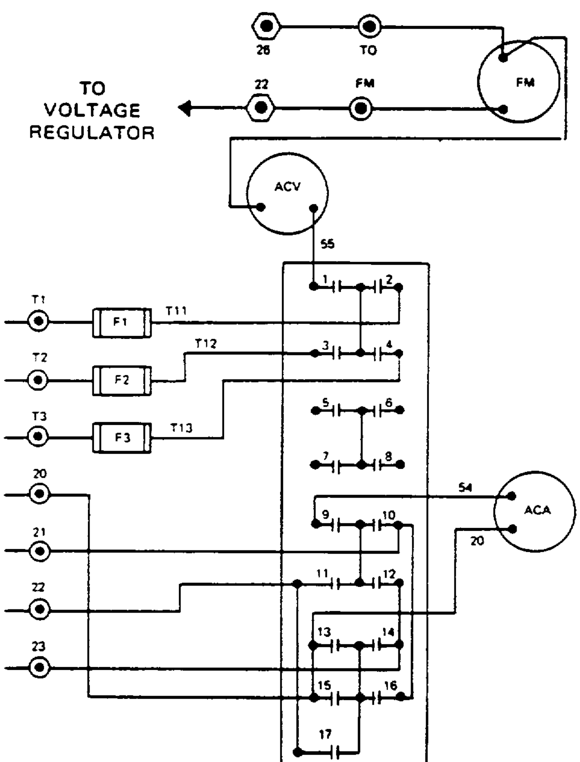
AC ammeter (ACA) gives an indication, in amperes, of the current from each phase of the generator to the load. Ammeter/voltmeter selector switch (AVS) is used to connect the ammeter to the current transformer on phase T1, T2 or T3; see Contact Chart. Ammeters normally have an input range from 0 to 5 amperes. Current transformer (CT1, CT2 or CT3) causes a reduction of the actual line current, in its respective phase lead, to a level within the input range of the ammeter. The ammeter is calibrated (has marks) to give an indication of the actual current flow in one phase load of the generator.

**NOTE: Several methods have been used to connect control panel instruments. The recommended method is shown in the diagrams.**

**CONTACT CHART FOR AVS**

| | OFF | 1 | 2 | 3 |
|---|---|---|---|---|
| 1 | | X | X | X |
| 2 | | X | | |
| 3 | | | X | |
| 4 | | | | X |
| 5 | | X | X | X |
| 6 | | X | | |
| 7 | | | X | |
| 8 | | | | X |
| 9 | | X | X | X |
| 10 | | X | | |
| 11 | | | X | |
| 12 | | | | X |
| 13 | X | | | |
| 14 | X | X | X | |
| 15 | | X | X | X |
| 16 | X | | X | X |
| 17 | X | X | | X |

**NOTE: X gives an indication of a closed contact. .Y on the line gives an indication of "make before break".**

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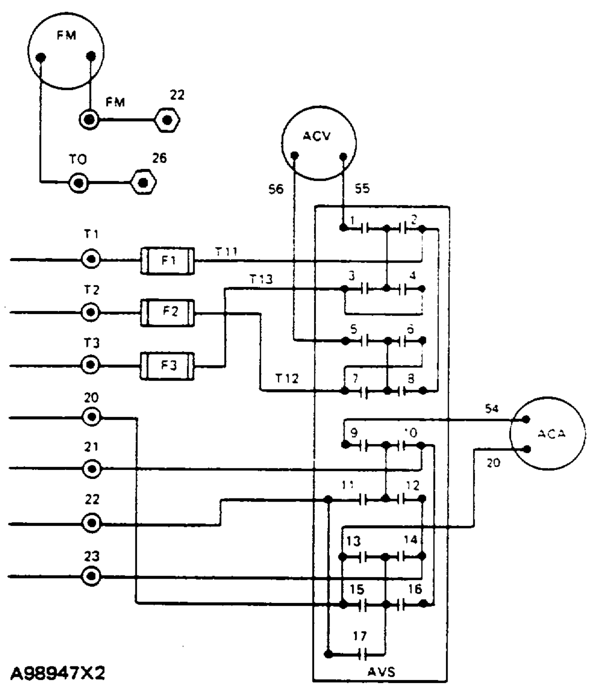
**(600V Control Panel Only)**

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**AMMETER/VOLTMETER SELECTOR SWITCH (AVS) WIRING DIAGRAMS**

| | | | |
|---|---|---|---|
| ACA | Alternating current ammeter | ⊙ | Terminal point on TS2 in control panel |
| ACV | Alternating current voltmeter | ⊙ | Terminal Point on TS3 part of voltage regulator |
| F1,2,3 | Fuses | | |
| FM | Frequency meter | | |

### ACS Engine Control Switch

Engine control switch (ACS) controls the engine start and stop systems. To start the engine, move the switch to the manual position. To stop the engine move the switch to the STOP or OFF position. For standby application (engine starts when remote initiating contact 1 closes), move the switch to the AUTO position. For more information on the operation of this switch, make reference to the AUTOMATIC START/STOP SYSTEM.

| CONTACT CHART FOR ACS | | | | |
|---|---|---|---|---|
| | AUTO | MAN | STOP | OFF |
| | 1 | 2 | 3 | 4 |
| 1 | X | X | X | X |
| 2 | X | | | |
| 3 | | X | | |
| 4 | | | X | |
| 5 | | | | X |
| 6 | X | X | X | X |
| 7 | X | | | |
| 8 | | X | | |
| 9 | | | X | |
| 10 | | | | X |

### ACV Alternating Current Voltmeter

AC voltmeter (ACV) shows the potential differential (voltage) between phase T1-T2, T2-T3 or T3-T1 at position 1, 2 or 3 respectively. Make reference to the ALTERNATING CURRENT AMMETER.

### DCA Direct Current Ammeter

This ammeter shows the amount of DC current in amperes, that flows in the alternator circuit (if so equipped).

### ENFL/RE Engine Failure Light/Reset Switch

Engine failure light/reset switch (ENFL/RE) will activate when the engine has a failure. One or more of the shutdown indicators will also activate to give an indication of the problem. Shutdown relay (SR) will activate to start the shutdown sequence. Make reference to SHUTDOWN CAUSED BY ENGINE FAILURE and ENGINE DOES NOT START.

**NOTICE**

**Turn engine control switch (ACS) to the STOP or OFF position immediately after engine shutdown caused by high water temperature, low oil pressure or overspeed. This will cause an open in the circuit to the arming relay (AR). Normally open contact of arming relay (AR2) will open and current flow to rack solenoid (RS) will stop. This will help prevent damage to the rack solenoid from too much current.**

### FM Frequency Meter

Frequency meter (FM) shows the hertz (cycles per second) of the electricity made when the generator set is in operation. There is a direct relation between the frequency of the electricity and the rpm of the generator set: see formula.

$$\text{frequency (hertz)} = \frac{\text{number of poles x rpm}}{120}$$

### GS Governor Switch

Governor switch (GS) is in place of button (2) when the engine is equipped with a remote control synchronizing motor for the governor. Engine speed is controlled with this switch.

### HS Heat Switch

Heat switch (HS) is in place of button (1) when the engine is equipped with glow plugs. This switch is used to operate the glow plugs for cold weather starting.

### OPG Oil Pressure Gauge

Oil pressure gauge (OPG) shows the pressure. in psi, of engine lubrication oil. When pressure switch (PSW) is closed, oil pressure gauge (OPG) is connected across battery voltage. There is a relation between the current flow in this circuit and the engine oil pressure read on oil pressure gauge (OPG). Oil pressure sender (OP) controls the current flow by a change in resistance according to the change in engine oil pressure.

### PAM Prealarm Module

Make reference to ATTACHMENTS.

### PL1,2 Panel Lamps

Light for the control panel is given by panel lamps (PL1 and PL2). These lamps are controlled by panel light switch (PLS).

**VLR Voltage Level Rheostat**

Voltage level rheostat (VLR) takes the place of voltage level rheostat (R2) on the generator regulator assembly. It is used to adjust the voltage output of the generator.

NOTE: Make reference to OPERATION OF GENERATOR; REGULATOR ADJUSTMENT. On generators equipped with a generator mounted control panel, the yellow wire from voltage level rheostat (R2) to terminal (7) on the regulator terminal strip is disconnected at terminal (7).

## AUTOMATIC START/STOP SYSTEM

### Introduction

The automatic start/stop system is normally used for standby operation. That is, without an operator. The generator set must start, pick up the load, operate the load, and stop after the load is removed. An automatic transfer switch controls the transfer of load to and from the generator set. When normal (commercial) power has a failure, initiating contactor (I), part of the automatic transfer switch, closes. This will begin the automatic start sequence. When the engine starts, the control panel instruments will show voltage and frequency. The automatic transfer switch will transfer the load to the generator set when voltage and frequency reach approximately rated value. When normal power returns, the automatic transfer switch will transfer the load back to normal power. Initiating contactor (I) will open. This will begin the automatic stop sequence. The generator set will also stop automatically if the engine has a failure.

**NOTE: For specifications on components located on the engine, make reference to the ENGINE SERVICE MANUAL.**

### Automatic Start

With engine control switch (ACS) in the AUTO position, contacts 1, 2 and 6 are closed. When commercial (normal) power has a failure, remote start initiating contact (I) closes. This makes a complete circuit from battery (BATT) to energize run relay (RR) and magnetic switch (MS).

When run relay (RR) is energized, contacts (RR2) open and contacts (RR1) close. (RR2) open prevents current flow to shutoff solenoid (SS) through pressure switch (PSW). (RR1) closed energizes dual speed switch (DSS) and overcrank timer (OCT).

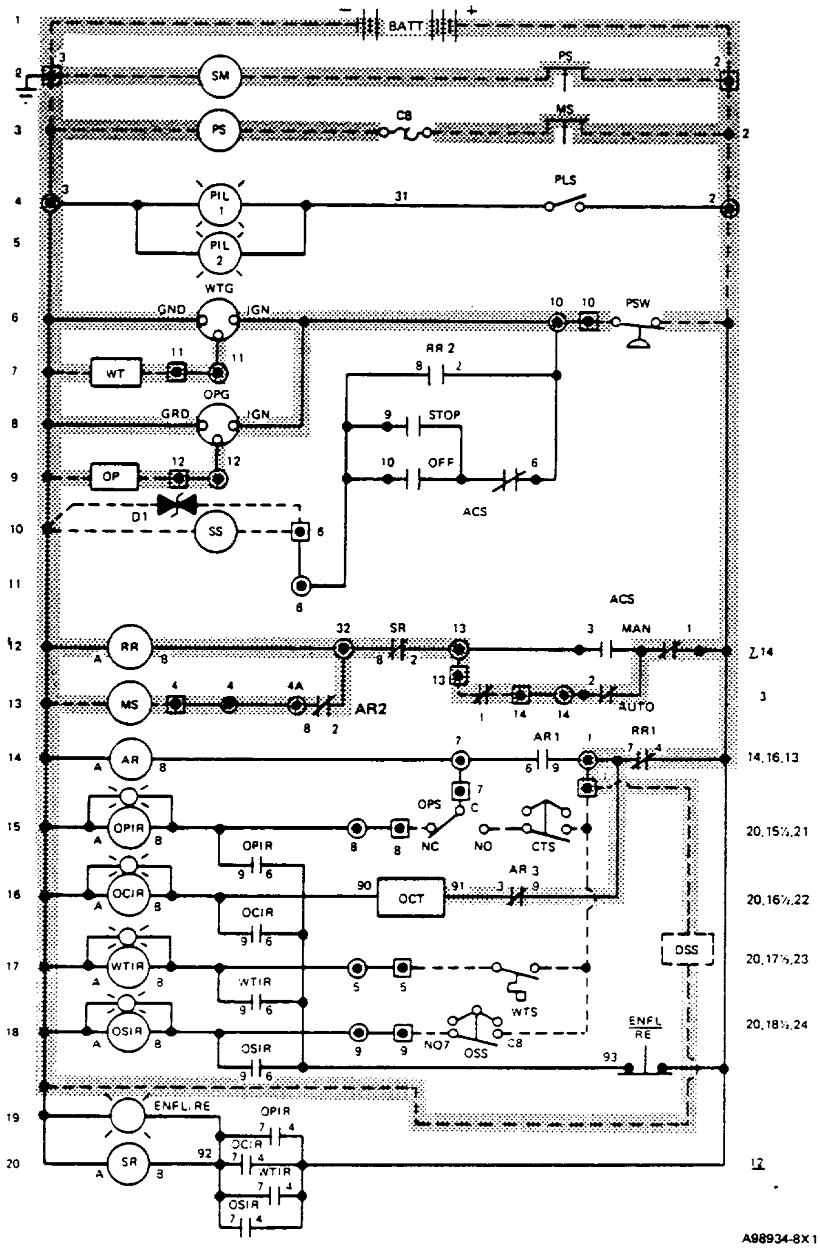
When dual speed switch (DSS) is energized, a magnetic pickup relays engine rpm to the switch. The dual speed switch has a crank terminate (CTS) circuit and an overspeed (OSS) circuit.

When overcrank timer (OCT) is energized, a timer will start. After the engine cranks for approximately 30 seconds the timer will stop. (OCT) contacts will close. Make reference to ENGINE DOES NOT START.

When magnetic switch (MS) is energized, (MS) contacts close and pinion solenoid (PS) is energized. This causes (PS) contacts to close, starting motor (SM) will crank the engine. (PSW) will close. This energizes water temperature gauge (WTG) and oil pressure gauge (OPG).

### Manual Start

The current flow for manual start is similar to automatic start except engine control switch (ACS) is turned to the MAN position. Contact (2) is open and contact (3) is closed. It is not necessary for remote start indicating contact (I) to close. Run relay (RR) and magnetic switch (MS) will energize as soon as contact (3) is closed.

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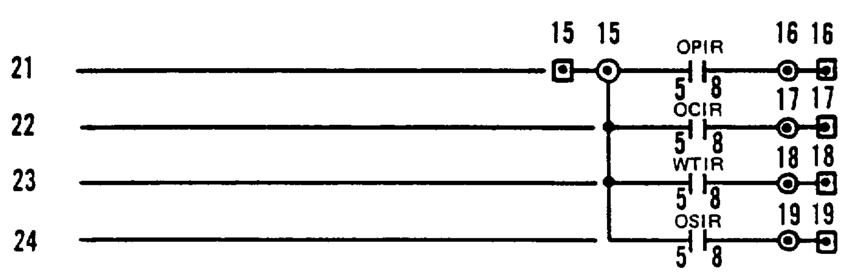


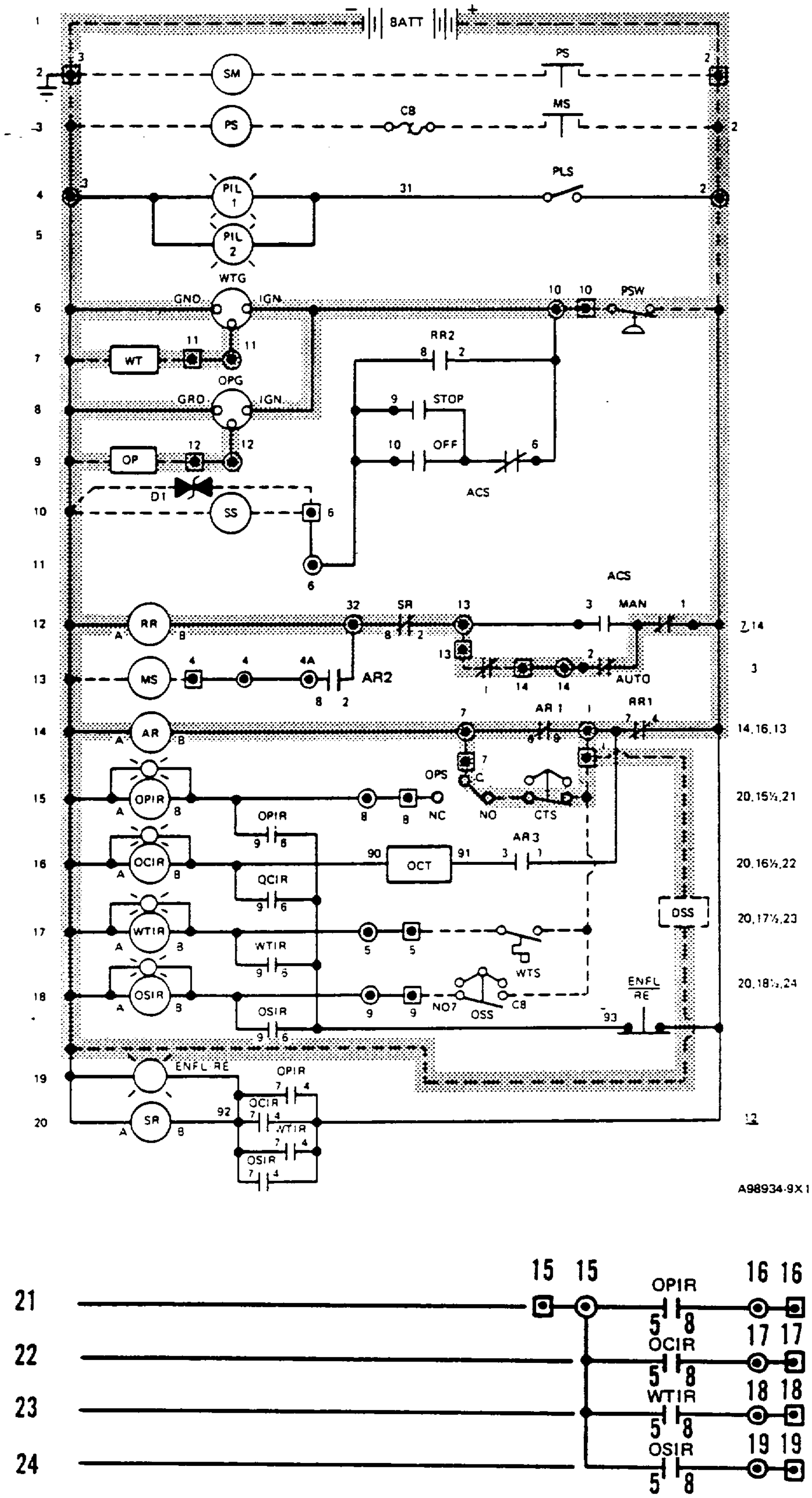

- A AMMETER
- ACS ENGINE CONTROL SWITCH
- ALT CHARGING ALTERNATOR
- AR ARMING RELAY
- ARX AUXILIARY RELAY MODULE
- BATT BATTERY
- B+ BATTERY POSITIVE
- B– BATTERY NEGATIVE
- CB CIRCUIT BREAKER
- CCM CYCLE CRANKING MODULE
- CCT CYCLE CRANK RELAY
- CRC CYCLE CRANK LOGIC TIMER
- CT CURRENT TRANSFORMER
- CTS CRANK TERMINATE SWITCH
- D DIODE
- DSS DUAL SPEED SWITCH (INCLUDES CTS AND OSS)
- ENFL ENGINE FAULT LIGHT WITH FAULT RESET FUNCTION
- GP GLOW PLUGS
- GS GOVERNOR SWITCH
- GSM GOVERNOR SYNCHRONIZING MOTOR
- HS GLOW PLUG HEAT SWITCH
- I RMEOTE START INITIATING CONTACT
- MS MAGNETIC SWITCH (CRANK CIRCUIT)
- MSG MAGNETIC SWITCH (GLOW PLUG CIRCUIT)
- OCIR OVERCRANK INDICATING RELAY
- OCT OVERCRANK TIMER
- OP OIL PRESSURE GAUGE SENDER
- OPG OIL PRESSURE GAUGE
- OPIR LOW OIL PRESSURE INDICATING RELAY
- OPS OIL PRESSURE SWITCH
- OSIR OVERSPEED INDICATING RELAY
- OSS OVERSPEED SWITCH
- PIL PANEL ILLUMINATION LAMP
- PLS PANEL LAMP SWITCH
- PS PINION SOLENOID
- PSW PRESSURE SWITCH
- RE FAULT RESET SWITCH, PART OF ENFL
- RR RUN RELAY
- SS SHUT-OFF SOLENOID
- SM STARTING MOTOR
- SR SHUTDOWN RELAY
- WT WATER TEMPERATURE GAUGE SENDER
- WTG WATER TEMPERATURE GAUGE
- WTIR HIGH WATER TEMPERATURE INDICATING RELAY
- WTS WATER TEMPERATURE SWITCH

- ⊙ TERMINAL STRIP POINT (CONTROL PANEL)
- ⊡ TERMINAL STRIP POINT (GENERATOR TERMINAL BOX)

**CONTROL PANEL**
**AUTOMATIC POSITION-ENGINE CRANKS**

### Engine Starts

At 600 rpm. crank terminate switch (CTS) closes. Oil pressure increases. This activates oil pressure switch (OPS). The normally closed contact opens and the normally open contact closes. The arming relay (AR) is now connected across battery voltage. Contacts (AR1) close and lock in the arming relay. Contacts (AR2) open. This de-energizes magnetic switch (MS). (MS) contacts open to de-energize pinion solenoid (PS). (PS) contacts open to de-energize starting motor. Contacts (AR3) open to de-energize overcrank timer (OCT).

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| | |
|---|---|
| A | AMMETER |
| ACS | ENGINE CONTROL SWITCH |
| ALT | CHARGING ALTERNATOR |
| AR | ARMING RELAY |
| ARX | AUXILIARY RELAY MODULE |
| BATT | BATTERY |
| B+ | BATTERY POSITIVE |
| B− | BATTERY NEGATIVE |
| CB | CIRCUIT BREAKER |
| CCM | CYCLE CRANKING MODULE |
| CCT | CYCLE CRANK RELAY |
| CRC | CYCLE CRANK LOGIC TIMER |
| CT | CURRENT TRANSFORMER |
| CTS | CRANK TERMINATE SWITCH |
| D | DIODE |
| DSS | DUAL SPEED SWITCH (INCLUDES CTS AND OSS) |
| ENFL | ENGINE FAULT LIGHT WITH FAULT RESET FUNCTION |
| GP | GLOW PLUGS |
| GS | GOVERNOR SWITCH |
| GSM | GOVERNOR SYNCHRONIZING MOTOR |
| HS | GLOW PLUG HEAT SWITCH |
| I | REMOTE START INITIATING CONTACT |
| MS | MAGNETIC SWITCH (CRANK CIRCUIT) |
| MSG | MAGNETIC SWITCH (GLOW PLUG CIRCUIT) |
| OCIR | OVERCRANK INDICATING RELAY |
| OCT | OVERCRANK TIMER |
| OP | OIL PRESSURE GAUGE SENDER |
| OPG | OIL PRESSURE GAUGE |
| OPIR | LOW OIL PRESSURE INDICATING RELAY |
| OPS | OIL PRESSURE SWITCH |
| OSIR | OVERSPEED INDICATING RELAY |
| OSS | OVERSPEED SWITCH |
| PIL | PANEL ILLUMINATION LAMP |
| PLS | PANEL LAMP SWITCH |
| PS | PINION SOLENOID |
| PSW | PRESSURE SWITCH |
| RE | FAULT RESET SWITCH, PART OF ENFL |
| RR | RUN RELAY |
| SS | SHUT-OFF SOLENOID |
| SM | STARTING MOTOR |
| SR | SHUTDOWN RELAY |
| WT | WATER TEMPERATURE GAUGE SENDER |
| WTG | WATER TEMPERATURE GAUGE |
| WTIR | HIGH WATER TEMPERATURE INDICATING RELAY |
| WTS | WATER TEMPERATURE SWITCH |

⊙ TERMINAL STRIP POINT (CONTROL PANEL)

⊡ TERMINAL STRIP POINT (GENERATOR TERMINAL BOX)

**CONTROL PANEL**
**AUTOMATIC POSITION-ENGINE STARTS**

**Engine Does Not Start**

If the engine does not start in approximately 30 seconds, overcrank timer (OCT) will let current flow to overcrank indicating relay (OCIR). (OCIR) contacts close and current flows to energize engine fault light (ENFL) and shutdown relay (SR).

(SR) contacts open. This de-energizes run relay (RR) and magnetic switch (MS).

When run relay (RR) is de-energized, contacts (RR2) close and contacts (RR1) open. (RR2) closed completes a circuit to shutoff solenoid (SS) until pressure switch (PSW) opens. (RR1) open de-energizes arming relay (AR), dual speed switch (DSS) and overcrank timer (OCT).

**NOTE: Pressure switch (PSW) is not always closed when the engine cranks. Pressure caused by starting motor rotation of the engine is not always enough to close (PSW).**

When magnetic switch (MS) is de-energized, (MS) contacts open. This de-energizes pinion solenoid (PS). (PS) contacts open and de-energize starting motor (SM).

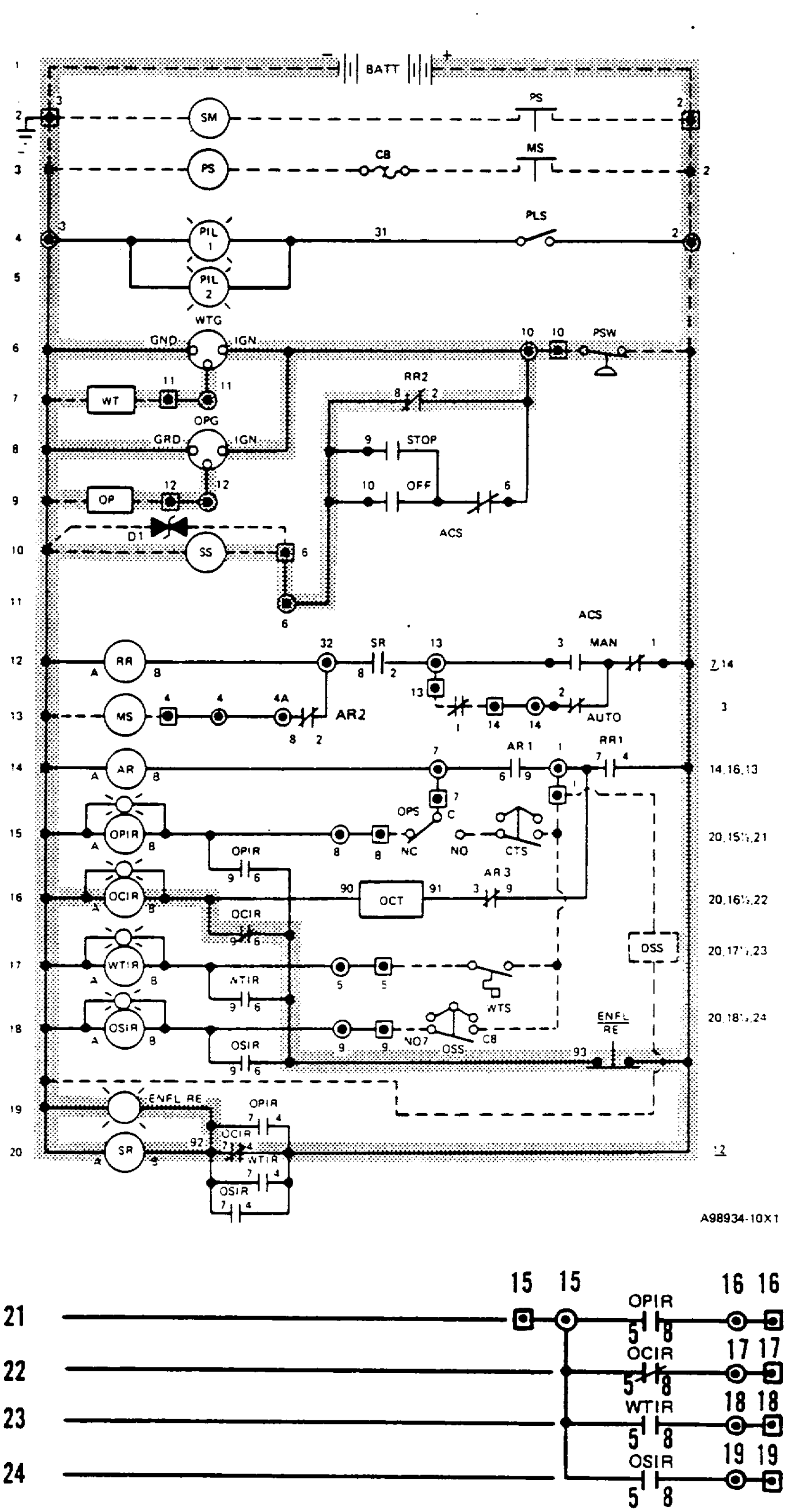
Overcrank indicating relay (OCIR) and engine fault light (ENFL) will give light. To start the engine, do the steps that follow:

1. Turn engine control switch (ACS) to OFF or STOP. This will prevent the engine from starting if (ENFL) is pushed.

2. Push and release engine fault light (ENFL). This will open (ENFL) contacts for a moment and de-energize overcrank indicating relay (OCIR). (OCIR) contacts will open and de-energize engine fault light (ENFL) and shutoff relay (SR).

3. Turn the engine control switch to AUTO. If the engine does not start in approximately 30 seconds, the overcrank indicating relay and engine fault light will give light.

4. Turn engine control switch (ACS) to OFF or STOP. Correct the problem that caused the engine not to start. Make reference to TROUBLESHOOTING.

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| | |
|---|---|
| A | AMMETER |
| ACS | ENGINE CONTROL SWITCH |
| ALT | CHARGING ALTERNATOR |
| AR | ARMING RELAY |
| ARX | AUXILIARY RELAY MODULE |
| BATT | BATTERY |
| B+ | BATTERY POSITIVE |
| B− | BATTERY NEGATIVE |
| CB | CIRCUIT BREAKER |
| CCM | CYCLE CRANKING MODULE |
| CCT | CYCLE CRANK RELAY |
| CRC | CYCLE CRANK LOGIC TIMER |
| CT | CURRENT TRANSFORMER |
| CTS | CRANK TERMINATE SWITCH |
| D | DIODE |
| DSS | DUAL SPEED SWITCH (INCLUDES CTS AND OSS) |
| ENFL | ENGINE FAULT LIGHT WITH FAULT RESET FUNCTION |
| GP | GLOW PLUGS |
| GS | GOVERNOR SWITCH |
| GSM | GOVERNOR SYNCHRONIZING MOTOR |
| HS | GLOW PLUG HEAT SWITCH |
| I | RMEOTE START INITIATING CONTACT |
| MS | MAGNETIC SWITCH (CRANK CIRCUIT) |
| MSG | MAGNETIC SWITCH (GLOW PLUG CIRCUIT) |
| OCIR | OVERCRANK INDICATING RELAY |
| OCT | OVERCRANK TIMER |
| OP | OIL PRESSURE GAUGE SENDER |
| OPG | OIL PRESSURE GAUGE |
| OPIR | LOW OIL PRESSURE INDICATING RELAY |
| OPS | OIL PRESSURE SWITCH |
| OSIR | OVERSPEED INDICATING RELAY |
| OSS | OVERSPEED SWITCH |
| PIL | PANEL ILLUMINATION LAMP |
| PLS | PANEL LAMP SWITCH |
| PS | PINION SOLENOID |
| PSW | PRESSURE SWITCH |
| RE | FAULT RESET SWITCH, PART OF ENFL |
| RR | RUN RELAY |
| SS | SHUT-OFF SOLENOID |
| SM | STARTING MOTOR |
| SR | SHUTDOWN RELAY |
| WT | WATER TEMPERATURE GAUGE SENDER |
| WTG | WATER TEMPERATURE GAUGE |
| WTIR | HIGH WATER TEMPERATURE INDICATING RELAY |
| WTS | WATER TEMPERATURE SWITCH |

| | |
|---|---|
| ⊙ | TERMINAL STRIP POINT (CONTROL PANEL) |
| ⊡ | TERMINAL STRIP POINT (GENERATOR TERMINAL BOX) |

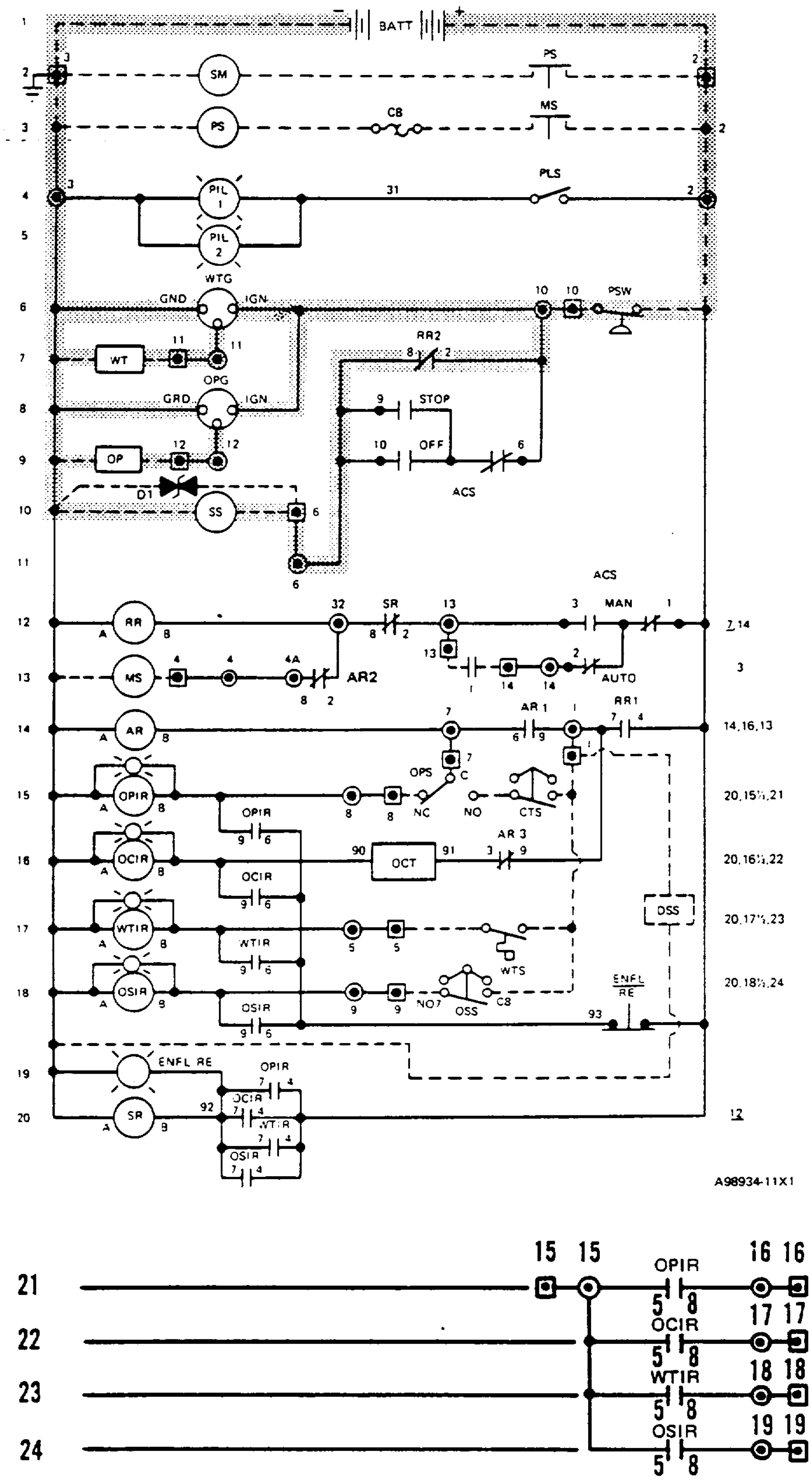
**CONTROL PANEL**
**AUTOMATIC POSITION-ENGINE DOES NOT START**

**Return of Commercial (Normal) Power**

When commercial power returns, the automatic transfer switch transfers the load to commercial power. Remote start initiating contacts (I) open. This de-energizes run relay (RR).

When run relay (RR) is de-energized, contacts (RR2) close and contacts (RR1) open. (RR2) closed completes a circuit to shut-off solenoid (SS). The shutoff solenoid moves the rack to the fuel OFF position. After the engine stops (PSW) will open to de-energize the shut-off solenoid. (RR1) open de-energizes arming relay (AR) and dual speed switch (DSS).

Diode (D1) is in the shut-off solenoid circuit to help prevent electrical sparks (arching), at the shut-off solenoid contacts, when the shut-off solenoid is deenergized.

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- **A** AMMETER
- **ACS** ENGINE CONTROL SWITCH
- **ALT** CHARGING ALTERNATOR
- **AR** ARMING RELAY
- **ARX** AUXILIARY RELAY MODULE
- **BATT** BATTERY
- **B+** BATTERY POSITIVE
- **B–** BATTERY NEGATIVE
- **CB** CIRCUIT BREAKER
- **CCM** CYCLE CRANKING MODULE
- **CCT** CYCLE CRANK RELAY
- **CRC** CYCLE CRANK LOGIC TIMER
- **CT** CURRENT TRANSFORMER
- **CTS** CRANK TERMINATE SWITCH
- **D** DIODE
- **DSS** DUAL SPEED SWITCH (INCLUDES CTS AND OSS)
- **ENFL** ENGINE FAULT LIGHT WITH FAULT RESET FUNCTION
- **GP** GLOW PLUGS
- **GS** GOVERNOR SWITCH
- **GSM** GOVERNOR SYNCHRONIZING MOTOR
- **HS** GLOW PLUG HEAT SWITCH
- **I** RMEOTE START INITIATING CONTACT
- **MS** MAGNETIC SWITCH (CRANK CIRCUIT)
- **MSG** MAGNETIC SWITCH (GLOW PLUG CIRCUIT)
- **OCIR** OVERCRANK INDICATING RELAY
- **OCT** OVERCRANK TIMER
- **OP** OIL PRESSURE GAUGE SENDER
- **OPG** OIL PRESSURE GAUGE
- **OPIR** LOW OIL PRESSURE INDICATING RELAY
- **OPS** OIL PRESSURE SWITCH
- **OSIR** OVERSPEED INDICATING RELAY
- **OSS** OVERSPEED SWITCH
- **PIL** PANEL ILLUMINATION LAMP
- **PLS** PANEL LAMP SWITCH
- **PS** PINION SOLENOID
- **PSW** PRESSURE SWITCH
- **RE** FAULT RESET SWITCH, PART OF ENFL
- **RR** RUN RELAY
- **SS** SHUT-OFF SOLENOID
- **SM** STARTING MOTOR
- **SR** SHUTDOWN RELAY
- **WT** WATER TEMPERATURE GAUGE SENDER
- **WTG** WATER TEMPERATURE GAUGE
- **WTIR** HIGH WATER TEMPERATURE INDICATING RELAY
- **WTS** WATER TEMPERATURE SWITCH

- ⊙ TERMINAL STRIP POINT (CONTROL PANEL)
- ⊡ TERMINAL STRIP POINT (GENERATOR TERMINAL BOX)

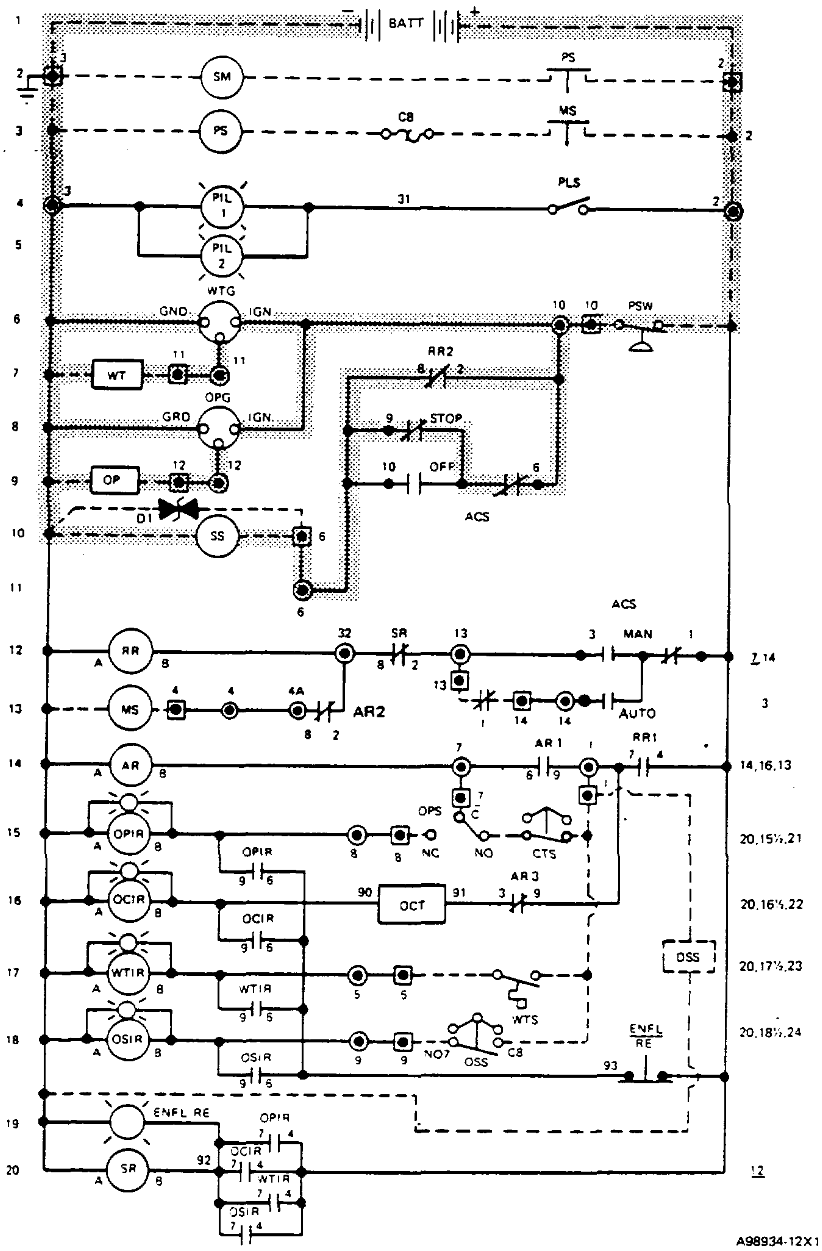
**CONTROL PANEL**
**AUTOMATIC POSITION-AUTOMATIC SHUTDOWN**

**Manual Shutdown**

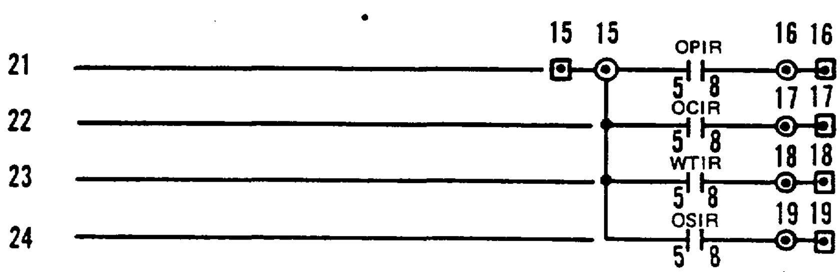
When engine control switch (ACS) is turned to the STOP or OFF position, contacts (9 or 10) close and contacts (2 and 3) are both open, no shutdown indicators can operate. (9 to 10) closed completes a circuit to shut-off solenoid (SS). The shut-off solenoid moves the rack to the fuel OFF position. (2 and 3) open deenergizes run relay (RR).

When run relay (RR) is de-energized, contacts (RR2) close and contacts (RR1) open. (RR2) closed completes a parallel circuit to shut-off solenoid (SS). This circuit is necessary to stop the engine when the engine control switch is in the AUTO or MAN position. After the engine stops, (PSW) will open to deenergize the shut-off solenoid. (RR1) open de-energizes arming relay (AR) and dual speed switch (DSS).

Diode (D1) helps prevent electrical sparks (arcing), at the contacts in the shut-off solenoid circuit when the shut-off solenoid is de-energized.




| | |
|---|---|
| A | AMMETER |
| ACS | ENGINE CONTROL SWITCH |
| ALT | CHARGING ALTERNATOR |
| AR | ARMING RELAY |
| ARX | AUXILIARY RELAY MODULE |
| BATT | BATTERY |
| B+ | BATTERY POSITIVE |
| B− | BATTERY NEGATIVE |
| CB | CIRCUIT BREAKER |
| CCM | CYCLE CRANKING MODULE |
| CCT | CYCLE CRANK RELAY |
| CRC | CYCLE CRANK LOGIC TIMER |
| CT | CURRENT TRANSFORMER |
| CTS | CRANK TERMINATE SWITCH |
| D | DIODE |
| DSS | DUAL SPEED SWITCH (INCLUDES CTS AND OSS) |
| ENFL | ENGINE FAULT LIGHT WITH FAULT RESET FUNCTION |
| GP | GLOW PLUGS |
| GS | GOVERNOR SWITCH |
| GSM | GOVERNOR SYNCHRONIZING MOTOR |
| HS | GLOW PLUG HEAT SWITCH |
| I | RMEOTE START INITIATING CONTACT |
| MS | MAGNETIC SWITCH (CRANK CIRCUIT) |
| MSG | MAGNETIC SWITCH (GLOW PLUG CIRCUIT) |
| OCIR | OVERCRANK INDICATING RELAY |
| OCT | OVERCRANK TIMER |
| OP | OIL PRESSURE GAUGE SENDER |
| OPG | OIL PRESSURE GAUGE |
| OPIR | LOW OIL PRESSURE INDICATING RELAY |
| OPS | OIL PRESSURE SWITCH |
| OSIR | OVERSPEED INDICATING RELAY |
| OSS | OVERSPEED SWITCH |
| PIL | PANEL ILLUMINATION LAMP |
| PLS | PANEL LAMP SWITCH |
| PS | PINION SOLENOID |
| PSW | PRESSURE SWITCH |
| RE | FAULT RESET SWITCH, PART OF ENFL |
| RR | RUN RELAY |
| SS | SHUT-OFF SOLENOID |
| SM | STARTING MOTOR |
| SR | SHUTDOWN RELAY |
| WT | WATER TEMPERATURE GAUGE SENDER |
| WTG | WATER TEMPERATURE GAUGE |
| WTIR | HIGH WATER TEMPERATURE INDICATING RELAY |
| WTS | WATER TEMPERATURE SWITCH |

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| | |
|---|---|
| ⊙ | TERMINAL STRIP POINT (CONTROL PANEL) |
| ⊡ | TERMINAL STRIP POINT (GENERATOR TERMINAL BOX) |

CONTROL PANEL
STOP POSITION-MANUAL SHUTDOWN

### Shutdown Caused by Engine Failure

The packaged generator set has shutdown sensors, shutdown indicators and shutdown circuit for the conditions that follow.

1. Low oil pressure
2. High water temperature
3. Overspeed
4. Overcrank.

For information about overcrank shutdown, make reference to ENGINE DOES NOT START.

Conditions (1, 2 or 3) will energize its respective indicating relay. The number (2) contacts of the respective relay will close to energize engine fault light (ENFL) and shut-off relay (SR). The number (1) contacts of the respective relay will close to lock in the relay.

When shutdown relay (SR) is energized, (SR) contacts open. This de-energizes run relay (RR). Contacts (RR2) close and contacts (RR1) open. (RR2) closed completes a circuit to shut-off solenoid (SS) until pressure switch (PSW) opens. (RR1) open de-energizes arming relay (AR) and dual speed switch (DSS).

Diode (D1) helps prevent electrical sparks (arcing) at the contacts in the shut-off solenoid circuit, when the shut-off solenoid is de-energized.

Engine fault light (ENFL) and the indicating relay for the fault condition will give light. To start the engine, do the steps that follow.

1. Turn engine control switch (ACS) to OFF or STOP.

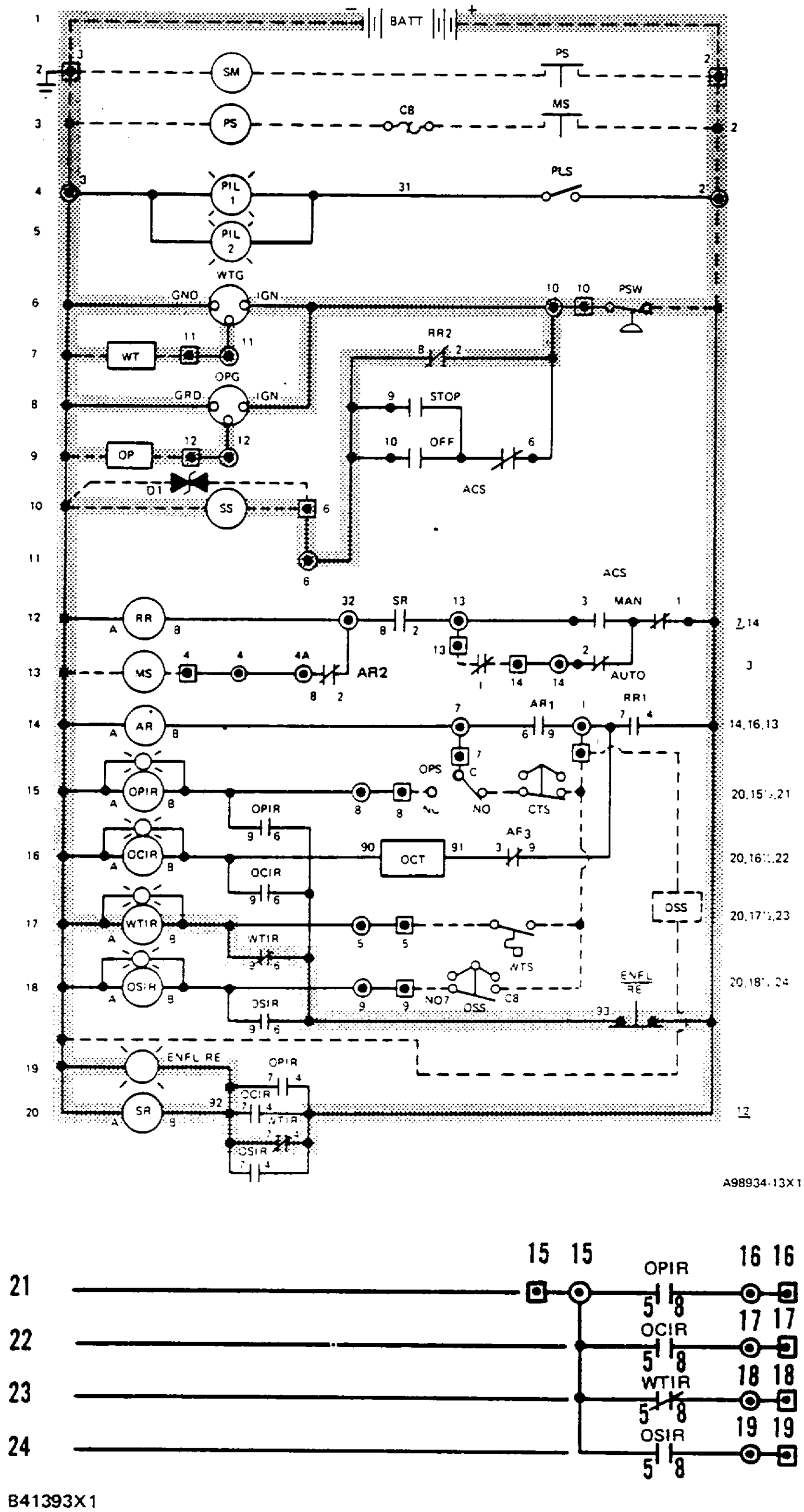
This will prevent the engine from starting it (ENFL) is pushed.

**NOTE: For start up when (OCIR) indicating relay gives light, make reference to ENGINE DOES NOT START.**

2. Correct the problem that caused the engine to shutdown.

3. Push and release engine fault light (ENFL). This will open (ENFL) contacts for a moment and deenergize the indicating relay. The indicating relay contacts will open and de-energize engine fault light (ENFL) and shutdown relay (SR).

**NOTE: Reset oil pressure or overspeed switch if necessary. The system is ready to start if engine control switch (ACS) is turned to MAN or AUTO.**




- **A** AMMETER
- **ACS** ENGINE CONTROL SWITCH
- **ALT** CHARGING ALTERNATOR
- **AR** ARMING RELAY
- **ARX** AUXILIARY RELAY MODULE
- **BATT** BATTERY
- **B+** BATTERY POSITIVE
- **B−** BATTERY NEGATIVE
- **CB** CIRCUIT BREAKER
- **CCM** CYCLE CRANKING MODULE
- **CCT** CYCLE CRANK RELAY
- **CRC** CYCLE CRANK LOGIC TIMER
- **CT** CURRENT TRANSFORMER
- **CTS** CRANK TERMINATE SWITCH
- **D** DIODE
- **DSS** DUAL SPEED SWITCH (INCLUDES CTS AND OSS)
- **ENFL** ENGINE FAULT LIGHT WITH FAULT RESET FUNCTION
- **GP** GLOW PLUGS
- **GS** GOVERNOR SWITCH
- **GSM** GOVERNOR SYNCHRONIZING MOTOR
- **HS** GLOW PLUG HEAT SWITCH
- **I** RMEOTE START INITIATING CONTACT
- **MS** MAGNETIC SWITCH (CRANK CIRCUIT)
- **MSG** MAGNETIC SWITCH (GLOW PLUG CIRCUIT)
- **OCIR** OVERCRANK INDICATING RELAY
- **OCT** OVERCRANK TIMER
- **OP** OIL PRESSURE GAUGE SENDER
- **OPG** OIL PRESSURE GAUGE
- **OPIR** LOW OIL PRESSURE INDICATING RELAY
- **OPS** OIL PRESSURE SWITCH
- **OSIR** OVERSPEED INDICATING RELAY
- **OSS** OVERSPEED SWITCH
- **PIL** PANEL ILLUMINATION LAMP
- **PLS** PANEL LAMP SWITCH
- **PS** PINION SOLENOID
- **PSW** PRESSURE SWITCH
- **RE** FAULT RESET SWITCH, PART OF ENFL
- **RR** RUN RELAY
- **SS** SHUT-OFF SOLENOID
- **SM** STARTING MOTOR
- **SR** SHUTDOWN RELAY
- **WT** WATER TEMPERATURE GAUGE SENDER
- **WTG** WATER TEMPERATURE GAUGE
- **WTIR** HIGH WATER TEMPERATURE INDICATING RELAY
- **WTS** WATER TEMPERATURE SWITCH

- ⊙ TERMINAL STRIP POINT (CONTROL PANEL)
- ⊡ TERMINAL STRIP POINT (GENERATOR TERMINAL BOX)

**CONTROL PANEL AUTOMATIC POSITION-SHUTDOWN (HIGH WATER TEMPERATURE)**

*C*

## GENERATOR MOUNTED CONTROL PANEL
## (TYPE 4 - CHANGE LEVEL 9 THRU 11)

### INTRODUCTION

The uses of the generator mounted control panel are:

To help control the electric power made by the generator set.

To monitor (check) the operation of the generator set.

To help protect the generator set from damage caused by low oil pressure, high coolant temperature, overspeed and overcrank.

To help with the transfer of electrical load to and from the generator set.

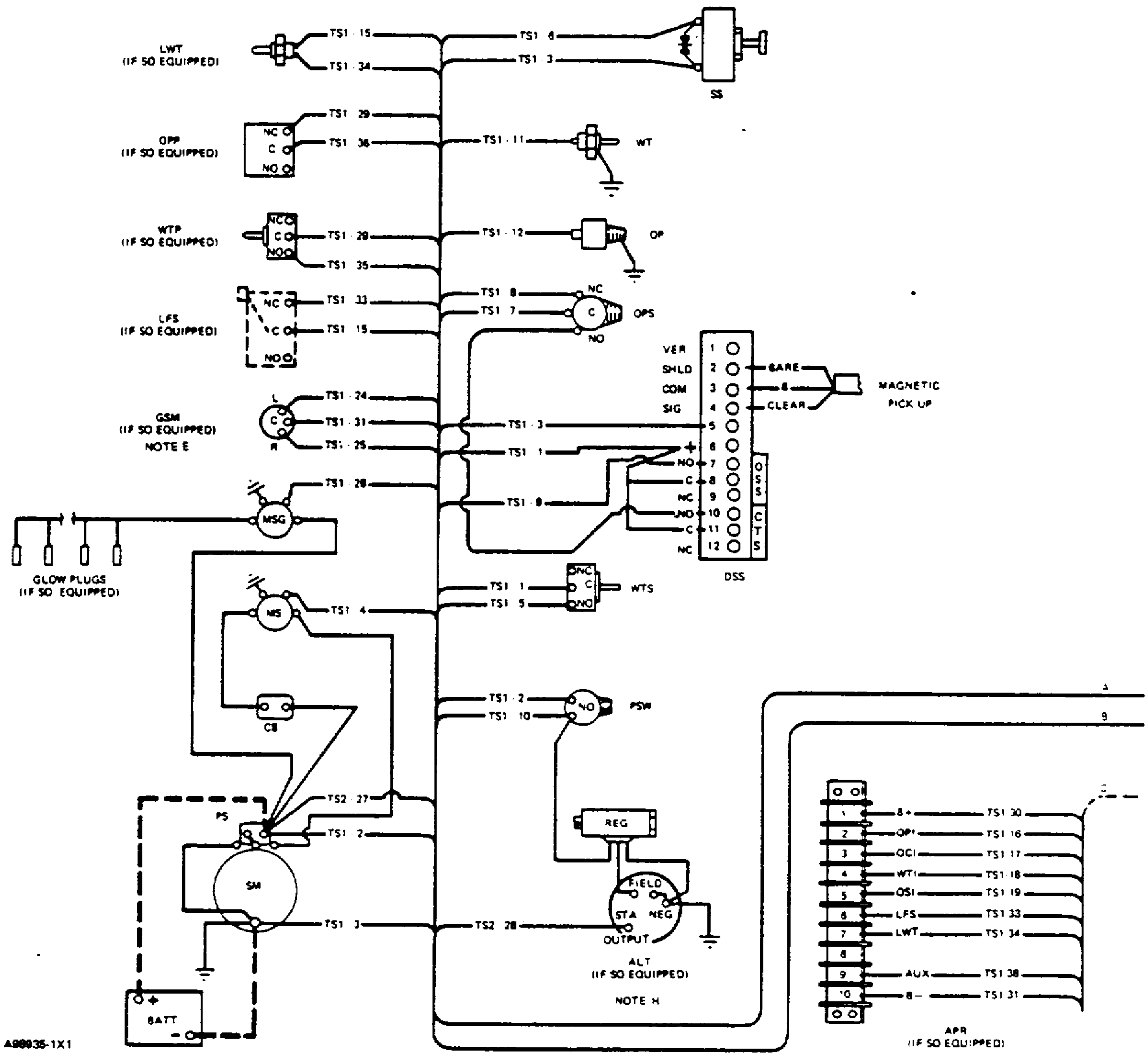
To help parallel two or more units onto the same bus.

### IDENTIFICATION

The location of the control panel is on the top of the regulator housing. This panel has a place for a heat switch and Prealarm module. The shutdown indicators are relay lamp type. The control panel has either a 12 or 13 place model number on the panel nameplate. The model number gives an indication of the control panel component part numbers. Make reference to the Parts Book, GENERATOR MOUNTED CONTROL PANEL, Form No. SEBP1068. The last digit (or two digits) of the model number is the change level to which the panel was built.

### WIRING

See the pages that follow for wiring diagrams, schematics and photographs for identification.


LWT
(IF SO EQUIPPED)
OPP
(IF SO EQUIPPED)
WTP
(IF SO EQUIPPED)
LFS
(IF SO EQUIPPED)
GSM
(IF SO EQUIPPED)
NOTE E
GLOW PLUGS
(IF SO EQUIPPED)
SS
WT
OP
OPS
PSW
WTS
MSG
MS
CS
PS
SM
BATT
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NOTE H
VER
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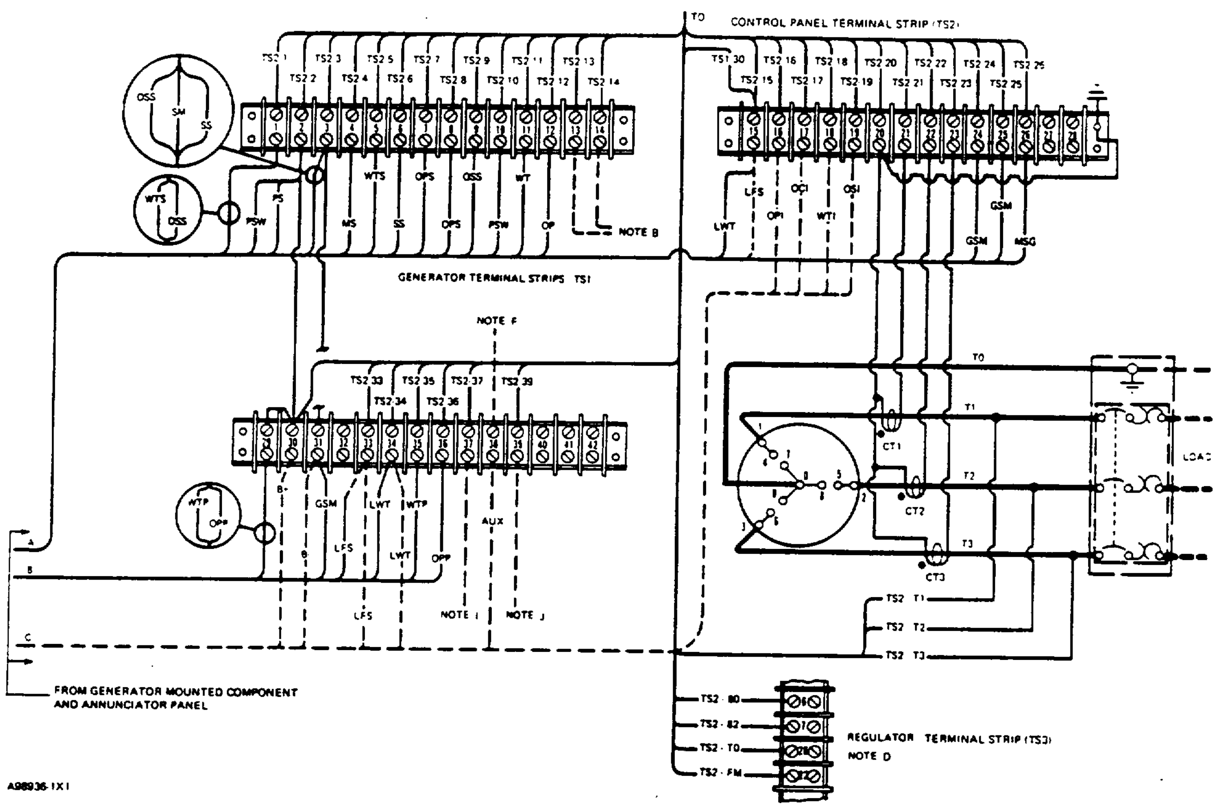
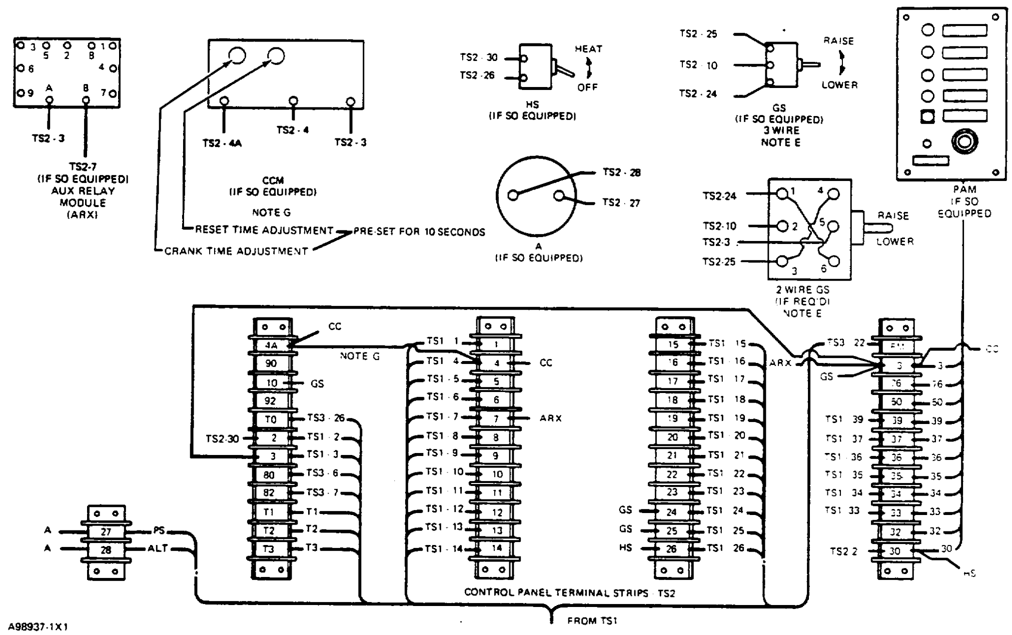



**GENERATOR TERMINAL STRIP TS1, REGULATOR TERMINAL STRIP TS3. GENERATOR, CURRENT TRANSFORMERS AND CIRCUIT BREAKER**

| | |
|---|---|
| A | AMMETER (CONTROL PANEL MOUNTED) |
| ALT | CHARGING ALTERNATOR (NOTE H) |
| APR | ANNUNCIATOR PANEL - REMOTE |
| ARX | AUXILIARY RELAY MODULE (CONTROL PANEL MOUNTED) |
| AUX | AUXILIARY CONTACT (NOTE F) |
| B- | BATTERY POSITIVE |
| B- | BATTERY NEGATIVE |
| BATT | BATTERY |
| CB | CIRCUIT BREAKER |
| CCM | CYCLE CRANKING MODULE (CONTROL PANEL MOUNTED) |
| CT | CURRENT TRANSFORMER |
| CTS | CRANK TERMINATE SWITCH |
| DSS | DUAL SPEED SWITCH |
| GS | GOVERNOR SWITCH (CONTROL PANEL MOUNTED) |
| GSM | GOVERNOR SYNC MOTOR |
| HS | HEAT SWITCH (CONTROL PANEL MOUNTED) |
| LFS | LOW FUEL LEVEL SWITCH |
| LWT | LOW WATER TEMP SWITCH |
| MS | MAGNETIC SWITCH (CRANK CIRCUIT) |
| MS | MAGNETIC SWITCH (GLOW PLUG CIRCUIT) |
| OCI | OVERCRANK INDICATOR |
| OP | OIL PRESSURE GAUGE SENDER |
| OPI | LOW OIL PRESSURE INDICATOR |
| OPP | OIL PRESSURE SWITCH (PRE-ALARM) |
| OPS | OIL PRESSURE SWITCH (SHUTDOWN) |
| OSI | OVERSPEED INDICATOR |
| OSS | OVERSPEED SWITCH (SHUTDOWN) |
| PAM | PREALARM MODULE (CONTROL PANEL MOUNTED) |
| PS | PINION SOLENOID |
| PSW | PRESSURE SWITCH |
| SS | SHUTOFF SOLENOID |
| SM | STARTING MOTOR |
| TS | TERMINAL STRIP |
| WT | WATER TEMPERATURE GAGE SENDER |
| WTI | HIGH WATER TEMPERATURE INDICATOR |
| WTP | WATER TEMPERATURE SWITCH (PRE-ALARM) |
| WTS | WATER TEMPERATURE SWITCH (SHUTDOWN) |



CONTROL PANEL COMPONENTS (PARTIAL) AND CONTROL PANEL TERMINAL STRIP TS2

**NOTE A:** Wire and cable shown dotted to be furnished by customer.

**NOTE B:** To be wired to engine starting contact (N.O.) in auto transfer switch by customer.

**NOTE C:** Each wire on terminal strip is identified on each end corresponding to terminal strip number.

**NOTE D:** Remove yellow wire and insulate from terminal 7 at TS3 before connecting wire from TS2.

**NOTE E:** Use 3 wire diagram with sodine 3 wire synchronizing motor. Use 2 wire diagram with 2 wire permanent magnet motor.

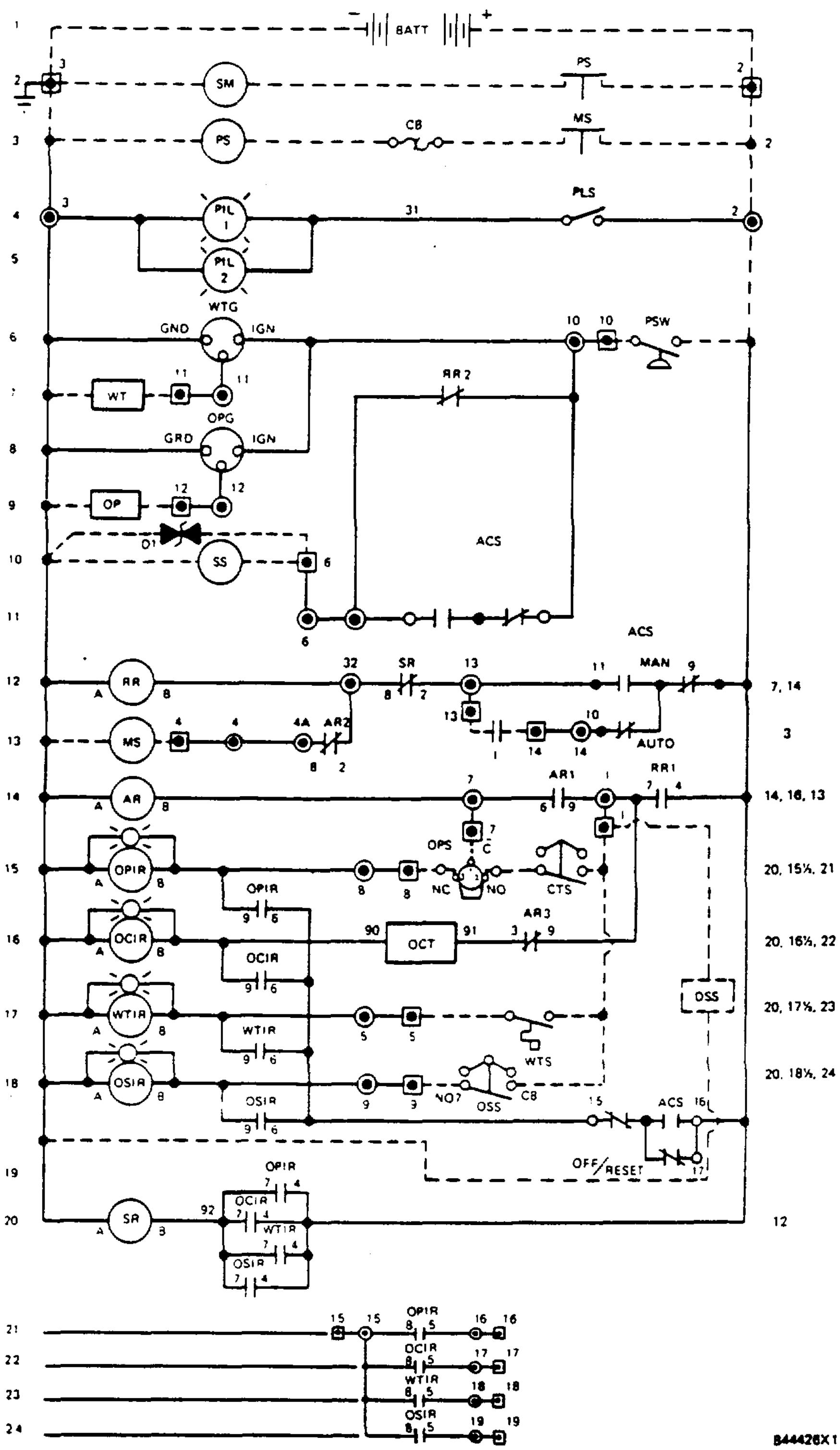
**NOTE F:** To be wired to auxiliary contact (N.O.) on emergency side of transfer switch. Req'd only when optional generator set Annunciator panel (remote) is provided. (generating indication).

**NOTE G:** Red jumper wire from TS2-4A to TS2-4 must be removed when cycle cranking module is used.

**NOTE H:** Do not operate alternator without a battery connected in the system. Do not polarize alternator. Do not operate alternator simultaneously with a DC generator to charge a common battery.

**NOTE I:** Provide 24 volts for remote low oil pressure (pre-alarm) (OPP) indication when pre-alarm module is used.

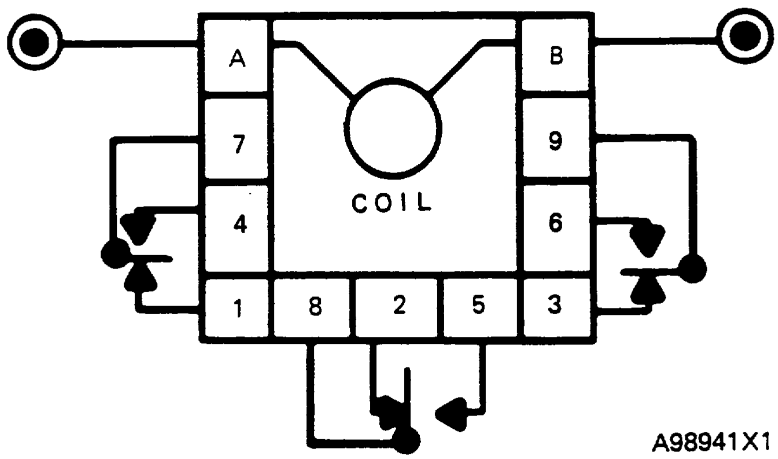
**NOTE J:** Provides 24V for customer provided remote shutdown and pre-alarm indicator when pre-alarm module is used.



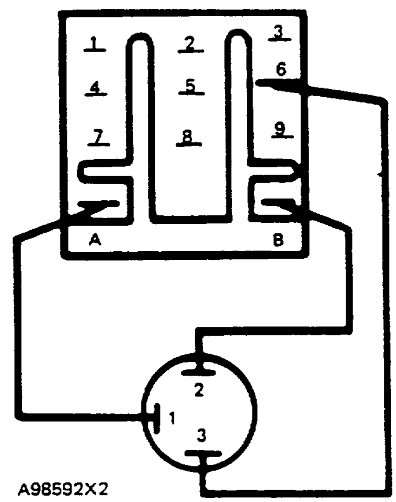

ADC AMMETER
ACS ENGINE CONTROL SWITCH
ALT CHARGING ALTERNATOR
AR ARMING RELAY
ARX AUXILIARY RELAY MODULE
BATT BATTERY
CB CIRCUIT BREAKER
CCM CYCLE CRANKING MODULE
CCT CYCLE CRANK RELAY
CDT COOL DOWN TIMER
CDTR COOL DOWN TIMER RELAY
CRC CYCLE CRANK LOGIC TIMER
CTS CRANK TERMINATE SWITCH
D DIODE
DSS DUAL SPEED SWITCH (INCLUDES CTS AND OSS)
GP GLOW PLUGS
GS GOVERNOR SWITCH
GSM GOVERNOR SYNCHRONIZING MOTOR
HS GLOW PLUG HEAT SWITCH
I REMOTE START INITIATING CONTACT
MS MAGNETIC SWITCH (CRANK CIRCUIT)
MSG MAGNETIC SWITCH (GLOW PLUG CIRCUIT)
OCIR OVERCRANK INDICATING RELAY
OCT OVERCRANK TIMER
OP OIL PRESSURE GAUGE SENDER
OPG OIL PRESSURE GAUGE
OPIR LOW OIL PRESSURE INDICATOR RELAY
OPS OIL PRESSURE SWITCH
OSIR OVERSPEED INDICATING RELAY
OSS OVERSPEED SWITCH
PIL PANEL ILLUMINATION LAMP
PLS PANEL LAMP SWITCH
PS PINION SOLENOID
PSW PRESSURE SWITCH
RR RUN RELAY
SS SHUT-OFF SOLENOID
SM STARTING MOTOR
SR SHUTDOWN RELAY
WT WATER TEMPERATURE GAUGE SENDER
WTG WATER TEMPERATURE GAUGE
WTIR HIGH WATER TEMPERATURE INDICATING RELAY
WTS WATER TEMPERATURE SWITCH

⊙ TERMINAL STRIP POINT (CONTROL PANEL)
⊡ TERMINAL STRIP POINT (GENERATOR TERMINAL BOX)

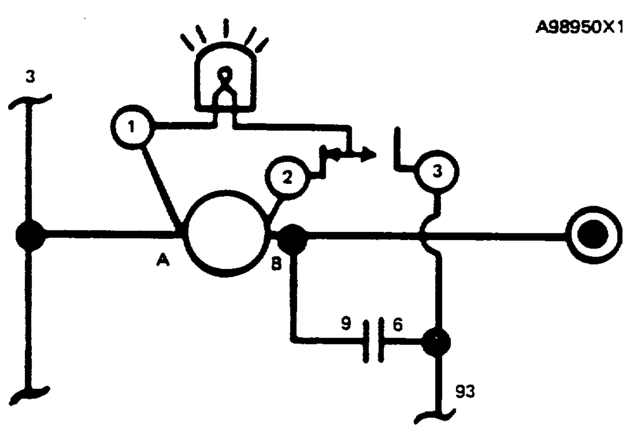
CONTROL PANEL
AUTOMATIC POSITION




RELAY CONTACT SCHEMATIC



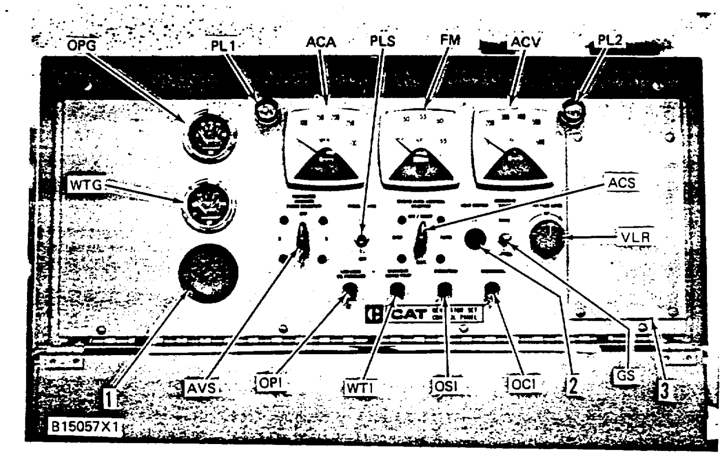

RELAY LAMP COMPONENT WIRING




RELAY LAMP SCHEMATIC

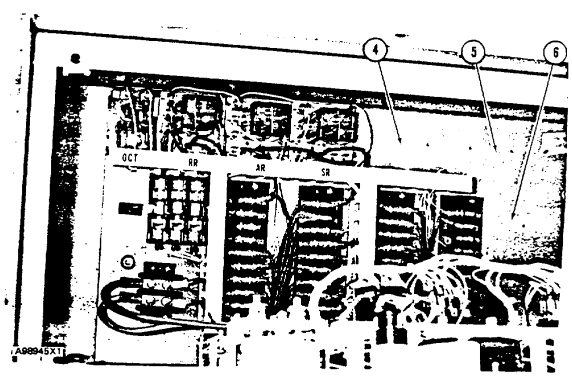
## COMPONENTS

**NOTE: For specifications on components located on the engine, make reference to the ENGINE SERVICE MANUAL.**




**CONTROL PANEL (TYPE 4 - CHANGE LEVEL 9 THRU 11)**

| | |
|---|---|
| ACA | Alternating current ammeter |
| ACS | Engine control switch |
| ACV | Alternating current voltmeter |
| AVS | Ammeter/voltage selector switch |
| FM | Frequency meter |
| PL1,2 | Panel lamps |
| PLS | Panel lamp switch |
| OCI | Overcrank indicator |
| OPG | Oil pressure gauge |
| OPI | Oil pressure indicator |
| OSI | Overspeed indicator |
| WTG | Water temperature gauge |
| WTI | Water temperature indicator |
| VLR | Voltage level rheostat |
| 1. | Button (Direct current ammeter DCA) |
| 2 | Button (heat switch HS, if so equipped) |
| 3. | Panel (Prealarm module PAM, if so equipped) |



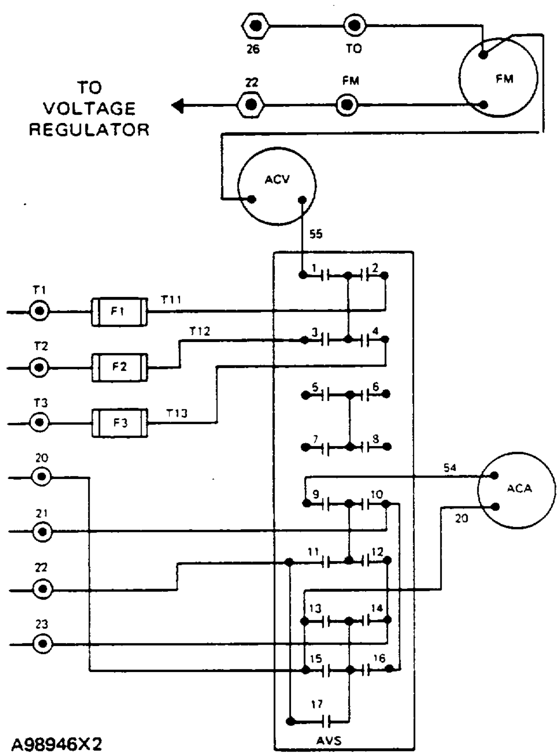

**INSIDE CONTROL PANEL**
**(TYPE 4 - CHANGE LEVEL 9 THRU 11)**

**4. Location for CDT (cool down timer, if so equipped). 5. Location for AUX (auxiliary relay, if so equipped). 6. Location for CCM (cycle crank module, if so equipped).**

## ACA Alternating Current Ammeter

AC ammeter (ACA) gives an indication. in amperes, of the current from each phase of the generator to the load. Ammeter/ voltmeter selector switch (AVS) is used to connect the ammeter to the current transformer on phase T1, T2 or T3; see Contact Chart. Ammeters normally have an input range from 0 to 5 amperes. Current transformer (CT1, CT2 or CT3) causes a reduction of the actual line current. in its respective phase lead. to a level within the input range of the ammeter. The ammeter is calibrated (has marks) to give an indication of the actual current flow in one phase load of the generator.

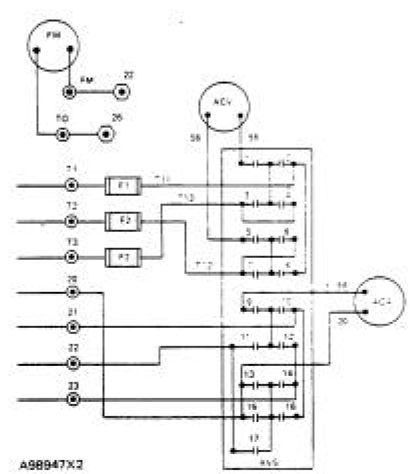
**NOTE: Several methods have been used to connect control panel instruments. The recommended method is shown in the diagrams.**




**(600V Control Panel Only)**

| | CONTACT CHART FOR AVS | | | |
|---|---|---|---|---|
| | PHASES | | | |
| CONTACT | OFF | 1 (T1) | 2 (T2) | 3 (T3) |
| 1 | X | X | X | X |
| 2 | | X | | |
| 3 | | | X | |
| 4 | | | | X |
| 5 | X | X | X | X |
| 6 | | X | | |
| 7 | | | X | |
| 8 | | | | X |
| 9 | X | X | X | X |
| 10 | | X | | |
| 11 | | | X | |
| 12 | | | | X |
| 13 | X | | | |
| 14 | X | X | X | |
| 15 | | X | X | X |
| 16 | X | | X | X |
| 17 | X | X | | X |

**NOTE: X gives an indication of a closed contact. X on the line gives an indication of "make before break."**



A98947X2

### AMMETER/VOLTMETER SELECTOR SWITCH (AVS) WIRING DIAGRAMS

**ACA** Alternating current ammeter
**ACV** Alternating current voltmeter
**F1,2,3** Fuses
**FM** Frequency meter

○ **Terminal point on TS2 in control panel**
⬡ **Terminal Point on TS3 part of voltage regulator**

## ACS Engine Control Switch

Engine control switch (ACS) controls the engine start and stop systems. To start the engine, move the switch to the MANUAL position. To stop the engine move the switch to the STOP or OFF/ RESET position. For standby application (engine starts when remote initiating contact I closes), move the switch to the AUTO position. To start after engine shutdown caused by high water temperature, low oil pressure or overspeed, turn switch to STOP position and correct fault. Then move switch to OFF/ RESET position. Engine can now be started in MANUAL or AUTO position. For more information on the operation of this switch, make reference to the AUTOMATIC START/STOP SYSTEM.

CONTACT CHART FOR ACS

| CONTACT | | OFF-RESET | | AUTO | | MAN | | STOP | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | | X | | X | | X | | X | |
| 2 | | | | X | | | | | |
| 3 | | | | | | X | | | |
| 4 | | | | | | | | X | |
| 5 | | X | | X | | X | | X | |
| 6 | | | | X | | | | | |
| 7 | | | | | | X | | | |
| 8 | | | | | | | | X | |
| 9 | | X | X | X | X | X | X | X | X |
| 10 | | | X | X | X | | | | |
| 11 | | | | | X | X | X | | |
| 12 | | | | | | | X | X | X |
| 13 | X | X | X | | | | | | |
| 14 | X | X | X | X | X | X | X | | |
| 15 | | | X | X | X | X | X | X | X |
| 16 | X | X | X | | X | X | X | X | X |
| 17 | X | X | X | X | X | | X | X | X |

**NOTE: X gives an indication of a closed contact, X on the line gives an indication of "make before break."**

## ACV Alternating Current Voltmeter

AC voltmeter (ACV) shows the potential differential (voltage) between phase T1 -T2, T2-T3 or T3-T1 at position 1, 2 or 3 respectively. Make reference to the ALTERNATING CURRENT AMMETER.

## DCA Direct Current Ammeter

DC Ammeter (DCA) is used in place of button (1) when the ammeter is ordered. This ammeter shows the amount of DC current in amperes, that flows in the alternator circuit (if so equipped).

## FM Frequency Meter

Frequency meter (FM) shows the hertz (cycles per second) of the electricity made when the generator set is in operation. There is a direct relation between the frequency of the electricity and the rpm of the generator set; see formula.

$$\text{frequency (hertz)} = \frac{\text{number of poles} \times \text{rpm}}{120}$$

## GS Governor Switch

Governor switch (GS) is used when the engine is equipped with a remote control synchronizing motor for the governor. Engine speed is controlled with this switch.

## HS Heat Switch

Heat switch (HS) is in place of button (2) when the engine is equipped with glow plugs. This switch is used to operate the glow plugs for cold weather starting.

## OPG Oil Pressure Gauge

Oil pressure gauge (OPG) shows the pressure, in psi, of engine lubrication oil. When pressure switch (PSW) is closed, oil pressure gauge (OPG) is connected across battery voltage. There is a relation between the current flow in this circuit and the engine oil pressure read on oil pressure gauge (OPG). Oil pressure sender (OP) controls the current flow by a change in resistance according to the change in engine oil pressure.

## PAM Prealarm Module

Make reference to ATTACHMENTS.

## PL1, 2 Panel Lamps

Light for the control panel is given by panel lamps (PL1 and PL2). These lamps are controlled by panel light switch (PLS).

## VLR Voltage Level Rheostat

Voltage level rheostat (VLR) takes the place of voltage level rheostat (R2) on the generator regulator assembly. It is used to adjust the voltage output of the generator.

**NOTE: Make reference to OPERATION OF GENERATOR; REGULATOR ADJUSTMENT. On generators equipped with a generator mounted control panel, the yellow wire from voltage level rheostat (R2) to terminal (7) on the regulator terminal strip is disconnected at terminal (7).**

# AUTOMATIC START/STOP SYSTEM

## AUTOMATIC START/STOP SYSTEM

### Introduction

The automatic start stop system is normally used for standby operation. That is. without an operator. The generator set must start, pick up the load. operate the load, and stop after the load is removed. An automatic transfer switch controls the transfer of load to and from the generator set. When normal (commercial) power has a failure. initiating contactor (1). part of the automatic transfer switch. closes. This will begin the automatic start sequence. When the engine starts, the control panel instruments will show voltage and frequency. The automatic transfer switch will transfer the load to the generator set when voltage and frequency reach approximately rated value. When normal power returns. the automatic transfer switch will transfer the load back to normal power. Initiating contactor (I) will open. This will begin the automatic stop sequence. The generator set will also stop automatically if the engine has a failure.

**NOTE: For specifications on components located on the engine, make reference to the ENGINE SERVICE MANUAL.**

### Automatic Start

With engine control switch (ACS) in the AUTO position. contacts (10) and (9) are closed. When commercial (normal) power has a failure. remote start initiating contact (I) closes. This makes a complete circuit from battery (BATT) to energize run relay (RR) and magnetic switch (MS).

When run relay (RR) is energized, contacts RR2) open and contacts (RR1) close. (RR2) open prevents current flow to shutoff solenoid (SS) through pressure switch (PSW). (RR1) closed energizes dual speed switch (DSS) and overcrank timer (OCT).

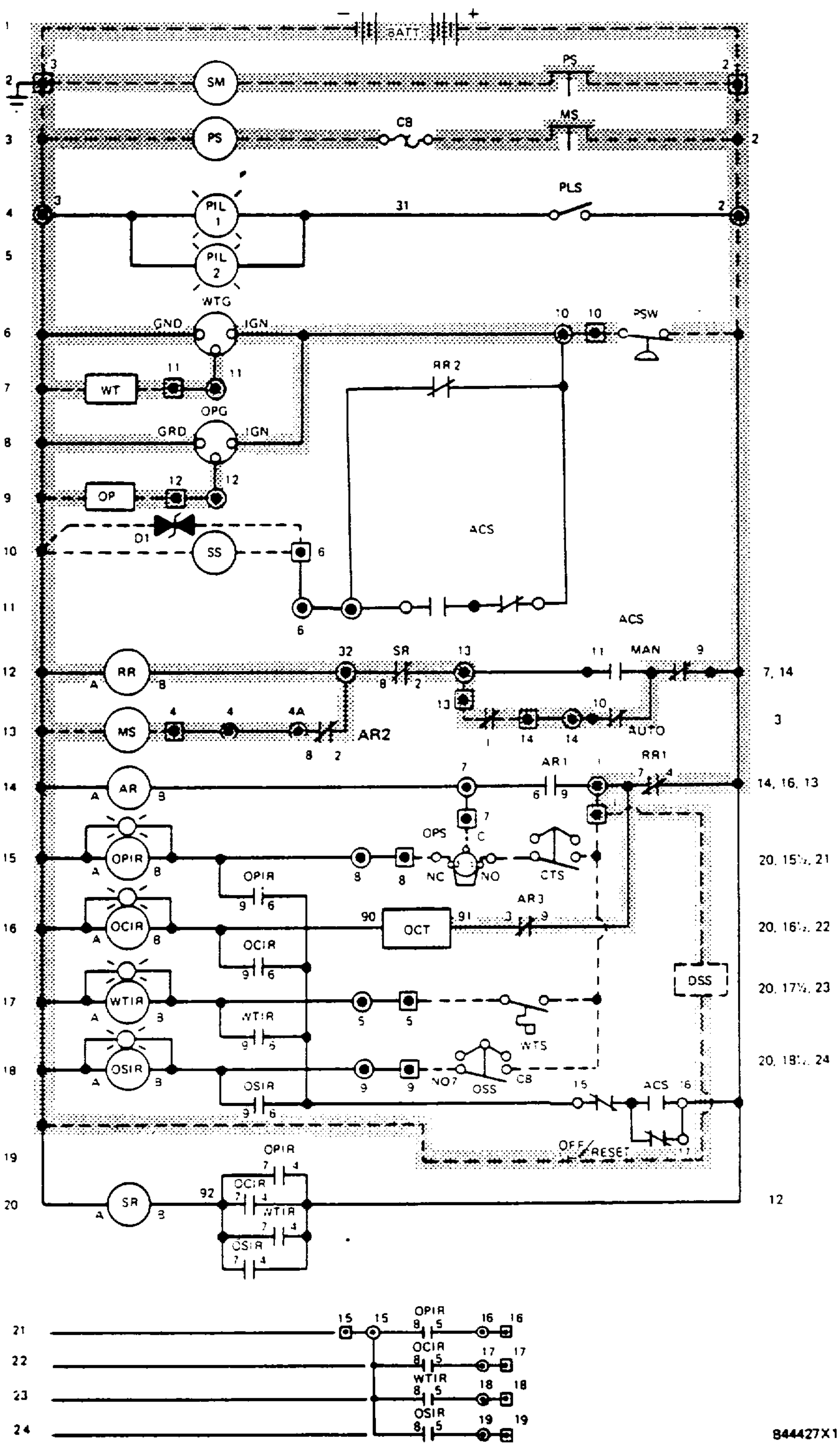
When dual speed switch (DSS) is energized, a magnetic pickup relays engine rpm to the switch. The dual speed switch has a crank terminate (CTS) circuit and an overspeed (OSS) circuit.

When overcrank timer(OCT) is energized. a timer will start. After the engine cranks for approximately 30 seconds the timer will stop. (OCT) contacts will close. Make reference to ENGINE DOES NOT START.

When magnetic switch (MS) is energized. (MS) contacts close and pinion solenoid (PS) is energized. This causes (PS) contacts to close. starting motor (SM) will crank the engine. (PSW) will close. This energizes water temperature gauge (\WTG) and oil pressure gauge (OPG).

### Manual Start

The current flow for manual start is similar to automatic start except engine control switch (ACS) is turned to the MAN position. Contact (10) is open and contact (11) is closed. It is not necessary for remote start indicating contact (I) to close. Run relay (RR) and magnetic switch (MS) will energize as soon as contact (11) is closed.




| | |
|---|---|
| ADC | AMMETER |
| ACS | ENGINE CONTROL SWITCH |
| ALT | CHARGING ALTERNATOR |
| AR | ARMING RELAY |
| ARX | AUXILIARY RELAY MODULE |
| BATT | BATTERY |
| CB | CIRCUIT BREAKER |
| CCM | CYCLE CRANKING MODULE |
| CCT | CYCLE CRANK RELAY |
| CDT | COOL DOWN TIMER |
| CDTR | COOL DOWN TIMER RELAY |
| CRC | CYCLE CRANK LOGIC TIMER |
| CTS | CRANK TERMINATE SWITCH |
| D | DIODE |
| DSS | DUAL SPEED SWITCH (INCLUDES CTS AND OSS) |
| GP | GLOW PLUGS |
| GS | GOVERNOR SWITCH |
| GSM | GOVERNOR SYNCHRONIZING MOTOR |
| HS | GLOW PLUG HEAT SWITCH |
| I | REMOTE START INITIATING CONTACT |
| MS | MAGNETIC SWITCH (CRANK CIRCUIT) |
| MSG | MAGNETIC SWITCH (GLOW PLUG CIRCUIT) |
| OCIR | OVERCRANK INDICATING RELAY |
| OCT | OVERCRANK TIMER |
| OP | OIL PRESSURE GAUGE SENDER |
| OPG | OIL PRESSURE GAUGE |
| OPIR | LOW OIL PRESSURE INDICATOR RELAY |
| OPS | OIL PRESSURE SWITCH |
| OSIR | OVERSPEED INDICATING RELAY |
| OSS | OVERSPEED SWITCH |
| PIL | PANEL ILLUMINATION LAMP |
| PLS | PANEL LAMP SWITCH |
| PS | PINION SOLENOID |
| PSW | PRESSURE SWITCH |
| RR | RUN RELAY |
| SS | SHUT-OFF SOLENOID |
| SM | STARTING MOTOR |
| SR | SHUTDOWN RELAY |
| WT | WATER TEMPERATURE GAUGE SENDER |
| WTG | WATER TEMPERATURE GAUGE |
| WTIR | HIGH WATER TEMPERATURE INDICATING RELAY |
| WTS | WATER TEMPERATURE SWITCH |

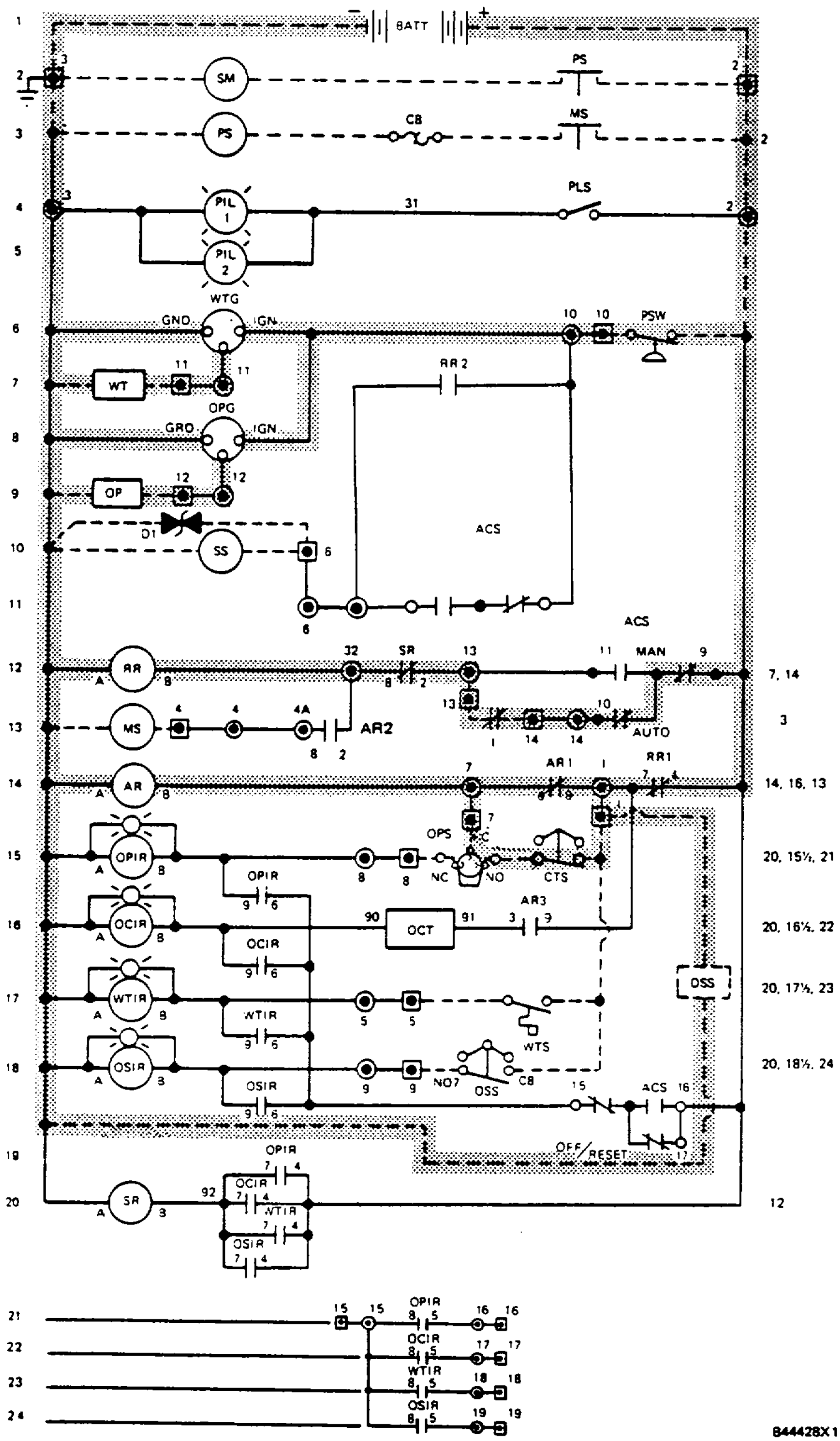
⊙ TERMINAL STRIP POINT (CONTROL PANEL)

⊡ TERMINAL STRIP POINT (GENERATOR TERMINAL BOX)

**CONTROL PANEL**
**AUTOMATIC POSITION - ENGINE CRANKS**

### Engine Starts

At 600 rpm, crank terminate switch (CTS) closes. Oil pressure increases. This activates oil pressure switch (OPS). The normally closed contact opens and the normally open contact closes. The arming relay (AR) is now connected across battery voltage. Contacts (AR1) close and lock in the arming relay. Contacts (AR2) open. This de-energizes magnetic switch (MS). (MS) contacts open to de-energize pinion solenoid (PS). (PS) contacts open to deenergize starting motor. Contacts (AR3) open to de-energize overcrank timer (OCT).




| | |
|---|---|
| ADC | AMMETER |
| ACS | ENGINE CONTROL SWITCH |
| ALT | CHARGING ALTERNATOR |
| AR | ARMING RELAY |
| ARX | AUXILIARY RELAY MODULE |
| BATT | BATTERY |
| CB | CIRCUIT BREAKER |
| CCM | CYCLE CRANKING MODULE |
| CCT | CYCLE CRANK RELAY |
| CDT | COOL DOWN TIMER |
| CDTR | COOL DOWN TIMER RELAY |
| CRC | CYCLE CRANK LOGIC TIMER |
| CTS | CRANK TERMINATE SWITCH |
| D | DIODE |
| DSS | DUAL SPEED SWITCH (INCLUDES CTS AND OSS) |
| GP | GLOW PLUGS |
| GS | GOVERNOR SWITCH |
| GSM | GOVERNOR SYNCHRONIZING MOTOR |
| HS | GLOW PLUG HEAT SWITCH |
| I | REMOTE START INITIATING CONTACT |
| MS | MAGNETIC SWITCH (CRANK CIRCUIT) |
| MSG | MAGNETIC SWITCH (GLOW PLUG CIRCUIT) |
| OCIR | OVERCRANK INDICATING RELAY |
| OCT | OVERCRANK TIMER |
| OP | OIL PRESSURE GAUGE SENDER |
| OPG | OIL PRESSURE GAUGE |
| OPIR | LOW OIL PRESSURE INDICATOR RELAY |
| OPS | OIL PRESSURE SWITCH |
| OSIR | OVERSPEED INDICATING RELAY |
| OSS | OVERSPEED SWITCH |
| PIL | PANEL ILLUMINATION LAMP |
| PLS | PANEL LAMP SWITCH |
| PS | PINION SOLENOID |
| PSW | PRESSURE SWITCH |
| RR | RUN RELAY |
| SS | SHUT-OFF SOLENOID |
| SM | STARTING MOTOR |
| SR | SHUTDOWN RELAY |
| WT | WATER TEMPERATURE GAUGE SENDER |
| WTG | WATER TEMPERATURE GAUGE |
| WTIR | HIGH WATER TEMPERATURE INDICATING RELAY |
| WTS | WATER TEMPERATURE SWITCH |
| ⊙ | TERMINAL STRIP POINT (CONTROL PANEL) |
| ▣ | TERMINAL STRIP POINT (GENERATOR TERMINAL BOX) |

CONTROL PANEL
AUTOMATIC POSITION - ENGINE STARTS

**Engine Does Not Start**

If the engine does not start in approximately 30 seconds, overcrank timer (OCT) will let current flow to overcrank indicating relay (OCIR). (OCIR) contacts close to lock in the (OCIR) relay and close shutdown relay (SR).

(SR) contacts open. This de-energizes run relay (RR) and magnetic switch (MS).

When run relay (RR) is de-energized. contacts (RR2) close and contacts (RR1) open. (RR2) closed completes a circuit to shutoff solenoid (SS) until pressure switch (PSW) opens. (RR1) open deenergizes arming relay (AR). dual speed switch (DSS) and overcrank timer (OCT).

**NOTE: Pressure switch (PSW) is not always closed when the engine cranks. Pressure caused by starting motor rotation of the engine is not always enough to close (PSW).**

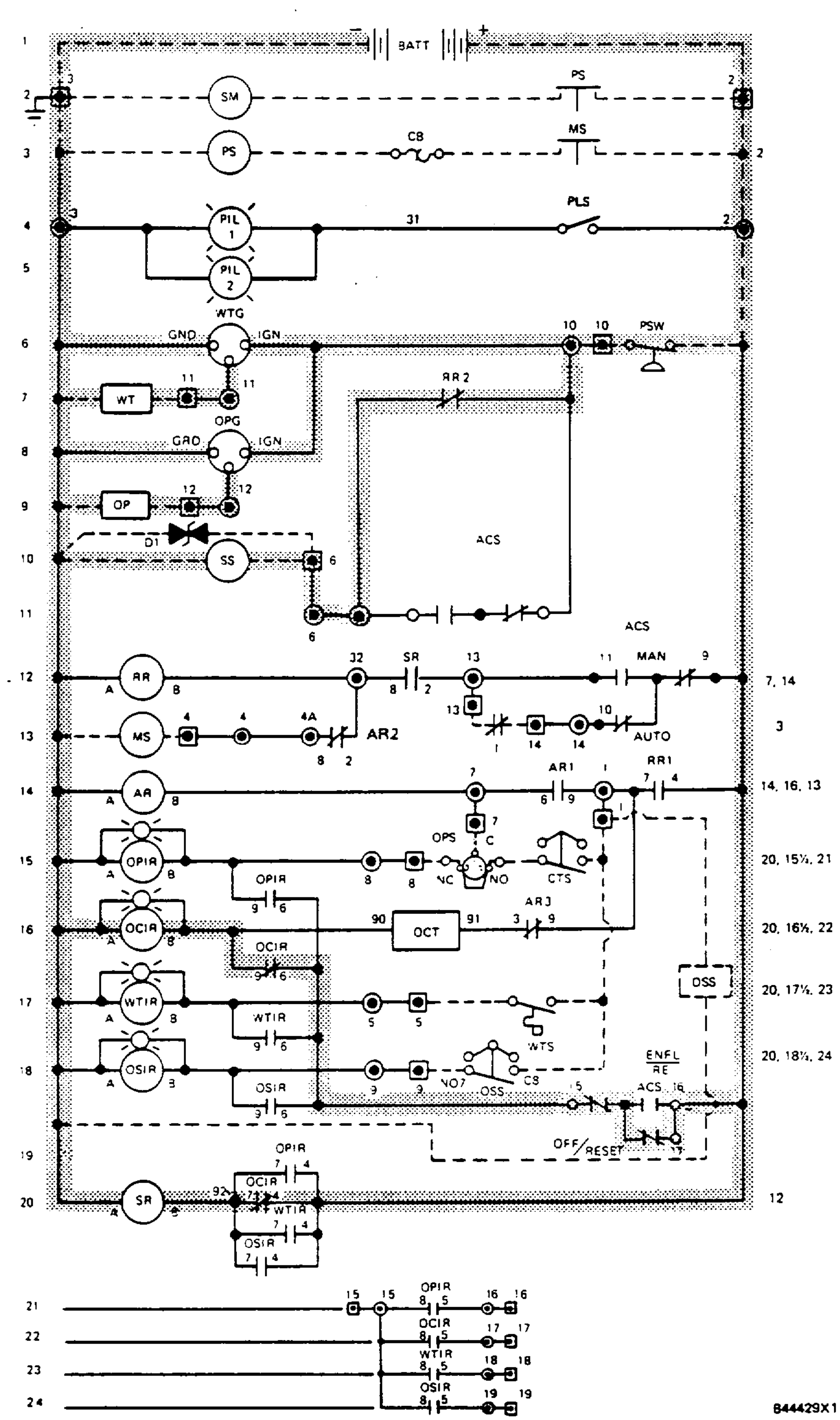
When magnetic switch (MS) is de-energized. (MS) contacts open. This de-energizes pinion solenoid (PS). (PS) contacts open and de-energize starting motor (SM).

Overcrank indicating relay (OCIR) will give light. To start the engine, do the steps that follow:

1. Turn engine control switch (ACS) to OFF RESET. This will open (ACS) contact (15) and de-energize overcrank indicating relay (OCIR). (OCIR) contacts will open and de-energize the shutoff relay (SR).

2. Turn the engine control switch to MANUAL or AUTO if I contact is closed. If the engine does not start in approximately 30 seconds. the overcrank indicating relay will give light.

3. Turn engine control switch (ACS) to STOP position. Observe fault lights and turn ACS to OFF RESET. Correct the problem that caused the engine not to start. Make reference to TROUBLESHOOTING.




ADC AMMETER
ACS ENGINE CONTROL SWITCH
ALT CHARGING ALTERNATOR
AR ARMING RELAY
ARX AUXILIARY RELAY MODULE
BATT BATTERY
CB CIRCUIT BREAKER
CCM CYCLE CRANKING MODULE
CCT CYCLE CRANK RELAY
CDT COOL DOWN TIMER
CDTR COOL DOWN TIMER RELAY
CRC CYCLE CRANK LOGIC TIMER
CTS CRANK TERMINATE SWITCH
D DIODE
DSS DUAL SPEED SWITCH (INCLUDES CTS AND OSS)
GP GLOW PLUGS
GS GOVERNOR SWITCH
GSM GOVERNOR SYNCHRONIZING MOTOR
HS GLOW PLUG HEAT SWITCH
I REMOTE START INITIATING CONTACT
MS MAGNETIC SWITCH (CRANK CIRCUIT)
MSG MAGNETIC SWITCH (GLOW PLUG CIRCUIT)
OCIR OVERCRANK INDICATING RELAY
OCT OVERCRANK TIMER
OP OIL PRESSURE GAUGE SENDER
OPG OIL PRESSURE GAUGE
OPIR LOW OIL PRESSURE INDICATOR RELAY
OPS OIL PRESSURE SWITCH
OSIR OVERSPEED INDICATOR RELAY
OSS OVERSPEED SWITCH
PIL PANEL ILLUMINATION LAMP
PLS PANEL LAMP SWITCH
PS PINION SOLENOID
PSW PRESSURE SWITCH
RR RUN RELAY
SS SHUT-OFF SOLENOID
SM STARTING MOTOR
SR SHUTDOWN RELAY
WT WATER TEMPERATURE GAUGE SENDER
WTG WATER TEMPERATURE GAUGE
WTIR HIGH WATER TEMPERATURE INDICATING RELAY
WTS WATER TEMPERATURE SWITCH

⊙ TERMINAL STRIP POINT (CONTROL PANEL)
⊡ TERMINAL STRIP POINT (GENERATOR TERMINAL BOX)

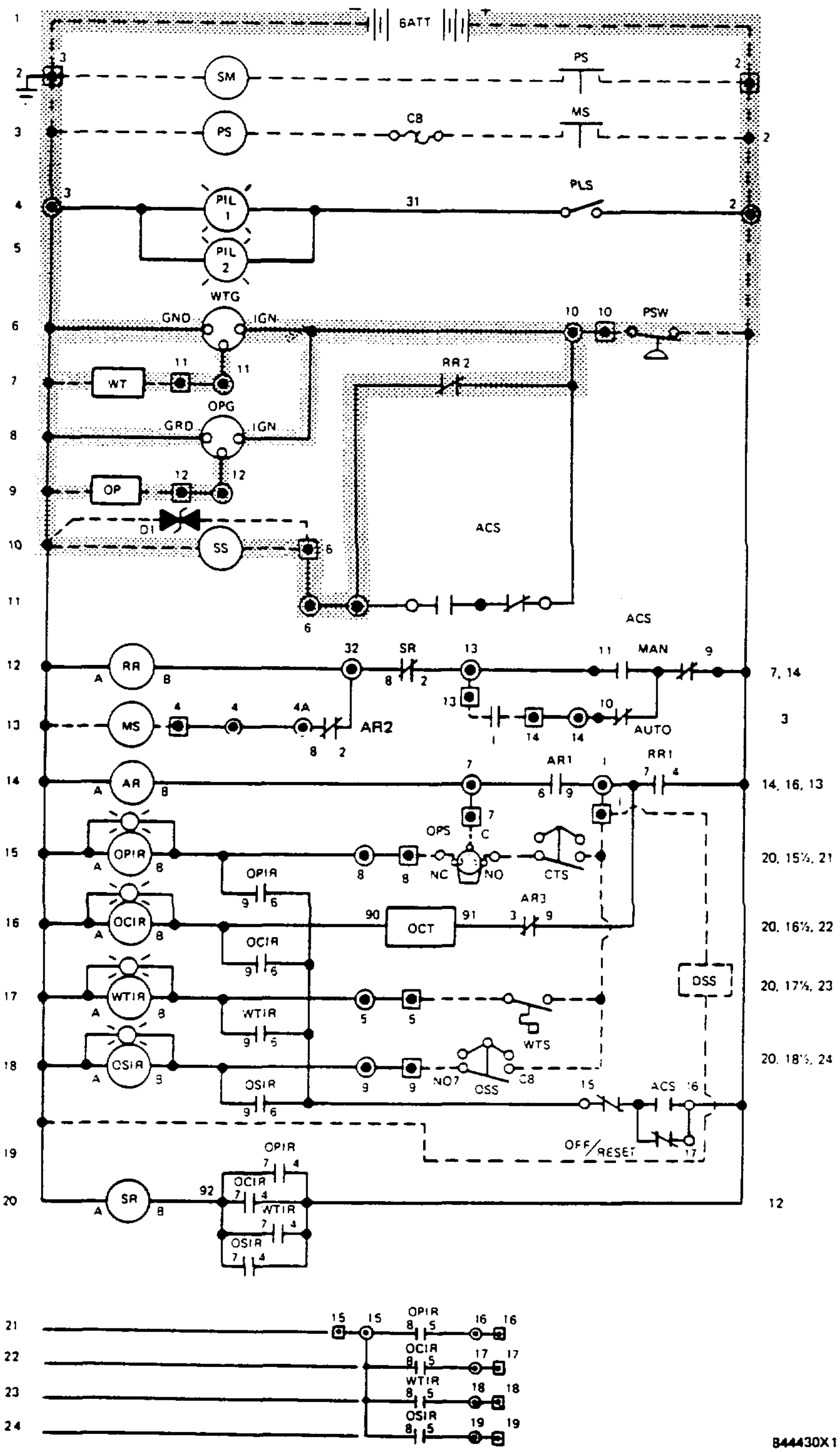
CONTROL PANEL
AUTOMATIC POSITION-ENGINE DOES NOT START

**Return of Commercial (Normal) Power**

When commercial power returns. the automatic transfer switch transfers the load to commercial power. Remote start initiating contacts (I) open. This de-energizes run relay (RR).

When run relay (RR) is de-energized, contacts (RR2) close and contacts (RR1) open. (RR2) closed completes a circuit to shut-off solenoid (SS). The shut-off solenoid moves the rack to the fuel OFF position. After the engine stops (PSW) will open to de-energize the shut-off solenoid. (RR1) open deenergizes arming relay (AR) and dual speed switch (DSS).

Diode (D1) is in the shut-off solenoid circuit to help prevent electrical sparks (arcing), at the shutoff solenoid contacts, when the shut-off solenoid is de-energized.



ADC AMMETER
ACS ENGINE CONTROL SWITCH
ALT CHARGING ALTERNATOR
AR ARMING RELAY
ARX AUXILIARY RELAY MODULE
BATT BATTERY
CB CIRCUIT BREAKER
CCM CYCLE CRANKING MODULE
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CDT COOL DOWN TIMER
CDTR COOL DOWN TIMER RELAY
CRC CYCLE CRANK LOGIC TIMER
CTS CRANK TERMINATE SWITCH
D DIODE
DSS DUAL SPEED SWITCH (INCLUDES CTS AND OSS)
GP GLOW PLUGS
GS GOVERNOR SWITCH
GSM GOVERNOR SYNCHRONIZING MOTOR
HS GLOW PLUG HEAT SWITCH
I REMOTE START INITIATING CONTACT
MS MAGNETIC SWITCH (CRANK CIRCUIT)
MSG MAGNETIC SWITCH (GLOW PLUG CIRCUIT)
OCIR OVERCRANK INDICATING RELAY
OCT OVERCRANK TIMER
OP OIL PRESSURE GAUGE SENDER
OPG OIL PRESSURE GAUGE
OPIR LOW OIL PRESSURE INDICATOR RELAY
OPS OIL PRESSURE SWITCH
OSIR OVERSPEED INDICATING RELAY
OSS OVERSPEED SWITCH
PIL PANEL ILLUMINATION LAMP
PLS PANEL LAMP SWITCH
PS PINION SOLENOID
PSW PRESSURE SWITCH
RR RUN RELAY
SS SHUT-OFF SOLENOID
SM STARTING MOTOR
SR SHUTDOWN RELAY
WT WATER TEMPERATURE GAUGE SENDER
WTG WATER TEMPERATURE GAUGE
WTIR HIGH WATER TEMPERATURE INDICATING RELAY
WTS WATER TEMPERATURE SWITCH

⊙ TERMINAL STRIP POINT (CONTROL PANEL)
⊡ TERMINAL STRIP POINT (GENERATOR TERMINAL BOX)

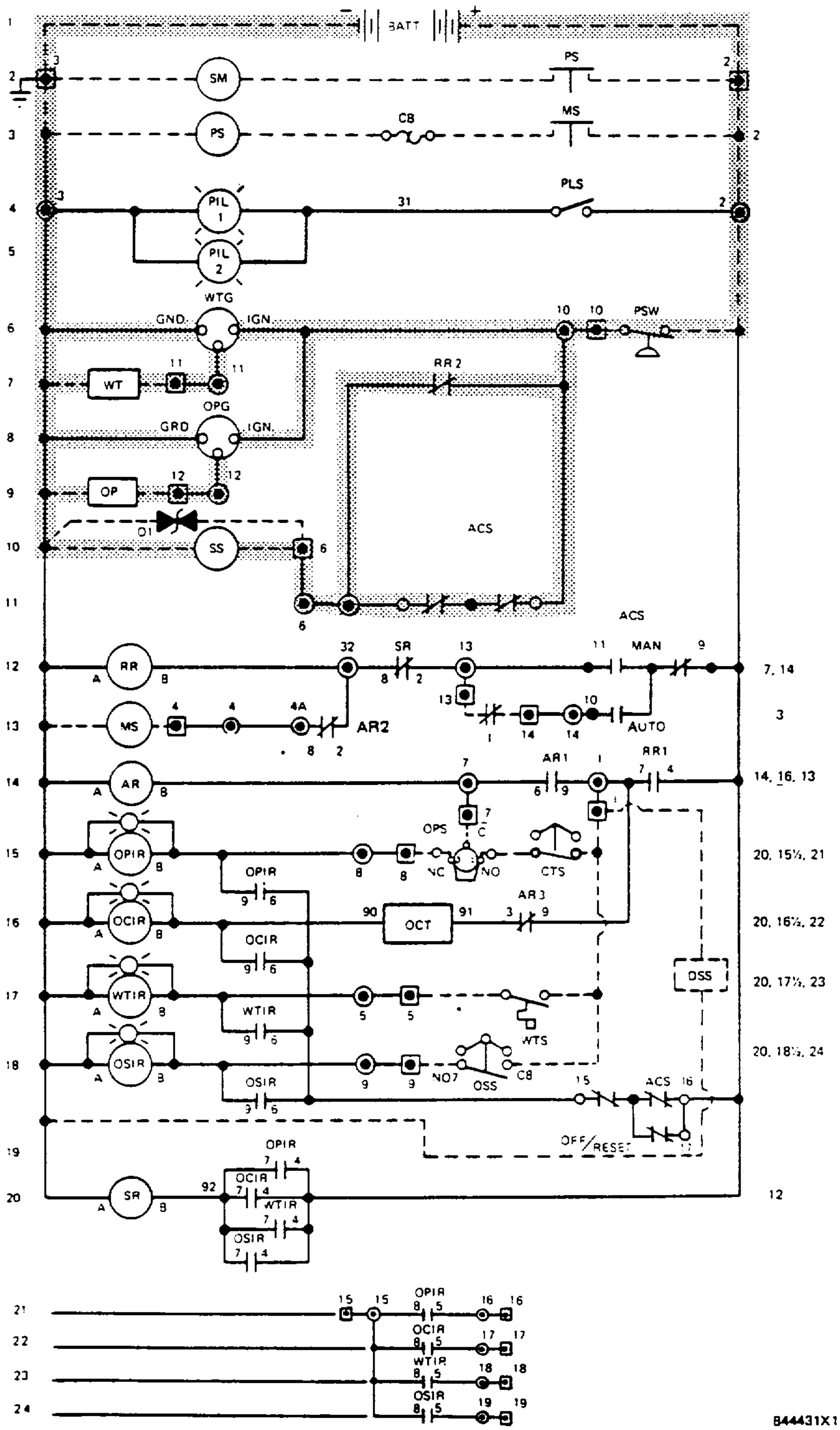
CONTROL PANEL
AUTOMATIC POSITION-AUTOMATIC SHUTDOWN

**Manual Shutdown**

When engine control switch (ACS) is turned to the STOP position or OFF, RESET position. contacts ( 10 and 11) are open. With contacts (10 and 11) open, the run relay (RR) de-energizes. In addition, the STOP position closes contacts (5 and 8). This provides another path to the shutoff solenoid (SS).

When run relay (RR) is de-energized, contact (RR2) closes and contact (RR1) opens. With (RR2) closed, it completes a circuit to the shut-off solenoid (SS). If the STOP position is used, closed contact (RR2) completes a parallel circuit to shutoff solenoid (SS). (This parallel circuit is necessary to stop the engine when the engine control switch is in the AUTO or MAN position.) After the engine stops, (PSW) will open to de-energize the shutoff solenoid. With contact (RR1) open, the arming relay (AR) and the dual speed switch (DSS) are de-energized.

Diode D1 helps prevent electrical sparks (arcing) at the contacts in the shutoff solenoid circuit when the shutoff solenoid is de-energized.




ADC AMMETER
ACS ENGINE CONTROL SWITCH
ALT CHARGING ALTERNATOR
AR ARMING RELAY
ARX AUXILIARY RELAY MODULE
BATT BATTERY
CB CIRCUIT BREAKER
CCM CYCLE CRANKING MODULE
CCT CYCLE CRANK RELAY
CDT COOL DOWN TIMER
CDTR COOL DOWN TIMER RELAY
CRC CYCLE CRANK LOGIC TIMER
CTS CRANK TERMINATE SWITCH
D DIODE
DSS DUAL SPEED SWITCH (INCLUDES CTS AND OSS)
GP GLOW PLUGS
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GSM GOVERNOR SYNCHRONIZING MOTOR
HS GLOW PLUG HEAT SWITCH
I REMOTE START INITIATING CONTACT
MS MAGNETIC SWITCH (CRANK CIRCUIT)
MSG MAGNETIC SWITCH (GLOW PLUG CIRCUIT)
OCIR OVERCRANK INDICATING RELAY
OCT OVERCRANK TIMER
OP OIL PRESSURE GAUGE SENDER
OPG OIL PRESSURE GAUGE
OPIR LOW OIL PRESSURE INDICATOR RELAY
OPS OIL PRESSURE SWITCH
OSIR OVERSPEED INDICATING RELAY
OSS OVERSPEED SWITCH
PIL PANEL ILLUMINATION LAMP
PLS PANEL LAMP SWITCH
PS PINION SOLENOID
PSW PRESSURE SWITCH
RR RUN RELAY
SS SHUT-OFF SOLENOID
SM STARTING MOTOR
SR SHUTDOWN RELAY
WT WATER TEMPERATURE GAUGE SENDER
WTG WATER TEMPERATURE GAUGE
WTIR HIGH WATER TEMPERATURE INDICATING RELAY
WTS WATER TEMPERATURE SWITCH

⊙ TERMINAL STRIP POINT (CONTROL PANEL)
⊡ TERMINAL STRIP POINT (GENERATOR TERMINAL BOX

CONTROL PANEL
STOP POSITION-MANUAL SHUTDOWN

### Shutdown Caused by Engine Failure

The packaged generator set has shutdown sensors, shutdown indicators and shutdown circuit for the conditions that follow.

1. Low oil pressure
2. High water temperature
3. Overspeed
4. Overcrank

For information about overcrank shutdown, make reference to ENGINE DOES NOT START.

Conditions (1, 2 or 3) will energize its respective indicating relay. The number (2) contacts of the respective relay will close to energize shut-off relay (SR). The number ( 1) contacts of the respective relay will close to lock in the relay.

When shutdown relay (SR) is energized, (SR) contacts open. This de-energizes run relay (RR). Contacts (RR2) close and contacts (RR1) open. (RR2) closed completes a circuit to shut-off solenoid (SS) until pressure switch (PSW) opens. (RR I) open de-energizes arming relay (AR) and dual speed switch (DSS).

Diode (D1) helps prevent electrical sparks (arcing) at the contacts in the shut-off solenoid circuit, when the shut-off solenoid is de-energized.

Indicating relay for the fault condition will give light. To start the engine, do the steps that follow.

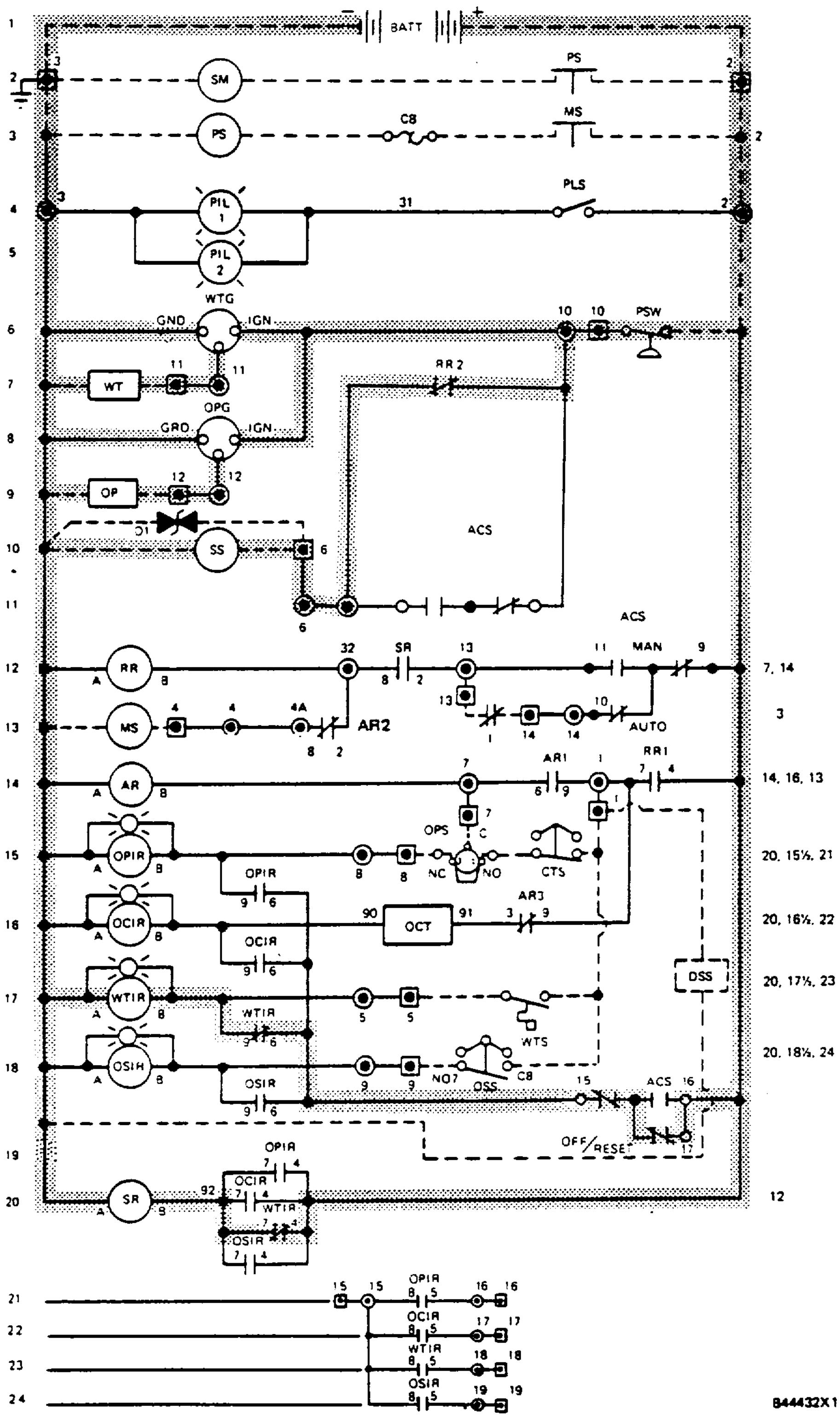
1. Turn engine control switch (ACS) to OFF or STOP.

**NOTE: For start up when (OCIR) indicating relay gives light, make reference to ENGINE DOES NOT START.**

2. Correct the problem that caused the engine to shutdown.

3. Rotate ACS to OFF RESET position. This de-energizes the indicating relay. The indicating relay contacts will open and de-energize the shutdown relay (SR).

**NOTE: Reset oil pressure or overspeed switch if necessary. The system is ready to start if engine control switch (ACS) is turned to MAN or AUTO.**




- **ADC** AMMETER
- **ACS** ENGINE CONTROL SWITCH
- **ALT** CHARGING ALTERNATOR
- **AR** ARMING RELAY
- **ARX** AUXILIARY RELAY MODULE
- **BATT** BATTERY
- **CB** CIRCUIT BREAKER
- **CCM** CYCLE CRANKING MODULE
- **CCT** CYCLE CRANK RELAY
- **CDT** COOL DOWN TIMER
- **CDTR** COOL DOWN TIMER RELAY
- **CRC** CYCLE CRANK LOGIC TIMER
- **CTS** CRANK TERMINATE SWITCH
- **D** DIODE
- **DSS** DUAL SPEED SWITCH (INCLUDES CTS AND OSS)
- **GP** GLOW PLUGS
- **GS** GOVERNOR SWITCH
- **GSM** GOVERNOR SYNCHRONIZING MOTOR
- **HS** GLOW PLUG HEAT SWITCH
- **I** REMOTE START INITIATING CONTACT
- **MS** MAGNETIC SWITCH (CRANK CIRCUIT)
- **MSG** MAGNETIC SWITCH (GLOW PLUG CIRCUIT)
- **OCIR** OVERCRANK INDICATING RELAY
- **OCT** OVERCRANK TIMER
- **OP** OIL PRESSURE GAUGE SENDER
- **OPG** OIL PRESSURE GAUGE
- **OPIR** LOW OIL PRESSURE INDICATOR RELAY
- **OPS** OIL PRESSURE SWITCH
- **OSIR** OVERSPEED INDICATING RELAY
- **OSS** OVERSPEED SWITCH
- **PIL** PANEL ILLUMINATION LAMP
- **PLS** PANEL LAMP SWITCH
- **PS** PINION SOLENOID
- **PSW** PRESSURE SWITCH
- **RR** RUN RELAY
- **SS** SHUT-OFF SOLENOID
- **SM** STARTING MOTOR
- **SR** SHUTDOWN RELAY
- **WT** WATER TEMPERATURE GAUGE SENDER
- **WTG** WATER TEMPERATURE GAUGE
- **WTIR** HIGH WATER TEMPERATURE INDICATING RELAY
- **WTS** WATER TEMPERATURE SWITCH

- ⊙ TERMINAL STRIP POINT (CONTROL PANEL)
- ⊡ TERMINAL STRIP POINT (GENERATOR TERMINAL BOX)

**CONTROL PANEL AUTOMATIC POSITION-SHUTDOWN (HIGH WATER TEMPERATURE)**

*C*

## GENERATOR MOUNTED CONTROL PANEL
## (TYPE 5 - CHANGE LEVEL 12)

### INTRODUCTION

The uses of the generator mounted control panel are: To help control the electric power made by the generator set.

To monitor (check) the operation of the generator set.

To help protect the generator set from damage caused by low oil pressure, high coolant temperature, overspeed and overcrank.

To help with the transfer of electrical load to and from the generator set.

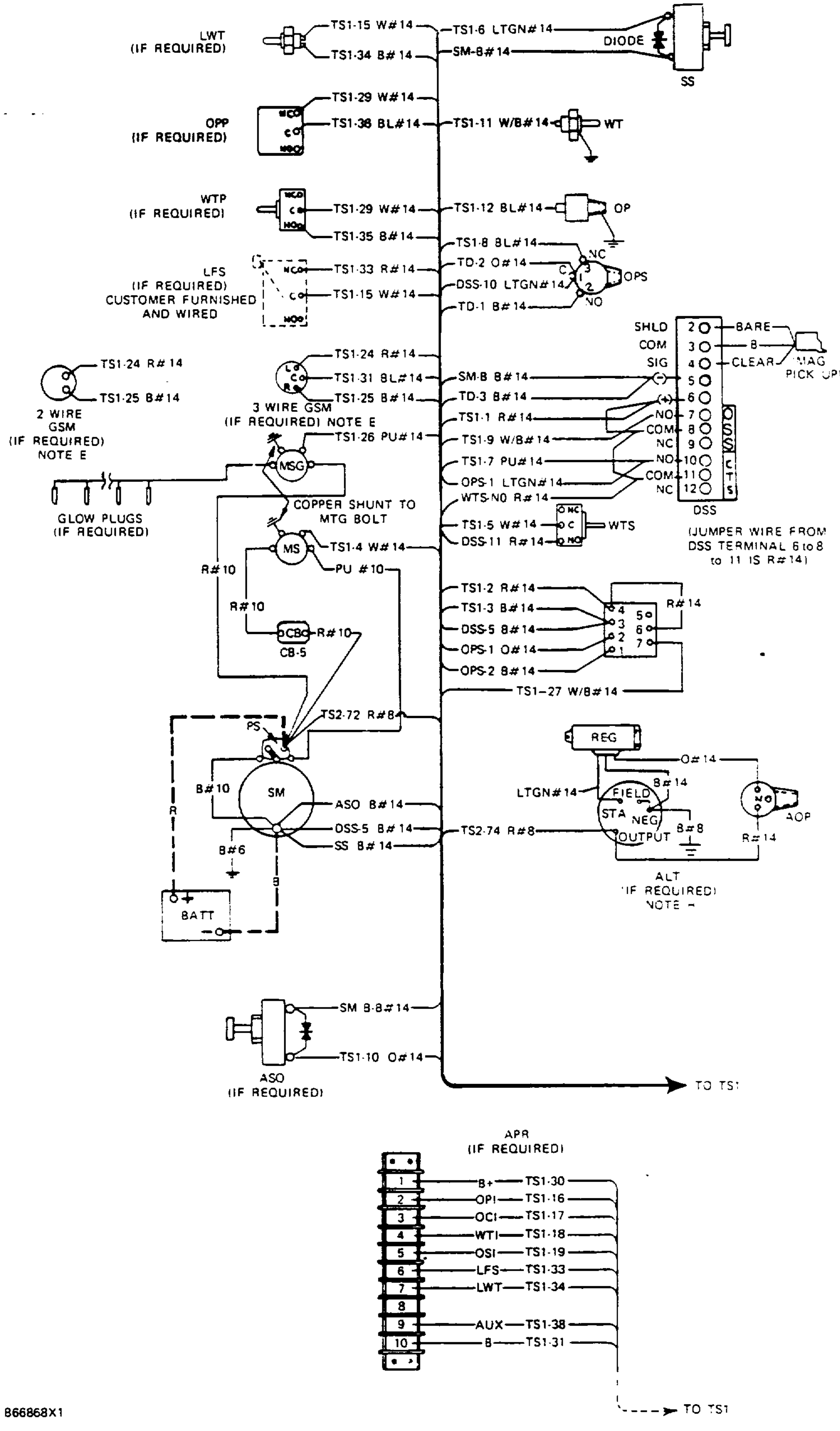
To help parallel two or more units onto the same bus.

### IDENTIFICATION

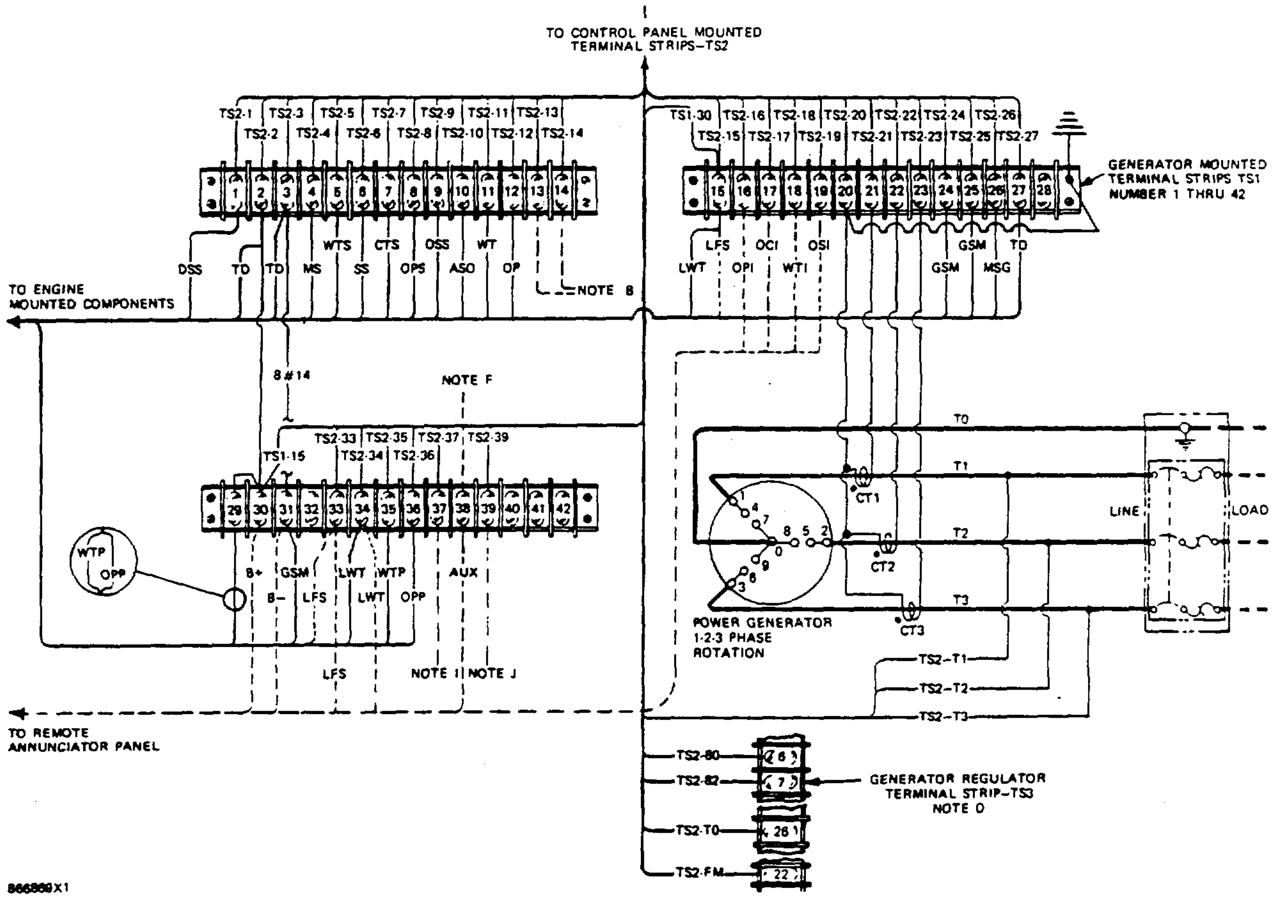
The location of the control panel is on the top of the regulator housing. This panel has a place for a heat switch and Prealarm module. The shutdown indicators are relay lamp type. The control panel has a 13 place model number on the panel nameplate located inside bottom surface of control panel. The model number gives an indication of the control panel component part numbers. Make reference to the Parts Book, GENERATOR MOUNTED CONTROL PANEL, Form No. SEBP1068. The last two digits of the model number are the change level to which the panel was built.

### WIRING

See the pages that follow for wiring diagrams, schematics and photographs for identification.

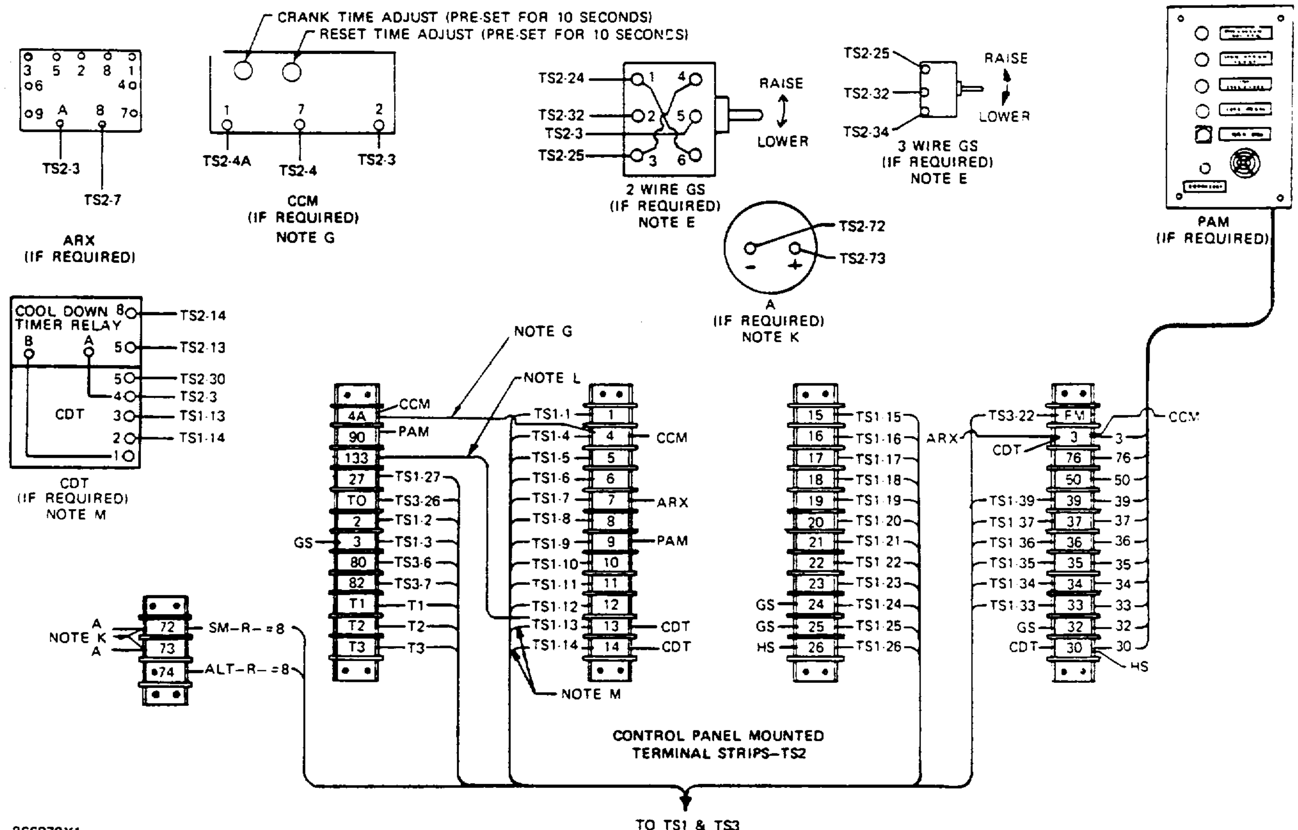



REMOTE AND ENGINE MOUNTED ELECTRICAL COMPONENTS




**GENERATOR TERMINAL STRIP TS1, REGULATOR TERMINAL-STRIP TS3, GENERATOR, CURRENT TRANSFORMERS AND CIRCUIT BREAKER.**

A AMMETER (CONTROL PANEL MOUNTED)
ALT CHARGING ALTERNATOR (NOTE H)
APR ANNUNCIATOR PANEL - REMOTE
ARX AUXILIARY RELAY MODULE (CONTROL PANEL MOUNTED)
ASO AIR SHUT-OFF SOLENOID
AUX AUXILIARY CONTACT (NOTE F)
B- BATTERY POSITIVE
B- BATTERY NEGATIVE
BATT BATTERY
CB CIRCUIT BREAKER
CCM CYCLE CRANKING MODULE (CONTROL PANEL MOUNTED)
CDT COOL DOWN TIMER (CONTROL PANEL MOUNTED)
CT CURRENT TRANSFORMER
CTS CRANK TERMINATE SWITCH
DSS DUAL SPEED SWITCH
GS GOVERNOR SWITCH (CONTROL PANEL MOUNTED)
GSM GOVERNOR SYNC MOTOR
HS HEAT SWITCH (CONTROL PANEL MOUNTED)
LFS LOW FUEL LEVEL SWITCH
LWT LOW WATER TEMP SWITCH
MS MAGNETIC SWITCH (CRANK CIRCUIT)
MSG MAGNETIC SWITCH (GLOW PLUG CIRCUIT)
OCI OVERCRANK INDICATOR
OP OIL PRESSURE GAUGE SENDER
OPI LOW OIL PRESSURE INDICATOR
OPP OIL PRESSURE SWITCH (PREALARM)
OPS OIL PRESSURE SWITCH (SHUTDOWN)
OSI OVERSPEED INDICATOR
OSS OVERSPEED SWITCH (SHUTDOWN)
PAM PREALARM MODULE (CONTROL PANEL MOUNTED)
PS PINION SOLENOID
SS SHUTOFF SOLENOID
SM STARTING MOTOR
TD TIME DELAY RELAY
TS TERMINAL STRIP
WT WATER TEMPERATURE GAGE SENDER
WTI HIGH WATER TEMPERATURE INDICATOR
WTP WATER TEMPERATURE SWITCH (PRE-ALARM)
WTS WATER TEMPERATURE SWITCH (SHUTDOWN)



CONTROL PANEL COMPONENTS (PARTIAL) AND CONTROL PANEL TERMINAL STRIP TS2

**NOTE: A: Wire and cable shown dotted to be furnished by customer.**

**NOTE B: To be wired to engine starting contact (N.O.) in auto transfer switch by customer.**

**NOTE C: Each wire on terminal strip is identified on each end - corresponding to terminal strip number.**

**NOTE D: Remove yellow wire and insulate from terminal 7 at TS3 before connecting wire from TS2.**

**NOTE E: Use 3 wire diagram with Bodine 3 wire synchronizing motor. Use 2 wire diagram with 2 wire permanent magnet motor.**

**NOTE F: To be wired to auxiliary contact (N.O.) on emergency side of transfer switch. Required only when optional generator set Annunciator panel (remote) is provided. (Generating indication).**

**NOTE G: Red jumper wire from TS2-4A to TS2-4 must be removed when cycle cranking module is used.**

**NOTE H: Do not operate alternator without a battery connected in the system. Do not polarize alternator. Do not operate alternator simultaneously with a DC generator to charge a common battery.**

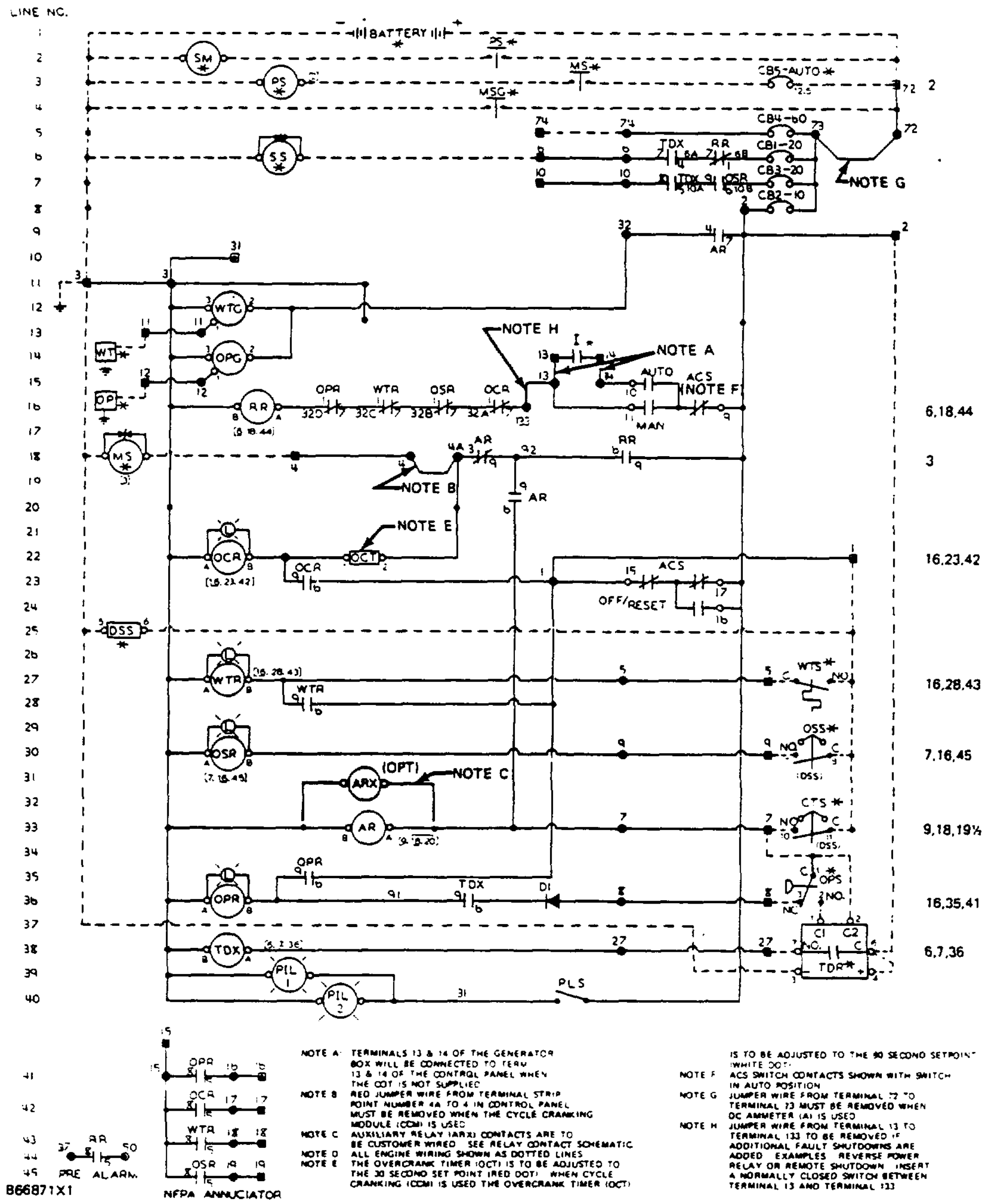
**NOTE I: Provides 24 volts for remote low oil pressure (pre-alarm) (OPP) indication when pre-alarm module is used.**

**NOTE J: Provides 24V for customer provided remote shutdown and pre-alarm indicator when pre-alarm module is used.**

**NOTE K: Jumper wire from TS2-72 to TS2-73 must be removed when ammeter is used.**

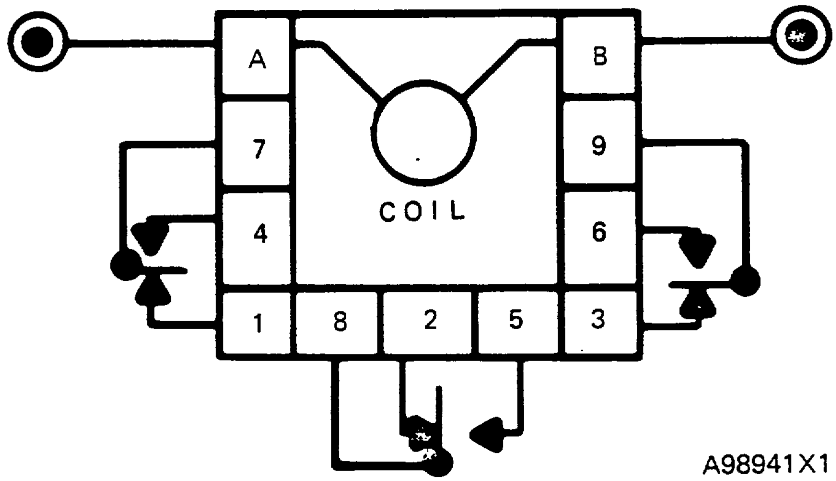
**NOTE L: Jumper wire from TS2-13 to TS2-133 to be removed if additional fault shutdowns are added. Example: Reverse power relay or remote shutdown.**

**NOTE M: When adding the engine cool down timer option, wires from TS1-13 and TS1-14 should be reconnected to CDT-3 and CDT-2.**

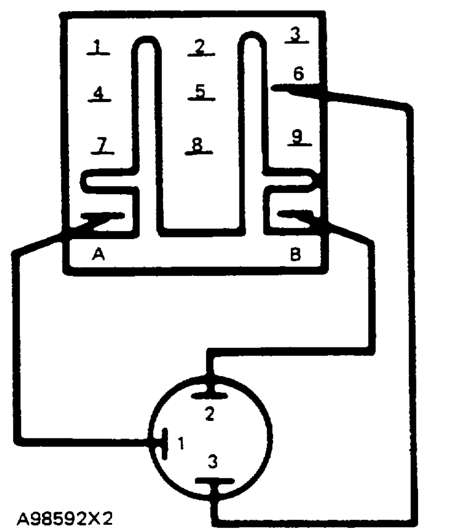



## CONTROL PANEL AUTOMATIC POSITION

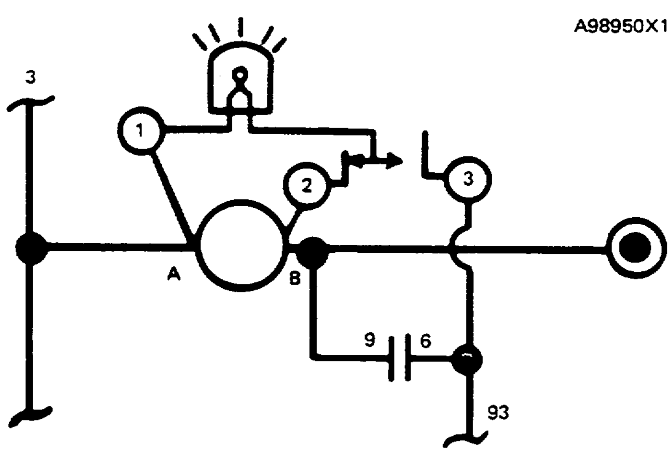
AR ARMING RELAY
ACS ENGINE CONTROL SWITCH
BATT BATTERY
CB CIRCUIT BREAKER
CCM CYCLE CRANKING MODULE
CTS CRANK TERMINATE SWITCH
D DIODE
DSS DUAL SPEED SWITCH (INCLUDES CTS AND OSS)
I REMOTE START INITIATING CONTACT
MS MAGNETIC SWITCH (CRANK CIRCUIT)
MSG MAGNETIC SWITCH (GLOW PLUG CIRCUIT)
OCIR OVERCRANK INDICATING RELAY
OCT OVERCRANK TIMER
OP OIL PRESSURE GAUGE SENDER
OPG OIL PRESSURE GAUGE
OPIR LOW OIL PRESSURE INDICATOR RELAY
OPS OIL PRESSURE SWITCH
OSIR OVERSPEED INDICATING RELAY
OSS OVERSPEED SWITCH
PIL PANEL ILLUMINATION LAMP
PLS PANEL LAMP SWITCH
PS PINION SOLENOID
RR RUN RELAY
SS SHUT-OFF SOLENOID
SM STARTING MOTOR
SR SHUTDOWN RELAY
TDR TIME DELAY RELAY
TDX TIME DELAY AUXILIARY
WT WATER TEMPERATURE GAUGE SENDER
WTG WATER TEMPERATURE GAUGE
WTIR HIGH WATER TEMPERATURE INDICATING RELAY
WTS WATER TEMPERATURE SWITCH
* INDICATES EQUIPMENT EXTERNAL TO CONTROL PANEL
○ TERMINAL STRIP POINT (CONTROL PANEL)
□ TERMINAL STRIP POINT (GENERATOR TERMINAL BOX)




RELAY CONTACT SCHEMATIC



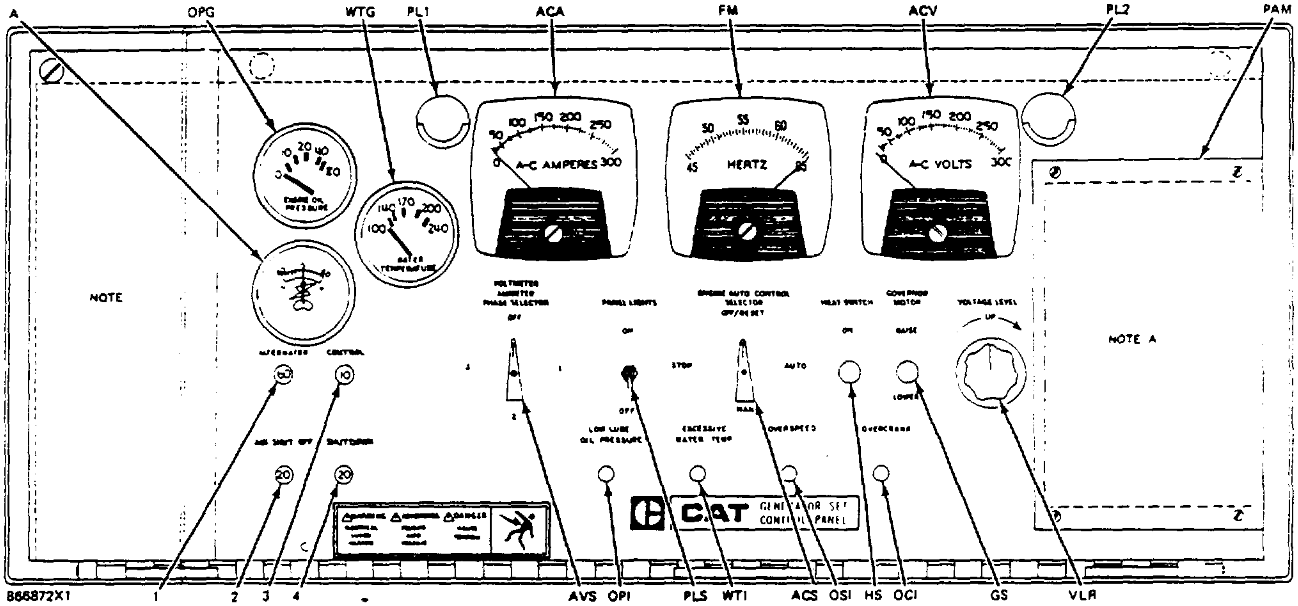

RELAY LAMP COMPONENT WIRING



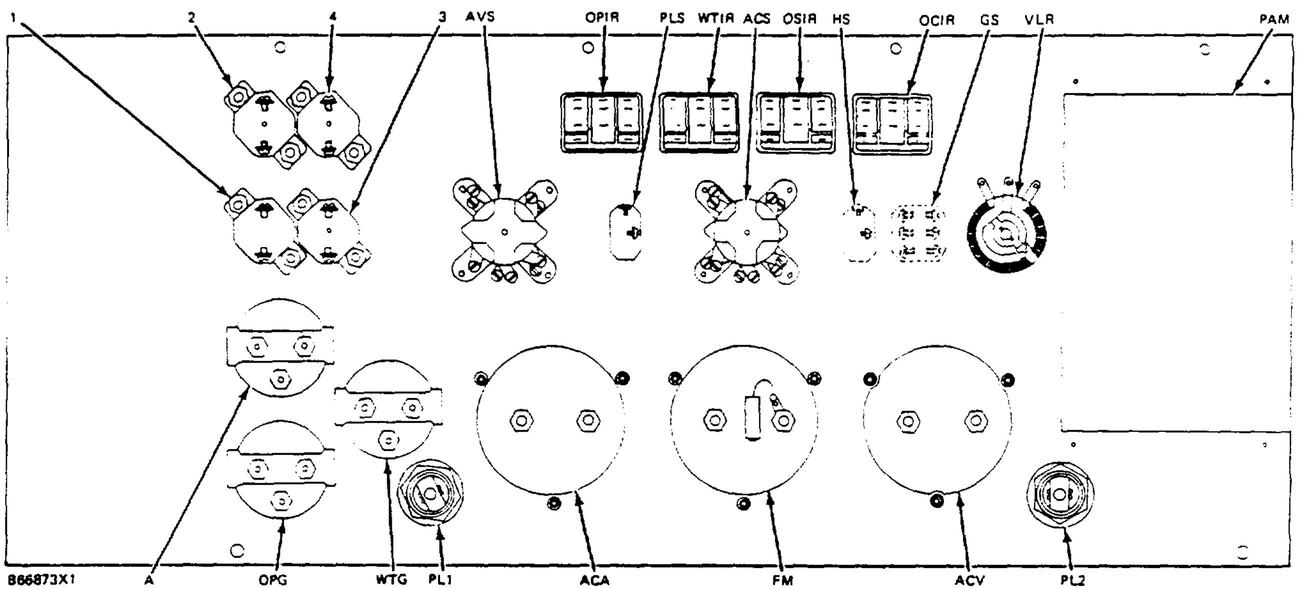

RELAY LAMP SCHEMATIC

## COMPONENTS

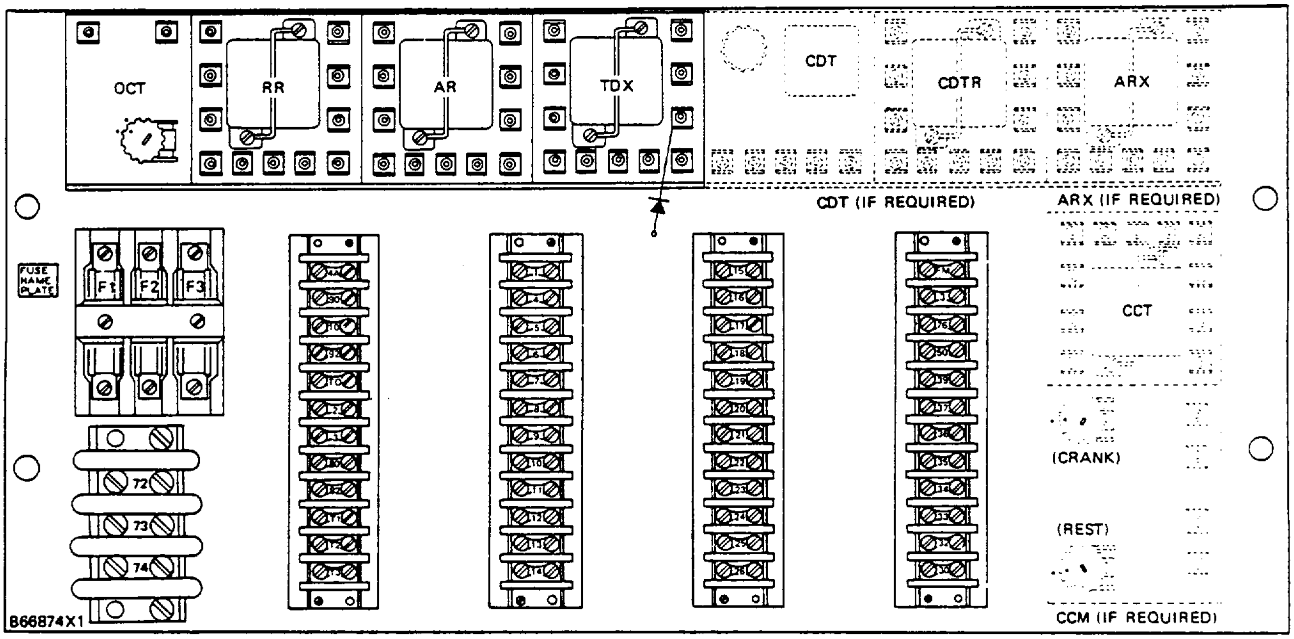
**NOTE: For specifications on components located on the engine, make reference to the ENGINE SERVICE MANUAL.**




**PANEL DOOR (TYPE 5 — CHANGE LEVEL 12)**
**(FRONT VIEW)**




**PANEL DOOR (TYPE 5 — CHANGE LEVEL 12)**
**(TOP VIEW WITH DOOR OPEN)**



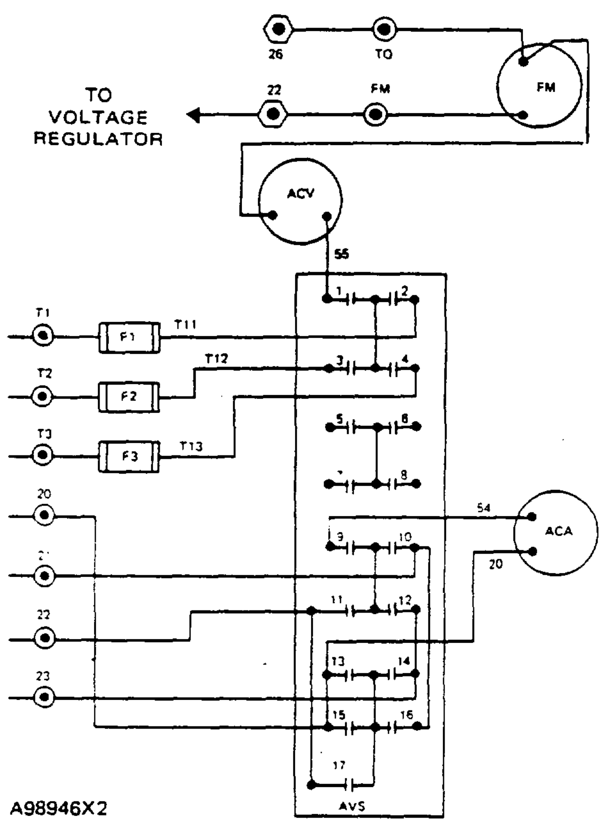

**LOGIC PANEL (TYPE 5 - CHANGE LEVEL 12)**
**(FRONT VIEW INSIDE PANEL)**

| | |
|---|---|
| 1. | 60 AMP CIRCUIT BREAKER (ALTERNATOR) |
| 2. | 20 AMP CIRCUIT BREAKER (AIR SHUT-OFF) |
| 3. | 10 AMP CIRCUIT BREAKER (CONTROL) |
| 4. | 20 AMP CIRCUIT BREAKER (SHUTDOWN) |
| A | AMMETER |
| ACA | ALTERNATING CURRENT AMMETER |
| ACS | ENGINE CONTROL SWITCH |
| ACV | ALTERNATING CURRENT VOLTMETER |
| AVS | AMMETER/VOLTAGE SELECTOR SWITCH |
| CDT | COOL DOWN TIMER |
| CDTR | COOL DOWN TIMER RELAY |
| CCM | CYCLE CRANKING MODULE |
| CCT | CYCLE CRANKING RELAY |
| F1 | FUSE |
| F2 | FUSE |
| F3 | FUSE |
| FM | FREQUENCY METER |
| GS | GOVERNOR SWITCH |
| HS | HEAT SWITCH |
| OCI | OVERCRANK INDICATOR |
| OCIR | OVERCRANK INDICATOR RELAY |
| OCT | OVERCRANK TIMER |
| OPG | OIL PRESSURE GAUGE |
| OPI | OIL PRESSURE INDICATOR |
| OPIR | OIL PRESSURE INDICATOR RELAY |
| OSI | OVERSPEED INDICATOR |
| OSIR | OVERSPEED INDICATOR RELAY |
| PAM | PREALARM MODULE |
| PL1, 2 | PANEL LAMPS |
| PLS | PANEL LAMP SWITCH |
| WTG | WATER TEMPERATURE GAUGE |
| WTI | WATER TEMPERATURE INDICATOR |
| WTIR | WATER TEMPERATURE INDICATOR RELAY |
| VLR | VOLTAGE LEVEL RHEOSTAT |

**ACA Alternating Current Ammeter**

AC ammeter (ACA) gives an indication, in amperes, of the current from each phase of the generator to the load. Ammeter voltmeter selector switch (AVS) is used to connect the ammeter to the current transformer on phase T1, T2 or T3; see Contact Chart. Ammeters normally have an input range from 0 to 5 amperes. Current transformer (CT1, CT2 or CT3) causes a reduction of the actual line current, in its respective phase lead, to a level within the input range of the ammeter. The ammeter is calibrated (has marks) to give an indication of the actual current flow in one phase load of the generator.

**NOTE: Several methods have been used to connect control panel instruments. The recommended method is shown in the diagrams.**

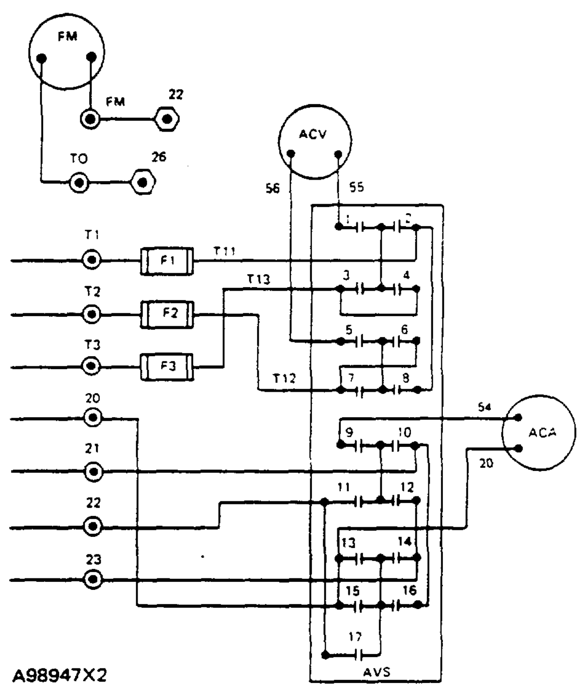



**(600V Control Panel Only)**

**CONTACT CHART FOR AVS**

| CONTACT | | PHASES OFF | | 1 (T1) | | 2 (T2) | | 3 (T3) | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | X | | X | | X | |
| 2 | | | | X | | | | | |
| 3 | | | | | | X | | | |
| 4 | | | | | | | | X | |
| 5 | | | | X | | X | | X | |
| 6 | | | | X | | | | | |
| 7 | | | | | | X | | | |
| 8 | | | | | | | | X | |
| 9 | | | X | X | X | X | X | X | |
| 10 | | | X | X | X | | | | |
| 11 | | | | | X | X | X | | |
| 12 | | | | | | | X | X | X |
| 13 | X | X | X | | | | | | |
| 14 | X | X | X | X | X | X | X | | |
| 15 | X | | X | X | X | X | X | X | X |
| 16 | X | X | X | | X | X | X | X | X |
| 17 | X | X | X | X | X | | X | X | X |

**NOTE: X gives an indication of a closed contact, X on the line gives an indication of "make before break."**




AMMETER/VOLTMETER SELECTOR SWITCH (AVS) WIRING DIAGRAMS

| | | | |
|---|---|---|---|
| ACA | Alternating current ammeter | ⨀ | Terminal point on TS2 in control panel |
| ACV | Alternating current voltmeter | | |
| F1,2.3 | Fuses | ⬡ | Terminal Point on TS3 part of voltage regulator |
| FM | Frequency meter | | |

### ACS Engine Control Switch

Engine control switch (ACS) controls the engine start and stop systems. To start the engine, move the switch to the MANUAL position. To stop the engine move the switch to the STOP or OFF/RESET position. For standby application (engine starts when remote initiating contact 1 closes), move the switch to the AUTO position. To start after engine shutdown caused by high water temperature, low oil pressure or overspeed, turn switch to STOP position and correct fault. Then move switch to OFF/RESET position. Engine can now be started in MANUAL or AUTO position. For more information on the operation of this switch, make reference to the AUTOMATIC START/STOP SYSTEM.

**CONTACT CHART FOR AVS**

| CONTACT | | OFF-RESET | | AUTO | | MAN | | STOP | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | | | | X | | X | | X | |
| 2 | | | | X | | | | | |
| 3 | | | | | | X | | | |
| 4 | | | | | | | | X | |
| 5 | | | | X | | X | | X | |
| 6 | | | | X | | | | | |
| 7 | | | | | | X | | | |
| 8 | | | | | | | | X | |
| 9 | | | X | X | X | X | X | X | X |
| 10 | | | X | X | X | | | X | |
| 11 | | | | | X | X | X | | |
| 12 | | | | | | | X | X | X |
| 13 | X | X | X | | | | | | |
| 14 | X | X | X | X | X | X | X | | |
| 15 | | | X | X | X | X | X | X | X |
| 16 | X | X | X | | X | X | X | X | X |
| 17 | X | X | X | X | X | | X | X | X |

NOTE: X gives an indication of a closed contact, X on the line gives an indication of "make before break."

### ACV Alternating Current Voltmeter

AC voltmeter (ACV) shows the potential differential (voltage) between phase T1-T2, T2-T3 or T3-T1 at position 1, 2 or 3 respectively. Make reference to the ALTERNATING CURRENT AMMETER.

### DCA Direct Current Ammeter

DC Ammeter (DCA) is used when-the ammeter is ordered. This ammeter shows the amount of DC current in amperes, that flows in the alternator circuit (if so equipped).

### FM Frequency Meter

Frequency meter (FM) shows the hertz (cycles per second) of the electricity made when the generator set is in operation. There is a direct relation between the frequency of the electricity and the rpm of the generator set; see formula.

$$\text{frequency (hertz)} = \frac{\text{number of poles x rpm}}{120}$$

### GS Governor Switch

Governor switch (GS) is used when the engine is equipped with a remote control synchronizing motor for the governor. Engine speed is controlled with this switch.

### HS Heat Switch

Heat switch (HS) is when the engine is equipped with glow plugs. This switch is used to operate the glow plugs for cold weather starting.

### OPG Oil Pressure Gauge

Oil pressure gauge (OPG) shows the pressure, in psi, of engine lubrication oil. When pressure switch (PSW) is closed, oil pressure gauge (OPG) is connected across battery voltage. There is a relation between the current flow in this circuit and the engine oil pressure read on oil pressure gauge (OPG). Oil pressure sender (OP) controls the current flow by a change in resistance according to the change in engine oil pressure.

### PAM Prealarm Module

Make reference to ATTACHMENTS.

### PL1, 2 Panel Lamps

Light for the control panel is given by panel lamps (PL1 and PL2). These lamps are controlled by panel light switch (PLS).

### VLR Voltage Level Rheostat

Voltage level rheostat (VLR) takes the place of voltage level rheostat (R2) on the generator regulator assembly. It is used to adjust the voltage output of the generator.

**NOTE: Make reference to OPERATION OF GENERATOR: REGULATOR ADJUSTMENT. On generators equipped with a generator mounted control panel, the yellow wire from voltage level rheostat (R2) to terminal (7) on the regulator terminal strip is disconnected at terminal (7).**

## AUTOMATIC START/STOP SYSTEM

### Introduction

The automatic start/stop system is normally used for standby operation. That is, without an operator. The generator set must start, pick up the load, operate the load, and stop after the load is removed. An automatic transfer switch controls the transfer of load to and from the generator set. When normal (commercial) power has a failure, initiating contactor (1), part of the automatic transfer switch, closes. This will begin the automatic start sequence. When the engine starts, the control panel instruments will show voltage and frequency. The automatic transfer switch will transfer the load to the generator set when voltage and frequency reach approximately rated value. When normal power returns, the automatic transfer switch will transfer the load back to normal power. Initiating contactor (1) will open. This will begin the automatic stop sequence. The generator set will also stop automatically if the engine has a failure.

The packaged generator set has shutdown sensors, shutdown indicators and shutdown circuit for the conditions that follow.

1. Low oil pressure
2. High water temperature
3. Overspeed
4. Overcrank

**NOTE: For specifications on components located on the engine, make reference to the ENGINE SERVICE MANUAL.**

### Automatic Start

With engine control switch (ACS) in the AUTO position, contacts (10) and (9) are closed. When commercial (normal) power has a failure, remote start initiating contact (1) closes. This makes a complete circuit from battery (BATT) to energize run relay (RR) through normally closed contacts of the four engine fault relays (OPR), (WTRI), (OSR1), (OCR).

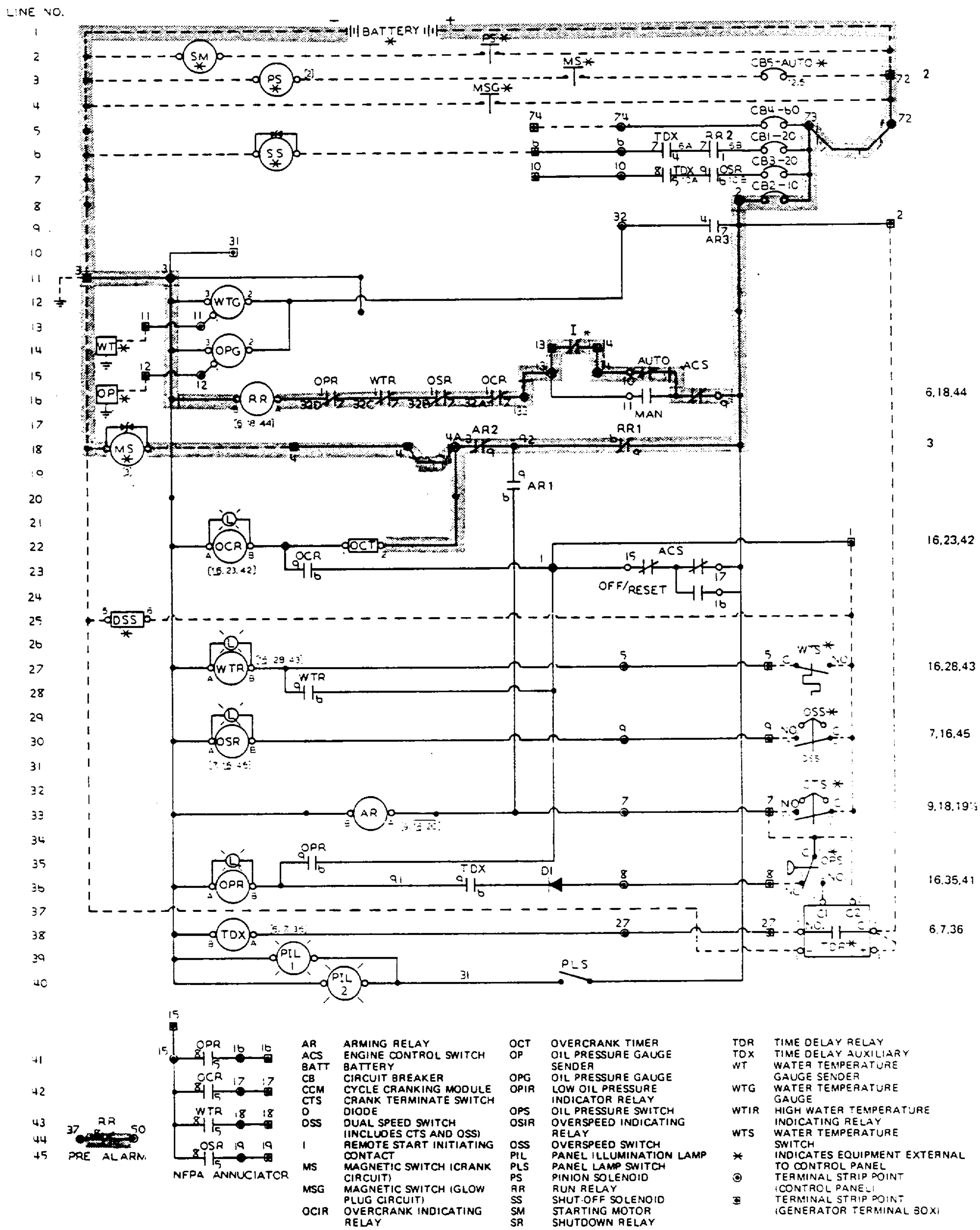
When run relay (RR) is energized. contact (RR2) opens and contact (RR1) closes. (RR2) open prevents current flow to shutoff solenoid (SS). (RR1) closed energizes the (MS) through a normally closed (AR2) contact. At the same time power is applied to the overcrank timer (OCT). A magnetic pickup relays engine rpm to the dual speed switch (DDS). The dual speed switch has a crank terminate (CTS) circuit and an overspeed (OSS) circuit.

When overcrank timer (OCT) is energized, a timer will start. After the engine cranks for approximately 30 seconds the timer will stop. (OCT) contacts will open. Make reference to ENGINE DOES NOT START.

When magnetic switch (MS) is energized, (MS) contacts close and pinion solenoid (PS) is energized. This causes (PS) contacts to close, starting motor (SM) will crank the engine.

### Manual Start

The current flow for manual start is similar to automatic start except engine control switch (ACS) is turned to the MAN position. Contact (10) is open and contact (11) is closed. It is not necessary for remote start indicating contact (1) to close. Run relay (RR) and magnetic switch (MS) will energize the same as with Automatic Start.

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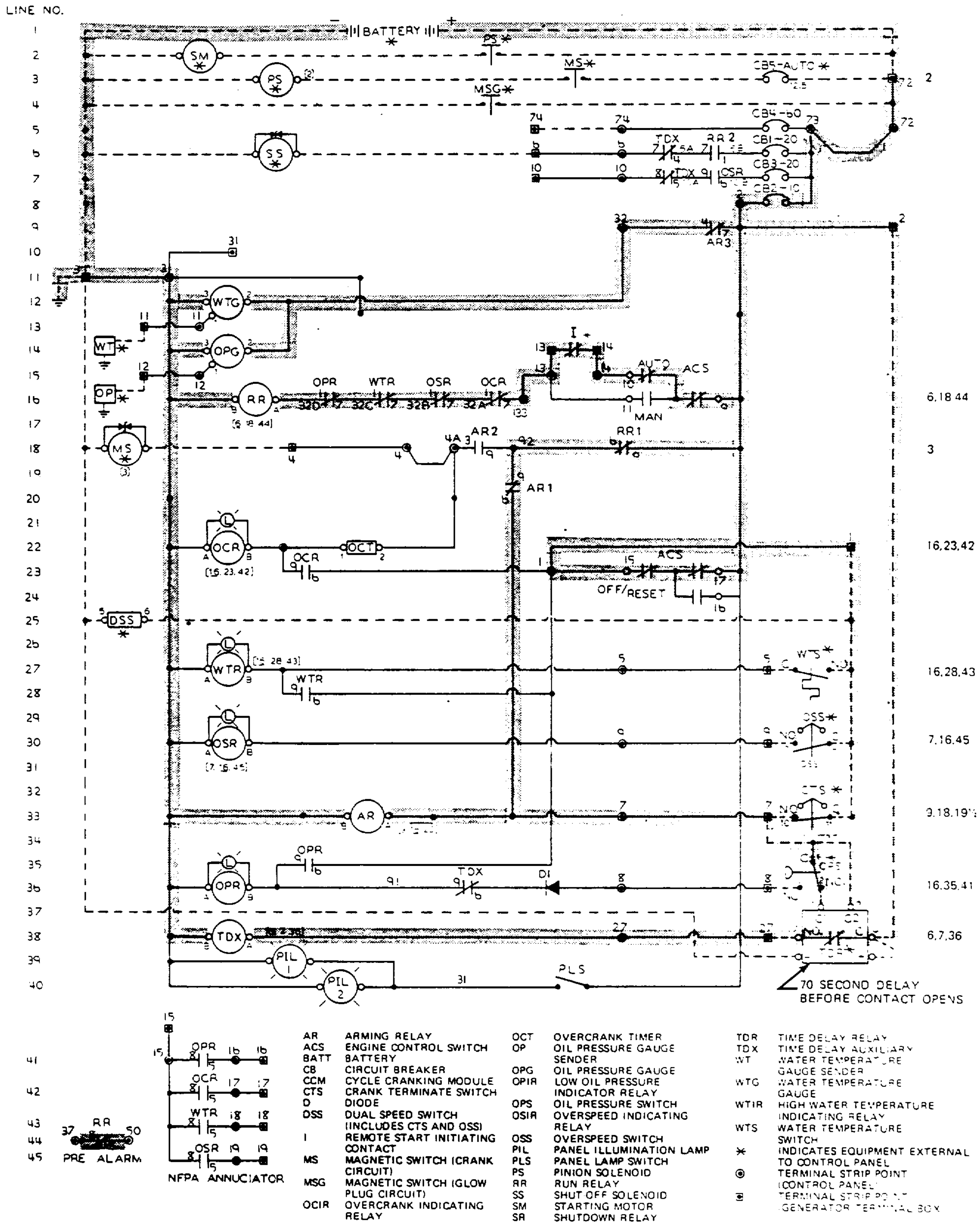
**CONTROL PANEL**
**AUTO POSITION (ENGINE CRANKS)**

**Engine Starts**

At 600 rpm, crank terminate switch (CTS) closes. This energizes the arming relay (AR). Contact (AR2) opens which disconnects the circuit to (MS) and the overcrank timer (OCT). The contact (AR2) closes to lock in the (AR) relay. Contact (AR3) closes to turn on the water temperature and oil pressure gauges.

At this same time, the (CTS) contact arms the time delay relay (TDR). The TDR has a fixed 9 second delay to allow for oil pressure build up. When oil pressure comes up, it actuates the oil pressure switch (OPS). The (OPS) contact clears the failure circuit and closes the (TDR) timer bypass contact.

When the TDR contact closes, it energizes the time delay auxiliary (TDX). The TDX arms the oil pressure failure circuit along with the shut-off solenoid (SS) and the optional air shut-off solenoid (ASO).

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**CONTROL PANEL**
**AUTO POSITION (ENGINE STARTS)**

**Engine Does Not Start**

If the engine does not start in approximately 30 seconds, overcrank timer (OCT) will let current flow to overcrank indicating relay (OCR). Contact (OCR2) closes to lock in the (OCR) relay and contact (OCR1) opens to open the RR relay circuit. This de-energizes run relay (RR) and magnetic switch (MS).

When run relay (RR) is de-energized, contact (RR2) closes and contact (RR1) opens. Contact (RR2) closed completes a circuit to shutoff solenoid (SS) until TDX opens.

**NOTE: TDR contact closes after 9 seconds into the 30 second cranking cycle. The TDX relay in turn energizes. This causes the TDX contacts to close. The TDX contacts will remain closed for 70 seconds after the end of the 30 second cranking cycle.**

Contact (RR1) open de-energizes arming relay (AR), and overcrank timer (OCT).

When magnetic switch (MS) is de-energized, (MS) contacts open. This de-energizes pinion solenoid (PS). (PS) contacts open and de-energize starting motor (SM).

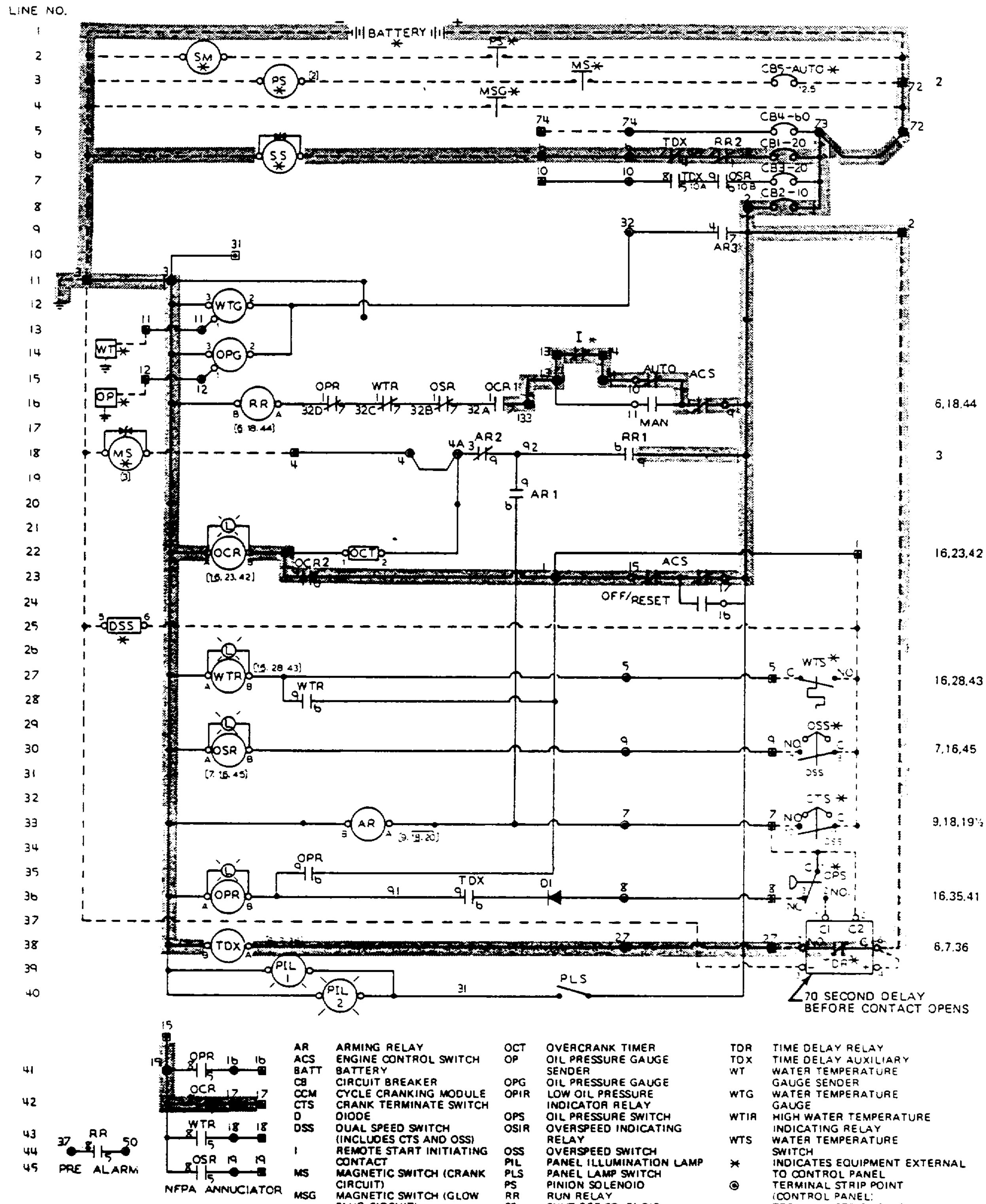
Overcrank indicating relaying (OCR) will give light. To start the engine, do the steps that follow:

1. Turn engine control switch (ACS) to OFF/RESET. This will open (ACS) contact (IS) and de-energize overcrank indicating relay (OCR). Contact OCR1 will close so that the run relay (RR) can be energized.

2. Turn the engine control switch to MANUAL or AUTO if I contact is closed. If the engine does not start in approximately 30 seconds, the overcrank indicating relay will give light.

3. Turn engine control switch (ACS) to STOP position. Observe fault lights and turn ACS to OFF/RESET. Correct the problem that caused the engine not to start. Make reference to TROUBLESHOOTING.

**NOTE: If the engine can not be started or stopped with the panel controls, check the condition of circuit breaker (CB2). (There is no visual indication of its condition). Press to reset.**




| | |
|---|---|
| AR | ARMING RELAY |
| ACS | ENGINE CONTROL SWITCH |
| BATT | BATTERY |
| CB | CIRCUIT BREAKER |
| CCM | CYCLE CRANKING MODULE |
| CTS | CRANK TERMINATE SWITCH |
| D | DIODE |
| DSS | DUAL SPEED SWITCH (INCLUDES CTS AND OSS) |
| I | REMOTE START INITIATING CONTACT |
| MS | MAGNETIC SWITCH (CRANK CIRCUIT) |
| MSG | MAGNETIC SWITCH (GLOW PLUG CIRCUIT) |
| OCIR | OVERCRANK INDICATING RELAY |
| OCT | OVERCRANK TIMER |
| OP | OIL PRESSURE GAUGE SENDER |
| OPG | OIL PRESSURE GAUGE |
| OPIR | LOW OIL PRESSURE INDICATOR RELAY |
| OPS | OIL PRESSURE SWITCH |
| OSIR | OVERSPEED INDICATING RELAY |
| OSS | OVERSPEED SWITCH |
| PIL | PANEL ILLUMINATION LAMP |
| PLS | PANEL LAMP SWITCH |
| PS | PINION SOLENOID |
| RR | RUN RELAY |
| SS | SHUT-OFF SOLENOID |
| SM | STARTING MOTOR |
| SR | SHUTDOWN RELAY |
| TDR | TIME DELAY RELAY |
| TDX | TIME DELAY AUXILIARY |
| WT | WATER TEMPERATURE GAUGE SENDER |
| WTG | WATER TEMPERATURE GAUGE |
| WTIR | HIGH WATER TEMPERATURE INDICATING RELAY |
| WTS | WATER TEMPERATURE SWITCH |
| * | INDICATES EQUIPMENT EXTERNAL TO CONTROL PANEL |
| ◉ | TERMINAL STRIP POINT (CONTROL PANEL) |
| ⊞ | TERMINAL STRIP POINT (GENERATOR TERMINAL BOX) |

866877X1

**CONTROL PANEL**
**AUTOMATIC POSITION (ENGINE DOES NOT START)**

**Return of Commercial (Normal) Power**

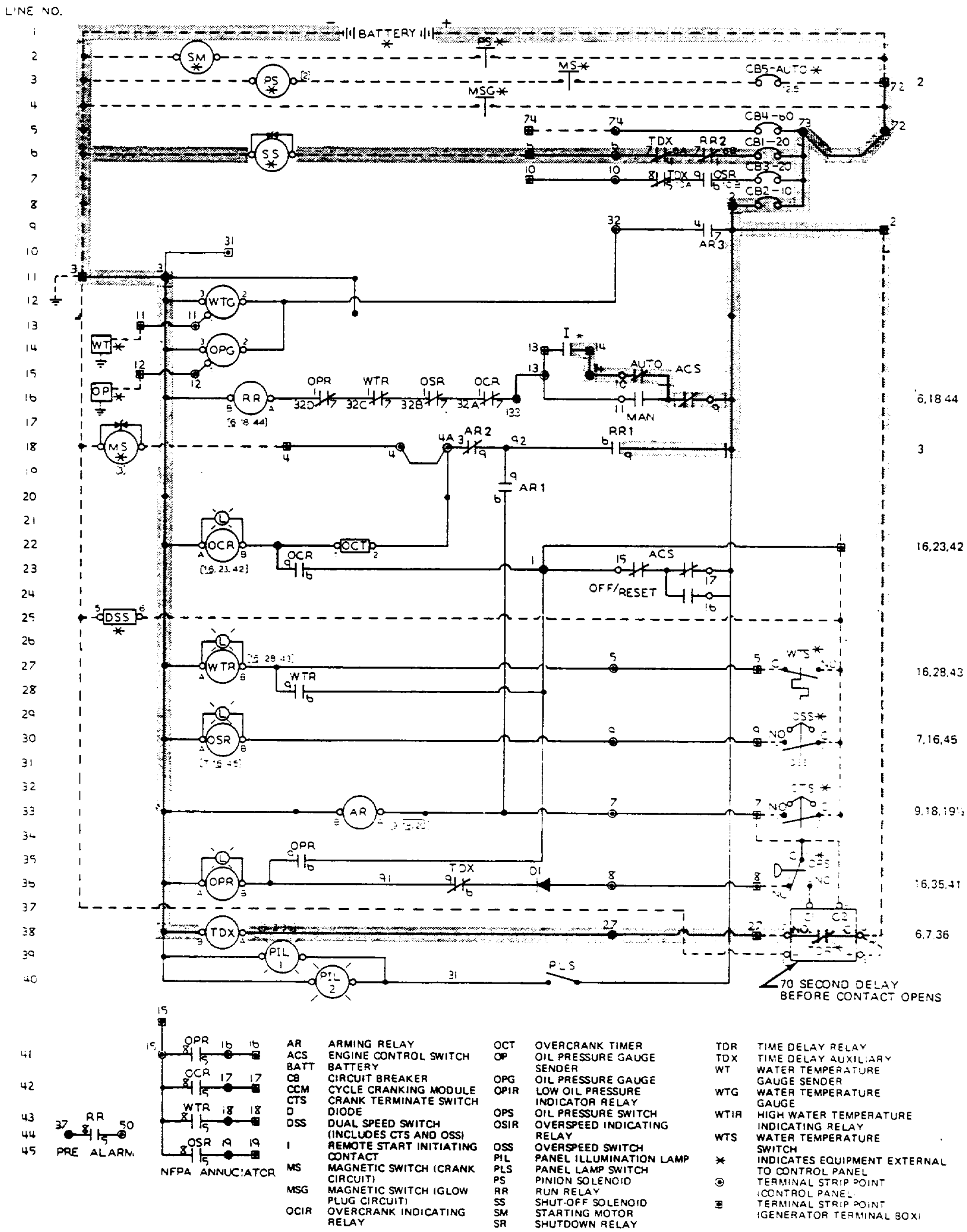
When commercial power returns, the automatic transfer switch transfers the load to commercial power. Remote start initiating contacts (1) open. This de-energizes run relay (RR).

When run relay (RR) is de-energized, contacts (RR2) close and contacts (RR1) open. (RR2) closed completes a circuit to shut-off solenoid (SS). The shut-off solenoid moves the rack to the fuel OFF position. (RR1) opens to de-energize the arming relay (AR).

After the engine stops, (TDX) contact will open to de-energize the shut-off solenoid.

**NOTE: TDX is operated by the TDR time delay relay. It has a fixed delay on drop out of 70 seconds. This means, the shut-off solenoid will remain energized for 70 seconds each time the unit is shutdown.**

Diode (Dl) is in the shut-off solenoid circuit to help prevent electrical sparks (arcing), at the shut-off solenoid contacts, when the shut-off solenoid is de-energized.

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**CONTROL PANEL**
**AUTOMATIC POSITION (AUTO SHUTDOWN)**

**Manual Shutdown**

When engine control switch (ACS) is turned to the STOP position or OFF/RESET position, contacts (10 and 11) are open. With contacts(10 and 11) open, the run relay (RR) de-energizes.

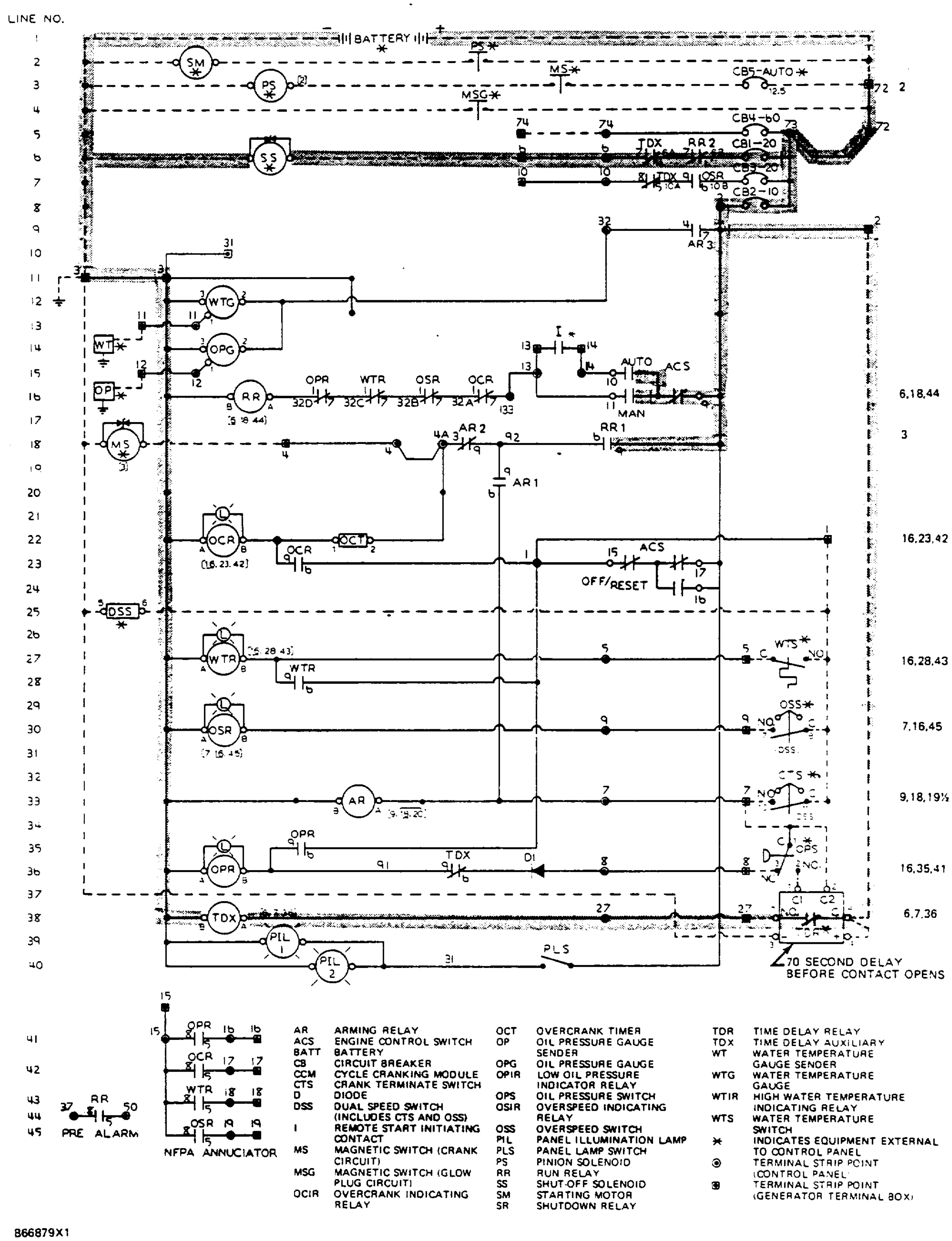
When run relay (RR) is de-energized, contact (RR2) closes and contact (RR1) opens. With (RR2) closed, it completes a circuit to the shut-off solenoid (SS). With contact (RR1) open, the arming relay (AR) is de-energized.

After the engine stops, (TDX) will open to de-energize the shutoff solenoid.

NOTE: TDX will remain closed for 70 seconds after the engine oil pressure switch (OPS) has gone to its normally closed position.

Diode DI helps prevent electrical sparks (arcing) at the contacts in the shutoff solenoid circuit when the shutoff solenoid is de-energized.

**NOTE: The shutdown solenoid (SS) is protected against overload by a circuit breaker (CB1). If the engine does not shut down when the ACS is turned to STOP, check the condition of CB1. Press to reset. [Button DOES NOT pop out when breaker is tripped].**




**CONTROL PANEL**
**STOP POSITION (MANUAL SHUTDOWN)**

**Engine Shutdown Caused by Water Temperature Failure**

When engine coolant temperature becomes too high, the normally open water temperature switch (WTS) closes. This, in turn, energizes the water temperature relay (WTR). Contact (WTR1) closes to lock in the relay (WTR).

The normally closed contact (WTR2) opens. This de-energizes run relay (RR). Contact (RR2) closes and contact (RR1) opens. (RR2) closed completes a circuit to shut-off solenoid (SS) until (TDX) opens (70 seconds after OPS opens). (RR1) open de-energizes the arming relay (AR).

Diode (DI) helps prevent electrical sparks (arcing) at the contacts in the shut-off solenoid circuit, when the shut-off solenoid is de-energized.

The water temperature indicating relay (WTR) will light. To start the engine, do the steps that follow:

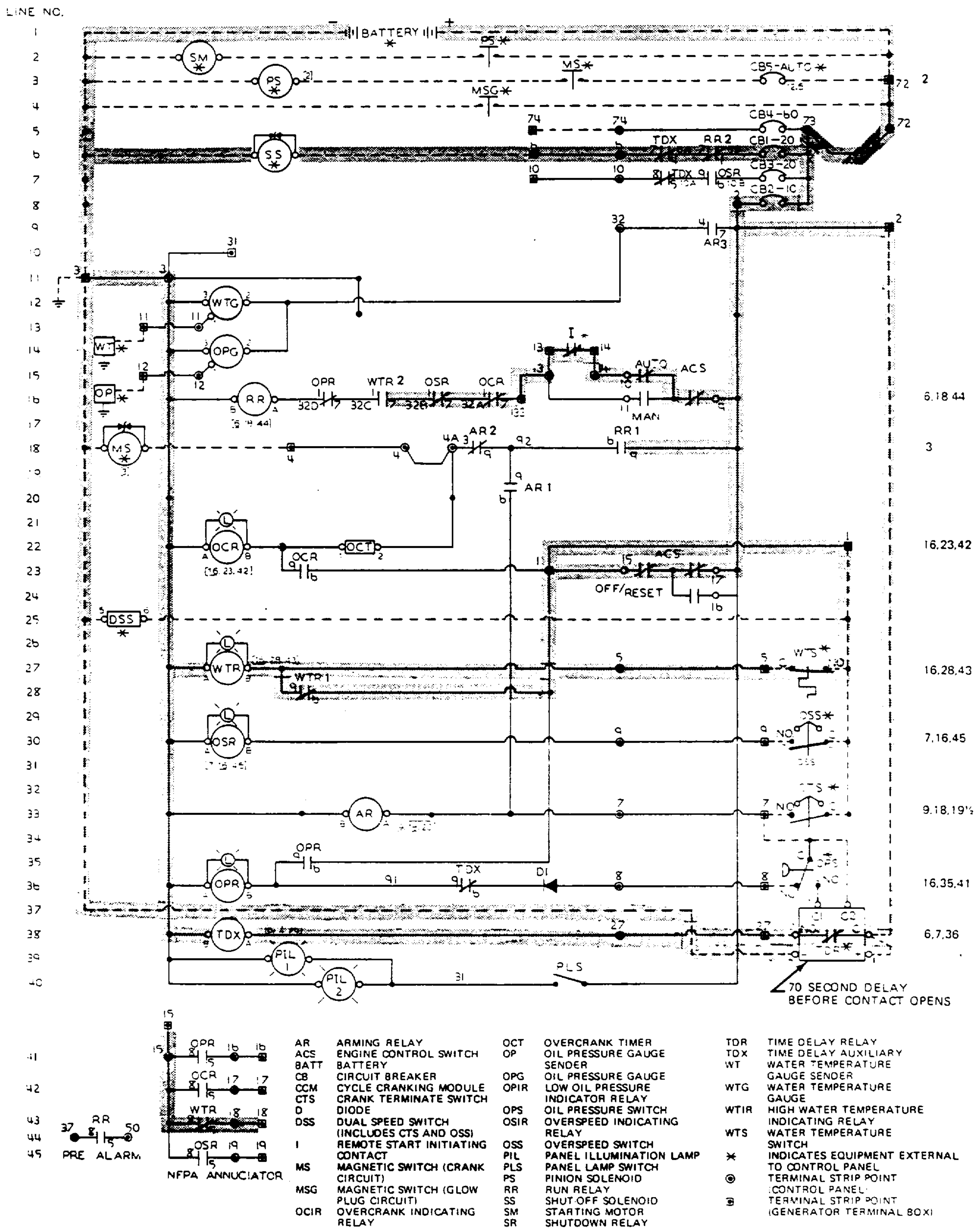
1. Turn engine control switch (ACS) to OFF or STOP.

**NOTE: For start-up when (OCR) indicating relay gives light, make reference to topic ENGINE DOES NOT START.**

2. Correct the high water temperature problem.

3. Rotate ACS to OFF/RESET position. This de-energizes the (WTR). Contact (WTR1) will close to energize the run relay coil. Contact (WTR2) will open to de-energize the shutdown solenoid.

4. The system is ready to start if engine control switch (ACS) is turned to MAN or AUTO.




866880X1

**CONTROL PANEL**
**SHUTDOWN (HIGH WATER TEMPERATURE)**

**Engine Shutdown Caused by Oil Pressure Failure**

Because crank termination is the job of the speed switch (C.T.S.), a time delay relay-(TDR) and time delay auxiliary (TDX) is required for oil pressure build-up after start-up.

When the engine is started and C.T.S. (crank termination switch) closes (at 600 rpm), the arming relay (AR) is energized. Contact (AR2) opens to de-energize the starting motor. Contact (AR1) closes to lock-in the (AR) relay. At this same time, (TDR) begins a 9 second delay. If oil pressure comes up and (OPS) goes to the N.O. position, the 9 second delay is bypassed and (TDX) will be energized immediately. At this time, the oil pressure failure circuit is armed thru the (TDX) contact.

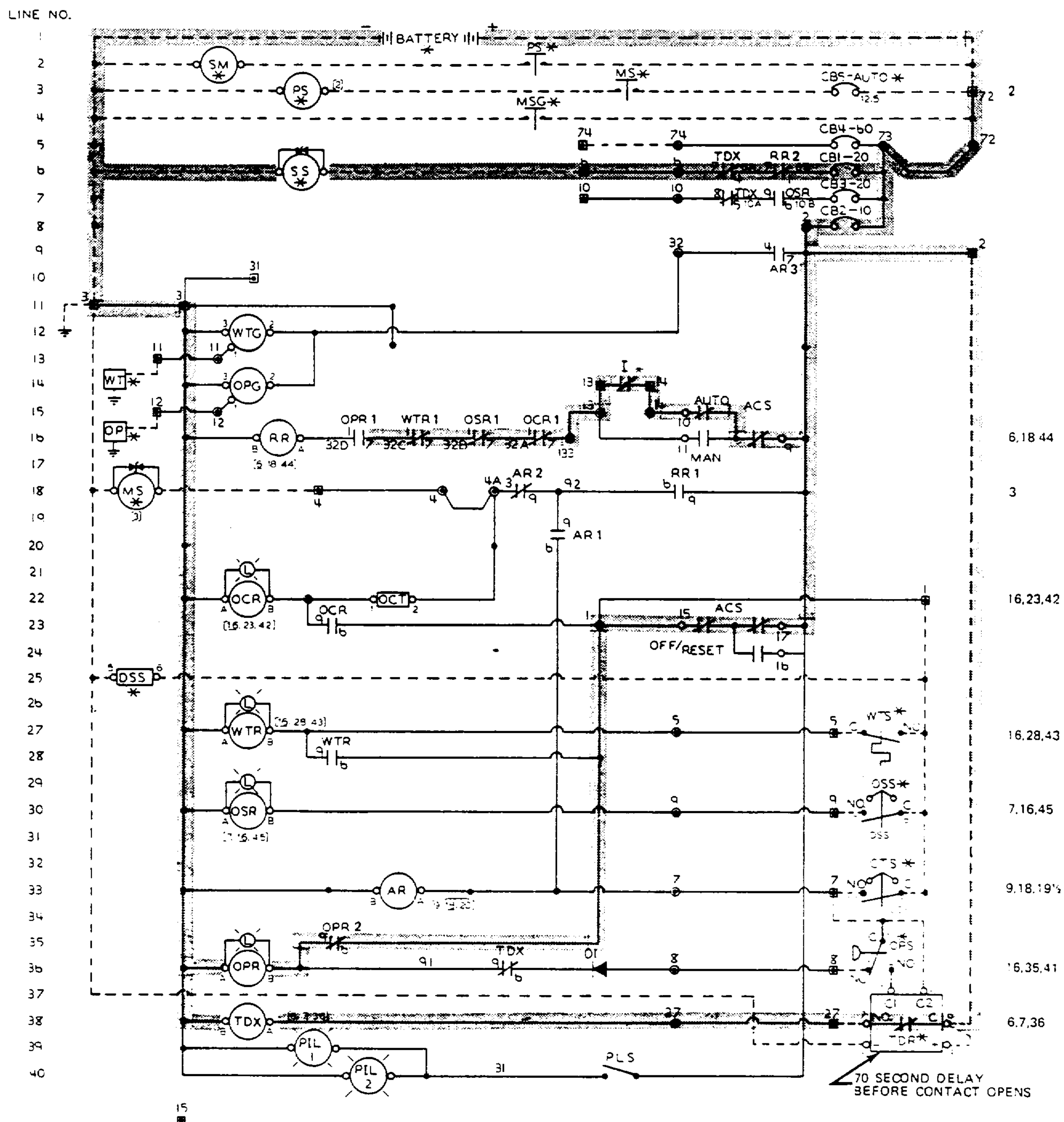
**NOTE: The shutdown and air shut-off circuits are also armed by TDX.**

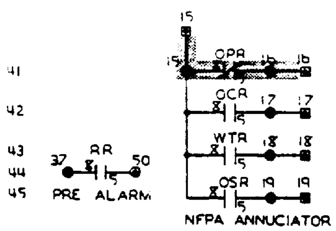
If a loss of oil pressure occurs, the oil pressure switch (OPS) will close. This causes (OPR) to energize through the contact TDX and diode Dl. Then (OPR1) contact opens to de-energize the run relay (RR) circuit. Contact (OPR2) closes to lock-in the relay (OPR) thru the OFF/RESET switch.

The engine will shut down when the normally closed (RR2) contact closes to energize the shutdown solenoid (SS).

If the engine should accidentally be started without oil in the crankcase, it will shutdown after the 9 second delay.

The time delay relay (TDR) also provides a 70 second delay before opening the shutdown and air shut-off solenoids after the engine stops.




| | |
|---|---|
| AR | ARMING RELAY |
| ACS | ENGINE CONTROL SWITCH |
| BATT | BATTERY |
| CB | CIRCUIT BREAKER |
| CCM | CYCLE CRANKING MODULE |
| CTS | CRANK TERMINATE SWITCH |
| D | DIODE |
| DSS | DUAL SPEED SWITCH (INCLUDES CTS AND OSS) |
| I | REMOTE START INITIATING CONTACT |
| MS | MAGNETIC SWITCH (CRANK CIRCUIT) |
| MSG | MAGNETIC SWITCH (GLOW PLUG CIRCUIT) |
| OCIR | OVERCRANK INDICATING RELAY |
| OCT | OVERCRANK TIMER |
| OP | OIL PRESSURE GAUGE SENDER |
| OPG | OIL PRESSURE GAUGE |
| OPIR | LOW OIL PRESSURE INDICATOR RELAY |
| OPS | OIL PRESSURE SWITCH |
| OSIR | OVERSPEED INDICATING RELAY |
| OSS | OVERSPEED SWITCH |
| PIL | PANEL ILLUMINATION LAMP |
| PLS | PANEL LAMP SWITCH |
| PS | PINION SOLENOID |
| RR | RUN RELAY |
| SS | SHUT OFF SOLENOID |
| SM | STARTING MOTOR |
| SR | SHUTDOWN RELAY |
| TDR | TIME DELAY RELAY |
| TDX | TIME DELAY AUXILIARY |
| WT | WATER TEMPERATURE GAUGE SENDER |
| WTG | WATER TEMPERATURE GAUGE |
| WTIR | HIGH WATER TEMPERATURE INDICATING RELAY |
| WTS | WATER TEMPERATURE SWITCH |
| * | INDICATES EQUIPMENT EXTERNAL TO CONTROL PANEL |
| ⊛ | TERMINAL STRIP POINT (CONTROL PANEL) |
| ⊞ | TERMINAL STRIP POINT (GENERATOR TERMINAL BOX) |

B66881X1

**CONTROL PANEL**
**OIL PRESSURE FAILURE SHUTDOWN**

**Shutdown Caused By Overspeed**

When the engine is shutdown due to an overspeed condition, the overspeed relay (OSR) is energized and locked in by the overspeed switch (OSS) contact of the dual speed switch (DSS).

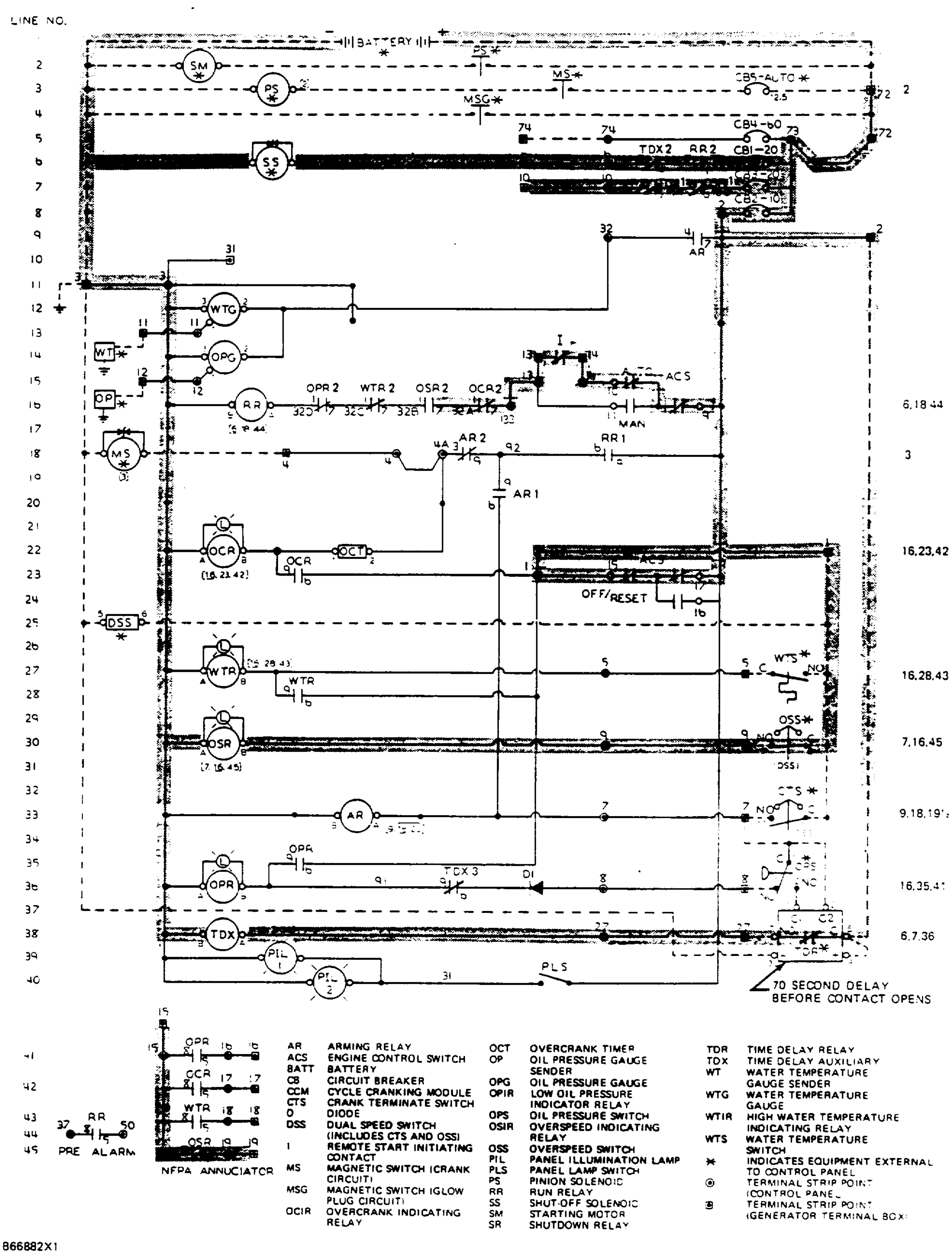
The normally closed contact (OSR2) opens to de-energize the run relay (RR). The normally open contact (OSR1) closes to complete a circuit through the closed (TDX1) contact.. This energizes the optional air shutoff solenoid (ASO).

Closed contacts (RR2) and (TDX2) will energize the shutdown solenoid (SS). As soon as the oil pressure switch (OPS) starts to close, (TDR) starts a time delay for 70 seconds. After 70 seconds, the (TDR) contact opens and de-energizes relay (TDX). Then all (TDX) contacts open.

To reset the overspeed fault relay, rotate the (ACS) to OFF/RESET. This will de-energize the dual speed switch and permit the OSS contact to open.

Before restarting, check for possible causes of the overspeed.

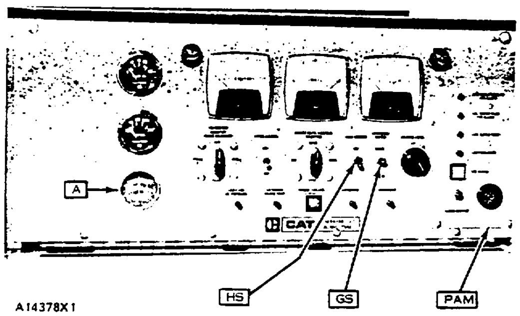
**NOTE: The shutdown solenoid and air shut-off solenoid are each protected with thermal type circuit breakers. If either solenoid does not energize to shutdown, check breaker condition by pressing button to reset.**




**CONTROL PANEL SHUTDOWN (OVERSPEED)**

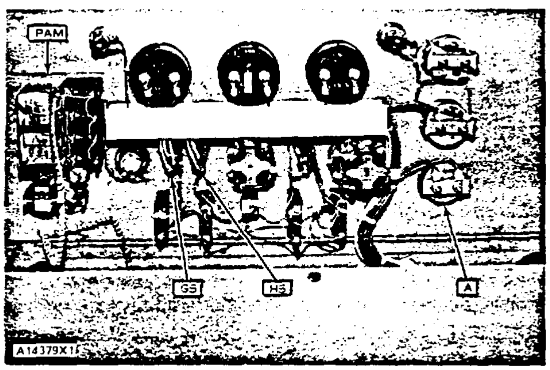
## GENERATOR MOUNTED CONTROL PANEL ATTACHMENTS

### IDENTIFICATION AND LOCATION



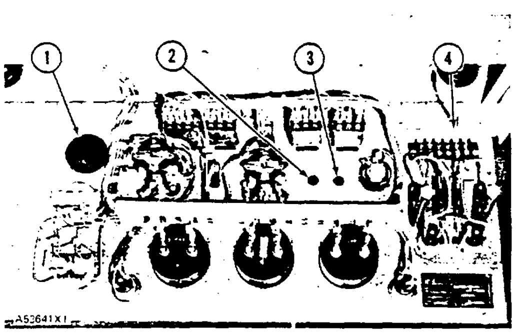

**CONTROL PANEL (FRONT VIEW) (TYPICAL)**

A. Ammeter. GS. Governor Switch. HS. Heat switch. PAM. Prealarm Module.



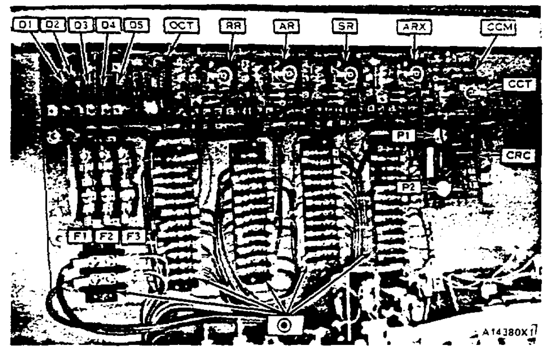

**OPEN CONTROL PANEL (TYPE 2)**

A. Ammeter. GS. Governor Switch. HS. Heat switch. PAM. Prealarm Module.



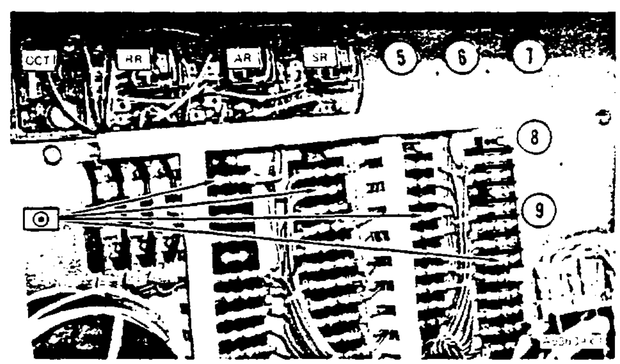

**OPEN CONTROL PANEL (TYPICAL FOR TYPE 3 AND 4)**

1. Location for D.C. ammeter. 2. Location for glow plug heat switch. 3. Location for governor switch. 4. Synchronizing Lights Module.




**INSIDE CONTROL PANEL HOUSING (TYPE 2)**

| | |
|---|---|
| AR | ARMING RELAY |
| ARX | AUXILIARY RELAY MODULE |
| CCM | CYCLE CRANKING MODULE |
| CCT | CYCLE CRANKING RELAY |
| CRC | CYCLE CRANK LOGIC TIMER |
| D1-D5 | DIODE |
| F1-F3 | FUSE |
| OCT | OVERCRANK TIMER |
| P1 | POTENTIOMETER FOR CRANK TIME |
| P2 | POTENTIOMETER FOR REST TIME |
| RR | RUN RELAY |
| SR | SHUTDOWN RELAY |
| | TERMINAL STRIP POINT (CONTROL PANEL) |




**INSIDE CONTROL PANEL HOUSING (TYPICAL FOR TYPE 3 AND 4)**

5. Location for Cool Down Timer (CDT). 6. Location for Cool Down Timer-Relay (CDTR). 7. Location for Auxiliary Relay (AUX). 8. Location for Cycle Crank Relay (CCT). 9. Location for Cycle Cranking Module (CCM). AR. Arming Relay. OCT. Overcrank Timer. RR. Run Relay. SR. Shutdown Relay.

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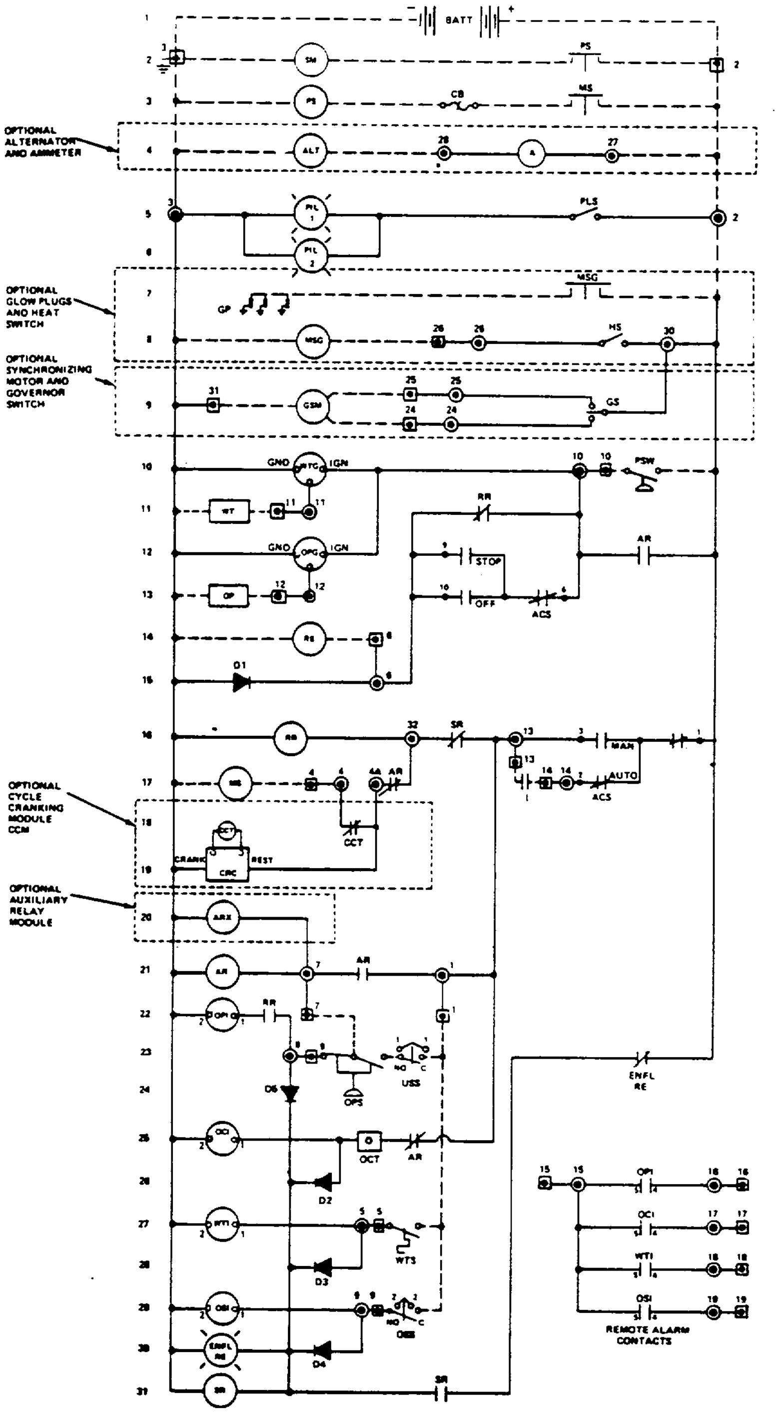


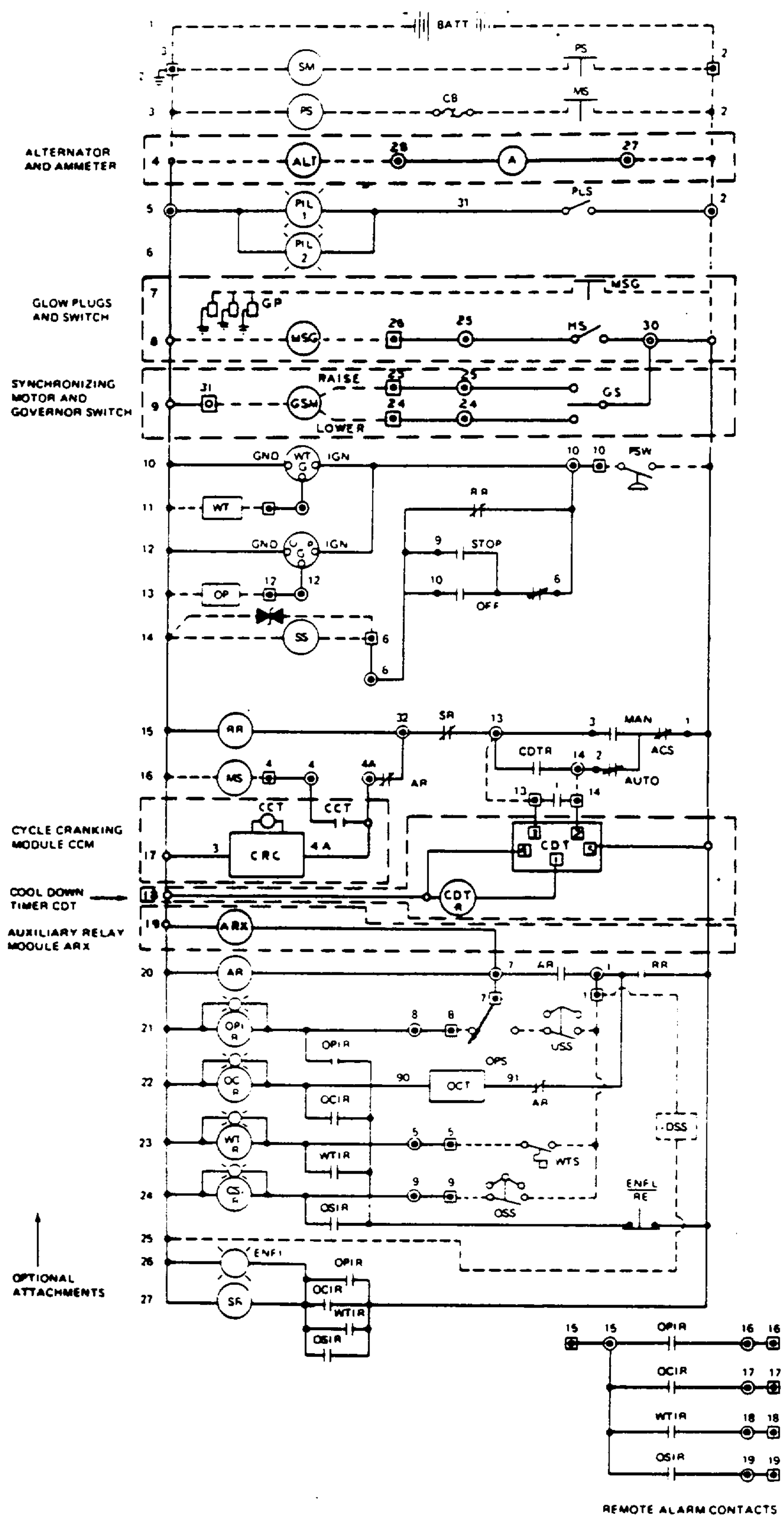

**ABBREVIATIONS**

A AMMETER
ACS ENGINE CONTROL SWITCH
ALT CHARGING ALTERNATOR
AR ARMING RELAY
ARX AUXILIARY RELAY MODULE
AUX AUXILIARY CONTACT
BATT BATTERY
B+ BATTERY POSITIVE
B– BATTERY NEGATIVE
CB CIRCUIT BREAKER
CCM CYCLE CRANKING MODULE
CCT CYCLE CRANK RELAY
CRC CYCLE CRANK LOGIC TIMER
CT CURRENT TRANSFORMER
D DIODE
ENFL ENGINE FAULT LIGHT WITH FAULT RESET FUNCTION
GP GLOW PLUGS
GS GOVERNOR SWITCH
GSM GOVERNOR SYNCHRONIZING MOTOR
HS GLOW PLUG HEAT SWITCH
I REMOTE START INITIATING CONTACT
MS MAGNETIC SWITCH (CRANK CIRCUIT)
MSG MAGNETIC SWITCH (GLOW PLUG CIRCUIT)
OCI OVERCRANK INDICATOR
OCT OVERCRANK TIMER
OP OIL PRESSURE GAUGE SENDER
OPG OIL PRESSURE GAUGE
OPI LOW OIL PRESSURE INDICATOR
OPS OIL PRESSURE SWITCH
OSI OVERSPEED INDICATOR
OSS OVERSPEED SWITCH
PIL PANEL ILLUMINATION LAMP
PLS PANEL LAMP SWITCH
PS PINION SOLENOID
PSW PRESSURE SWITCH
RE FAULT RESET SWITCH, PART OF ENFL
RR RUN RELAY
RS SHUTOFF SOLENOID
SM STARTING MOTOR
SR SHUTDOWN RELAY
USS UNDERSPEED SWITCH
WT WATER TEMPERATURE GAUGE SENDER
WTG WATER TEMPERATURE GAUGE
WTI HIGH WATER TEMPERATURE INDICATOR
WTS WATER TEMPERATURE SWITCH

⊙ TERMINAL STRIP POINT (CONTROL PANEL)
⊡ TERMINAL STRIP POINT (GENERATOR TERMINAL BOX)

**SCHEMATIC OF CONTROL PANEL WITH ALL ATTACHMENTS SHOWN (TYPE 2)**

The schematic shows the normal condition of all relays.




ABBREVIATIONS

| | |
|---|---|
| A | AMMETER |
| ACS | ENGINE CONTROL SWITCH |
| ALT | CHARGING ALTERNATOR |
| AR | ARMING RELAY |
| ARX | AUXILIARY RELAY MODULE |
| AUX | AUXILIARY CONTACT |
| BATT | BATTERY |
| B+ | BATTERY POSITIVE |
| B- | BATTERY NEGATIVE |
| CB | CIRCUIT BREAKER |
| CCM | CYCLE CRANKING MODULE |
| CCT | CYCLE CRANK RELAY |
| CDT | COOL DOWN TIMER |
| CDTR | COOL DOWN TIMER RELAY |
| CRC | CYCLE CRANK LOGIC TIMER |
| CT | CURRENT TRANSFORMER |
| D | DIODE |
| DSS | DUAL SPEED SWITCH (INCLUDES USS AND OSS) |
| ENFL | ENGINE FAULT LIGHT WITH FAULT RESET FUNCTION |
| GP | GLOW PLUGS |
| GS | GOVERNOR SWITCH |
| GSM | GOVERNOR SYNCHRONIZING MOTOR |
| HS | GLOW PLUG HEAT SWITCH |
| I | REMOTE START INITIATING CONTACT |
| MS | MAGNETIC SWITCH (CRANK CIRCUIT) |
| MSG | MAGNETIC SWITCH (GLOW PLUG CIRCUIT) |
| OCIR | OVERCRANK INDICATING RELAY |
| OCT | OVERCRANK TIMER |
| OP | OIL PRESSURE GAUGE SENDER |
| OPG | OIL PRESSURE GAUGE |
| OPIR | LOW OIL PRESSURE INDICATING RELAY |
| OPS | OIL PPESSURE SWITCH |
| OSIR | OVERSPEED INDICATING RELAY |
| OSS | OVERSPEED SWITCH |
| PIL | PANEL ILLUMINATION LAMP |
| PLS | PANEL LAMP SWITCH |
| PS | PINION SOLENOID |
| PSW | PRESSURE SWITCH |
| RE | FAULT RESET SWITCH PART OF ENFL |
| RR | RUN RELAY |
| SM | STARTING MOTOR |
| SR | SHUTDOWN RELAY |
| SS | SHUTOFF SOLENOID |
| USS | UNDERSPEED SWITCH |
| WT | WATER TEMPERATURE GAUGE SENDER |
| WTG | WATER TEMPERATURE GAUGE |
| WTIR | HIGH WATER TEMPERATURE INDICATING RELAY |
| WTS | WATER TEMPERATURE SWITCH |
| ⊙ | TERMINAL STRIP POINT (CONTROL PANEL) |
| ⊡ | TERMINAL STRIP POINT (GENERATOR TERMINAL BOX) |

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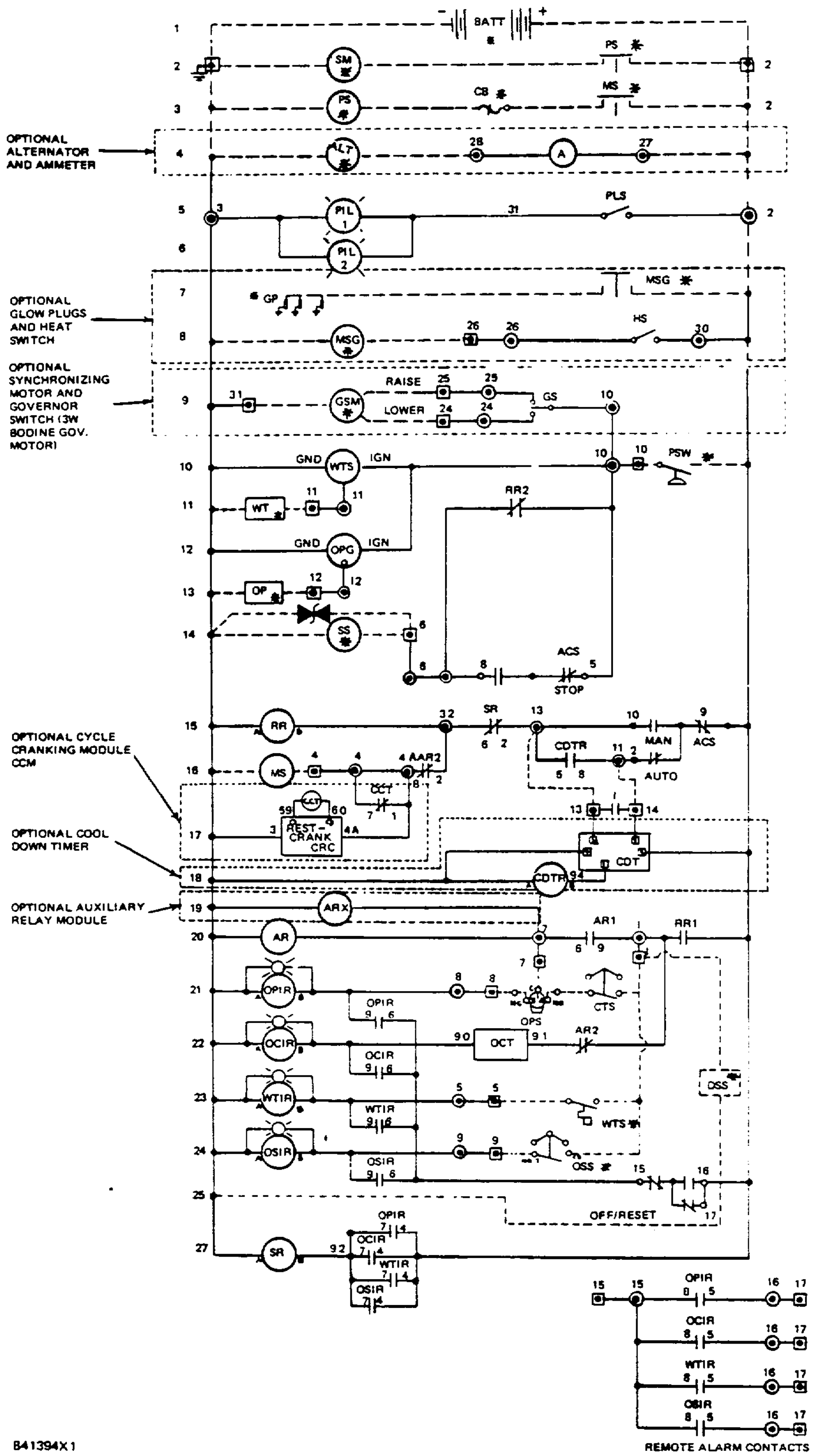
**SCHEMATIC OF CONTROL PANEL WITH ALL ATTACHMENTS SHOWN (TYPE 3)**

The schematic shows the normal condition of all relays.



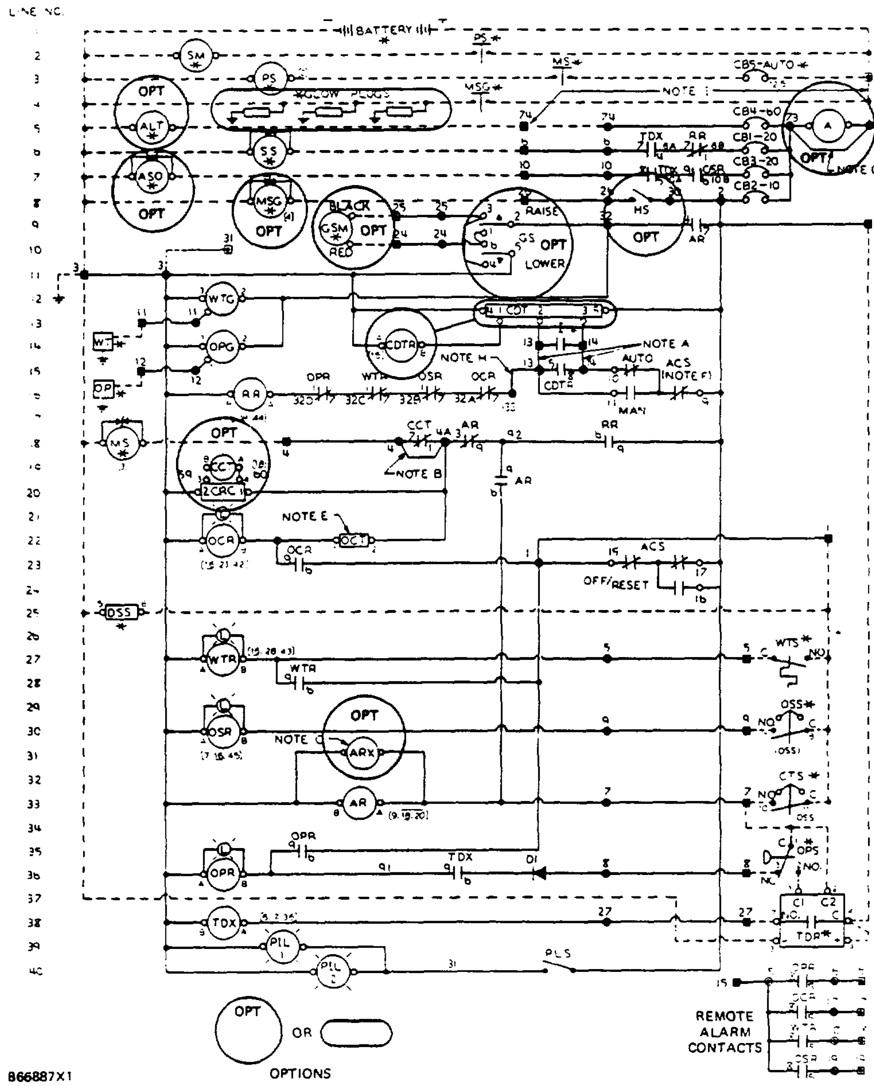

ADC AMMETER
ACS ENGINE CONTROL SWITCH
ALT CHARGING ALTERNATOR
AR ARMING RELAY
ARX AUXILIARY RELAY MODULE
BATT BATTERY
CB CIRCUIT BREAKER
CCM CYCLE CRANKING MODULE
CCT CYCLE CRANK RELAY
CDT COOL DOWN TIMER
CDTR COOL DOWN TIMER RELAY
CRC CYCLE CRANK LOGIC TIMER
CTS CRANK TERMINATE SWITCH
D DIODE
DSS DUAL SPEED SWITCH (INCLUDES CTS AND OSS)
GP GLOW PLUGS
GS GOVERNOR SWITCH
GSM GOVERNOR SYNCHRONIZING MOTOR
HS GLOW PLUG HEAT SWITCH
I REMOTE START INITIATING CONTACT
MS MAGNETIC SWITCH (CRANK CIRCUIT)
MSG MAGNETIC SWITCH (GLOW PLUG CIRCUIT)
OCIR OVERCRANK INDICATING RELAY
OCT OVERCRANK TIMER
OP OIL PRESSURE GAUGE SENDER
OPG OIL PRESSURE GAUGE
OPIR LOW OIL PRESSURE INDICATOR RELAY
OPS OIL PRESSURE SWITCH
OSIR OVERSPEED INDICATING RELAY
OSS OVERSPEED SWITCH
PIL PANEL ILLUMINATION LAMP
PLS PANEL LAMP SWITCH
PS PINION SOLENOID
PSW PRESSURE SWITCH
RR RUN RELAY
SS SHUT-OFF SOLENOID
SM STARTING MOTOR
SR SHUTDOWN RELAY
WT WATER TEMPERTAURE GAUGE SENDER
WTG WATER TEMPERATURE GAUGE
WTIR HIGH WATER TEMPERATURE INDICATING RELAY
WTS WATER TEMPERATURE SWITCH

* INDICATES EQUIPMENT EXTERNAL TO CONTROL PANEL
⊙ TERMINAL STRIP POINT (CONTROL PANEL)
▣ TERMINAL STRIP POINT (GENERATOR TERMINAL BOX)

**SCHEMATIC OF CONTROL PANEL WITH ALL ATTACHMENTS SHOWN (TYPE 4)**

The schematic shows the normal condition of all relays.

C

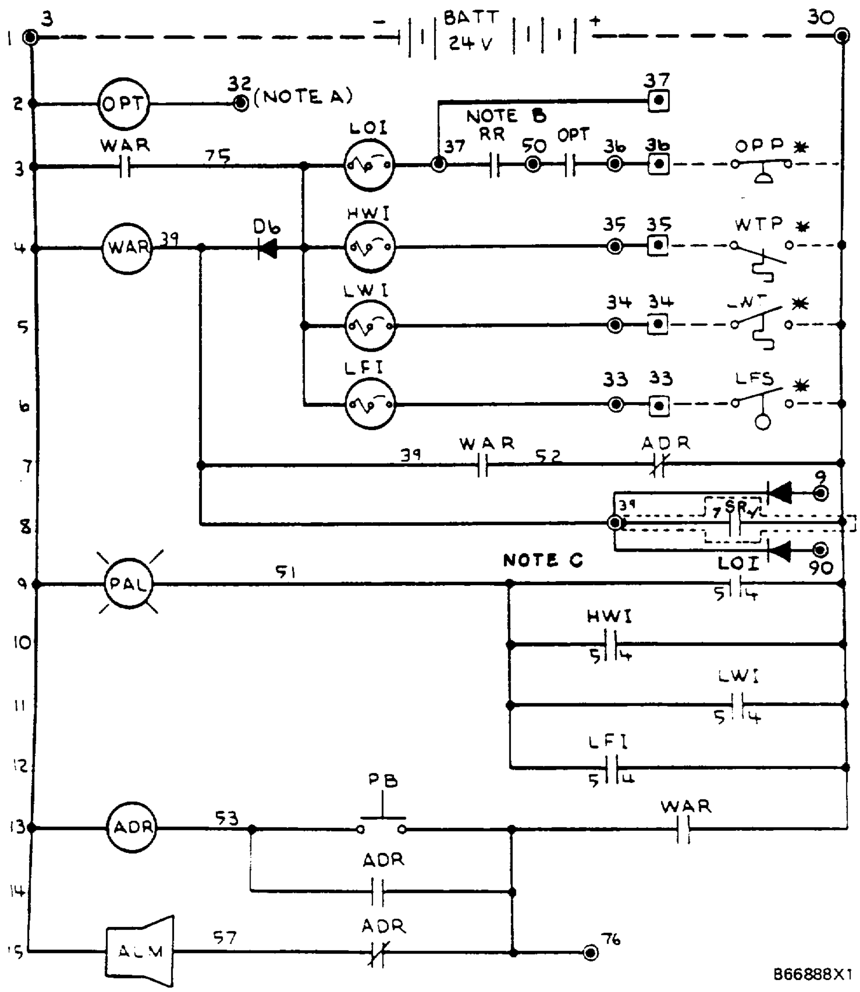



**SCHEMATIC OF CONTROL PANEL WITH ALL ATTACHMENTS SHOWN (TYPE 5)**

The schematic shows the normal condition of all relays.

| | |
|---|---|
| A | DC AMMETER |
| ACS | ENGINE CONTROL SWITCH |
| ALT | CHARGING ALTERNATOR |
| AR | ARMING RELAY |
| ARX | AUXILIARY RELAY MODULE |
| ASO | AIR SHUT OFF SOLENOID |
| BATT | BATTERY |
| CB | CIRCUIT BREAKER |
| CCM | CYCLE CRANKING MODULE |
| CCT | CYCLE CRANK RELAY |
| CDT | COOL DOWN TIMER |
| CDTR | COOL DOWN TIMER RELAY |
| CRC | CYCLE CRANK LOGIC TIMER |
| CTS | CRANK TERMINATE SWITCH |
| D | DIODE |
| DSS | DUAL SPEED SWITCH (INCLUDES CTS AND OSS) |
| GP | GLOW PLUGS |
| GS | GOVERNOR SWITCH |
| GSM | GOVERNOR SYNCHRONIZING MOTOR |
| HS | GLOW PLUG HEAT SWITCH |
| I | REMOTE START INITIATING CONTACT |
| MS | MAGNETIC SWITCH (CRANK CIRCUIT) |
| MSG | MAGNETIC SWITCH (GLOW PLUG CIRCUIT) |
| OCIR | OVERCRANK INDICATING RELAY |
| OCT | OVERCRANK TIMER |
| OP | OIL PRESSURE GAUGE SENDER |
| OPG | OIL PRESSURE GAUGE |
| OPIR | LOW OIL PRESSURE INDICATOR RELAY |
| OPS | OIL PRESSURE SWITCH |
| OSIR | OVERSPEED INDICATING RELAY |
| OSS | OVERSPEED SWITCH |
| PIL | PANEL ILLUMINATION LAMP |
| PLS | PANEL LAMP SWITCH |
| PS | PINION SOLENOID |
| RR | RUN RELAY |
| SS | SHUT-OFF SOLENOID |
| SM | STARTING MOTOR |
| SR | SHUTDOWN RELAY |
| TOR | TIME DELAY RELAY |
| TDX | TIME DELAY AUXILIARY |
| WT | WATER TEMPERATURE GAUGE SENDER |
| WTG | WATER TEMPERATURE GAUGE |
| WTIR | HIGH WATER TEMPERATURE INDICATING RELAY |
| WTS | WATER TEMPERATURE SWITCH |
| * | INDICATES EQUIPMENT EXTERNAL TO CONTROL PANEL |
| ○ | TERMINAL STRIP POINT (CONTROL PANEL) |
| □ | TERMINAL STRIP POINT (GENERATOR TERMINAL BOX) |

## PREALARM MODULE




**PREALARM MODULE (PAM)**

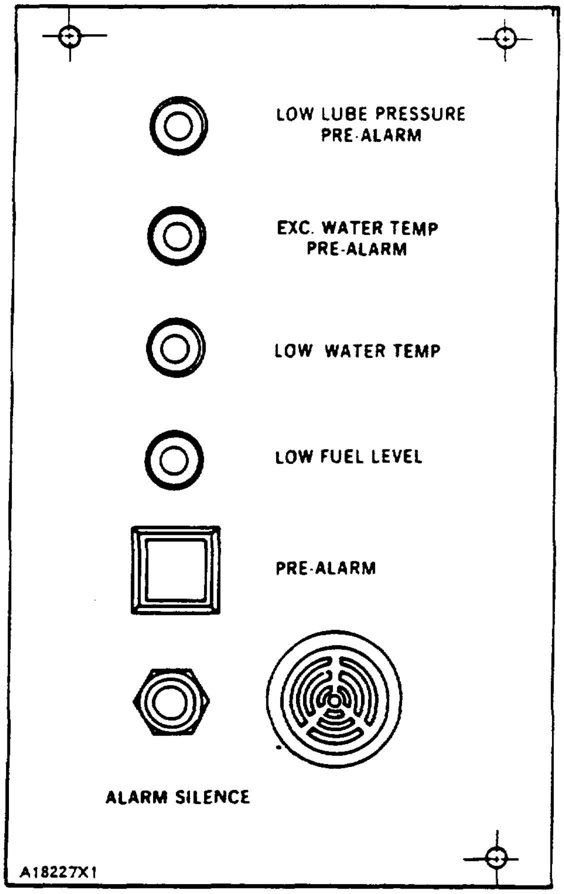
ADR ALARM DISCONNECT RELAY
ALM ALARM (SONALERT)
D DIODE
HWI HIGH WATER TEMP. INDICATOR
LFI LOW FUEL LEVEL INDICATOR
LFS LOW FUEL LEVEL SWITCH
LOI LOW OIL PRESSURE INDICATOR
LWI LOW WATER TEMPERATURE INDICATOR
LWT LOW WATER TEMPERATURE SWITCH
OPP OIL PRSSURE SWITCH-PRELIMINARY
OPT OIL PRESSURE TIMER
PAL PRELIMINARY ALARM LIGHT
PB ALARM SILENCE PUSH BUTTON
RR RUN RELAY
SR SHUTDOWN RELAY (TYPE I THROUGH 4 CONTROL PANELS)

WAR WARNING ALARM RELAY
WTP WATER TEMPERATURE
SWIT CH-PRELIMINARY
TERMINAL BOARD POINT IN PANEL
TERMINAL BOARD POINT ON ENGINE
ENGINE MOUNTED EQUIPMENT

NOTE A: Terminal (32) Is energized by battery positive when the engine cranks. Battery positive Is removed when the engine stops.

NOTE B: Terminal (37) can be connected to a remote low lubrcation oil pressure indicator Installed by the customer.

NOTE C: Type 5 Control Panel requires diodes to sound an alarm on overspeed and overcrank conditions.




**PREALARM MODULE (PAM)**

The Prealarm module fits the requirements in National Fire Protection Association-76A paragraph 631. It fits in the right side of the control panel. The purpose of the Prealarm module is to give a warning of conditions that can become a problem before they are serious enough to keep the engine from starting or running. The Prealarm module activates its warning system for the following conditions:

When the engine has one of these conditions, the switch which measures it closes. This closes the circuit to the indicator in the control panel for that condition. The indicators are circuit breakers of the push button type. When the circuit breaker first gets the current from the switch, it is in its normally closed position. The circuit is closed to the warning auxiliary relay (WAR) which activates and closes its own hold in circuit and the circuit to the alarm (ALM) which is a warning horn. The circuit breaker activates and opens the circuit to the warning alarm relay (WAR) and closes the circuit to the preliminary alarm light (PAL). This makes the preliminary alarm light (PAL) operate.

The preliminary alarm light (PAL) and the alarm (ALM) operate until they are manually disconnected by the operator. The alarm silence push button (PB). when pushed by the operator, closes the circuit to the alarm disconnect relay (ADR). It activates and closes its own hold in circuit. At the same time, it opens the circuit to the alarm (ALM) and to warning alarm relay (WAR). When the circuit to the warning alarm relay (WAR) opens, its contacts move to their normal positions. This disconnects the alarm disconnect relay (ADR). When the operator pushes the push button for the circuit breaker, it disconnects the preliminary alarm light (PAL).

**NOTE**: If the engine still has the same conditions, the alarm system activates again when the push button for the circuit breaker is pushed.

The circuit which is between the indicator for low oil pressure in the engine (LOW LUBE PRESSURE PREALARM) and the oil pressure switch-preliminary (OPP) is open until the run relay (RR) contacts and the oil pressure timer (OPT) contacts are closed. The run relay (RR) closes its contacts when the signal to start the engine is felt. The oil pressure timer (OPT) starts to operate at the same time. After approximately 90 seconds, the oil pressure timer (OPT) closes it contacts. The oil pressure switch preliminary (OPP) opens at approximately 19 psi (130 kPa) when the pressure is increasing. It closes at approximately 15 psi ( 105 kPa) when the pressure is decreasing. If the oil pressure switch-preliminary (OPP) is closed for any reason. it now causes the circuit breaker for the LOW LUBE PRESSURE PREALARM to activate. The alarm system activates normally from this point.

When the engine has a normal shutdown. the circuit to run relay (RR) is disconnected. Run relax (RR) contacts go to the normally open position in the oil pressure circuit. This keeps the oil pressure switch-preliminary (OPP) from activating the low oil pressure indicator (LOI) when the oil pressure decreases because of normal engine shutdown.

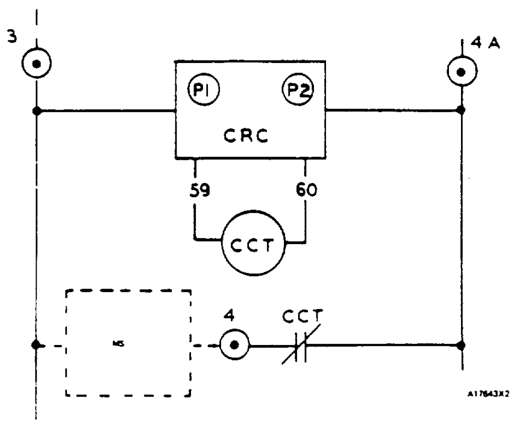
The alarm (ALM.) in the Prealarm module operates when the automatic start-stop system causes shutdown of the engine because of an engine problem. When the shutdown relay (SR) is activated by one of the switches in the automatic start-stop system, some of the contacts close a circuit through terminal 39 which activates the warning alarm relay (WAR). This causes alarm (ALM) to operate. (See Note C.)

**NOTE**: This does not cause the preliminary alarm light (PAL) to operate.

The alarm silence push button (PB) must be manually operated to stop the operation of the alarm (ALM).

| INDICATOR | CONDITION |
|---|---|
| LOW LUBE PRESSURE PREALARM | Engine oil pressure less than approximately 15 psi (105 kPa). |
| EXC. WATER TEMP PREALARM | Engine coolant temperature more than 197F (92°C). |
| LOW WATER TEMP | Engine coolant temperature less than 70'F (21°C). |
| LOW FUEL LEVEL | Fuel supply of approximately 3 hrs. |

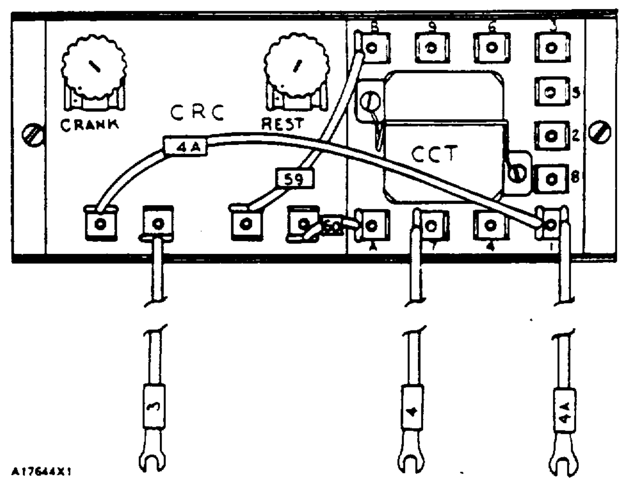
**CYCLE CRANKING MODULE**
NOTE: Jumper between TB2-4 and 4a must be removed when the cycle cranking module is used.




**WIRING DIAGRAM**

The cycle cranking module (CCM) has a cycle cranking relay (CCT) and a cycle crank logic timer (CRC). The cycle crank relay (CCT) controls the circuit to the magnetic switch (MS) which controls the circuit to the starting motor (SM). The cycle crank logic timer (CRC) controls the cycle crank relay (CCT). The overcrank timer (OCT) controls the time that the cycle crank module (CCM) is activated.

The cycle crank logic timer (CRC) has a CRANK POT (P1) and a REST POT (P2). When the cycle cranking module (CCM) is activated, the cycle crank relay (CCT) is in its normally closed condition. The starting motor activates. At the same time the cycle crank logic timer (CRC) starts to measure the time electronically. The time for operation of the starting




**CYCLE CRANKING MODULE**

**CCT CYCLE CRANK RELAY**
**CRC CYCLE CRANK LOGIC TIMER**

motor is controlled by the adjustment of CRANK POT (PI). When the time is done. the cycle crank logic timer (CRC) activates the cycle crank relay (CCT). The cycle crank relay (CCT) opens the circuit that controls the starting motor (SM). At the same time the cycle crank logic timer (CRC) starts to measure the time. according to the adjustment of REST POT (P2). When the time is done, the cycle crank logic timer (CRC) opens the circuit to the cycle crank relay (CCT) and starts to measure time according to CRANK POT (P1) again. The CRANK POT (P1)'and REST POT (P2) are each adjusted to 10 seconds at the factory. This series of cycles does not stop until the circuit, which activates the cycle cranking module (CCM). is opened by the shutoff relay (SR) or arming relay (AR).

The overcrank timer (OCT) Is adjusted to activate the shutdown relay after a total of 90 seconds when the cycle cranking module (CCM) Is installed. , when the engine starts the overcrank timer (OCT) and cycle cranking module (CCM) are disconnected by the arming relay (AR).

**HEAT SWITCH**

**NOTE**: Available on Type 2, Type 3 and Type 4 control panels.

Heat switch (HS) is used on generator sets equipped with glow plugs. When the heat switch is held closed, magnetic switch (MSG) is energized. This closes magnetic switch contacts and glow plugs (GP) heat the precombustion chambers to aid cold weather starting. When the heat switch is released, the magnetic switch is de-energized and current flow to the glow plugs stops.

**NOTICE**

**Do not energize the glow plugs when the engine is warm.**

**AMMETER**

**NOTE**: Available on all control panels.

Ammeter (A) is a DC ammeter used to show the rate of charge or discharge in the alternator circuit. The purpose of the optional alternator circuit is to charge batteries (BATT).

**GOVERNOR- SWITCH**

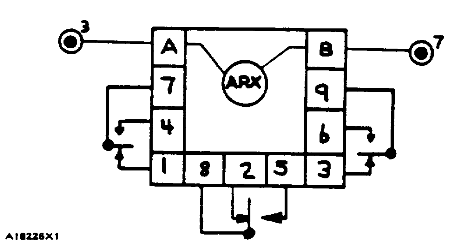
**NOTE**: Available on all control panels.

When the engine governor is equipped with a synchronizing motor, governor switch (GS) is used to change engine rpm. Move the switch up to increase rpm, down to decrease rpm.

**AUXILIARY RELAY MODULE**

**NOTE**: Available on all control panels.

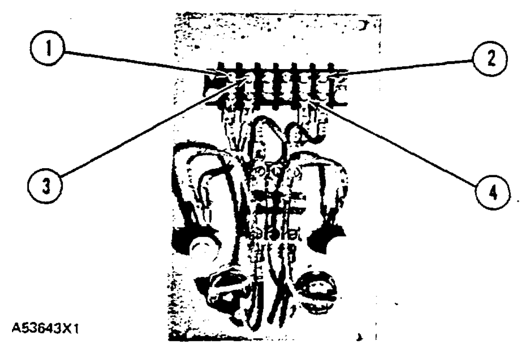
Auxiliary relay module (ARX) is in a parallel circuit with arming relay (AR). The (ARX) coil is energized during engine operation. The auxiliary relay module has both normally open and normally closed contacts. They are available for use as desired by the customer.




**AUXILIARY RELAY-MODULE (ARX)**

**SYNCHRONIZING LIGHTS MODULE**

**NOTE**: Available for Type 3 and 4 control panels. This module is located in the same place as Prealarm module (PAM).




**BACK OF SYNCHRONIZING LIGHTS MODULE**
**1. Terminal L3. 2. Terminal T1. 3. Terminal L1. 4. Terminal T3.**

Terminal T1 (2) connects to a terminal of phase 1 on the generator side of the circuit breaker.

Terminal T3 (4) connects to a terminal of phase 3 on the generator side of the circuit breaker.

Terminal L3 ( I) connects to the terminal of phase 3 on the load side of the circuit breaker.

Terminal L1 (3) connects to terminal of phase 1 on the load side of the circuit breaker.

**NOTE**: IF the synchronizing lights rapidly go ON and OFF, when the engine is running, do not close the circuit breaker. Check for one of the conditions that follow.

Engine speed (frequency) not the same as the load.

Voltage level not the same as the load.

Wires from the synchronizing lights module not correctly connected to the phase terminals on the circuit breaker.

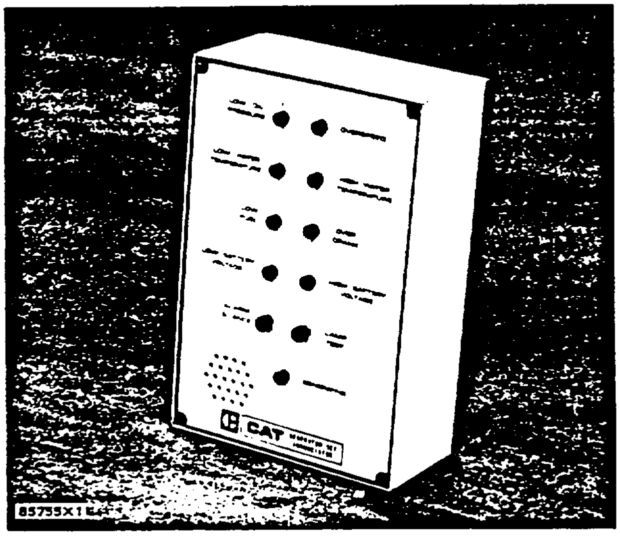
If each light goes ON and OFF, but not at the same time, the phase rotation of the generator is opposite to the phase rotation of the load.

**NOTICE**

**Never close the circuit breaker with either synchronizing light ON or with switch OFF.**

## REMOTE ANNUNCIATOR PANEL

**NOTE**: Available for all control panels. If ordered. an Annunciator panel is available for installation in an area where the safety indicators on the generator set can be constantly checked. Horn (H) and



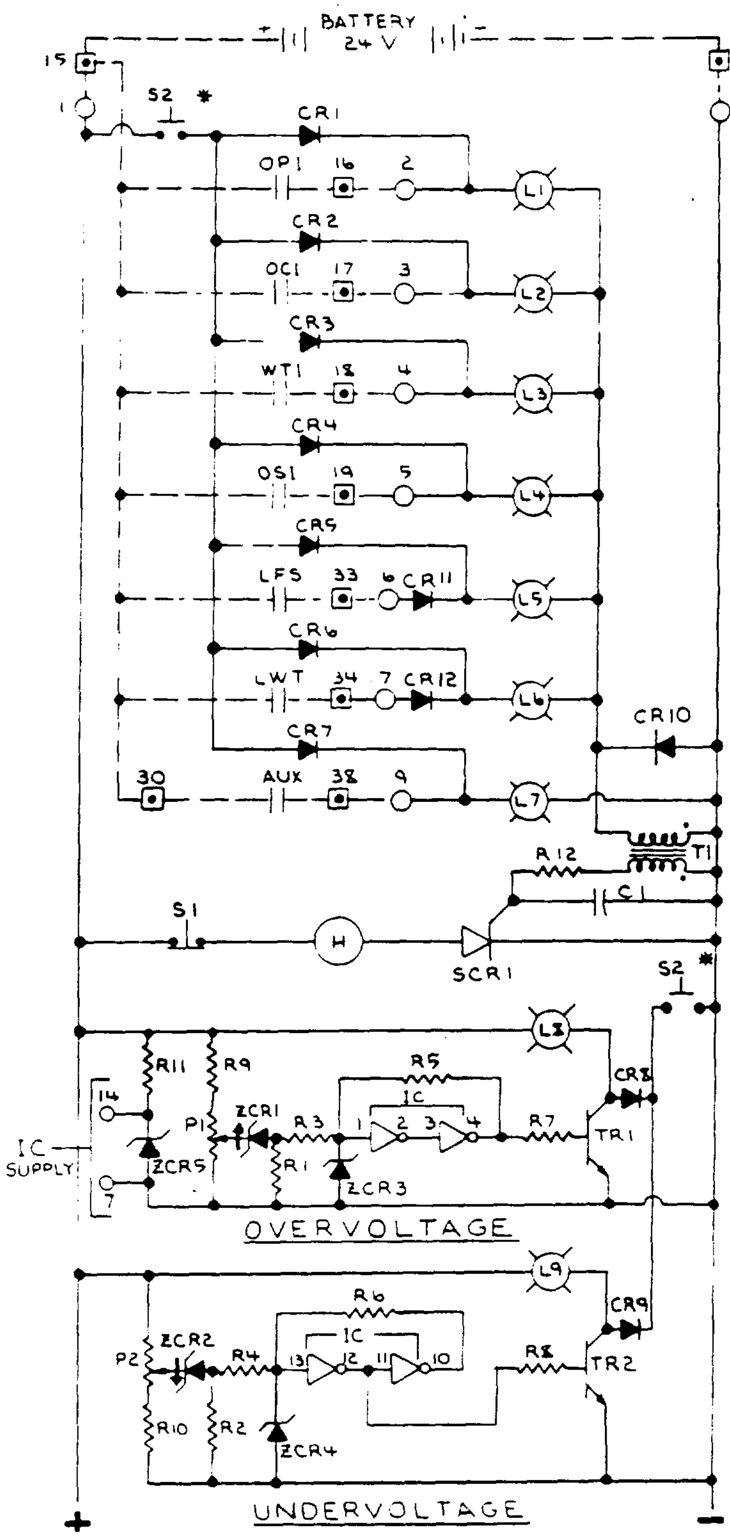

**ANNUNCIATOR PANEL**

one of the panel lights (L1 through L4) operate for the following conditions: a safety shutdown caused by low oil pressure, high water temperature. overspeed or overcrank. The horn and a light will also operate to show conditions of low fuel level or low water temperature. The low fuel level light (L5) operates when the fuel supply is only enough to keep the engine running for three hours. The low water temperature light (L6) operates when the water temperature is below 70°F (21°C). This condition shows that the jacket water heater (attachment) is either disconnected or has a failure.

The Annunciator panel is also equipped with two lights (L8 and L9) to show high or low battery voltage. The high voltage light (L8) operates when the battery voltage is approximately 29 volts. The low voltage light (L9) operates when the battery voltage is approximately 25 volts. The horn does not operate for a high or low voltage condition. A generating light (L7) is connected to terminal point 38 on the terminal strip in the generator housing. An auxiliary contact (normally open) on the emergency side of the remote transfer switch is connected between terminal point 38 and terminal point 30 on the same terminal strip. When the transfer switch has connected the load to the generator set and the generator is operating. light (L7) will also operate.

To stop the horn from operating. push alarm silence switch (S1). This "turn off"" the silicon control rectifier (SCR1). To test the condition of the panel lights. push lamp test switch (S2).

**SCHEMATIC OF ANNUNCIATOR PANEL**




**ABBREVIATIONS**

| | |
|---|---|
| AUX | AUXILIARY CONTACT |
| C1 | DISC CAPACITOR |
| CR1-12 | RECTIFIER DIODES |
| H | HORN |
| IC | INTEGRATED CIRCUITS |
| L1-9 | PANEL LIGHTS |
| LFS | LOW FUEL LEVEL SWITCH |
| LWT | LOW WATER TEMPERATURE CONTACTOR |
| OC1 | OVERCRANK INDICATOR |
| OP1 | OIL PRESSURE INDICATOR |
| OS1 | OVERSPEED INDICATOR |
| P1 | HIGH VOLTAGE POTENTIOMETER |
| P2 | LOW VOLTAGE POTENTIOMETER |
| R1-12 | RESISTORS |
| S1 | ALARM SILENCE SWITCH |
| S2 | LAMP TEST SWITCH* |
| SCR1 | SILICON CONTROL RECTIFIER |
| T1 | PULSE TRANSFORMER |
| TR1-TR2 | TRANSISTOR |
| WT1 | HIGH WATER TEMPERATURE INDICATOR |
| ZCR1-5 | ZENER DIODE |

*Push to test.
O Terminal points on terminal strip in annunciator panel.
⊙ Terminal points on terminal strip in control panel.
⊡ Terminal points on terminal strip in generator housing.
Dash (- - -) lines show the circuits of components on the engine and in the generator housing and control panel.

A54561X1

CATERPILLAR



MARCH 1983

FORM NO. SENR7968-03

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**CATERPILLAR**

# SPECIAL INSTRUCTION

•ALIGNMENT OF SINGLE-BEARING GENERATORS **4450**
ALIGNEMENT DES ALTERNATEURS A PALIER UNIQUE
AUSRICHTUNG EINFACH GELAGERTER GENERATOREN
ALINEACION DE GENERADORES DE UN SOLO COJINETE

| | | | |
|---|---|---|---|
| •D330 | 568,81B, 85B, 29F | 3412 | 38S |
| D330C | 2B, 48 | D346 | 39J |
| 3304 | 2B4364,4B6032 | D348 | 36J |
| D333 | 588, 79B, 87B, 34F | G348 | 92R |
| D333C | 66D | D349 | 61P |
| G333C | 680 | G349 | 93R |
| 3306 | 66D8891, 68D | D353 | 46B, 77B |
| D334 | 92B | G353 | 648 |
| D336 | 55B | D379 | 68B, 768 |
| D342 | 31B, 49B | G379 | 72B |
| G342 | 718 | D398 | 66B, 758 |
| D343 | 62B | G398 | 738 |
| G343 | 97N | D399 | 35B |
| 3406 | 90U | G399 | 49C |
| 3408 | 67U | | |

•Dimensions in inches (mm)
Cotes en pouces (mm)
Maie in Zoll (mm)
Dimensiones en pulgadas (mm)

Torques in lb.ft. (N-m)
Serage en pieds-livres (N .m}
Anzugnomente in lb.ft. (N-m)
Par de apriete en lb-pie (N -m)

•-This instruction has been completely changed.
-Ces instructions ont et entidaement rivistes.
-Gesamte Anderung wurde revidiert.
-Estas instrucciones se han revisado completamente.

• This instruction shows the installation and alignment procedure for electric sets with single-bearing generators. Do not start the alignment procedure until the electric set is permanently installed. If the electric set is moved to a different location, check the alignment and make any corrections necessary. The alignment between the generator and the engine must be correct to get maximum performance and long life from the electric set.

On trouvera ci-apres des instructions pour le montage et l'alignement des groupes electrogenes avec altemateurs a palier unique. Ne pas entreprendre les operations d'alignement tant que le groupe electrogene nest pas monte A demeure. Si le groupe electrogene est transporte A un autre emplacement, controler l'alignement et le corriger au besoin. Un alignement correct entre l'altemateur et le moteur assure un rendement maximal et une longue durte de service du groupe electrogene.

Diese Anleitung besctireibt Einbau und Ausrichtung von Stromaggregaten mit einfach gelagerten Generatoren. Die Ausrichtung ist erst dann vorzunehmen, wenn das Stromaggregat fest eingebaut ist. Wird das Stromaggregat bewegt, mul die Ausrichtung gepruft und notigenfalls nochmals vorgenommen werden. Um Hochstleistung und lange Lebensdauer des Stromaggregats zu gewahrleisten, mussen Generator und Motor korrekt ausgerichtet sein.

Estas instrucciones indican el procedimiento para instalar y alinear grupos electrogenos con generadores que tienen un solo cojinete. No empiece el procedimiento de alineacien hasta que el grupo electregeno este instalado en forma permnanente. Si se va a mover el grupo electregeno a un punto diferente, compruebe la alineacien y haga las correcciones necesarias. La alineacion entre el generador y el motor debe estar correcta para obtener el rendimiento maximo y larga duracien del grupo electrbgeno.

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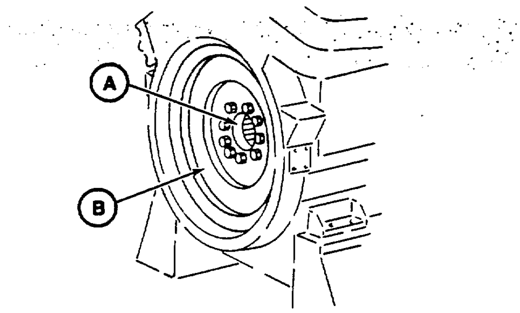
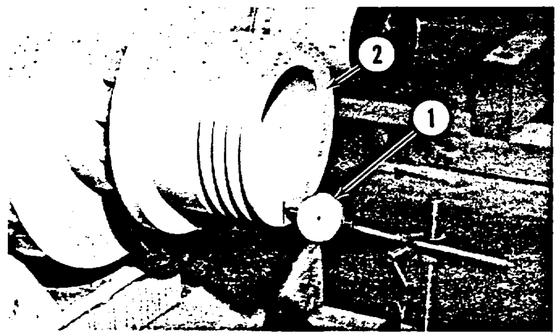
CATERPILLAR FUNDAMENTAL ENGLISH

FORM SMHS7259
(FORMERLY GM002382'

•INSTALLATION OF THE GENERATOR
MONTAGE DE L'ALTERNATEUR
ANBAU DES GENERATORS
INSTALACION DEL GENERADOR




(1) Remove all dirt, burrs and paint from the contact surfaces of the generator supports and the base. Remove the protection material (compound) from the flywheel pilot bore (A) and from the surface (B) that makes contact with the coupling. All contact surfaces of the engine, coupling and generator must be completely clean.

Enlever la poussiere, les bavures et la peinture des surfaces des supports de l'altemateur et de la base. Oter le matdriau de protection qui se trouve dans l'alesage pilote (A) du volant et sur la surface de contact (B) avec le plateau de l'aitemateur. Toutes les surfaces de contact du moteur, du plateau et de l'alternateur doivent Etre propres.

Schmutz, Grate und Farbe von den Berdhrungsflichen der Generatorauflager und des Grundrahmens vollstindig entfernen. Den Schutzbelag von der Fiihrungsbohrung (A) des Schwungrads und von der Flache (B), die mit dem VerbindungsstLick in BerOhrung steht, entfernen. Alle Beriihrungsflichen von Motor, Verbindungsstick und Generator missen vollstAindig sauber sein.

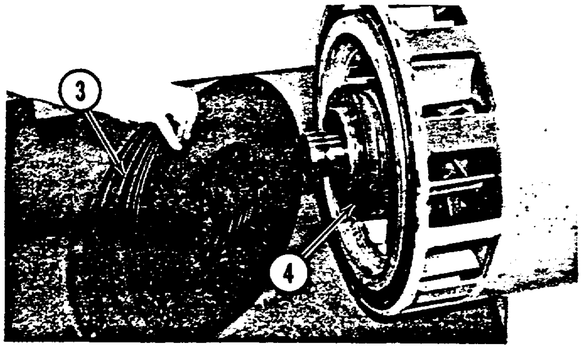
Remueva toda la suciedad, rebabas y pintura de las superficies de contacto de los soportes del generador y de la base. Remueva el compuesto de proteccien de la perforacien gu fa del volante (A) y de la superficie (B) que hace contacto con el acoplamiento. Todas las superficies de contacto del motor, acoplamiento y generador deben estar completamente limpias.

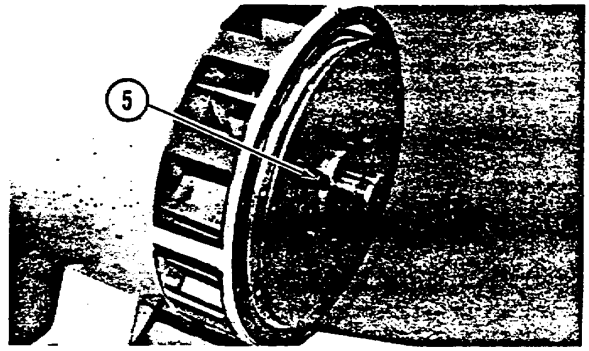
(2) Remove the timing pointer cover from the flywheel housing. Install indicator group (1) as shown on the front of the engine with the tip of the indicator on the face of crankshaft pulley (2). Use a bar between the flywheel and flywheel housing to push the crankshaft toward the flywheel to remove all end play. Put the dial indicator in the "zero" position. Move the crankshaft to its most forward position, and make a record of the Total Indicator Reading (TIR). The TIR is the end play of the crankshaft.

Deposer le couvercie de l'index fixe du carter de volant. Monter un comparateur (1) a l'avant du moteur comme indiqud en placant le toucheau du comparateur contre la poulie du vilebrequin (2). A l'aide d'un levier place entre le volant et son carter, enfoncer le vilebrequin vers le volant pour supprimer completement le jeu en bout. Placer l'aiguille du comparateur sur "0". Ramener le vilebrequin au maximum vers l'avant et noter la valeur donnde par le comparateur (TIR). Cette valeur correspond au jeu en bout du vilebrequin.

Einstelldeckel vom Schwungradgehiuse abbauen. Melluhr (1) wie gezeigt am Frontende des Motors anbringen, so daBl die Spitze des Fiihlers auf der Stirnseite der Kurbelwellenscheibe (2) angesetzt ist. Eine Stange zwischen Schwungrad und Schwungradgehiuse ansetzen, und die Kurbelwelle in Richtung Schwungrad schieben, um jedes Endspiel zu beseitigen. Mefuhr nullen. Kurbelwelle ganz nach vorn schieben und die Gesamtmel3ablesung (GMA) registieren. Dieser Gesamtwert stellt das Endspiel der Kurbelwelle dar.

Remueva la tapa del puntero.de distribuci6n de la caja del volante. Instale el grupo indicador (1) como se muestra en la parte delantera del motor, con la punta del indicador en la cara de la polea del ciguenal (2). Use una barra entre el volante y su caja para empujar el cigueial hacia el volante, a fin de eliminar todo el juego axial. Coloque el indicador de esfera en cero. Mueva el cigieial a su posicion maxima hacia adelante, y anote la lectura total del indicador. Esta lectura es el juego axial del cigueial.




(3) Put plate assembly (3) in position in the bore of the flywheel to check for clearance. There must be clearance between the outside diameter of plate assembly (3) and the inside diameter of the bore in the flywheel. CAUTION: Damage to the engine and/or generator can be the result if the electric set is run with a plate assembly that does not have this clearance.

Placer la plaque (3) dans l'alesage du volant pour mesurer le jeu. Il doit y avoir un certain jeu entre le diametre exterieur de la plaque (3) et le diametre interieur de I'aldsage du carter de volant. ATTENTION: Sans ce jeu, le moteur et/ou I'altemateur risquent d'etre endommagds.

Platten (3) in die Schwungradbohrung einpassen, um das Spiel zu priifen. Zwischen dem AuGendurchmesser der Platten (3) und dem Innendurchmesser der Bohrung des Schwungradgehiuses mug ein Abstand bestehen. VORSICHT: Der Betrieb des Stromaggregates, ohne diesen Abstand, kann zu Schiden an Motor und/oder Generator fihren.

Coloque la plancha (3) en posici6n en la perforacien del volante para comprobar la luz existente. Debe haber una luz entre el diametro exterior de la plancha (3) y el diimetro interior de la perforacibn en el volante. ADVERTENCIA: puede danarse el motor y el generador si el grupo electrogeno funciona con una plancha que no tiene esta luz.

(4) Install a full shim pack (4) and plate assembly (3) on the generator with bolts (5). On D379, G379, D398, G398, D399 and G399 engines, tighten bolts (5) to a torque of 370 + 35 lb.ft. (505 t 45 N-m). On all other engines, tighten bolts (5) to the standard torque.

•NOTE: The total thickness of shims (4) must be enough to cause a reduction in the crankshaft end play (as measured in step 2) but not enough to bend plate assembly (3) when the generator is installed.

Fixer la plaque (3) sur l'altemateur a l'aide de vis (5) et de I'epaisseur requise de cales (4).Sur les Moteurs 0379, G3/9, D398, G398, D399 et G399, serrer les vis (5) a 370 + 35 pieds-livres (505 +± 45 N.m). Sur tous les autres moteurs, serrer les vis (5) au couple standard.

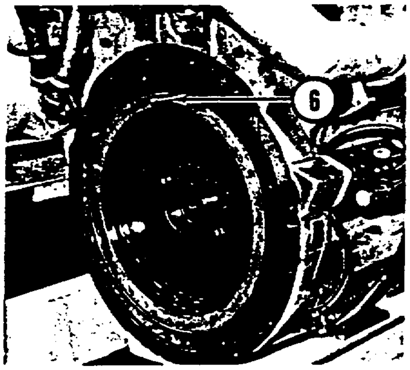
NOTA: L'epaisseur totale des cales (4) doit etre suffisante pour reduire le jeu en bout du vilebrequin (comme mesure au point 2) mais insuffisante pour ne pas plier la plaque (3) quand I'altemateur est monte.

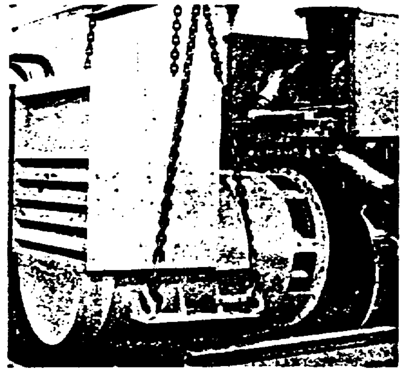
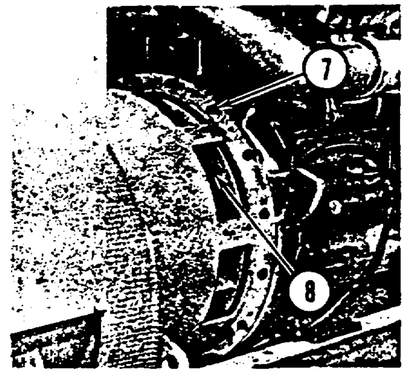
Einen ganzen Satz Beilagscheiben (4) und die Platten (3) mit den Schrauben (5) an den Generator anbauen. Bei den Motortypen D379, G379, D398, G398, D399 und G399 sind die Schrauben (5) mit einem Drehmoment von 370 + 35 Ib.ft. (505 + 45 Nm) an- zuziehen. Bei allen anderen Motoren sind die Schrauben (5} mit dem normalen Drehmoment anzuziehen.

HINWEIS: Die Gesam tdicke der Beilagscheiben (4) mul groB genug sein, um das Endspiel der Kurbelwelle (wie es in Schritt 2 gemessen wurde) zu verkleinern, jedoch nicht so grog, daB die Platten (3) beimrn Anbau des Generators gebogen werden.

Instale un paquete completo de lainas (4) y plancha (3) en el generador con pernos (5). En los motores D379, G379, etc., apriete los pemos (5) a un parde 370 + 35 lb-pie (505 + 45 N m). En todos los otros motores, apriete los pemrnos (5) al par estandar.

NOTA: El espesor total de lain as (4) debe ser suficiente para producir una reduccion en el jMego axial del cigoenal, medido en la fase (2), pero no lo suficiente para doblar la plancha (3) cuando se instala el generador.



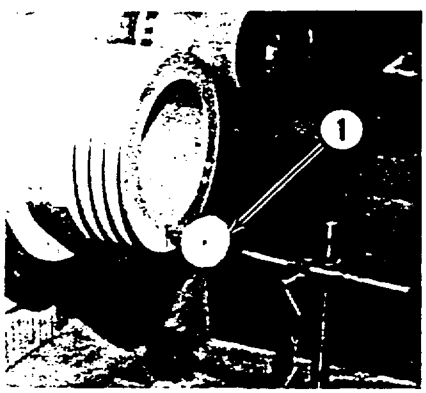



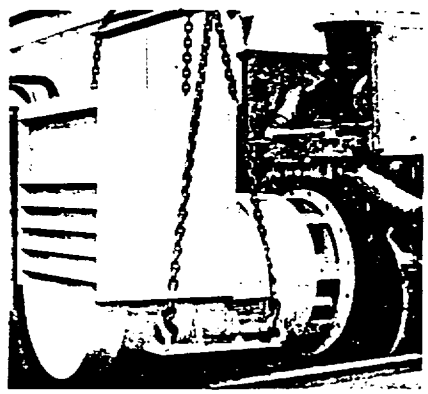
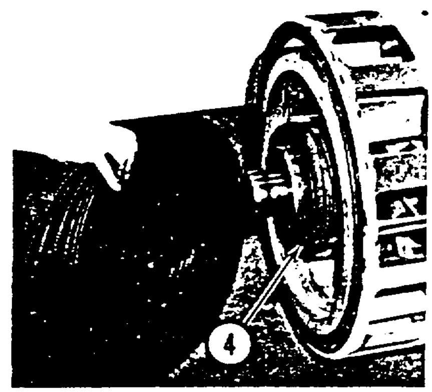

(1) Install guide bolt (6) in the flywheel. Put the generator in position on the engine, and install bolts (7) and (8). Tighten bolts (7) and (8) but do not bend the locks under bolts (8) at this time.

Monter la vis de guidage (6) dans le volant. Mettre I'altemateur en place sur le moteur et placer les vis (7) et (8). Serrer les vis (7) et (8) mais ne pas plier les freins en dessous des vis (8) pour le moment.

Fihrungsschraube (6) in das Schwungrad einbauen. Generator am Motor einpassen und Schrauben (7) und (8) einsetzen und anziehen, die Sicherungen unter den Schrauben (8) jedoch noch nicht umbiegen.

Instale el pemo gufa (6) en el volante. Coloque el generador en posici6n en el motor, e instale los pemos (7) y (8). Apriete los pernos (7) y (8), pero no doble las trabas debajo de los pernos (8) en este momento.



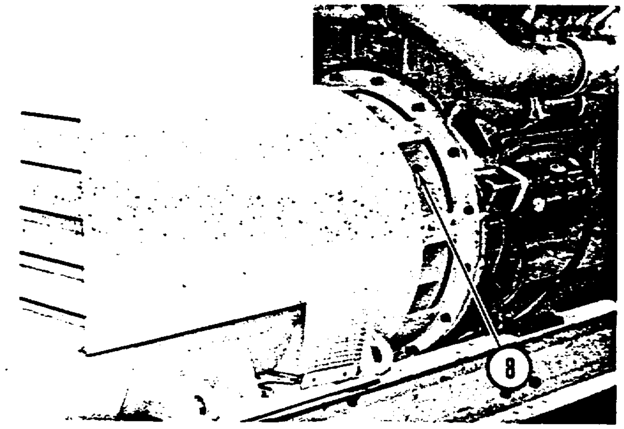




(6) Use dial indicator (1) to check crankshaft end play (do not use force to hold the crankshaft in position). Remove the generator. Remove only enough shims (4) to get the original amount of end play as shown in step 2.

Verifier le jeu axial du vilebrequin a I'aide du comparateur (1). Ne pas agir sur le vilebrequin a I'aide d'un levier. Deposer I'altemateur. Ne retirer que I'epaisseur de cales (4) necessaire pour obtenir le mime jeu en bout qu'au point 2.

Mit Hilfe der Meuhr (1) Endspiel der Kurbelwelle priifen (wobei die Kurbelwelle nicht gewaltsam in der einen oder anderen Lage gehalten werden darf). Generator entfernen. Nur so viele Beilagscheiben (4) fortnehmen, daB das urspriingliche Endspiel, wie in Schritt 2 gezeigt, erhalten wird.

Use el indicador de esfera ( 1 ) para comprobar el juego axial del cigueiial (no utilice fuerza para mantener el cigoenal en posicionj. Remueva el generador. Remueva solamente lis lainas (4) suficientes para obtener la cantidad original de juego axial, en la forma indicada en la fase 2.

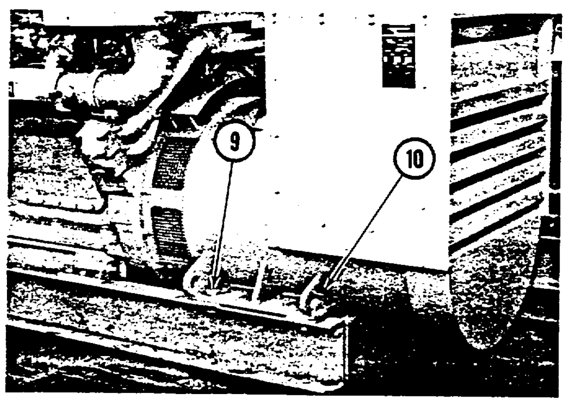



(7) Install the generator and again check the crankshaft end play. After the correct amount of shims has been installed, bend the locks under bolts (8).

Monter I'altemateur et verifier encore une fois le jeu en bout du vilebrequin. Apres montage de I'epaisseur de cales requise, plier les freins sous les vis (8).

Generator anbauen und Endspiel der Kurbelwelle erneut prifen. Nach dem Einlegen der korrekten Menge von Beilagscheiben, die Sicherungen unter den Schrauben (8) umbiegen.

Instale el generador y compruebe nuevamente el juego axial del cigefiial. Despues de haber instalado la cantidad correcta de lainas, doble las trabas debajo de los pernos (8).



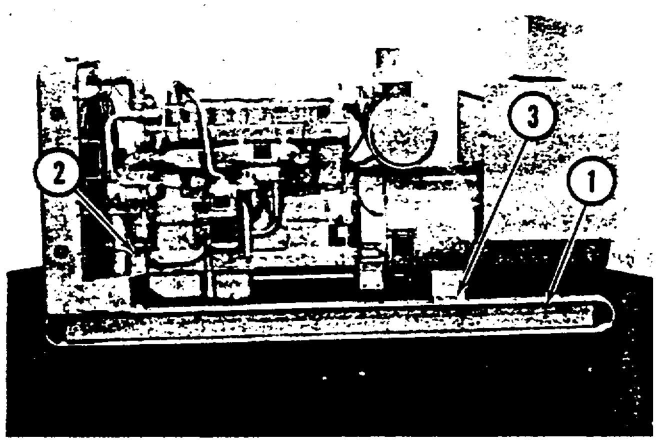

(8) Install but do not tighten all bolts (9) that fasten generator supports (10) to the base. Align the generat or to the engine as shown on page 6 for electric sets without supports at the flywheel housing or page 8 for electric sets with supports at the flywheel housing.

Sans les serrer, monter toutes les vis (9) qui fixent les supports de I'altemateur (10) a la base. Aligner I'aitemateur sur le moteur cornme indique A la page 6 pour les groupes electrogenes depourvus de supports sur le carter de volant, ou A la page 8 pour les groupes electrogenes munis de supports sur le carter de volant.

Alle Schrauben (9), die die Generatorauflager (10) am Grundrahmen befestigen, einsetzen, jedoch nicht anziehen. Den Generator nach dem Motor ausrichten, wie es auf Seite 6 fur Stromaggregate ohne Auflager am Schwungradgehiuse oder auf Seite 8 fiir Stromaggregate mit Auflager am Schwungradgehduse gezeigt wird.

Instale todos los pernos (9) que unen los soportes del generador a la base, pero no apriete los pernos. Ponga en I inea el generador con el motor, como se indica en la pagina 6, para grupos electregenos sin soportes en la caja del volante, o en la pagina (8), para grupos electr6genos con soportes en la caja del volante.

• ALIGNMENT OF ELECTRIC SETS WITHOUT SUPPORTS AT THE FLYWHEEL HOUSING
ALIGNEMENT DES GROUPES ELECTROGENES DEPOURVUS DE SUPPORTS SUR LE CARTER DE VOLANT
AUSRICHTUNG VON STROMAGGREGATEN OHNE AUFLAGER AM SCHWUNGRADGEHAUSE
ALINEACION DE GRUPOS ELECTROGENOS SIN SOPORTES EN LA CAJA DEL VOLANTE




(1) If base (1) of the electric set is fastened to a foundation, loosen all base-to-foundation bolts. Loosen all bolts (2) and (3) that fasten the generator supports and engine supports to base (1).

Si la base (1) du groupe electrogene est fixee sur un socle, desserrer les vis de fixation de la base sur le socle. Desserrer toutes les vis (2) et (3) qui fixent les supports de I'alternateur et les supports du moteur sur la base (1).

Falls der Grundrahmen (1) desStromaggregats auf einem Sockel befestigt wird, sind alle dazu dienenden Schrauben zu losen. Alle Schrauben (2) und (3), die die Generator- und Motorauflager am Grundrahmen (1) befestigen, 16sen.

Si la base (1) del grupo electregeno esta unida al cimiento, afloje todos los pernos de la base al cimiento. Afloje todos los pernos (2) y (3) que unen los soportes del generador y los soportes del motor a la base (1).

(2) Check to be sure there is clearance between the bolts and the bolt holes in the base, engine supports and generator supports at all locations.

S'assurer qu'il y a I'acartement necessaire entre les vis et les trous de vis dans la base, les supports du moteur et les suports de I'alternateur.

Kontrollieren, ob zwischen den Schrauben und den Schraubenlechern im Grundrahmen, in den Motor- und Generatorauflagern genugend Abstand vorhanden ist.

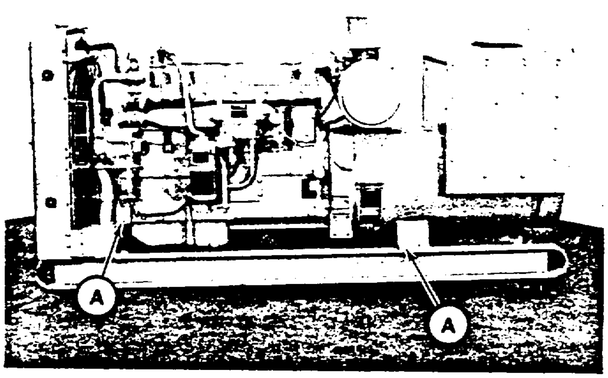
Asegturese de que existe juego entre los pernos y las perforaciones en la base, soportes del motor y soportes del generador en todos sus puntos, haciendo una inspeccion de estos.

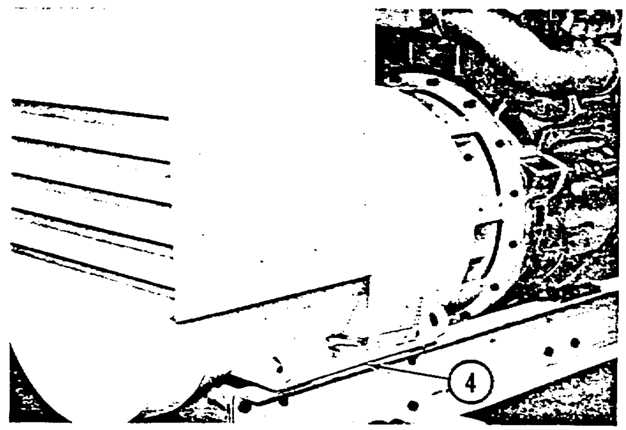
(3) Check the clearance between the base and its foundation at all mounting locations. Use shims as necessary to prevent deflection of the base as the base-to-foundation bolts are tightened. When there is no deflection in the base, tighten all base-to-foundation bolts to their final torque.

Verifier le jeu entre la base et son socle au point d'ancrage. Utiliser les cales requises pour empecher une deformation de la base lorsque la base est fixee a I'aide des vis sur le socle. Si la base ne prdsente pas de deformation, serrer les vis de fixation de la base sur le socle au couple voulu.

Den Abstand zwischen dem Grundrahmen und dem Sockel an allen Befestigungsstellen prifen. Nach Bedarf Beilagscheiben verwenden, umrn ein Verbiegen des Grundrahmens beim Anziehen der Schrauben zwischen Grundrahmen und Sockel zu verhindern. Wenn kein Verbiegen im Grundrahmen auftritt, alle Schrauben zur Befestigung des Grundrahmens am Sockel mit dem endgultigen Drehmoment anzieheh.

Compruebe el juego entre la base y los cimientos en todos los puntos de montaje. Use lainas en la forma necesaria, para impedir deflexion de la base, a medida que se aprietan los pernos de la base a los cimientos. Cuando no exista deflexion en la base, apriete todos los pernos de la base a los cimientos, a su par de apriete final.



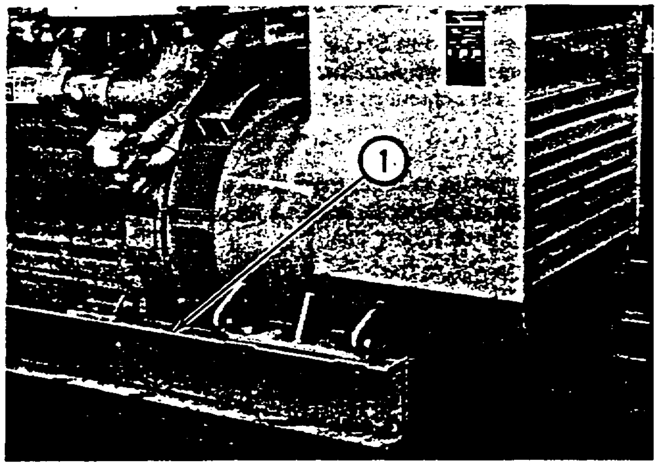

(4) Check the clearance between the base and the engine and generator supports at all four locations (A). Be sure to check the clearance over the entire length of the support. This is especially important on generators with long supports (4), since some surfaces may not be square or parallel. Use shims as necessary to prevent deflection of the supports as the bolts are tightened. After all the necessary shims have been installed, tighten all mounting bolts to their final torque.

Verifier le jeu entre la base et les supports de moteur et d'altemateurs au point (A). Verifier le jeu sur toute la longueur du support. Ceci est particulidrement important pour les altemateurs munis de longs supports (4), dtant donne que certaines surfaces peuvent ne pas etre d'dquerre ou paralleles. Utiliser les cales ndcessaires pour empecher une deformation des supports lors du serrage des vis. Apres installation des cales requises, serrer toutes les vis de montage au couple voulu.

Den Abstand zwischen dem Grundrahmen und den Motor- und Generatorauflagern an allen vier Stellen (A) prifen. Sicherstellen, daB der Abstand Ober die ganze Linge des Auflagers gepruift wird, was besonders bei Generatoren mit langen Auflagern (4) wichtig ist, da manche Flachen nicht rechtwinklig oder parallel sein konnen. Beilagscheiben nach Bedarf verwenden, um ein Verbiegen der Auf-lager beim Anziehen der Schrauben zu verhindern. Nach dem Einsetzen der erforderlichen Beilagscheiben sind alle Befestigungsschrauben mit ihrem endgiiltigen Drehmoment anzuziehen.

Compruebe el juego entre la base y los soportes del motor y generador, en los cuatro puntos (A). Asegurese de comprobar el juego en la Iongitud total del soporte. Esto es especialmente importante en generadores con soportes (4) largos, ya que algunas superficies puede que no esten a escuadra o paralelas. Use lainas en la forma necesaria para impedir deflexi6n de los soportes, a medida que se aprietan los pemos. Despues de haber instalado las lainas necesarias, apriete todos los pernos de montaje a su par de apriete final.

•ALIGNMENT OF ELECTRIC SETS WITH SUPPORTS AT THE FLYWHEEL HOUSING
ALIGNEMENT DES GROUPES ELECTROGENES DANTS LE CARTER DE VOLANT EST MUNI DE SUPPORTS
AUSRICHTUNG VON STROMAGGREGATEN MIT AUFLAGERN AM SCHWUNGRADGEHAUSE
ALINEACION DE GRUPOS ELECTROGENOS CON SOPORTES EN LA CAJA DEL VOLANTE




(1) If base (1) of the electric set is fastened to a foundation, loosen all base-to-foundation bolts. Loosen all bolts that fasten the engine and generator supports to the base.

Si la base (1) du groupe Slectrogine est fixee sur un socle, desserrer toutes les vis de fixation de la base sur le socle. Desserrer toutes les vis qui fixent les supports de moteur et d'altemateur sur la base.

Falls der Grundrahmen (1) des Stromaggregats auf einem Sockel befestigt wird, sind alle dazu dienenden Schrauben zu ldsen. Alle Schrauben 16sen, die die Motor- und Generatorauflager am Grundrahmen befestigen.

Si la base (1) del grupo electrogeno esta unida a los cimientos, afloje todos los pemos de la base a los cimientos. Afloje todos los pernos que unen todos los soportes del motor y generador a la base.

(2) Check to be sure there is clearance between the bolts and the bolt holes in the base, engine supports and generator supports at all locations.

S'assurer qu'il y a le jeu necessaire entre les vis et les trous de vis dans la base, les supports de moteur et de generateur.

Kontrollieren, ob zwischen den Schrauben und den Schraubenlochern im Grundrahmen, in den Motor- und Generatorauflagern iberall Abstand besteht.

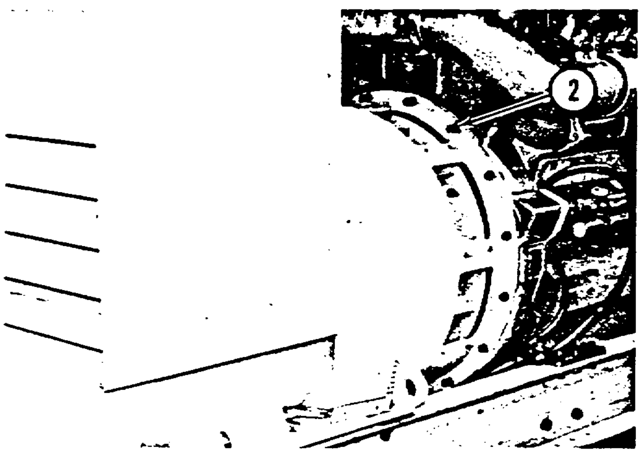
Asegurese de que existe juego entre los pernos y las perforaciones para estos, en todos los puntos de la base, soportes del motor y soportes del generador, haciendo una inspeccion.

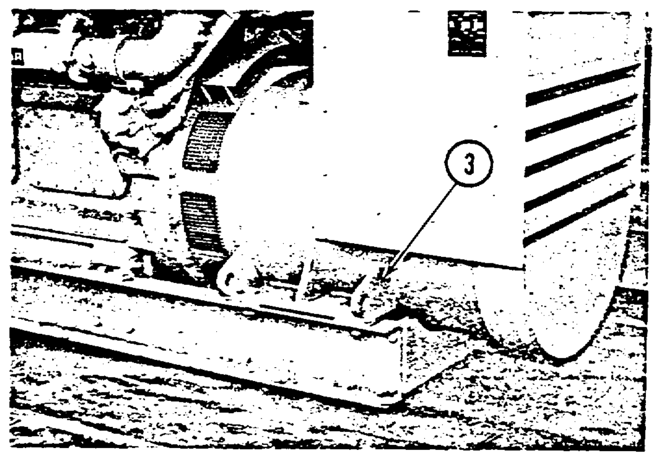
(3) Check the clearance between the base and its foundation at all mounting locations. Use shims as necessary to prevent deflection of the base as the base-to-foundation bolts are tightened. When there is no deflection in the base, tighten all base-to-foundation bolts to their final torque.

Verifier le jeu entre la base et son socle au point de montage. Utiliser les cales d'epaisseur necessaires pour empecher une deformation de la base quand les vis de fixation de la base sur le socle sont serres. S'il n'y a pas de deformation de la base, serrer toutes les vis de la fixation de la base sur le socle au couple voulu.

Den Abstand zwischen Grundrahmen und Sockel an allen Befestigungsstellen prifen. Nach Bedarf Beilagscheiben verwenden, um ein Verbiegen des Grundrahmens beim Anziehen der Schrauben zu verhindern. Wenn im Grundrahmen kein Verbiegen auftritt, sind alle Schrauben zur Befestigung des Grundrahmens am Sockel mit deren endgiiltigem Drehmoment anzuziehen.

Compruebe el juego entre la base y los cimientos en todos los puntos de montaje. Use lainas en la forma necesaria para impedir deflexion de la base, a medida que se aprietan los pernos de la base a los cimientos. Cuando no exista deflexi6n de la base, apriete todos los pernos de la base a los cimientos a su par de apriete final.



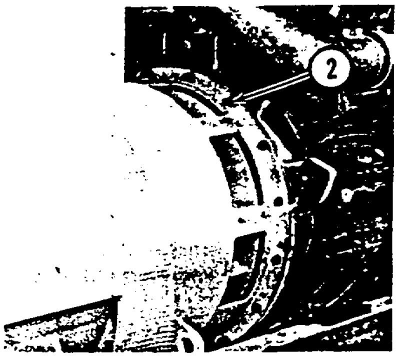



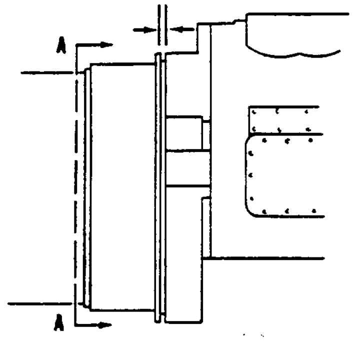

(4) Loosen all bolts (2) that fasten the generator to the flywheel housing. Tighten every other bolt to its final torque. Check the clearance between the base and the engine and generator supports at all six locations. Be sure to check the clearance over the entire length of the supports. This is especially important on generators with long supports (3). Install shims as necessary until all of the mounting surfaces are flat and parallel.

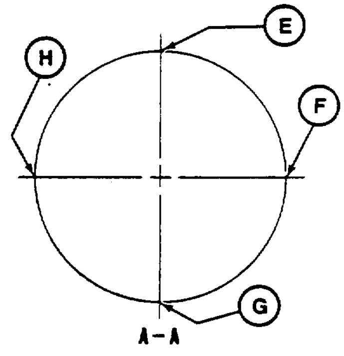
Desserrer toutes les vis (2) qui fixent l'altemateur sur le carter de volant. Serrer une vis sur deux au couple voulu. Verifier le jeu entre la base et les supports de moteur et d'altemateurs aux six points de fixation. Ne pas oublier de verifier le jeu sur toute la longueur des supports. Ceci est particulierement important pour les altemateurs equipes de supports tres longs (3). Utiliser les cales d'epaisseur necessaires jusqu'a ce que toutes les surfaces de montage soient planes et paralleles.

Alle Schrauben (2) 16sen, die den Generator am Schwungradgehiuse befestigen. Jede andere Schraube mit ihrem endgtiltigen Drehmoment anziehen. Den Abstand zwischen dem Grundrahmen und den Motor- und Generatorauflagern an allen sechs Stellen prufen. Sicherstellen, daB der Abstand iuber die ganze Linge der Auflager kontrolliert wird, was besonders bei Generatoren mit langen Auflagern (3) wichtig ist. Nach Bedarf Beilagscheiben einsetzen, bis alle Auflageflichen eben und parallel sind.

Afloje todos los pernos (2) que unen el generador a la caja del volante. Apriete un perno de cada dos, a su par final de apriete. Cornpruebe la luz entre la base y los soportes del motor y del generador, en los seis puntos indicados. Aseg6rese de comprobar la luz en la longitud total de los soportes. Esto es especialmente importante en generadores con soportes (3) largos. Instale lainas en la forma necesaria, hasta que todas las superficies de montaje esten planas y paralelas.




(5) Tighten all bolts that fasten the engine and generator supports to the base to one-half of their final torque. Loosen all bolts (2), and check the gap between the generator and the flywheel housing at locations (E), (F), (G) and (H). Location (E) must always be at the top. Make a record of each measurement.

Serrer toutes les vis qui fixent les supports de moteur et d'altemateurs A la base A la moitid du couple voulu. Desserrer toutes les vis (2) et verifier l'ecart entre les carters d'altemateurs et de volant aux points (E), (F), (G) et (H). Le point (E) doit toujours se trouver en haut. Prenez note des valeurs relevees.

Alle Schrauben, die die Motor- und Generatorauflager am Grundrahmen befestigen, mit ihrem halben endgiiltigen Drehmoment anziehen. Alle Schrauben (2) 16sen und den Abstand zwischen Generator und Schwungradgehiuse an den Stellen (E), (F), (G) und (H) kontrollieren. Die Stelle (E) mull immer oben sein. Jede Messung registrieren.

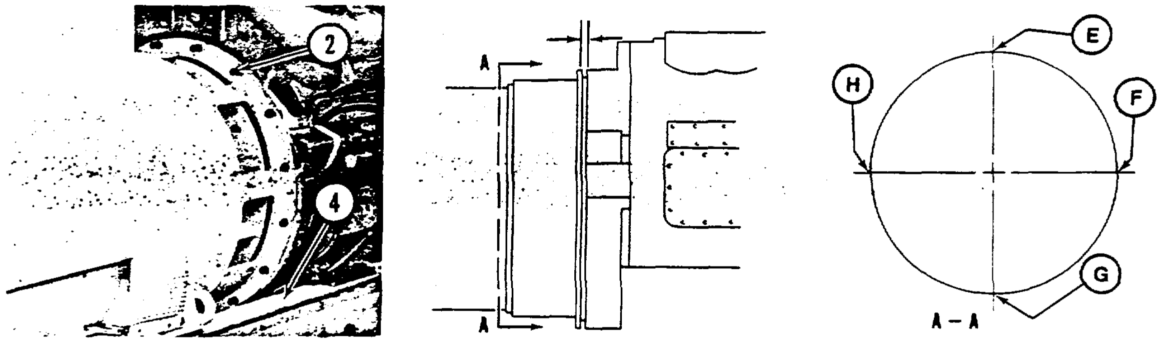
Apriete todlos los pemos que unen los soportes del motor y del generador a la base, a la mitad de su par final de apriete. Afloje todos los pemrnos (2) y compruebe la luz entre eli generador y la caja del volante, en los puntos (E), (F), (G) y (H). El punto (E) debe estar siempre en la parte de arriba. Anote cada una de estas dimensiones.

(6) If the gap at location (E) is larger than the gap at location (G) by more than .005" (0.13), install an equal amount of shims under each generator support as necessary. If the gap at location (G) is larger than the gap at location (E) by more than .005" (0.13), remove an equal amount of shims from under each generator support as necessary. After a correction has been made to shim thickness, tighten the generator support as necessary. After a correction has been made to shim thickness, tighten the generator support bolts to one-half of their final torque and again check the gap at locations (E) and (G). Use this procedure again and again until the difference in gap measurements is .005" (0.13) or less.

Si l'ecart en (E) est superieur A l'ecart en (G) de plus de 0.005" (0,13), utiliser une meme epaisseur de cales sous chaque support de generateur. Si l'ecart en (G) est superieur a l'ecart en (E) de plus de 0.005" (0,13), retirer une meme epaisseur de cales de chaque support de generateur. Apres correction de l'epaisseur des cales, serrer le support de generateur selon besoin. Apres correction de l'epaisseur des cales, serrer les vis du support de generateur a la moitid du couple requis, puis verifier a nouveau l'ecart en (E) et (G). Repetter l'operation jusqu'A ce que la difference entre les ecarts soit de 0.005" (0,13) ou moins.

Falls der Abstand an der Stelle (E) um mehr als 0,005" (0,13) groBller als der Abstand an der Stelle (G) ist, eine fir den Ausgleich erforderliche Anzahl von Beilagscheiben unter jedem Generatorauflager zuf'igen. Falls der Abstand an der Stelle (G) um mehr als 0,005" (0,13) greber ist als der Abstand an der Stelle (E). ist eine fir den Ausgleich erforderliche Anzahl von Beilagscheiben unter jedem Generatorauflager zu entnehmen. Nach Ausgleichen der Beilagstarke Schrauben an den Generatorauflagern mit ihrem halben endgtiltigen Drehmoment anziehen und den Spielraum an den Stellen (E) und (G) erneut kontrollieren. Dieses Verfahren so lange wiederholen, bis der Unterschied in den Abstandmessungen 0,005" (0,13) oder weniger betrigt.

Si la luz en el punto (E) es mayor que la luz en el punto (G), en mas de 0,005" (0,13), instale una cantidad igual de lainas debajo de cada soporte del generador, en la forma que sea necesaria. Si la luz en el punto (G) es mayor que la luz en el punto (E), en mas de 0,005" (0,13), remueva una cantidad igual de lainas de debajo de cada soporte del generador, en la forma necesaria. Despues de haber corregido los espesores de las lainas, apriete el soporte del generador, en la forma necesaria. Despues de haber corregido los espesores de lainas, apriete los pemrnos de soporte del generador a la mitad de su par final y compruebe de nuevo la distancia en los puntos (E) y (G). Repita esta operacion tantasveces como sea necesario, hasta que la diferencia en las medidas sea de 0,005" (0,13) o menos.




(7) If the gap at location (F) is larger than the gap at location (H) by more than 005" (0.13), loosen the bolts in the generator supports and move the rear of the generator to the right. If the gap at location (H) is larger than the gap at location (F) by more than .005" (0.13), loosen the bolts in the generator supports and move the rear of the generator to the left. Do this procedure again and again until the difference in gap measurements is .005" (0.13) or less. Tighten bolts (2) to their final torque.

Si l'ecart en (F) est superieur a l'ecart en (H) de plus de 0.005" (0,13), desserrer les vis des supports de l'altemateur et deplacer l'arrijire de l'altemateur vers la droite. Si l'ecart en (H) est superieur a l'ecart en (F) de plus de 0.005" (0,13), desserrer les vis des supports de l'alternateur et deplacer I'arriere de 'altemateur vers la gauche. Repeter cette operation jusqu'A ce que la difference entre les ecarts soit de 0.005" (0,13) ou moins. Serrer les vis (2) au couple voulu.

Falls der Abstand an der Stelle (F) urn mehr als 0,005" (0,13) groBer als der Abstand an der Stelle (H) ist, die Schrauben in den Generatorauflagern lesen und das hintere Ende des Generators nach rechts dricken. Fails der Abstand an der Stelle (H) umrn mehr als 0,005" (0,13) groger als der Abstand (F) ist, Schrauben in den Generatorauflagern Ibsen und das hintere Ende des Generators nach links schieben. Dieses Verfahren so lange wiederholen, bis der Unterschied in den Abstandmessungen 0,005" (0,13) oder weniger betrigt. Schrauben (2) mit ihrem endgultigen Drehmoment anziehen.

Si la distancia en (F) es mayor que la distancia en (H), en mas de 0,005" (0,13), afloje los pernos en los soportes del generador y mueva la parte de atrias del generador hacia la derecha. Si la distancia en el punto (H) es mas grande que la distancia en el punto (F), en mis de 0,005" (0,13), afloje los pernos en los soportes del generador y mueva la parte de atras del generador hacia la izquierda. Ejecute esta operacibn tantas veces como sea necesario, hasta que la diferencia en las medidas sea de 0,005" (0,13) o menos. Apriete los pernos (2) a su par final de apriete.

(8) Install a dial indicator on base (4) with the indicator tip next to a support mounting bolt. Tighten this bolt to its final torque, and at the same time check the indicator. If there is more than .005" (0.13) of indicator movement, the shim thickness is incorrect under that bolt. Install shims as necessary. Do this procedure again and again until all engine and generator support mounting bolts have been tightened to their final torque and support deflection is within specification.

Installer un comparateur sur la base (4) en placant le toucheau juste apres une vis de fixation du support. Serrer cette vis au couple voulu et vrifier en mime temps le comparateur. Si le comparateur se deplace de plus de 0.005" (0,13), l'epaisseur des cales sous cette vis est incorrecte. Rectifier l'epaisseur des cales. Repeter cette operation jusqu'A ce que les vis de montage du support de moteur et de l'altemateur soient serrees au couple voulu et que la deformation du support corresponde aux specifications.

Eine Meguhr am Grundrahmen (4) mit der Megspitze in unmittelbarer Nihe einer Auflagerschraube anbringen. Diese Schraube mit ihrem endgilltigen Drehmoment anziehen und gleichzeitig die Meluhr ablesen. Falls sich die Mespitze umrn mehr als 0,005" (0,131 bewegt, ist die Beilagstirke unter dieser Schraube falsch. Nach Bedarf Beilagscheiben einfiigen. Dieses Verfahren so lange wiederholen, bis alle Befestigungsschrauben der Motor- und Generatorauflager mit ihrem endgiiltigen Drehmoment angezogen und die Auflagerverbiegung innerhalb der Spezifikation liegt.

Instale un indicador de esfera en la base (4), con la punta del indicador contigua al perno de montaje de un soporte. Apriete este pemrno a su par final, y a la vez observe la lectura del indicador. Si hay mas de 0,005" (0,13) de movimiento del indicador, el espesor de lainas es incorrecto debajo de ese pemrno. Instale lainas en la forma necesaria. Ejecute esta operacien tantas veces como sea necesario, hasta que los pernos de montaje del soporte del motor y del generador se hallan apretado a su par final y la deflexi6n del soporte este dentro de las especificaciones.

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Perkins engines

# OPERATORS MANUAL FOR MARINE DIESEL ENGINES

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| 4.108 | 6.354 | T6.354MGT |
| 4.154 | T6.354 | V8.510 |
| 4.236 | HT6.354 | TV8.510 |

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This handbook is an adaptation of the original Marine Engine Operators Manual produced by the Service Publications Department of Perkins Engines Ltd., Peterborough, England. Every endeavor has been made to ensure that the information contained within this handbook is correct at the date of publication but, because of continuous developments, Perkins Engines reserves the right to alter the contents without notice.

**HANDBOOK FOR**
**MARINE**
**DIESEL ENGINES**

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This marine handbook is general in content and encompasses the whole range of current Perkins marine engines that are marketed in North America. Workshop manuals involving the overhaul of Perkins engines and relevant gearboxes are available, if required, from any Perkins Marine Distributor.

This handbook is distributed to provide guidance for correctly operating and maintaining Perkins marine diesel engines. If correctly installed, correctly operated and correctly maintained, a Perkins diesel engine will provide its owner with years of dependable service.
This handbook also includes information relating to Marine propulsion, trouble-shooting and performing minor engine repairs while afloat.

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**Perkins engines**

## LIMITED MARINE ENGINE WARRANTY

1. DURATION OF WARRANTY
Perkins Engines, Inc. (hereinafter called Perkins) warrants each new engine sold under the trademark "Perkins," and operated in the United States of America or Canada to power marine applications to the first retail purchaser thereof for a period of 12 months or 1,800 hours, whichever event shall first occur, to be free from defects in workmanship and material from the date of delivery to such purchaser.

2. REPLACEMENT OF PARTS UNDER WARRANTY
The responsibility of Perkins is limited to repairing or replacing, at its option, any part or parts of such engines that are returned to Perkins or any authorized Perkins distributor or dealer, with transportation charges prepaid, and which upon examination by Perkins shall disclose to Perkins' satisfaction to have been thus defective.

3. PAYMENT OF REPAIR LABOR COST UNDER WARRANTY
During the first 12 months or 1,800 hours of engine operation, whichever event shall occur first, from the date of delivery to the first purchaser, Perkins or any authorized Perkins distributor or dealer will cover the cost of reasonable labor required to repair any engine or replace any parts found by Perkins to be defective.

4. Perkins' obligation under this Warranty shall not apply to: (a) Starters, Alternators, Transmissions, Clutches. Radiators, or any other proprietary fittings not manufactured by Perkins. These are warranted by their respective manufacturers and not by Perkins. (b) Any engine which shall have been subject to negligence, misuse, accident, misapplication or overspeeding. (c) Any engine that has been repaired or altered by anyone in a manner which in Perkins' sole judgement adversely affects its performance or reliability. (d) Any engine which has been fitted with or repaired with parts or components not manufactured or approved by Perkins which in Perkins' sole judgement adversely affect its performance or reliability. (e) Engine tune-ups, normal maintenance services including but not limited to valve adjustment, normal replacement of service items, fuel and lubricating oil filters, lubricating oil, fan belts, antifreeze, etc. (f) Damages caused by prolonged or improper storage of the engine after shipment from a Perkins factory. (g) Loss of operating time to the user while the engine or engine driven equipment is out of operation, and damage to equipment powered by this engine.

5. This warranty and the obligation of Perkins Engines, Inc. here-under is in lieu of all other express warranties including, without limitations, all other representations to the purchaser. Any implied warranties, including any warranty of merchantability or fitness for a particular purpose, are expressly limited to the duration of this written warranty. In no event shall the purchaser be entitled to recover for incidental or consequential damages. Some states do not allow limitations on how long an implied warranty lasts, so the above limitation may not apply to you. Some states do not allow the exclusion or limitation of incidental or consequential damages, so the above limitation or exclusion may not apply to you. This warranty gives you specific legal rights, and you may also have other rights which vary from state to state.

SPECIAL NOTE

Perkins engines are marketed throughout the world to many manufacturers of original equipment. In order to meet the special requirements of these, engines may on occasion be covered by specific warranties applicable to the requirements of the driven equipment. In these instances the warranty extended by Perkins to said manufacturer supersedes the above warranty.

ENGINE IDENTIFICATION

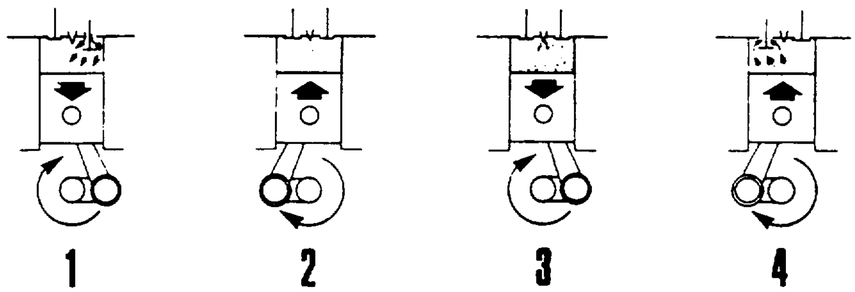
Each Perkins engine is identified by means of an identification code (see page 7). To ensure prompt, efficient results when ordering parts, requesting repairs or information, record the identification code in the space provided below so that it will be available when needed.

Engine Identification Code: ______________________________

## INTRODUCTION

Dependable performance can be expected from a Perkins marine diesel engine when the operation and maintenance procedures are based upon a clear understanding of diesel engine operating principles. Each moving part of the engine affects the operation of every other moving part and the engine as a whole.

Perkins diesel engines are four stroke cycle engines with either a direct or indirect combustion system. Diesel engines differ from other internal combustion engines in several ways. Compression ratios are higher than in gasoline engines. The intake stroke provides air only to the cylinder. Fuel is delivered to the cylinder in an atomized form by an injector. This fuel, in accurately metered quantities and with exact timing, is delivered to the injectors via extremely high pressure from the fuel injection pump. Ignition of the fuel is effected by the heat developed from compressing the air into the combustion chamber.




## PERKINS DIESEL FOUR STROKE CYCLE

1. INTAKE STROKE - The piston travels down the cylinder, the intake valve is open and the exhaust valve is closed. The partial vacuum created by the downward stroke of the piston pulls air from outside through the open intake valve into the cylinder.

2. COMPRESSION STROKE - At the end of the intake stroke, the intake valve closes while the piston travels upward on the compression stroke. The exhaust valve remains closed. At the end of the compression stroke, the air in the combustion chamber has been forced by the piston into a space that is one-sixteenth (or less) the original volume available at the beginning of the stroke. Thus, the compression ratio is 16:1 (or, for some engines, greater).

   Compressing the air into a small space causes the temperature to rise to approximately 1000 degrees F. Just before T.D.C., a small atomized, metered charge of fuel is injected into the combustion chamber, the fuel is ignited by the hot air and starts to burn.

3. POWER STROKE - During the power stroke, the piston travels down the cylinder and both intake and exhaust valves are closed. As the air and fuel mixture burns, the gases become hotter and hotter, rapidly expand and add force to crankshaft rotation.

4. EXHAUST STROKE - During the exhaust stroke, the intake valve remains closed, the exhaust valve is open, and the piston on the upward stroke forces the burned gases out of the combustion chamber through the open exhaust valve port.

Turbocharged engines utilize the exhaust to power the turbine and "boost" the density of the intake air, which results in an increase in engine power.

The standard direction of rotation for Perkins marine diesel engines is counterclockwise when viewing the engine from the gearbox end (rear) of the engine. Contrarotating engines (rotation is clockwise when viewing the engine from the rear) are the exception.

Perkins marine engines are manufactured to meet all general marine requirements and to be compatible with specific applications. The engines depicted on pages 12 through 27 do not necessarily typify all the various marine engines in use worldwide.

**Safety Precautions:**

Disregarding fundamental safety rules and precautions may result in injuries to persons coming into contact with or located near an engine. Care should be exercised at all times, particularly in the following respects:

1. The coolant in an operating or recently stopped engine is very hot and under pressure. If the filler pressure cap is suddenly removed the liquid may spurt and cause injury by scalding. Always stop an engine and allow it to cool before removing the cap. Once cool, loosen the cap slowly to relieve the pressure.

2. External assemblies and accessories driven by an engine, such as the pulleys, belts, and alternator/generator, are hazardous to anyone attempting to repair or service it while it is operating. If possible, always stop an engine before servicing it. When necessary to repair or adjust an operating engine, use extreme caution and do not wear loose clothing.

3. The direction of engine rotation and the rotation of any attached or auxiliary drive device are not always the same. The rotation direction of the output shaft should be determined before attaching any auxiliary mechanism that is to be driven by the engine. Failure to consider the respective rotations could result in an unexpected rotation of the mechanism and cause injury.

4. Use extraordinary care when hoisting an engine. Ensure that the hoist is correctly arranged and correctly attached to the engine. Failure to do so may result in fracture of the lifting brackets or other mishap.

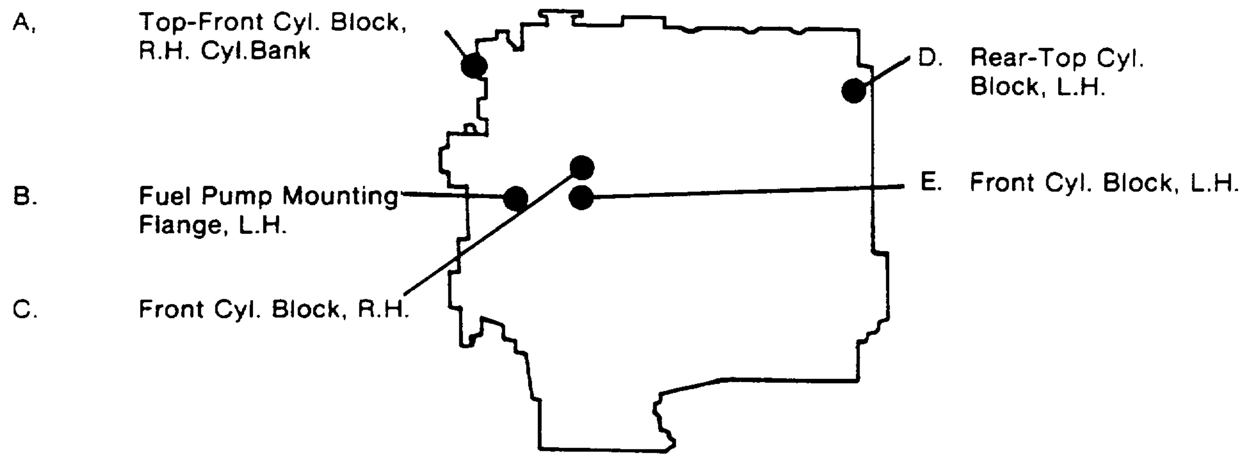
5. Stop the engine before refueling it.

Look for this symbol - it means:
ATTENTION! BECOME ALERT!
YOUR SAFETY IS INVOLVED!
HEED THE INSTRUCTIONS!

Because of the variety of engine applications and their respective uses, it is not possible to anticipate and provide safety precautions for all the potentially hazardous situations that may be encountered during the servicing and operation of a marine engine. In respect to this, each person involved with service and operation should be alert and safety conscious at all times.

**ENGINE IDENTIFICATION LOCATION**

| | |
|---|---|
| A. | V8.510, TV8.510 |
| B. | 4.108, 6.354, T6.354<br>HT6.354, T6.354 MGT |
| C. | 4.236 |
| D. | 4.154 |
| E. | 4.154 (Newer Engines)<br>4.236 (Newer Engines) |




| | |
|---|---|
| "R.H."= | Right Hand or<br>Alternator Side |
| "L.H."= | Left Hand, Fuel Injection,<br>Pump Side |

**Note:**

Left and right hand locations are given assuming that the engine is viewed from the rear.

**ENGINE IDENTIFICATION**

This handbook is applicable to the following marine engine type designations:

| | |
|---|---|
| 4.108 | (M) |
| 4.154 | (M) |
| 4.236 | (M) |
| 6.354 | (M) |
| T6.354 | (M) |
| T6.354 | (MGT)* |
| HT6.354 | (M) |
| V8.510 | (M) |
| TV8.510 | (M) |

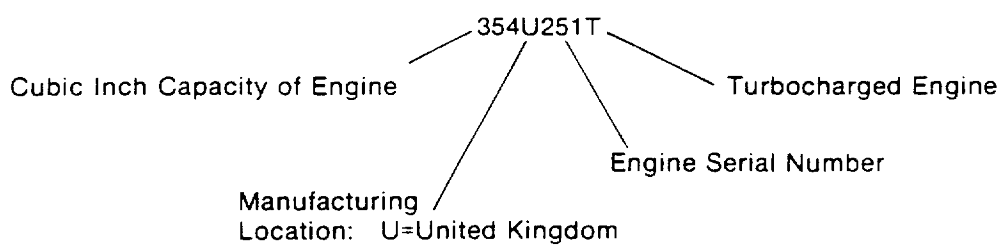
The first numeral (e.g., 4) in the engine designation denotes the number of cylinders, while the second group of numerals (e.g., 108) denotes the cubic inch displacement (C.I.D.) of the engine. The prefix letters (e.g.,T) denote the following:

T - Turbocharged Engine
H - Horizontally Inclined Engine
V - Two banks of cylinders in "V" formation.

*Special version of the T6.354 Marine engine.

The letter "M" in parenthesis indicates the applicable engine was manufactured specifically for marine applications.

Apart from physical differences, each engine can be identified by the engine identification code stamped into the cylinder block. The code is comprised of a combination of numerals and letters (Alphanumeric). At the present time, two identification formats are in existence. The earlier format (e.g., 354U251T) represents the following data:




In addition to the above, contra-rotating (clockwise) engines are further identified by the letter "X" stamped immediately after the manufacturing location code letter (e.g., 354UX252T).

Additional suffix letters may also be included in the code for certain engines. For example:

H - Horizontally Inclined Engine
L - Lip Type Rear Main Bearing Seal

The location of the identification code, as applicable to each engine, is-depicted in the following series of illustrations (Fig. 2a through Fig. 2e). When information, replacement parts or assistance is required, the complete engine identification code should always be quoted.

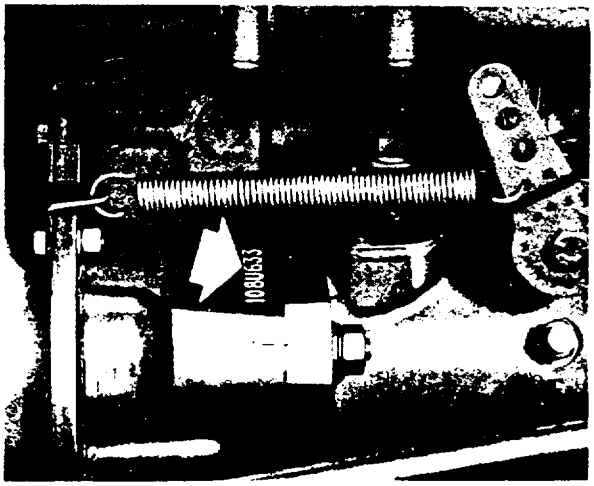



*Fig. 2 (a)*
Engine Identification Location
4.108

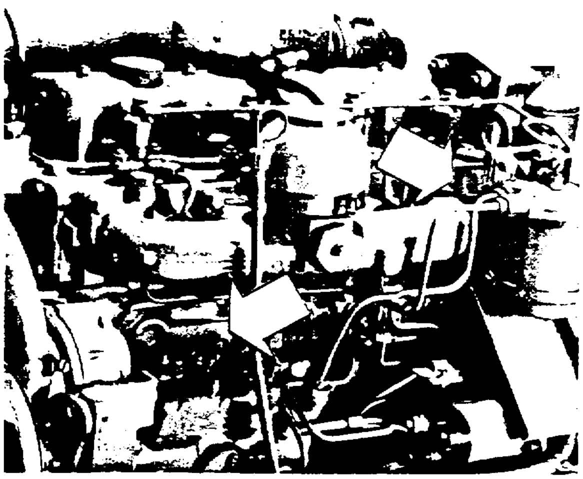


*Fig. 2 (b)*

4.154 Engine Identification Location. Rear-Top of Cylinder Block, Left-Hand Side of Engine. Newer Engines: Left-Hand Side of Engine, above fuel injection pump.

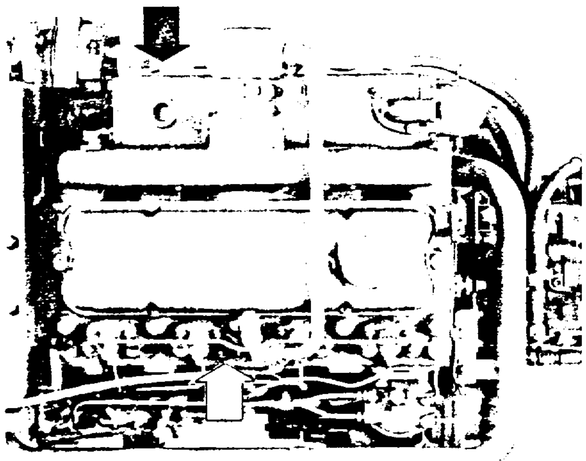


*Fig. 2 (c)*

4.236 Engine Identification Location. Machined Pad Immediately Above and Aft of Alternator, Right-Hand Side of Engine. Newer Engines: Left-Hand Side of Engine, above Fuel Injection Pump.

*Fig. 2 (d)*
6.354, T6.354, HT6.354, and T6.354MGT Engine Identification Location. Fuel Injection Pump Mounting Flange. Left-Hand Side of Engine.

*Fig. 2 (e)*
V8.510 and TV8.510 Engine Identification Location. Top-Front of Cylinder Block, Right-Hand Cylinder Bank.

**NEW FORMAT**

The new format for engine identification will be incorporated by all Perkins manufacturing operations in the near future. At the present time, engines produced in England, Germany, Mexico, and the United States are being identified according to the new format. As with its predecessor, the identification of each engine is accomplished via an alphanumeric code, which can be comprised of up to 15 characters (if a secondary parts list reference is required, six additional characters will be used). The standardized location for each engine's identification is a machined pad situated near the fuel injection pump (left side of engine when viewing from rear). Exceptions to this location may arise for certain engines. The following data is represented in sequence by the alphanumeric identification code characters.

| DATA | CHARACTERS |
|---|---|
| 1. Engine Family | One Alphabetic Letter |
| 2. Engine Type/Phase | One Alphabetic Letter |
| 3. Parts List (Or Standard Option Scheme Order) Reference' | Five Numerals (Or Letter "A" and Four Numerals) |
| 4. Country of Origin | One Alphabetic Letter |
| 5. Production (Or Rebuild) Serial Number | Maximum of Six Numerals (Or Letter "R" and Maximum of Five Numerals) |
| 6. Year of Manufacture | One Alphabetic Letter |

**EXAMPLE:**

TE22282N1256C

*Certain engines may also have a secondary parts list reference stamped immediately below the primary parts list reference.

**EXAMPLE:**

TE20696U501376C
NAP12N

Engine Family and Type/Phase Code Interpretations:
The first two characters of the identification code will always be letters. The first letter represents the engine family and the second represents the engine type/phase. The following interpretation are applicable to engine identification codes.

| FAMILY | TYPE | CODE | FAMILY | TYPE | CODE | FAMILY | TYPE | CODE |
|---|---|---|---|---|---|---|---|---|
| 4.108 | | E | 6.354 | | T | V8.510 | | X |
| | 4.99 | EA | | 6.354 | TC | | V8.510 | XA |
| | 4.107 | EB | | H6.354 | TD | | TV8.510 | XB |
| | T4.107 | EC | | T6.354 | TE | | | |
| | 4.108 | ED | | HT6.354 | TF | | | |
| 4.154 | | G | | 6.3541 | TG | | | |
| | 4.154 | GA | | T6.3541 | TH | | | |
| | | | | 6.3542 | TJ | | | |
| 4.236 | | L | | 6.3543 | TN | | | |
| | 4.236 | LD | | HT6.3543 | TQ | | | |
| | | | | T6.3544 | TU | | | |
| | | | | 6.3544 | TW | | | |

Parts List References:

Following the first two characters (engine family and type/phase code letters) will be either a group of five numerals or the letter "A" followed by a group of four numerals. If five numerals are used, they will be the reference for the engine build parts list. When an engine Is built to a Standard Option Scheme (S.O.S.) order, the reference for the order is comprised of the letter "A" and the last four digits of the order number. The following are examples of both references:

| | |
|---|---|
| PARTS LIST REFERENCE: | 21376 |
| ENGINE IDENTIFICATION CODE: | TR21376U500120C |
| STANDARD OPTION SCHEME NUMBER: | A018752 |
| STANDARD OPTION SCHEME ORDER REFERENCE: | A8752 |
| ENGINE IDENTIFICATION CODE: | LDA8752U501234C |

Country of Origin Code Interpretations:

The next character will be a one-letter code that represents the country where the basic engine was produced. The following interpretations are applicable to engine identification codes.

COUNTRY OF ORIGIN

| | | |
|---|---|---|
| A .................Argentine | G ....................Greece | S ..............India |
| B .................Brazil | J .....................Japan | T...............Turkey |
| C .................Australia | L......................Italy | U .............United Kingdom |
| D .................Germany | 'M ....................Mexico | X...............Peru |
| E .................Spain | N .....................U.S.A. | Y ..............Yugoslavia |
| F ..................France | P .....................Poland | |

*Motores Perkins S.A., Mexico, started using the new identification format in its infancy and uses the letters "MX" vice "M" as the code for Mexico.

Engine Serial Numbers:

Each engine family (if produced at the specific manufacturing location) will have a separate production serial number series initiated at each manufacturing location. To distinguish the new engine serial numbering from that used previously, Peterborough, United Kingdom will start numbering the first produced engine of each family with 500001. All other manufacturing operations will start with 251. Upon attaining serial number 999999, each series will revert to 251. Serial numbers 1 through 250 will always be reserved for prototype engines by each manufacturing operation.

Each manufacturing operation will group rebuilt engines as one type and serialize them progressively regardless of their respective engine family. The serial numbering will start with 251 and progress through 1000 (if necessary) at each location. The letter "R" will be used as a prefix to denote "Rebuilt Engine". For example:

R417

Year of Manufacture Code Interpretations:

The last character in the engine identification code will be a code letter that represents the calendar year during which the engine was either produced or rebuilt. The following interpretations are applicable to engine identification codes:

| LETTER | YEAR |
|---|---|
| B | 1975 |
| C | 1976 |
| D | 1977 |
| E | 1978 |
| F | 1979 |

NOTE: The letters I.O,Q,R, and Z will not be used to represent the year of manufacture.

**ENGINE PHOTOGRAPHS**

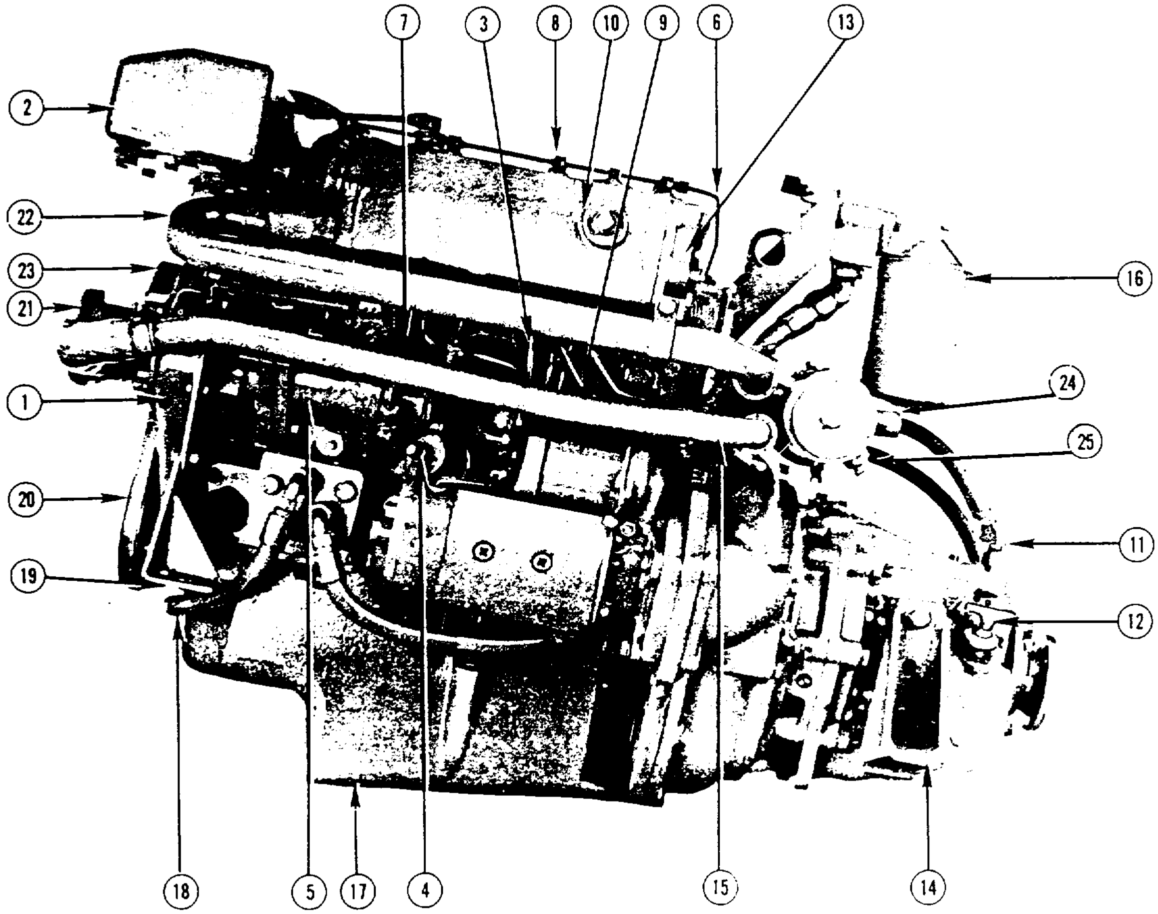



*Fig. 3(a)*
KEY TO 4.108 (M) ENGINE PHOTOGRAPHS

1. Timing Case Cover
2. Header Tank
3. Lub Oil Dipstick
4. Lub Oil Pressure Sender
5. Field Injection Pump
6. Injector Leak-Off Pipe
7. Pressure Pipes, Injection Pump to injectors
8. Injector
9. Fuel Pipes, Filter to Injection Pump
10. Exhaust Manifold
11. Gearbox Forward and Reverse Lever
12. Gearbox Fluid Filler Hole/Dipstick
13. Exhaust Flange
14. Rear Engine Support
15. Sea Water Pipe, to Sea Water Pump Heat Exchanger
16. Lub Oil Filter
17. Oil Pan
18. Hose from Oil Cooler
19. Front Engine Support
20. Crankshaft Pulley
21. Sea Water Pump
22. Fresh Water Pipe, Exhaust Manifold to Heat Exchanger
23. Fresh Water Pump
24. Sea Water Outlet
25. Zinc Anode

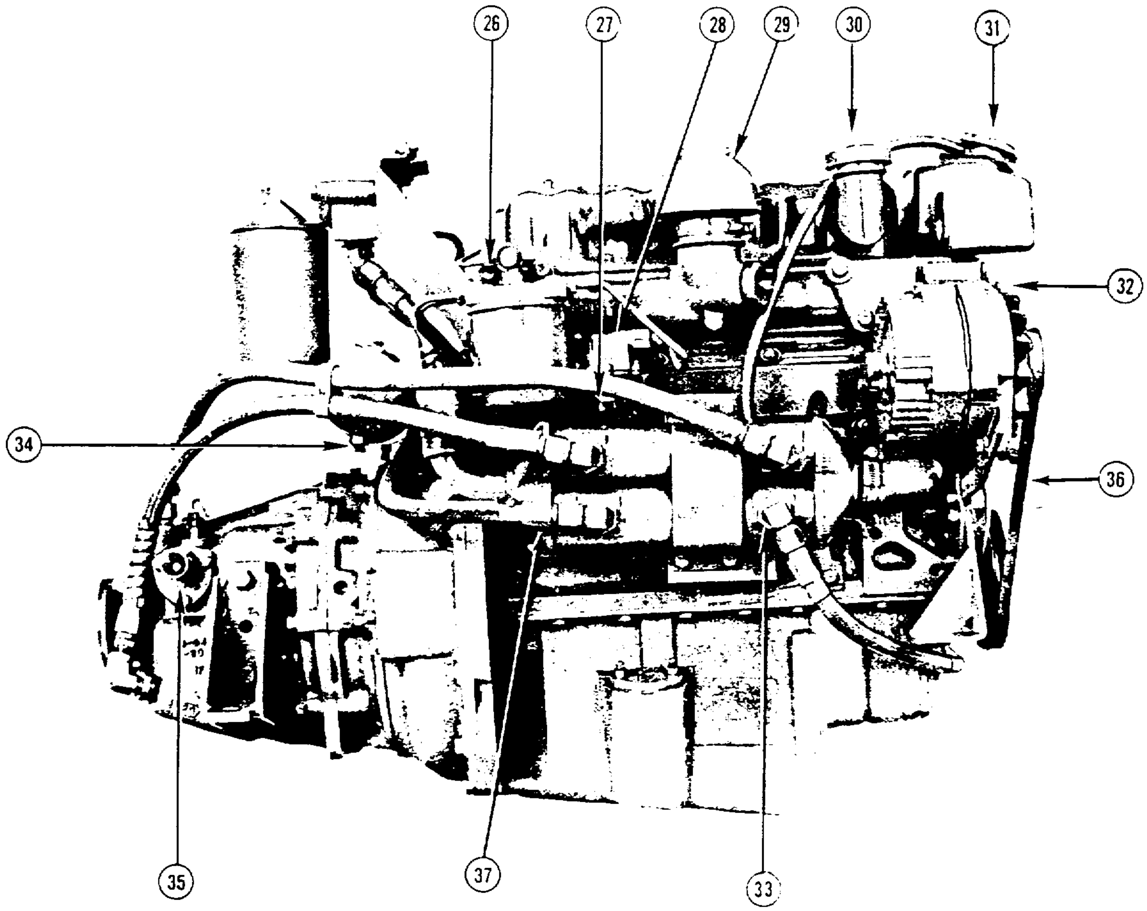



*Fig. 3 (b)*

26. Fuel Filter
27. Fuel Transfer Pump Priming Lever
28. Fuel Transfer Pump
29. Air Filter
30. Lub Oil Filler Cap
31. Fresh Water Filler Cap
32. Alternator
33. Oil Coolers (Engine and Transmission)
34. Heat Exchanger
35. Gearbox Neutral Switch
36. Alternator/Fresh Water Pump Drive Belt
37. Oil Cooler Water Drain

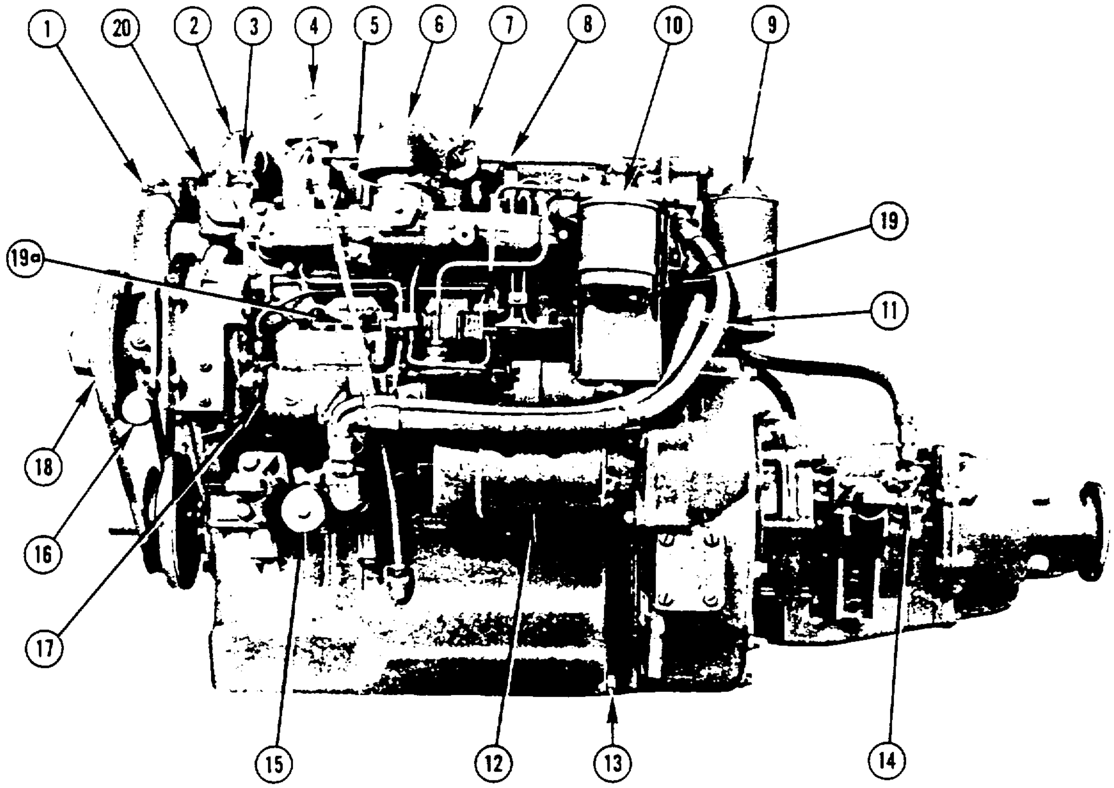



*Fig. 3(c)*
KEY TO 4.154 (M) ENGINE PHOTOGRAPHS

1. Sea Water Pipe from Pump to Heat Exchanger
2. Fresh Water Pipe from Engine to Heat Exchanger
3. Water Temperature Sender
4. Lubricating Oil Dipstick
5. Lubricating Oil Filler Cap
6. Induction Air Filter
7. Closed Circuit Breather Pipe
8. Injector
9. Lubricating Oil Filter
10. Fuel Filter
11. Flexible Lubricating Oil Hoses
12. Starter Motor
13. Lubricating Oil Pan Drain Plug
14. Gear Box Filler and Dipstick
15. Engine Lubricating Oil Pressure Sender
16. Sea Water Pump Inlet
17. Fuel Injection Pump
18. Sea Water Pump
19. Engine Serial Number (Older Engines)

19a. Engine Serial Number (Newer Engines)

20. Thermostat Housing and Water Temperature Sender

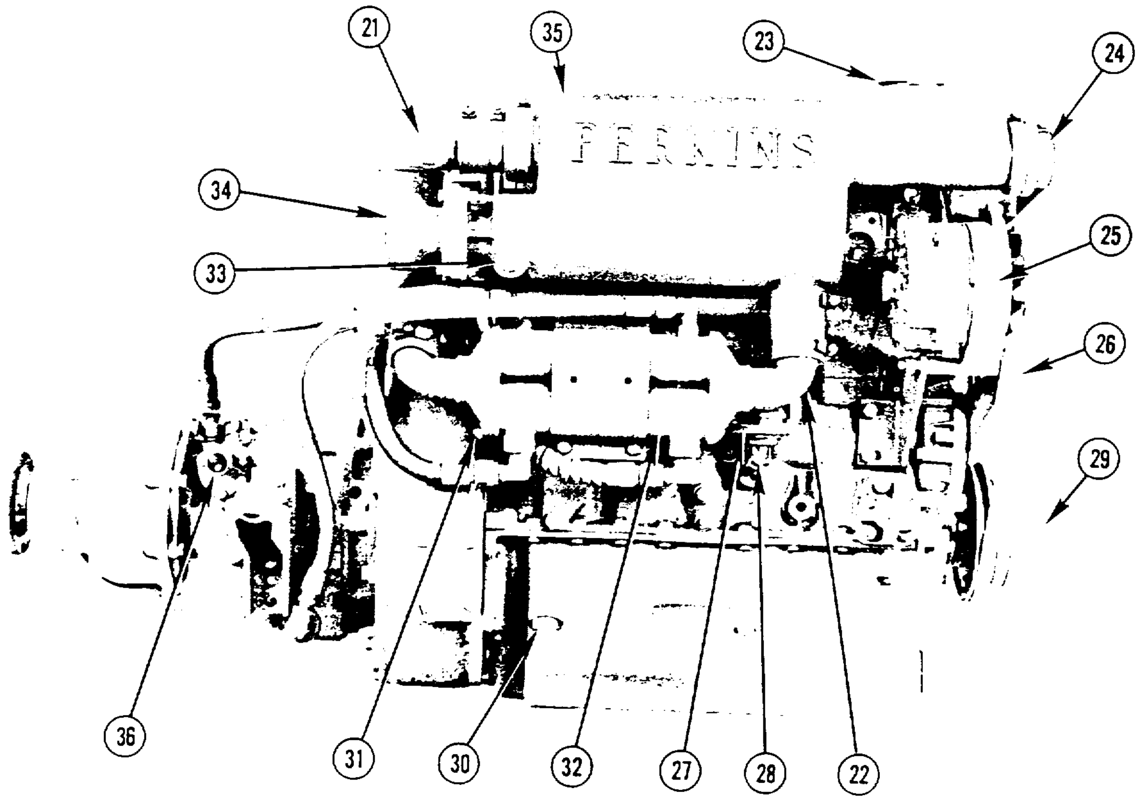



*Fig. 3(d)*

21. Sea Water Outlet From Heat Exchanger
22. Fresh Water Pipe to Lubricating Oil Cooler
23. Fresh Water Filler Cap
24. Sea Water Inlet to Heat Exchanger
25. Alternator
26. Alternator/Fresh Water Pump Drive Belt
27. Fuel Transfer Pump
28. Fuel Transfer Pump Priming Lever
29. Power Take-Off Shaft
30. Lubricating Oil Pan Drain Pump (Position)
31. Lubricating Oil Cooler Water Drain Plug (or Tap)
32. Lubricating Oil Cooler
33. Heat Exchanger/Exhaust Manifold Fresh Water Drain Plug
34. Exhaust Manifold Flange
35. Header Tank/Heat Exchanger, Exhaust Manifold
36. Gear Box Neutral Switch

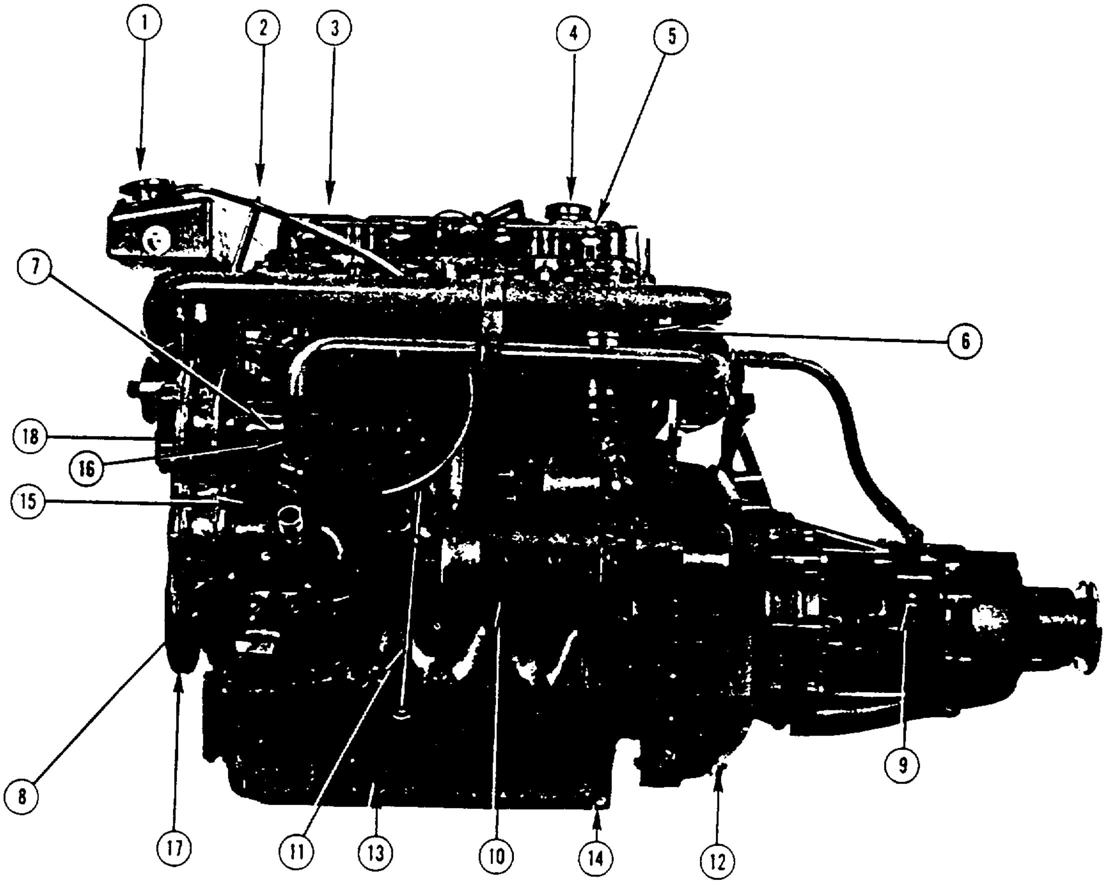



*Fig. 3(e)*
KEY TO 4.236 (M) ENGINE PHOTOGRAPHS

1. Coolant Filler Cap
2. Front Lifting Eye
3. Rocker Cover
4. Lubricating Oil Filler Cap
5. Injector
6. Fuel Oil Filter
7. Fuel Injection Pump
8. Sea Water Inlet to Sea Water Pump
9. Gearbox Filler Plug and Dip-Stick
10. Starter Motor
11. Engine Oil Dipstick
12. Flywheel Housing
13. Lubricating Oil Pan
14. Lubricating Oil Pan Drain Plug
15. Sea Water Pump
16. Water Pipe from Sea Water Pump to Cooler
17. Crankshaft Pulley
18. Timing Case Cover
19. Alternator Pulley
20. Heat Exchanger

20a. Zinc Anode

21. Engine Oil Cooler

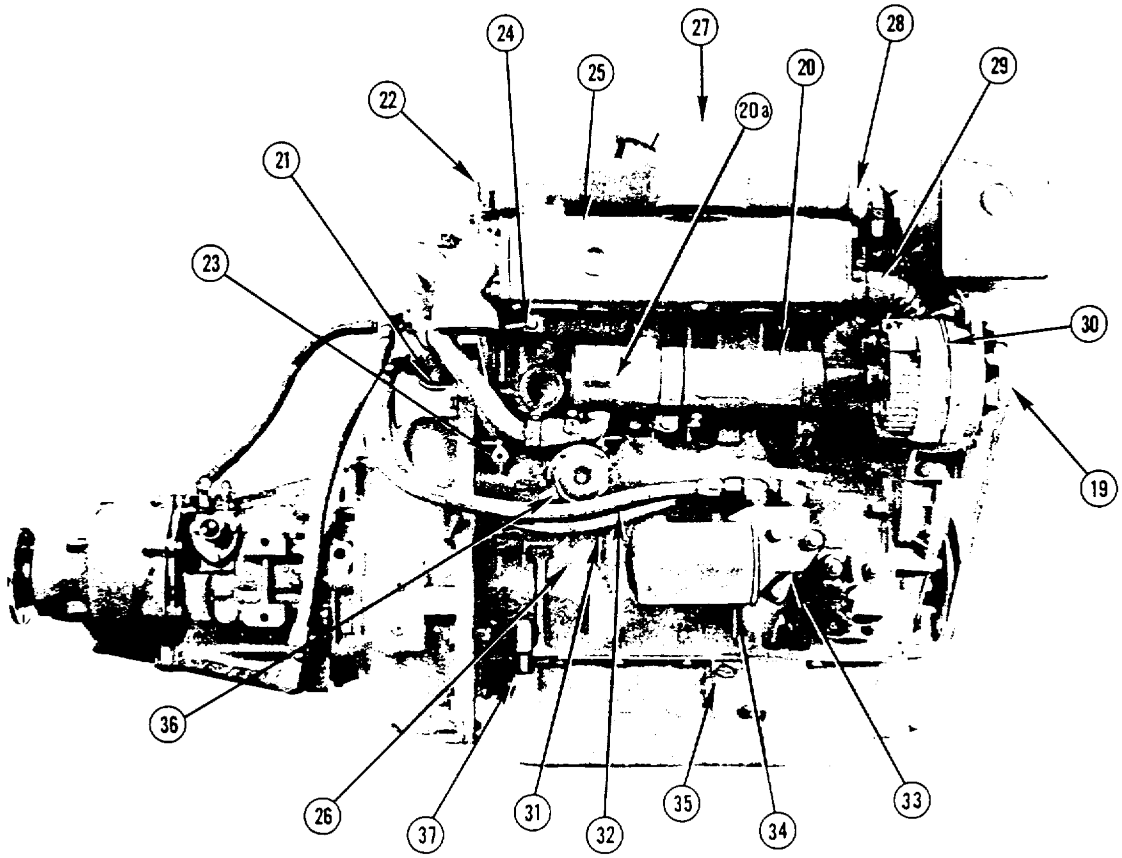



*Fig. 3(f)*

22. Rear Lifting Eye
23. Cylinder Block Drain Tap
24. Exhaust Manifold Drain Tap
25. Exhaust Manifold
26. Cylinder Block
27. Air Filter
28. Induction Manifold
29. Water Pipe from Heat Exchanger to Exhaust Manifold
30. Alternator
31. Oil Pipe to Cooler
32. Oil Pipe from Cooler
33. Oil Filter Adaptor
34. Lubricating Oil Filter
35. Optional Dipstick Position
36. Fuel Transfer Pump
37. Oil Pan Draining Connection

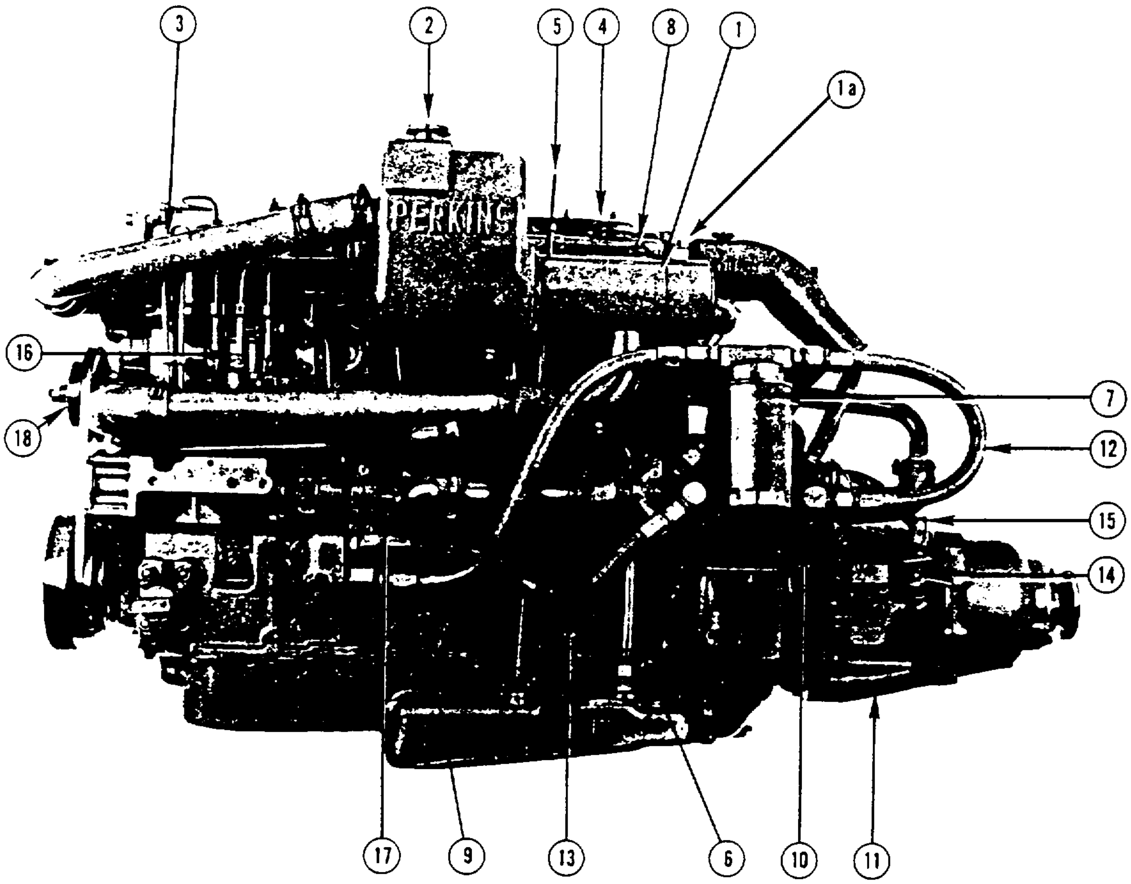



*Fig. 3(g)*

KEY TO 6.354 (M) ENGINE PHOTOGRAPHS

1. Heat Exchanger
1a. Zinc Anode
2. Fresh Water Filler Cap
3. Fuel Filter
4. Lubricating Oil Filler Cap
5. Lub Oil Dipstick
6. Engine Breather Pipe
7. Lubricating Oil Filter
8. Injector
9. Lubricating Oil Hose, Filter to Adaptor
10. Engine Oil Cooler
11. Gearbox
12. Lubricating Oil Hose, Filter to Cooler
13. Lubricating Oil Hose, Cooler to Adaptor
14. Gearbox Filler/Dipstick
15. Forward/Reverse Lever
16. Injection Pump
17. Sea Water Pump
18. Fresh Water Pump

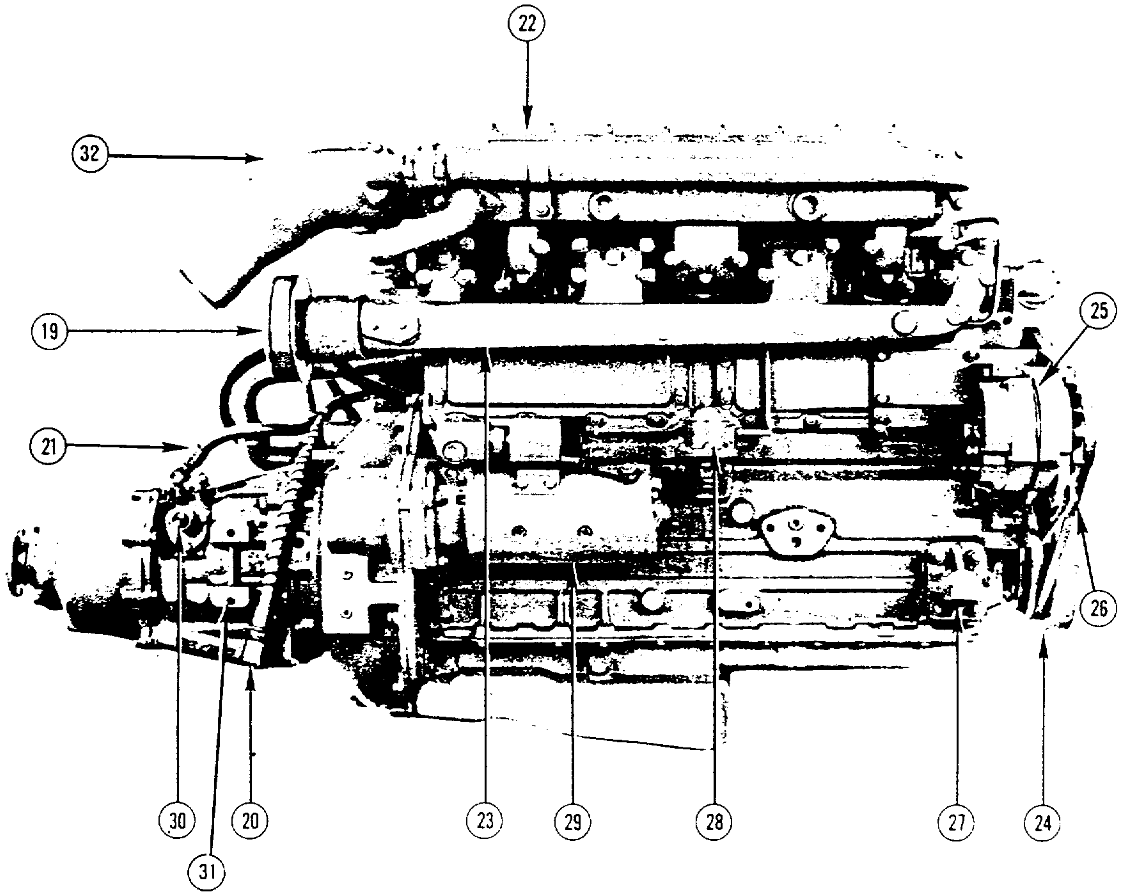



*Fig. 3(h)*

19. Air Filter
20. Gearbox Fluid Hose from Cooler
21. Gearbox Fluid Hose to Cooler
22. Water Cooled Exhaust Manifold
23. Intake Manifold
24. Crankshaft Pulley
25. Alternator
26. Alternator and Fresh Water Pump Drive Belt
27. Engine Front Support Bracket
28. Fuel Oil Transfer Pump (with Priming Lever)
29. Starter Motor
30. Gearbox Neutral Switch
31. Rear Mounting Position
32. Wet Elbow Exhaust

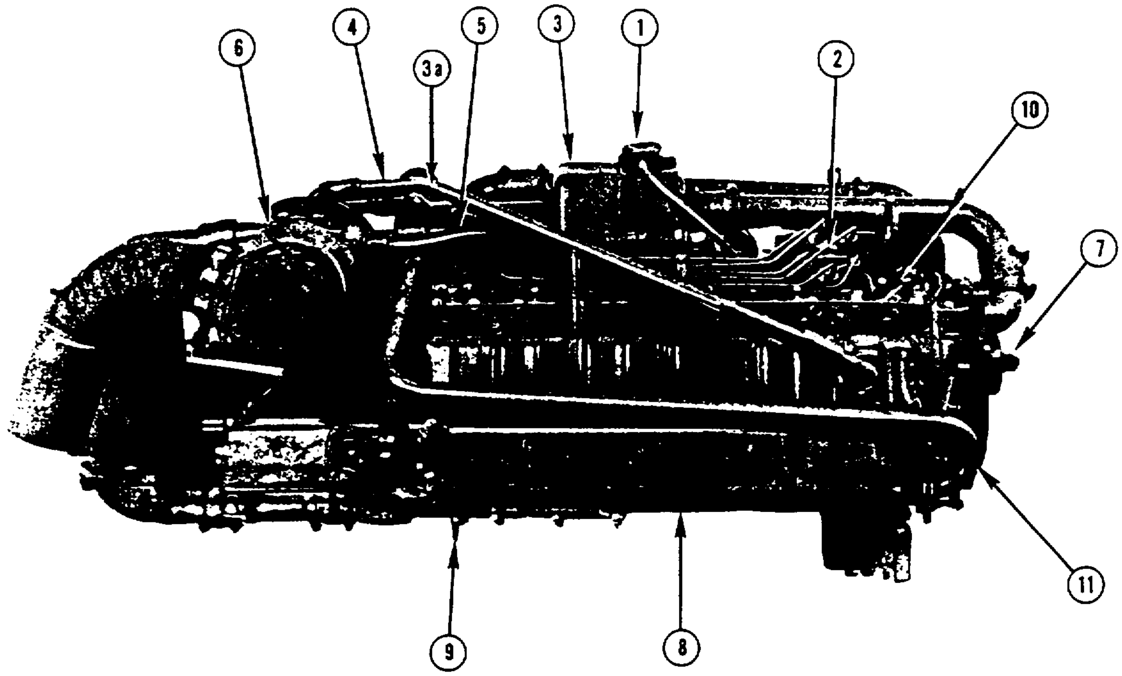



*Fig. 3(i)*

KEY TO HT6.354 (M) ENGINE PHOTOGRAPHS

1. Fresh Water Filler Cap
2. Fuel Injection Pump
3. Header Tank

3a. Zinc Anode

4. Engine Breather Pipe
5. Lubricating Oil Pressure Feed Hose to Turbocharger
6. Turbocharger
7. Fresh Water Pump
8. Exhaust Manifold
9. Water Drain Tap
10. Injector
11. Heat Exchanger to Exhaust Manifold Pipe

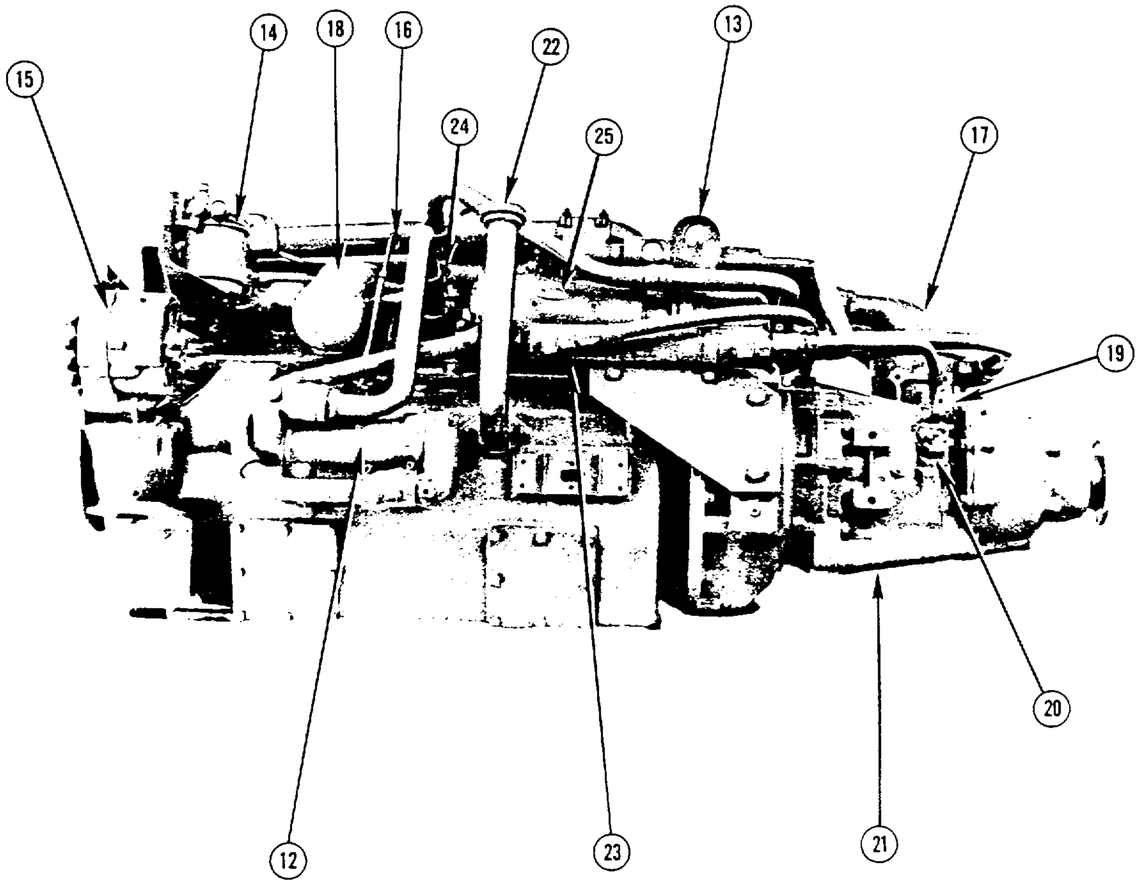



*Fig. 3(j)*

12. Oil Cooler
13. Lifting Bracket
14. Fuel Filter
15. Alternator
16. Dipstick
17. Air Charge Cooler
18. Lub Oil Filter
19. Gearbox Forward/Reverse Lever
20. Gearbox Filler/Dipstick
21. Gearbox
22. Lub Oil Filler Cap
23. Lub Oil/Gearbox Fluid Cooler
24. Sea Water Pump
25. Starter Motor

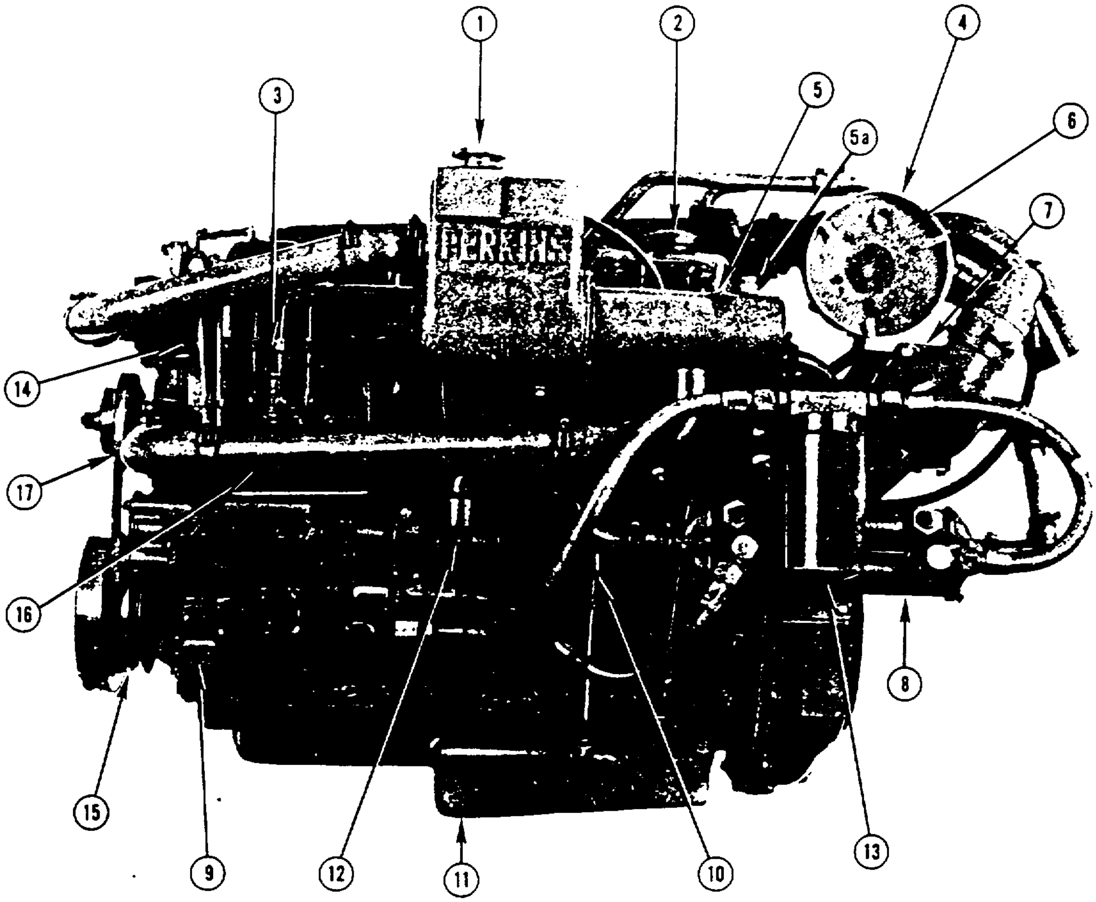



*Fig. 3(k)*

KEY TO T6.354 (M) ENGINE PHOTOGRAPH

1. Fresh Water Filler Cap
2. Lubricating Oil Filler Cap
3. Fuel Injection Pump
4. Turbocharger Air Intake
5. Heat Exchanger
5a. Zinc Anode
6. Air Cleaner
7. Air Charge Cooler
8. Oil Coolers
9. Front Engine Support Bracket
10. Lubricating Oil Pan Dipstick
11. Lubricating Oil Pan
12. Sea Water Pump (L.H. Rotating Engine)
13. Lubricating Oil Filter
14. Fuel Filter
15. Crankshaft Pulley
16. Fresh Water Pipe (Heat Exchanger to Pump)
17. Fresh Water Pump Pulley

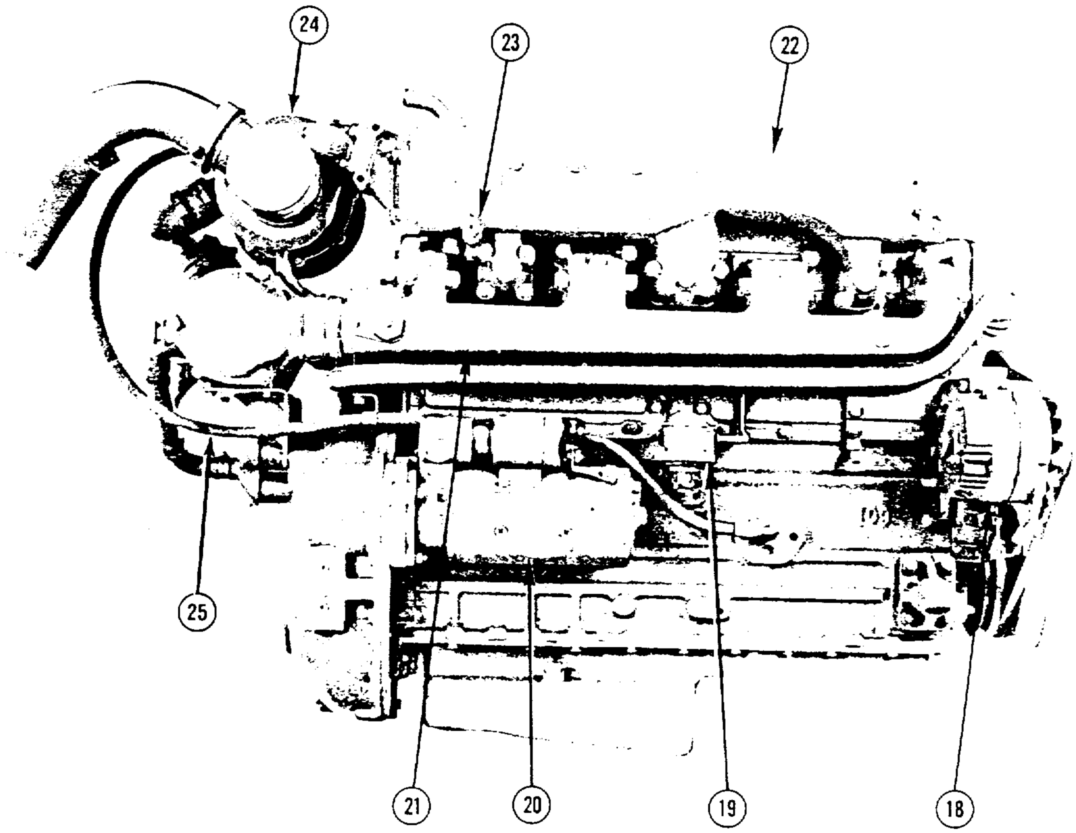



*Fig. 3(l)*

18. Alternator
19. Fuel Transfer Pump (with Priming Lever)
20. Starter Motor
21. Intake Manifold
22. Exhaust Manifold
23. Water Drain Tap
24. Turbocharger
25. Oil Line To Turbocharger

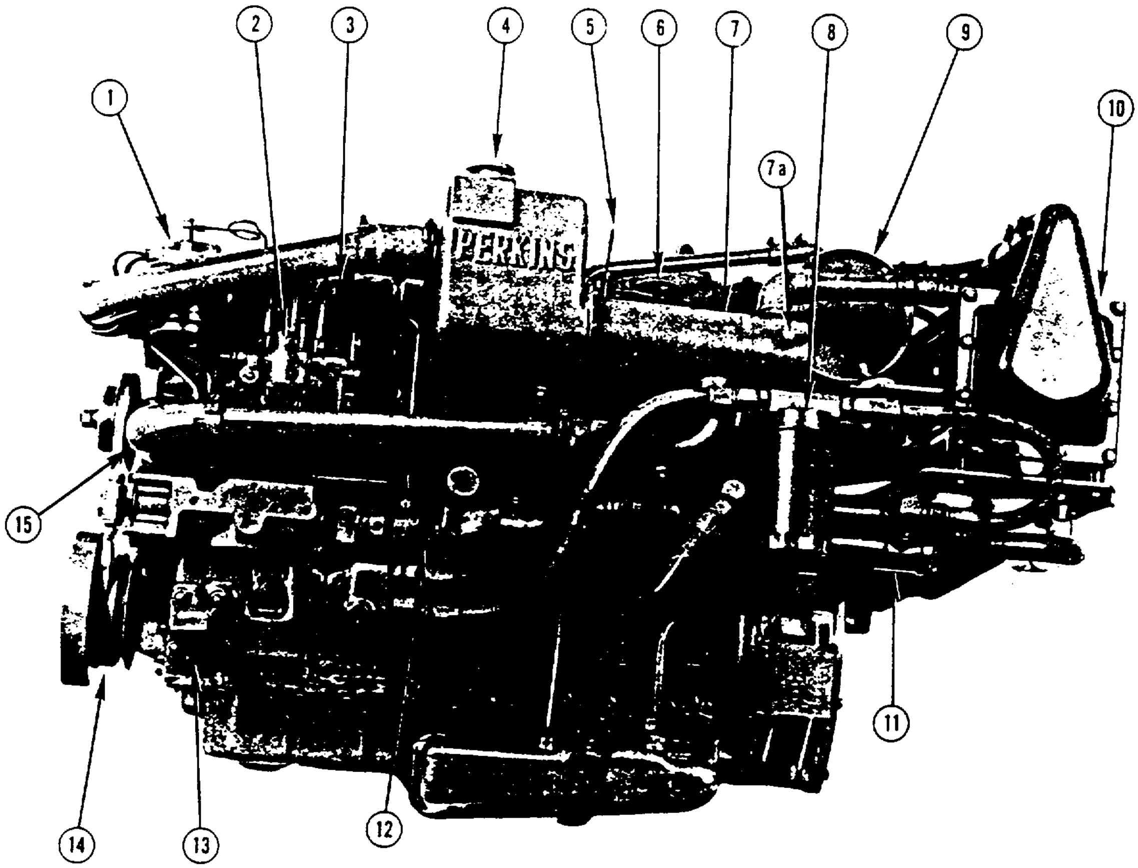



*Fig. 3 (m)*

KEY TO T6.354 MGT ENGINE PHOTOGRAPHS

1. Fuel Filter
2. Injection Pump
3. Injector
4. Fresh Water Filler Cap
5. Lub Oil Dipstick
6 Lub Oil Filler Cap
7. Heat Exchanger
7a. Zinc Anode
8. Lub Oil Filter
9. Air Filter
10. Intercooler
11. Oil Coolers
12. Sea Water Pump
13. Front Engine Mount
14. Crankshaft Pulley
15. Fresh Water Pump

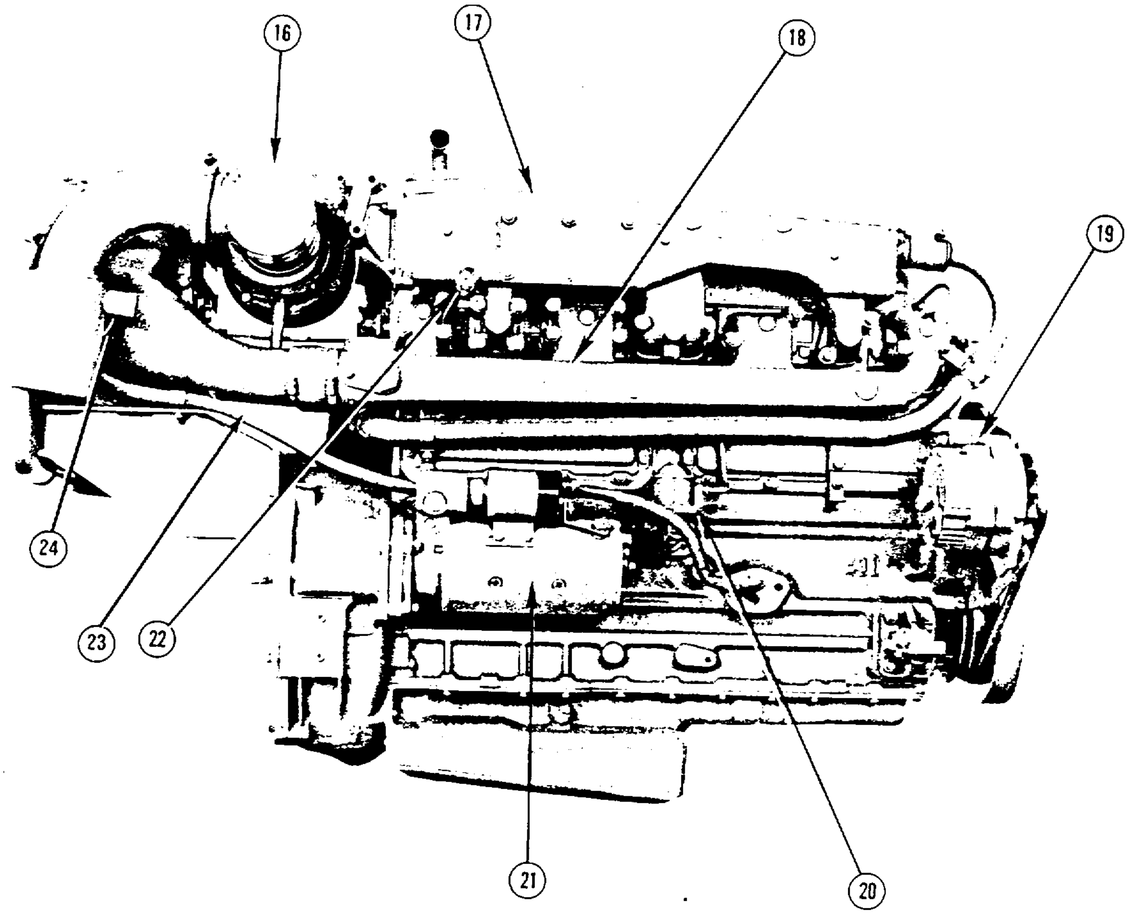



*Fig. 3(n)*

16. Turbocharger
17. Exhaust Manifold
18. Intake Manifold
19. Alternator
20. Fuel Lift Pump (with Priming Lever)
21. Starter Motor
22. Drain Tap
23. Oil Line to Turbocharger
24. Sea Water Inlet from Exhaust Manifold

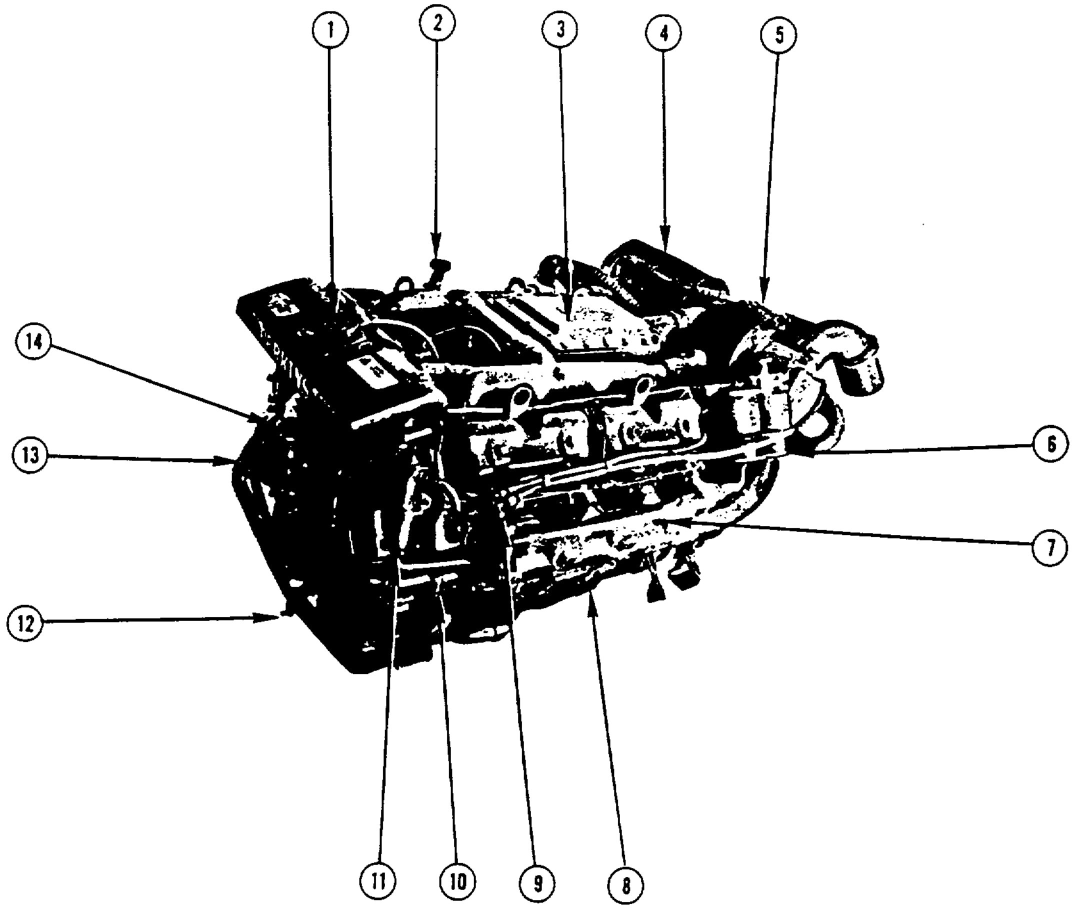



*Fig. 3(o)*

KEY TO TV8.510 (M) ENGINE PHOTOGRAPH

1. Fresh Water Filler Cap
2. Lub Oil Filler Cap
3. Intercooler
4. Air Filter
5. Turbocharger
6. Twin Element Fuel Filter
7. Exhaust Manifold
8. Starter Motor
9. Injector
10. Sea Water Pump
11. Oil Pan Drain Pump
12. Drain Tap
13. Alternator
14. Fresh Water Pump

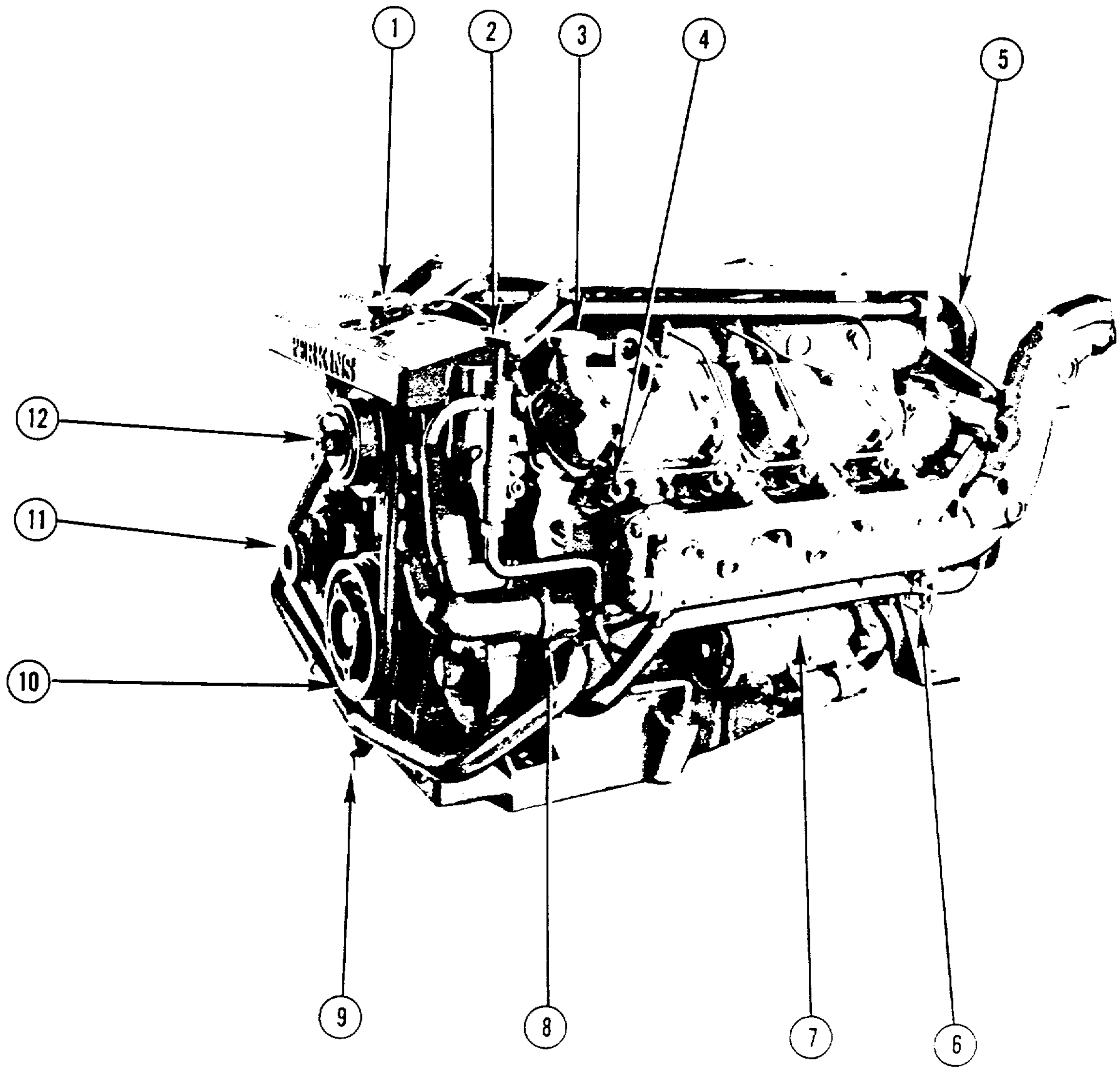



*Fig. 3(p)*

KEY TO V8.510 (M) ENGINE PHOTOGRAPH

1. Fresh Water Filler Cap
2. Oil Pan Drain Pump
3. Lub Oil Filler Cap
4. Injector
5. Air Intake Filter
6. Water Drain Tap
7. Starter Motor
8. Sea Water Pump
9. Water Drain Tap
10. Crankshaft Pulley
11. Alternator
12. Fresh Water Pump

**ENGINE SPECIFICATIONS**

| | 4.108 (M) |
|---|---|
| Engine Type: | In-Line 4-Cylinder, 4-Cycle, Indirect Injection |
| Maximum Shaft Horsepower: | 47 @ 4000* rpm (35.1 skw), 45 @ 3600 rpm (32.8 skw) |
| Displacement: | 107.4 cu. in. (1.76 Litres) |
| Bore and Stroke: | 3.125 x 3.5 in. (79.4 mm x 88.9 mm) |
| Compression Ratio: | 22:1 |
| Firing Order: | 1, 3, 4, 2 |
| Lub Oil Capacity: | 4.2 U.S. Quarts (3.97 Litres) |
| Coolant Capacity: | 2 U.S. Gallons (7.57 Litres) |
| *Special Rating | |

| | 4.154 (M) |
|---|---|
| Engine Type: | In-Line 4-Cylinder, 4 cycle, Indirect Injection |
| Maximum Shaft Horsepower: | 58 @ 3000 rpm (43.3 skw) |
| Displacement: | 153.9 cu. in. (2.53 Litres) |
| Bore and Stroke: | 3.5 x 4.0 in. (88.9 mm x 101.6 mm) |
| Compression Ratio: | 21.5:1 |
| Firing Order: | 1, 3, 4, 2 |
| Lub Oil Capacity: | 9.9 U.S. Quarts (9.37 Litres) |
| Coolant Capacity: | 3. U.S. Gallons (11.6 Litres) |

| | 4.236 (M) |
|---|---|
| *Engine Type: | In-Line 4-Cylinder, 4-cycle, Direct Injection |
| Maximum Shaft Horsepower: | 72 @ 2500 rpm (53.7 skw) |
| Displacement: | 235.9 cu. in. (3.88 Litres) |
| Bore and Stroke: | 3.875 x 5.0 in. (98.43 mm x 127 mm) |
| Compression Ratio: | 16:1 |
| Firing Order: | 1, 3, 4, 2 |
| Lub Oil Capacity: | 8.4 U.S. Quarts (7.95 Litres) |
| Coolant Capacity: | 3.5 U.S. Gallons (13.25 Litres) |

| | 6.354 (M) |
|---|---|
| Engine Type: | In-Line 6-Cylinder, 4-cycle, Direct Injection |
| Maximum Shaft Horsepower: | 115 @ 2800 rpm (85.8 skw) |
| Displacement: | 354.0 cu. in. (5.8 Litres) |
| Bore and Stroke: | 3.875 x 5.0 in. (98.4 mm x 127 mm) |
| Compression Ratio: | 16.1 |
| Firing Order: (Standard Rotation) | 1, 5, 3, 6, 2, 4 |
| Firing Order: (Contra-Rotation) | 1, 4, 2, 6, 3, 5 |
| Lub Oil Capacity: | 10.8 U.S. Quarts (10.22 Litres) |
| Coolant Capacity: | 5.4 U.S. Gallons (20.44 Litres) |

| | T6.354 (M) & HT6.354 (M) |
|---|---|
| Engine Type: | Turbocharged In-Line 6-Cylinder 4-Cycle, Direct Injection |
| Maximum Shaft Horsepower: | 145 @ 2400 rpm (108.2 skw) |
| Displacement: | 354.0 cu. in. (5.8 Litres) |
| Bore and Stroke: | 3.875 x 5.0 in. (98.4 mm x 127 mm) |
| Compression Ratio: | 15.5:1 |
| Firing Order (Standard Rotation) | 1, 5, 3, 6, 2, 4 |
| Firing Order: (Contra-Rotation) | 1, 4, 2, 6, 3, 5 |
| Lub Oil Capacity T6.354M | 12.6 U.S. Quarts (11.92 Litres) |
| Lub Oil Capacity HT6.354M | 13.8 U.S. Quarts (13.05 Litres) |
| Coolant Capacity: | 5.4 U.S. Gallons (20.44 Litres) |

| | T6.354 MGT |
|---|---|
| Engine Type: | Turbocharged In-Line 6-Cylinder, 4-Cycle, Direct Injection |
| Maximum Shaft Horsepower: | 175 @ 2400 rpm (130.6 skw) |
| Displacement: | 354.0 cu. in. (5.8 Litres) |
| Bore and Stroke: | 3.875 x 5.0 in. (98.4 mm x 127 mm) |
| Compression Ratio: | 15.5:1 |
| Firing Order: (Standard Rotation) | 1, 5, 3, 6, 2, 4 |
| Firing Order: (Contra-Rotation) | 1: 4, 2, 6, 3, 5 |
| Lub Oil Capacity: | 10.8 U.S. Quarts (10.22 Litres) |
| Coolant Capacity: | 5.4 U.S. Gallons (20.44 Litres) |

| | V8.510 (M) |
|---|---|
| Engine Type: | 90° V8-Cylinder, 4-Cycle, Direct Injection |
| Maximum Shaft Horsepower: | 172 @ 2800 rpm (128.3 skw) |
| Displacement: | 510.7 cu. in. (8.36 Litres) |
| Bore and Stroke: | 4.25 x 4.50 in. (108 mm x 114.3 mm) |
| Compression Ratio: | 16.5:1 |
| Firing Order: | 1, 8, 7, 5, 4, 3, 6, 2 |
| Lub Oil Capacity:. | 18.6 U.S. Quarts (17.6 Litres) |
| Coolant Capacity: | 9.3 U.S. Gallons (35.2 Litres) |

| | TV8.510 (M) |
|---|---|
| Engine Type: | Turbocharged 90° V8-Cylinder, 4-Cycle Direct Injection |
| Maximum Shaft Horsepower: | 235 @ 2600 rpm (175.3 skw) |
| Displacement: | 510.7 cu. in. (8.36 Litres) |
| Bore and Stroke: | 4.25 x 4.50 in. (108 mm x 114.3 mm) |
| Compression Ratio: | 15:1 |
| Firing Order: | 1, 8, 7, 5, 4, 3, 6, 2 |
| Lub Oil Capacity: | 18.6 U.S. Quarts (17.6 Litres) |
| Coolant Capacity: | 9.3 U.S. Gallons (35.2 Litres) |

## INSTRUMENTS

Engine monitoring instruments provide the operator with important information concerning the operating condition of the engine. Generally, the instruments are not as precise as test instruments but they will provide sufficiently accurate indications of the operating condition of the engine.

### ENGINE OIL PRESSURE GAUGE

This is one of the most important instruments and should be checked as soon as the engine starts. Normal oil pressure is 30/60 P.S.I. (2.1/4.2 kgf/cm 2) at maximum engine speed with the engine at normal operating temperature. During the life of the engine, as bearing surfaces wear, there will be a gradual decrease in pressure, There will also be a slight decrease in pressure when the oil is hot or if the wrong grade of oil is used during certain climatic conditions. Refer to page 58 for the correct oil grades.

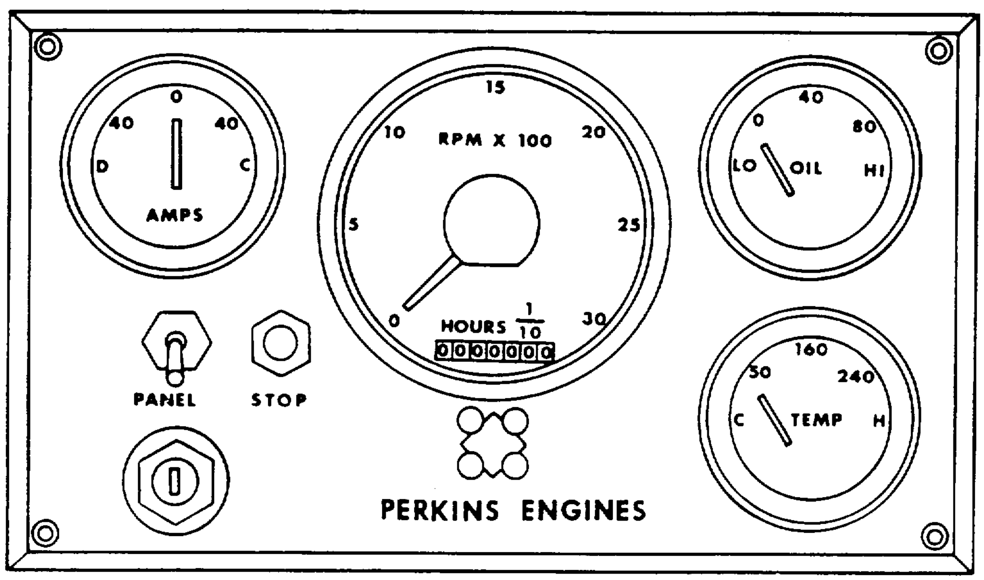



*Fig. 4 Typical Instrument Panel*

### TACHOMETER

This instrument provides the operator with the speed, in revolutions per minute (rpm), of the engine crankshaft. The value indicated on the dial usually has to be multiplied by one hundred (100) to arrive at the engine rpm. (e.g., 20 x 100 = 2,000 rpm).

<u>NOTE</u>: Initial calibration may be required for certain tachometers.

### WATER TEMPERATURE GAUGE

This instrument provides the operator with the temperature of the engine coolant. The coolant temperature (normal) should remain within the ranges listed on page 54. If a higher than normal temperature is experienced, investigate and correct immediately (refer to page 54).

### AMMETER

This instrument provides the operator with an indication of whether or not the battery is being charged by the alternator. An indication that the battery is discharging should be investigated and corrected immediately.

## STARTING AND STOPPING ENGINE

### PREPARATION FOR STARTING

ENSURE FUEL IS TURNED ON!

Open engine coolant seacocks (does not apply to keel cooled engines).

Check coolant level in header tank.

Check engine and gearbox lubricating oil levels (see pages 56 and 59 for oil specifications).

When checking oil level on HT6.354 engines, the procedure outlined on page 56 should be followed. If a V8.510 engine (with in-line pump) has not been running for a period exceeding one month, a pint of engine lube oil should be added to the fuel injection pump through the filler plug. (See 1, Fig. 12 (b), page 50).

Ensure that the fuel tank contains considerably more than the amount of fuel necessary for the intended voyage. The fuel oil should conform to one of the specifications listed on page 45.

External assemblies and accessories driven by an engine, such as pulleys, belts, and alternator/generator, are hazardous to anyone attempting to repair or service it while it is operating. If possible, always stop your engine before servicing it. When necessary to repair or adjust an operating engine, use extreme caution and do not wear loose clothing.

### STARTING THE ENGINE

Engine controls and instruments will vary according to each individual boat builders preference but, in general, the following instructions are applicable to all Perkins marine engines installed in boats manufactured in North America.

1. Place the gearbox in neutral position (Borg-Warner gearboxes have a neutral safety switch that prevents starting in any other position).

   If the engine has not been started for five or more days, it may be necessary to either turn the engine over several times with the starter or operate the priming lever several times to build up the fuel pressure.

2. Place the engine speed control at the maximum *speed position.

3. Press start button or turn the key in clockwise direction release as soon as the engine starts. If the engine fails to run, ensure that the starter pinion and engine have stopped rotating before re-engaging the starter motor. Otherwise, the flywheel ring and starter pinion could be damaged.

4. Place the engine speed control at the position of desired engine rpm.

*For TV8.510 (M) engines, place the engine speed control at one-quarter (1/4) of maximum speed if the engine or weather is warm or at the maximum speed position, if cold.

**COLD WEATHER STARTING**

The exact temperature where use of a "Thermostart" is necessary varies from engine to engine and also according to many other variables. In general, if the temperature is below 40°F (30 4°C) and, upon attempting to start an engine, it turns over rapidly, exhausts white smoke but does not start, the use of a "Thermostart" is necessary.

TO USE A THERMOSTART -

1. If the fuel line has a valve, ensure that it is turned to the "on" position.

2. Move the speed control to the maximum position.

3. Push and hold the button labeled "Heater" for 15 to 20 seconds. (Note: Some installations employ key start switches with a "Heater" position).

4. Engage the starter motor. If the engine does not start in 20 seconds, release the button. After 10 seconds re-engage the starter motor. If the engine will not start, check to ensure there is fuel at the inlet and 12Vat the electrical terminal on the "Thermostart". If both are present, remove the air filter housing (or air duct) and visually observe the device to determine if it glows red when the heater switch is engaged. If not, the device is faulty and must be replaced. If there is no fuel at the inlet, ensure that all valves between the fuel supply source and the "Thermostart" are open. If this is not the cause, the next step is to "bleed" the low pressure fuel system. Refer to "bleeding", page 46. If 12V are not available, troubleshoot electrical system.

5. As soon as the engine starts, release starter switch, adjust the throttle for the lowest smooth running engine rpm and allow the engine to warm up.

6. If applicable, close the "Thermostart" fuel supply valve.

**INITIAL OPERATING CHECKS**

When the engine starts, check:
1. Oil pressure gauge for sufficient oil pressure.
2. Alternator ammeter for an indication that the battery is being re-charged.
3. Sea water coolant discharge for evidence of proper circulation (not applicable to keel cooled engines).

**OPERATING PRECAUTIONS**

A new Perkins engine can be operated at full load when first used, provided sufficient time Is allowed for the engine to attain a temperature of at least 140°F (60°C) before full load is applied. Gradual engine "break-in" is not necessary. In fact, prolonged engine operation with a light load can be harmful because, under these conditions, the piston rings may not seat properly within the cylinder liners.

Engine oil pressure and level should be very closely monitored until it has been established that the engine is functioning normally.

Do not operate the engine at maximum speed for long periods of time. The table on page 33 lists the maximum intermittent and continuous speeds for each respective engine type. An engine should not be operated at maximum speed for a period in excess of one hour. After operating at maximum speed, reduce the speed to maximum continuous rpm* for at least 15 minutes before returning to maximum speed. If an engine is "loaded down" and runs at less than the maximum speed when at full throttle, the same precaution applies.

*The speed of pleasure craft TV8.510 (M) engines must be reduced 200 rpm for a period of two hours before being returned to maximum.

| ENGINE TYPE | MAXIMUM INTERMITTENT SPEED (RPM) | MAXIMUM CONTINUOUS SPEED (RPM) |
|---|---|---|
| 4.108 (M) | 3,600<br>4,000<br>(Special Rating) | 3,000 |
| 4.154 (M) | 3,000 | 3,000 |
| 4.236 (M) | 2,500 | 2,250 |
| 6.354 (M) | 2,800 | 2,400 |
| T6.354 (M)<br>HT6.354 (M) | 2,400 | 2,250 |
| T6.354 MGT | 2,400 | 2,250 |
| V8.510 (M) | 2,800 | 2,500<br>(Medium Duty Rating)<br>2,000<br>(Heavy Duty Rating) |
| TV8.510 (M) | 2,600<br>(Pleasure Craft, planing and light displacement) | 2,400 |
| | 2,400<br>(Light Commercial craft) | 2,200 |

**STOPPING THE ENGINE**

A spring loaded "stop control" push button switch (electric) is located on or near the instrument panel. This switch, in conjunction with a solenoid on the injection pump, functions to stop the flow of fuel to the injection pump.

To stop the engine, press the button until the engine stops running, release, turn the key to the "off" position and place the engine speed control in the minimum speed position.

Some boats may have a mechanical spring loaded pull-to-stop control instead of an electric push button. To stop an engine having this type of control, pull the knob and hold until engine rotation ceases. Upon releasing the knob, ensure it returns to its normal position (i.e., the "run" position) so that the engine may be re-started without difficulty.

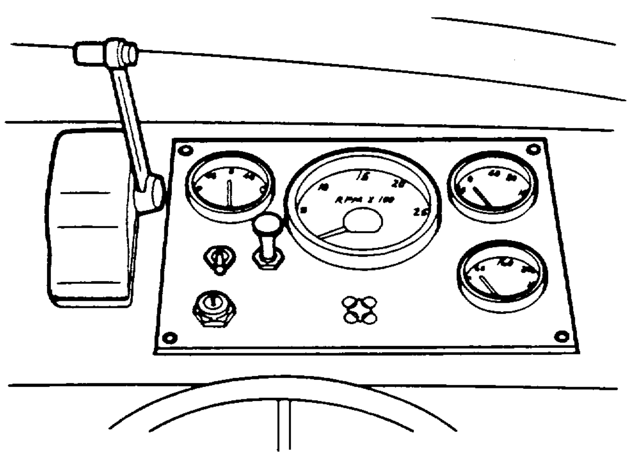


*Fig. 5 Typical Engine Control Console*

## SCHEDULED MAINTENANCE

A Perkins marine engine will have a long and trouble free life provided it is maintained in accordance with the following schedule:

<u>4.108 (M) Engines</u>

DAILY

Check coolant in header tank (see warning on Page 54).
Check engine lube oil level (see page 56).
Check engine oil pressure (if equipped with gauge).
Check gearbox fluid level (see page 59).

FIRST 25/50 HOURS

Change engine lube oil (see page 58).
Renew engine lube oil filter element (s) (see page 57).
Check cylinder head nuts/setscrews for correct torque (see page 41).
Set valve clearances to 0.012 in. (0.30 mm) cold (see page 61).
Check coolant level (header tank) and inspect for coolant leaks.
Check external nuts, setscrews, mounting, etc. for tightness.
Check drive belt tension (see page 56).
Check electrical equipment and connections.
Check for lube and fuel oil leaks.
Check engine idling speed (see page 50).
Check general performance of engine.

EVERY 100 HOURS OR 2 MONTHS (WHICHEVER OCCURS FIRST)

Change engine lube oil (see page 58).
Renew engine lube oil filter element (s) (see page 57).
Clean air intake filter.
* Check drive belt tension (see page 56).
Clean water trap (if equipped).
Check engine for leakage of oil and water.
Change gearbox fluid (Paragon) (see page 61).

EVERY 400 HOURS OR 12 MONTHS (WHICHEVER OCCURS FIRST)

Renew final fuel filter element (see page 49).
Check hoses and clamps.
Drain and clean fuel tank.
Change gearbox fluid (Borg-Warner) (see page 59).

EVERY 800 HOURS

Check sea water pump impeller (see page 54).

EVERY 2,400 HOURS

Arrange for examination and service of accessory equipment, (i.e., starter motor, alternator, etc.).
Service injectors (see page 53).
Check and adjust valve tip clearances (see page 61).

*Drive belt tension should be checked monthly on engines rated above 3000 rpm.

4.154 (M) Engines

DAILY

Check coolant level in header tank(see warning on page 54).
Check engine lube oil level (see page 56).
Check engine oil pressure (if equipped with gauge).
Check gearbox fluid level (see page 59).

FIRST 25/50 HOURS

Change engine lube oil (see page 58).
Renew engine Lub oil filter element (s) (see page 57).
Check cylinder head nuts/setscrews for correct torque (see page 41).
Set valve clearances to 0.012 in (0.30mm) cold (see page 61).
Check coolant level (header tank) and inspect for coolant leaks.
Check external nuts, setscrews, mountings, etc. for tightness.
Check drive belt tension (see page 56).
Check electrical equipment and connections.
Check for lube and fuel oil leaks.
Check engine idling speed (see page 50).
Check general performance of engine.

EVERY 100 HOURS OR 2 MONTHS (WHICHEVER OCCURS FIRST)

Clean air intake filter.

EVERY 200 HOURS OR 4 MONTHS (WHICHEVER OCCURS FIRST)

Change engine Lub oil (see page 58).
Renew engine Lub oil filter element (s) (see page 57).
Check drive belt tension (see page 56).
Check engine for leakage of oil and water.
Clean water trap (if equipped).

EVERY 400 HOURS OR 12 MONTHS (WHICHEVER OCCURS FIRST)

Renew final fuel filter element.
Check hoses and clamps.
Drain and clean fuel tank.
Change gearbox fluid (see page 59).

EVERY 800 HOURS

Check sea water pump impeller (see page 54).

EVERY 2,400 HOURS

Arrange for examination and service of accessory equipment (i.e., starter motor, alternator, etc.).
Check and adjust valve tip clearances (see page 61).
Service injectors (see page 53).

4.236 (M) Engines

DAILY
Check coolant level in header tank (see warning on page 54).
Check engine lube oil level (see page 56).
Check engine oil pressure (if equipped with gauge).
Check gearbox fluid level (see page 59).

FIRST 25/50 HOURS
Change engine lube oil (see page 58).
Renew engine lube oil filter element (s) (see page 57).
Check cylinder head nuts/setscrews for correct torque (see page 41).
Set valve clearances to 0.012 in. (0.30 mm) cold (see page 61).
Check coolant level (header tank) and inspect for coolant leaks.
Check external nuts, setscrews, mounting, etc. for tightness.
Check drive belt tension (see page 56).
Check electrical equipment and connections.
Check for lube and fuel oil leaks.
Check engine idling speed (see page 50).
Check general performance of engine.

EVERY 100 HOURS OR 2 MONTHS (WHICHEVER OCCURS FIRST)
Clean air intake filter.

EVERY 200 HOURS OR 4 MONTHS (WHICHEVER OCCURS FIRST)
Change engine lube oil (see page 58).
Renew engine lube oil filter element (s) (see page 57).
Check drive belt tension (see page 56).
Check engine for leakage of oil and water.
Clean water trap (if equipped).

EVERY 400 HOURS OR 12 MONTHS (WHICHEVER OCCURS FIRST)
Renew final fuel filter element (see page 49).
Check hoses and clamps.
Clean fuel lift pump strainer.
Drain and clean fuel tank.
Change gearbox fluid (see page 59).

EVERY 800 HOURS
Check sea water pump impeller (see page 54).

EVERY 2,400 HOURS
Arrange for examination and service of accessory equipment
(i.e., starter motor, alternator, etc.)
Service injectors (see page 53).
Check and adjust valve tip clearances (see page 61).

6.354 (M), T6.354 (M), T6.354 MGT & HT6.354 (M) Engines

DAILY

Check coolant level (see warning on page 54).
Check engine lube oil level (see page 56).
Check engine oil pressure (if equipped with gauge).
Check gearbox fluid level (see page 59).

FIRST 25/50 HOURS

Change engine lube oil (see page 58).
Renew engine lube oil filter element (s) (see page 57).
Check cylinder head nuts/setscrews for correct torque (see page 40).
Set valve clearances to 0.012 in. (0.30 mm) cold (see page 61).
Check coolant level (header tank) and inspect for coolant leaks.
Check external nuts, setscrews, mountings, etc. for tightness.
Check drive belt tension (see page 56).
Check electrical equipment and connections.
Check for lube and fuel oil leaks.
Check engine idling speed (see page 50).
Check general performance of engine.

EVERY 100 HOURS OR 2 MONTHS WHICHEVER OCCURS FIRST)

Clean air intake filter.
Change engine lube oil - Turbocharged engines with API "CC" oil only. (see page 58).
Service Injectors (T6.354 MGT only).

EVERY 200 HOURS OR 4 MONTHS (WHICHEVER OCCURS FIRST)

Change engine lube oil (see page 58).
Renew engine lube oil filter element (s) (see page 57).
Check drive belt tension (see page 56).
Clean water trap (if equipped).
Check engine for leakage of oil and water.

EVERY 400 HOURS OR 12 MONTHS (WHICHEVER OCCURS FIRST)

Clean fuel lift pump strainer.
Renew final fuel filter element (see page 49).
Check hoses and clamps.
Drain and clean fuel tank.
Change gearbox fluid (Borg-Warner), (see page 59).

EVERY 800 HOURS

Clean turbocharger impeller, diffuser and oil drain pipe.
Change gearbox lube oil (Twin Disc MG-502 and MG-506), (see page 59).
Check sea water pump impeller (see page 54).
(NOTE: For engines equipped with air charge (intercoolers) coolers refer to page 55).

EVERY 2,400 HOURS

Arrange for examination and service of accessory equipment(i.e., starter motor, alternator, etc.).
Service Injectors (see page 53).
Check and adjust valve tip clearances (see page 61).

V8.510 (M) Engines

DAILY
Check coolant level (see warning on page 54).
Check engine lube oil level (see page 56).
Check oil pressure (if equipped with gauge).
Check gearbox fluid or lube oil level (see pages 59 and 61).

FIRST 25/50 HOURS
Change engine lube oil (see page 58).
Renew engine lube oil filter element (s) (see page 57).
Set valve clearances to 0.012 in. (0.30 mm) cold (see page 61).
Check coolant level (header tank) and inspect for coolant leaks.
Check external nuts, setscrews, mountings, etc. for tightness.
Check drive belt tension (see page 56).
Check electrical equipment and connections.
Check for lube and fuel oil leaks.
Check engine idling speed (see page 50).
Check general performance of engine.

EVERY 100 HOURS OR 2 MONTHS (WHICHEVER OCCURS FIRST)
Clean air intake filter.

EVERY 200 HOURS OR 4 MONTHS (WHICHEVER OCCURS FIRST)
Change engine lube oil (see page 58).
Renew engine lube oil filter elements (see page 57).
Check drive belt tension (see page 56).
Clean water trap (if equipped)
Check engine for leakage of oil and water.

EVERY 400 HOURS OR 12 MONTHS (WHICHEVER OCCURS FIRST)
Renew final fuel filter elements (see page 49).
Service injectors (see page 53).
Check and adjust valve tip clearances (see page 61).
Check hoses and clamps.
Drain and clean fuel tanks.
Change gearbox fluid (Borg-Warner), (see page 59).
Clean fuel lift pump strainer.

EVERY 800 HOURS
Check sea water pump impeller (see page 54).
Change gearbox lube oil (Twin Disc MG-506 and MG-502), (see page 59).

EVERY 2,400 HOURS
Arrange for examination and service of accessory equipment (i.e., starter motor, alternator, etc.).

TV8. 510 (M) Engines

DAILY
Check coolant level (see warning on page 54).
Check engine lube oil level (see page 56).
Check gearbox fluid or lube oil level (see pages 59 and 61).
Check oil pressure (if equipped with gauge).

FIRST 25/50 HOURS
Change engine lube oil (see page 58).
Renew engine lube oil filter elements (see page 57).
Set valve clearances to 0.012 in (0.30 mm) cold (see page 61).
Check coolant level (header tank) and inspect for coolant leaks.
Check external nuts, setscrews, mountings, etc., for tightness.
Check drive belt tension (see page 56).
Check electrical equipment and connections.
Check for lube and fuel oil leaks.
Check engine idling speed (see page 50).
Check general performance of engine.

EVERY 100 HOURS OR 2 MONTHS (WHICHEVER OCCURS FIRST)
Clean air intake filter.
Change engine lube oil if using API "CC" oil (see page 58).

EVERY 200 HOURS OR 4 MONTHS (WHICHEVER OCCURS FIRST)
Change engine lube oil if using API "CD" oil (see page 58).
Renew engine lube oil filter elements (see page 57).
Check drive belt tension (see page 56).
Service injectors (see page 53).
Clean water trap (if equipped).
Check engine for leakage of oil and water.

EVERY 400 HOURS OR 12 MONTHS (WHICHEVER OCCURS FIRST)
Renew final fuel filter elements (see page 49).
Check and adjust valve tip clearances (see page 61).
Check hoses and clamps.
Drain and clean fuel tanks.
Change gearbox fluid (Borg-Warner), (see page 59).
Check gearbox oil/fluid cooler for water flow restrictions (see page 55).
Clean fuel lift pump strainer.

EVERY 800 HOURS
Clean turbocharger impeller, diffuser and oil drain pipe.
Check sea water pump impeller (see page 54).
Change gearbox lube oil (Twin Disc MG-502 and MG-506) (see page 59).

EVERY 2,400 HOURS
Arrange for examination and service of accessory equipment (i.e., starter motor, alternator, etc.). See page 62 for Air Charge Cooler servicing.

ALL ENGINES

The intervals listed are general in their application. The operator should compare the maintenance schedule for his particular engine with the schedule established by the manufacturer of his boat and should always adopt the shorter interval. Also, the maintenance intervals should be reduced to conform with any exceptional operating condition. such as continuous sustained high speeds or temperatures.

An operator usually is familiar with the water he is operating in, therefore, checking the weed trap (at the water intake) at appropriate intervals is left to his discretion.

The zinc pencil (anode) in the heat exchanger will need replacing periodically in accordance with the operating conditions of the boat and engine. Refer to the engine photographs for the respective location (not applicable to 4.154 (M) and V8.510/TV8. 510 (M) engines).

The thermostat, in carrying out its function of controlling temperature can, contrary to general thoughts on the method of its operation, open and close numerous times during each hour of engine operation. In so doing, like any other type of mechanical device, it may not maintain its efficiency indefinitely. Therefore, it is recommended that it be replaced after each two years of operation or more frequently if there are indications that it is not functioning correctly.

CYLINDER HEAD TIGHTENING SEQUENCES

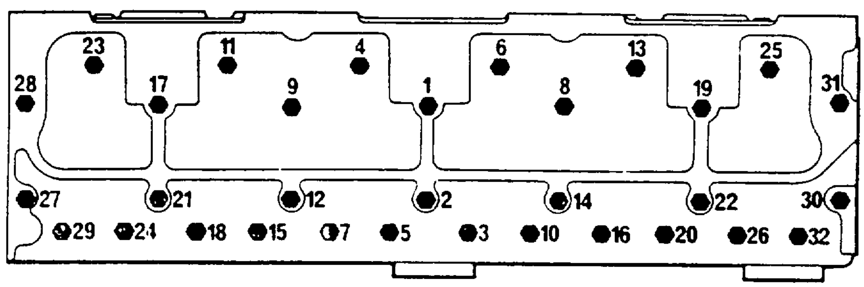



*Fig. 6(a) Tightening Sequences for Cylinder Head Nuts and/or Setscrews*
*6.354 (M), T6,354 (M), HT6.354 (M), T6.354 MGT*

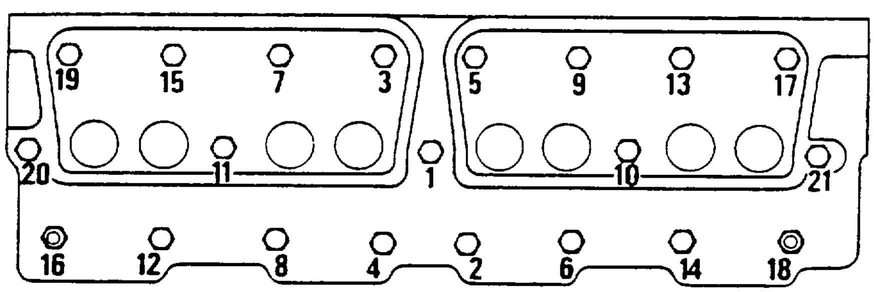



*Fig. 6(b) Tightening Sequence for Cylinder Head Nuts and/or Setscrews*
*V8.510/TV8.510 (M)*
*(Applicable To Both Banks.)*

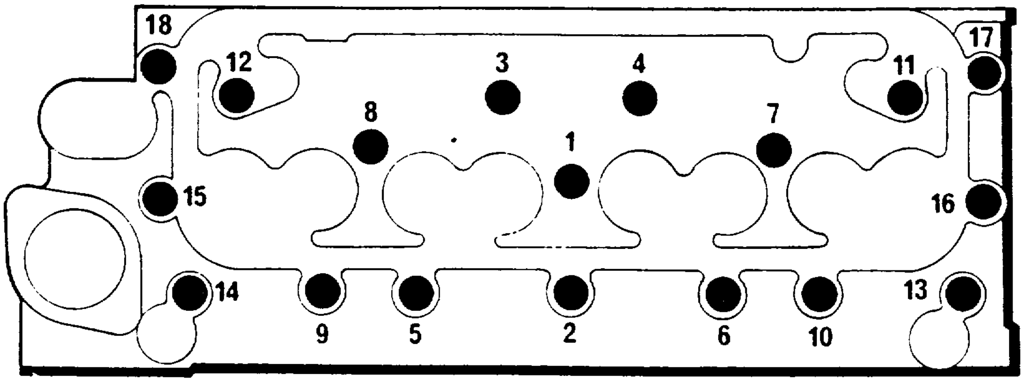



*Fig. 6(c) 4.108 (M)*

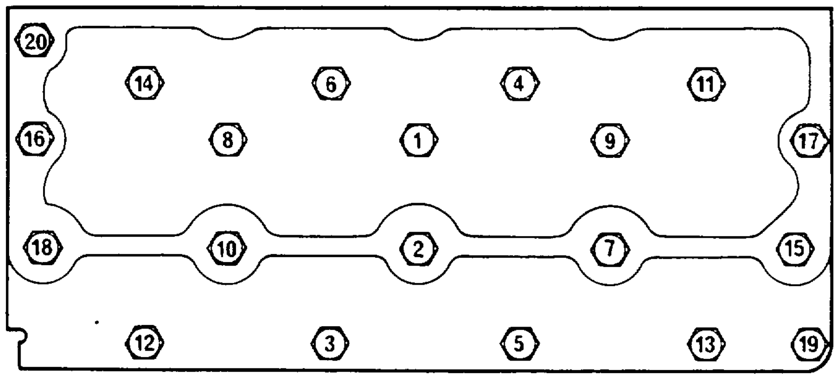



*Fig. 6 (d) 4.154 (M)*

| Cylinder Head Nuts and/or Setscrews | Torque lbf ft. | Tension kgf m |
|---|---|---|
| 4.108 (M) | 60 | 8.3 |
| 4.154 (M) | 85 | 11.75 |
| 4.236 (M) | 100 | 13.8 |
| 6.354 (M) | 100 | 13.8 |
| T6.354 (M), HT6.354 (M), T6.354 MGT | 100 | 13.8 |
| V8.510/TV8.510 (M) | 125 | 17.3 |

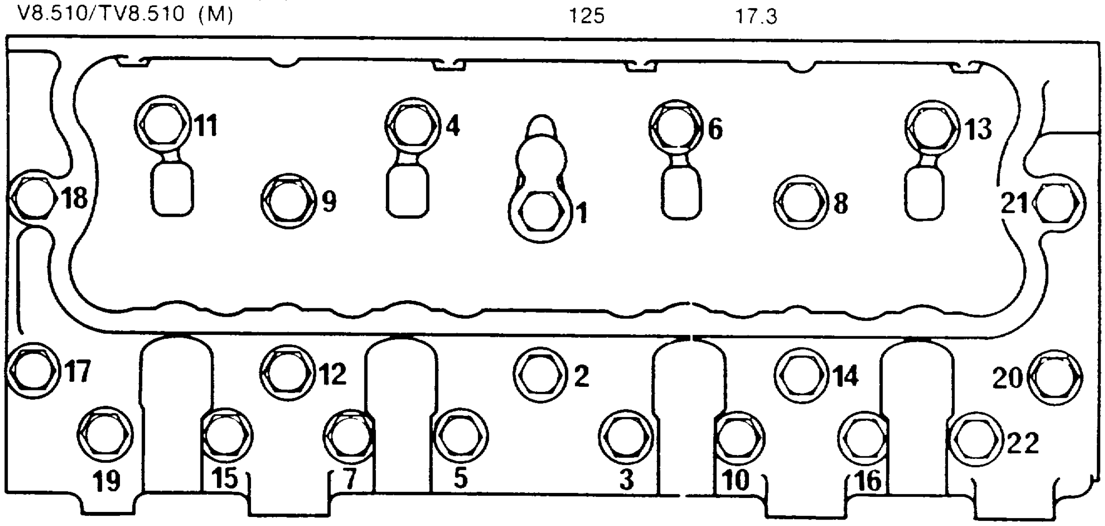



*Fig. 6 (e) 4.236 (M)*

## ENGINE PRESERVATION

If a boat is to be stored for several months, the engine should be preserved as follows:

1. Clean all external parts.
2. Run engine until warm. Stop and drain the lube oil pan.
3. Discard lube oil filter element (s), clean base (s), fill elements with new oil of an approved grade and install new element (s) (refer to page 57).
4. Clean engine breather pipe (s).
5. Fill lube oil pan to correct level with new oil of an approved grade (refer to page 58).
6. Drain all fuel oil from fuel tanks and filters. Put at least one gallon of inhibiting oil into the fuel tank (refer to "Oil Recommended for Preservation of Fuel System", Page 44). If, because of the construction of the fuel tank, this quantity of oil is inadequate, disconnect the fuel feed line before the first filter and connect a small capacity auxiliary tank. If the tank (s) cannot be drained, they should be filled with fuel and a temporary tank (inserted in the fuel feed line) should be filled with an inhibiting oil.
7. Bleed the fuel system as detailed on page 46.
8. Start engine and run it at half speed for 15 minutes to circulate the oil through the injection pump, pipes and injectors.
9. Seal the tank air vent (or filler cap) with waterproof adhesive tape.

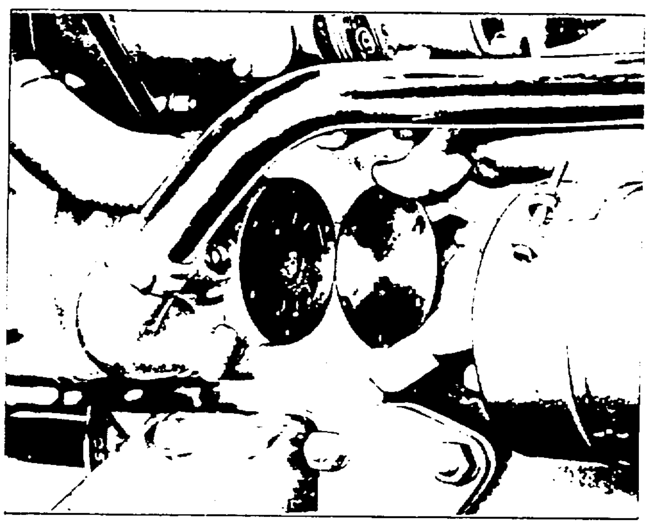


*Fig. 7 (a)*

*Fig. 7 (b)*

10. Drain water from heat exchanger and engine cylinder block. The heat exchanger should be removed and serviced. The cylinder block may be back-flushed through the drain points with the thermostat removed. If it is decided to refill the fresh water system partially with antifreeze, the precaution on page 45 should be noted. For 4.108 engines, "bleeding" may be necessary when filling the cooling system (refer to page 44, item 6)

11. Remove the end plate from the sea water circulating pump and lubricate the interior of the pump body with Glycerine or MARFAK 2HD grease (refer to Fig. 7) or remove impeller for the preservation period.

12. Remove the injectors and spray into the cylinder bores 1/4 pint (0.014 litre) of lubricating oil divided between all cylinders. Rotate the crankshaft one complete revolution and replace injectors. Direct injection engines require an atomized spray.

13. Remove the air cleaner (s) and any piping. Seal the air intake with waterproof adhesive tape.

14. Remove the exhaust pipe (s) and seal the manifold port.

15. Remove cylinder head cover (s), lubricate the rocker assembly and replace cover (s).

16. Remove water pump drive belt (s).

17. BATTERIES
    a. Remove the battery (s) and fill cells with distilled water.
    b. Recharge (see warning on page 63).
    c. Clean the terminals and lightly smear with petroleum jelly.
    d. Store in a cool, dry, dust free place. Avoid any freezing risk.
    e. Recharge once a month.
18. STARTERS AND ALTERNATORS
    Clean terminals and smear lightly with petroleum jelly. The alternator, starter, and terminals must be protected from precipitation.

## OIL RECOMMENDED FOR PRESERVATION OF FUEL SYSTEM

A fuel oil having the following characteristics should be used for preservation of the fuel system.

| | |
|---|---|
| Viscosity: | Should not be greater than 22 centistokes at the lowest ambient temperature expected upon restarting. |
| Pour Point: | Must be at least 15º (-10°C) lower than the lowest ambient temperature expected upon restarting and should be lower than the lowest temperature likely to be encountered during the storage period. |
| Example: | Shell Fusus "A" or equivalent. In the event an oil of this type is not available, use clean, new #1 diesel fuel to prevent waxing at low temperatures. |

## PREPARING THE ENGINE FOR OPERATION

When the engine is to be returned to operating condition, the following procedure must be followed:

1. Thoroughly clean all external parts and reinstall the sea water pump impeller (if removed).
2. Remove tape from the fuel tank vent (or filler cap).
3. Drain fuel tank to remove any remaining oil and condensed water and refill the tank with fuel oil. If tanks have been filled in lieu of draining, drain the water from the trap (if provided by the boat builder).
4. Install new fuel filter element and vent the filter (see page 46).
5. Vent and prime the fuel injection pump (see page 46).
6. Close all coolant drain taps and fill the system with clean coolant. Check for leaks. If a 4.108 marine engine is installed with the front of the engine lower than the rear of the engine (this is note recommended installation), it is possible for an air lock to develop when the cooling system is refilled. To prevent this, loosen the plugs on top of the manifold and cylinder head so that the air can escape during the refilling operation.
7. Rotate fresh water coolant pump by hand to ensure freedom of the water pump seals. If the pump will not rotate with a reasonable amount of force, it will have to be removed to determine the cause of the restriction.
8. Reinstall water pump drive belt (s).
9. Remove the rocker cover (s), lubricate rocker assembly (s) with engine oil, and replace cover (s).
10. Remove tape from the air intake (s), clean filter (s), reinstall the air cleaner (s), and any removed intake pipe.
11. Remove tape from the exhaust manifold port and reinstall the exhaust pipe (s).
12. STARTER AND ALTERNATOR Wipe the petroleum jelly from the terminals and check that all connections are secure.
13. Connect the battery (s)
14. Check the level and condition of the lub oil in the oil pan. Change the oil if necessary. Attend to the oil level in the in-line fuel injection pump (see page 48).
15. Open raw water seacocks.
16. Start the engine in the normal manner and check for sufficient oil pressure and battery charge. While the engine is reaching its normal operating temperature, check for water and oil leaks.

**NOTE:**
**If the foregoing instructions are observed, the storage and return to operation should be efficient and without any adverse effect on the engine. However, Perkins Engines cannot accept liability for direct or consequential damage that might arise following periods of storage.**

**COLD WEATHER PRECAUTIONS**

Precautions against damage from freezing should be taken If the engine is to be left exposed to cold weather. Either drain the cooling system or, where this is not convenient, a good quality anti-freeze that incorporates a suitable corrosion inhibitor may be used.

If anti-freeze Is used to protect an engine from freeze damage, ascertain whether it is suitable for use in Perkins Engines and also ensure that it will have no harmful effect on the cooling system in general. Most popular brands (e.g., Prestone) are acceptable.

**WARNING: HARMFUL OR FATAL IF SWALLOWED. If anti-freeze is swallowed, induce vomiting immediately. Call a physician. Do not store in open or unlabeled containers. KEEP OUT OF REACH OF CHILDREN.**

To drain the cooling system, the taps on the cylinder block must be opened. There may be other drain taps on the exhaust manifold, oil cooler. etc., all of which must be opened.

When the engine is drained, the fresh water pump will also drain but. In sub-freezing weather. rotation of the pump may be prevented by:

a. locking of the impeller by ice because the pump hole was blocked by sediment and the pump was not completely drained.
b. locking of the seal because of frozen globules of moisture between the seal and the gland.

When operating in sub-freezing weather:

1. Before starting the engine turn the fresh water pump by hand; this will indicate if the pump is frozen. If frozen, this should free any ice formation.
2. If it is impossible to turn the pump by hand, the engine should be filled with warm water
3. To avoid this trouble, it is advisable, after the water has been drained, to run the engine for a few seconds at idling speed. This will disperse any moisture remaining In the pump After an anti-freeze solution has been used, the cooling system should be thoroughly flushed in accordance with the manufacturers instructions before refilling with normal coolant.

If the foregoing action is taken no harmful effects should be experienced but Perkins cannot be held responsible for any freeze damage or corrosion which may be Incurred.

**FUEL SYSTEM**

The importance of cleanliness in all parts of the fuel system cannot be overstressed. Dirt and sludge can destroy an engine.

**FUEL OIL SPECIFICATIONS**

Diesel fuel oil refined according to the following specifications are acceptable for Perkins engines:

ASTM Classification ........ D-975-66T
Grades ........ No. 1 or No. 2
Federal Specification........ VV-F-800
Grades ........ DF-A (Arctic), DF-1 or DF-2
Cetane No. (Ignition Quality)........ 45 (Minimum)

**BLEEDING THE FUEL SYSTEM**

If the boat runs out of fuel, or whenever any part of the system between the fuel tank and fuel injection pump has been disconnected, the fuel system will have to be bled.

<u>Engines Equipped with C.A.V. DPA Rotary Type Fuel Injection Pumps</u>

1. Loosen the air vent screw on the side of the governor housing (refer to fig. 8(a) (b) (c) (d) (e) NOTE: Two wrenches may be required for 6.354 engines if the screw is coated with paint.

2. Loosen the vent attached to one of the two hydraulic head locking screws. Refer to figs. 8(f) (g) (h) (i). Unscrew vent plug on top of fuel filter (if equipped).

3. Operate priming lever on fuel transfer pump (if this is not possible, the camshaft driving the pump lever may be on maximum lift; turn engine one revolution) and when fuel, free from air bubbles, issues from each venting point, tighten the screws in the following order:

    1. Fuel Filter Cover Vent Screw.
    2. Head Locking Screw.
    3. Control Gear Vent Screw.

4. Slacken the pipe union nut (See Fig. 8(j) (k) (l) at the pump inlet, operate the priming lever and retighten when fuel free from air bubbles, issues from around the threads.

5. Slacken union nuts at the injector ends of two of the high pressure pipes.

*Fig. 8 (a) 4.108*
For newer engines see 11 (d)

*Fig. 8 (b) 4.154*

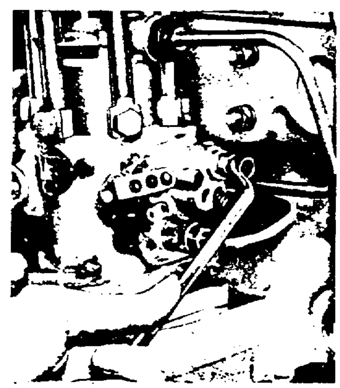


*Fig. 8 (c) 6.354, T6.354*

*Fig. 8 (d) T6.354 MGT*

*Fig. 8 (e) 4.236*

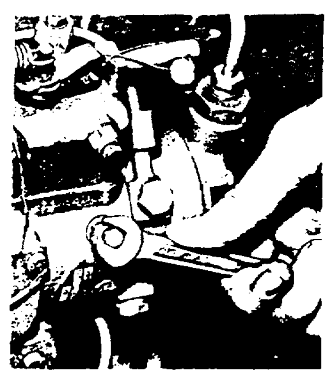


*Fig. 8 (f) 4.236*

6. Set throttle at the fully open position (ensure stop/run lever is in run position).
7. Turn engine with starter until fuel, free from air bubbles, issues from both fuel pipes.
8. Tighten the union nuts on both fuel pipes. The engine is ready for starting.

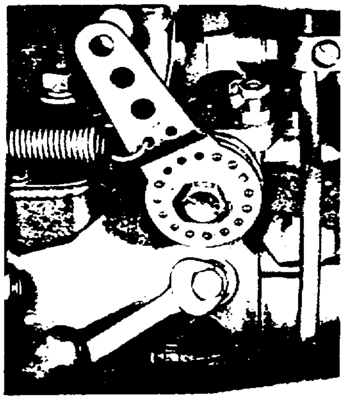


*Fig. 8 (g) 4.108*

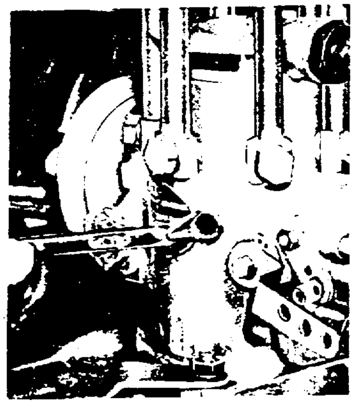


*Fig. 8 (h) 6.354 (all)*

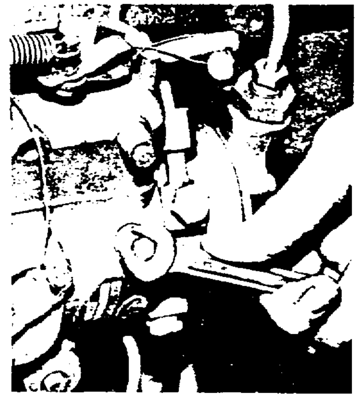


*Fig. 8 (i) 4.154*

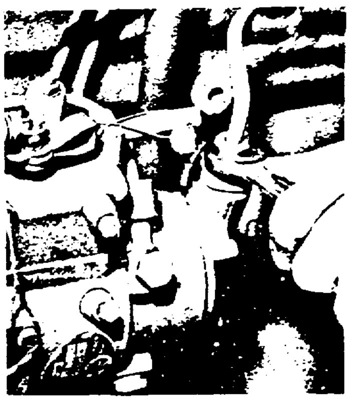


*Fig. 8 (j) 4.236 & 4.154*

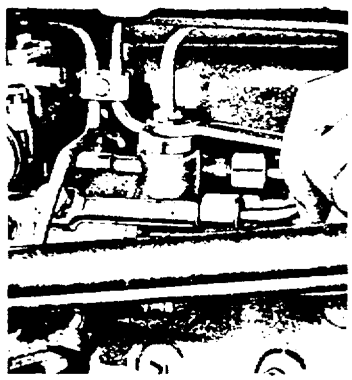


*Fig. 8 (k) 4.108*

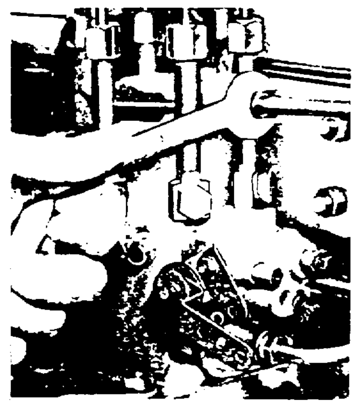


*Fig 8 (l) 6.354 (all)*

<u>V8.510 Engines equipped with in-line fuel injection pumps</u>

1. Unscrew final filter vent plug (see Fig. 9 (a) ).

2. Unscrew the two vent plugs or vent screws on the fuel injection pump by two or three turns. These plugs are located on each side of the fuel inlet connection on the right hand side of the pump (See Fig. 9 )b) ).

3. Operate priming lever on the fuel transfer pump. If the transfer pump driving cam Is on maximum lift, it will not be possible to operate the hand primer. If so, turn the engine through one revolution and proceed.

When fuel free from air bubbles, issues from the venting points, tighten the fuel filter vent plug and then the fuel injection pump vent plugs.

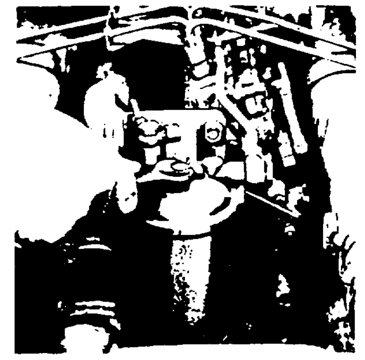


Fig. 9 (a)

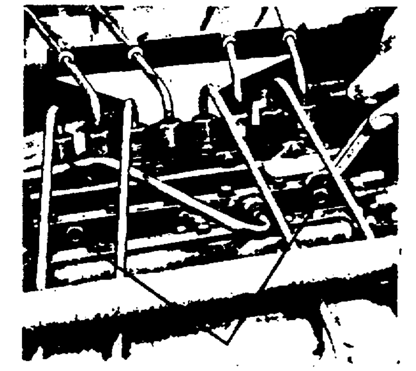


Fig. 9 (b)

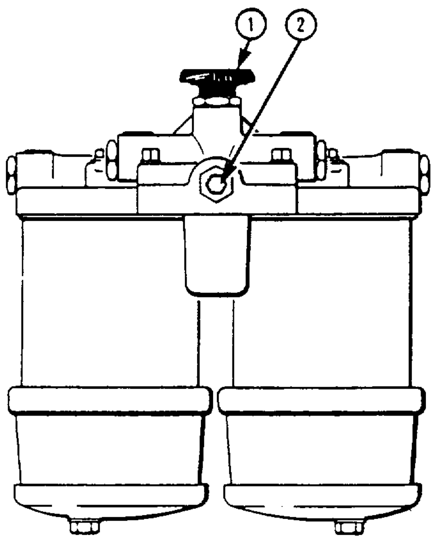


Fig. 9 (c)

Key to Fig. 9(c) TV8.510 (M)
1. Priming Pump Handle
2. Fuel Filter Vent Plug

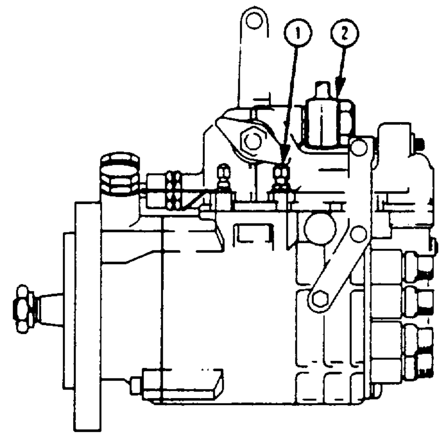


Fig. 9 (d)

Key to Fig. 9 (d) TV8. 510 (M)
1. Idling Speed Adjusting Screw
2. Fuel Pump Return Connection

Engines equipped with S.I.G.M.A. rotary type fuel injection pumps

1. Unscrew the vent plug on the front of the fuel filter (see Fig. 9(c) two or three turns.
2. Unscrew the priming pump handle on top of the filter and operate the pump until fuel, free from air bubbles, issues from the connection. Tighten the connection.
4. Screw the priming pump handle securely back into the filter head casting.
5. Slacken the unions at the injector end of two of the high pressure pipes.
6. Place the accelerator in the fully open position and turn the engine with starter until fuel, free from air bubble, issues from both pipes.
7. Tighten the unions of the fuel pipes. The engine is ready to start.

FUEL FILTERS

Two fuel filters are usually installed on Perkins Marine Engines, one in the fuel transfer pump and the other, a self contained unit with renewable element, mounted on the engine. 4.108 engines do not have a filter in the fuel transfer pump. A fine wire mesh filter within the fuel tank filter and a water trap between the tank and transfer pump are highly recommended to pre-filter the fuel.

To renew filter elements

1. Clean exterior of filter assembly.
2. Unscrew setscrew at top of filter head (see Fig. 10 (a) ).
3. Lower base and discard element (see Fig. 10 (b) ).
4. Clean filter head and base in suitable cleaning fluid.
5. Install sealing rings.
6. Install new element in base.
7. Place square against filter head and tighten setscrew.
8. Bleed fuel system as described previously.

*Fig. 10 (a)*

*Fig. 10 (b)*

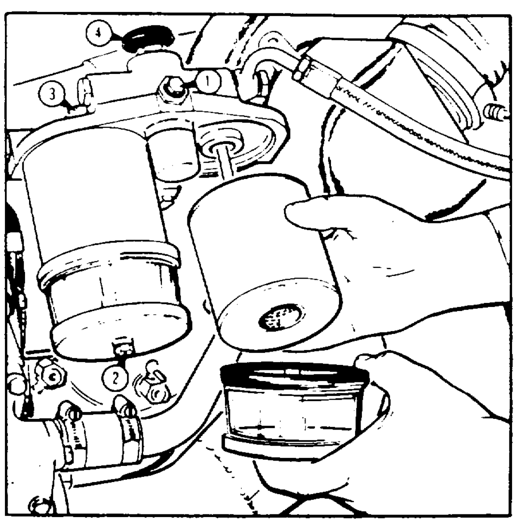



*Fig. 10 (c)*

To Renew Final Fuel Filter Elements TV8.510 (M)

Both elements should be changed at the same time, as follows:

1. Thoroughly clean exterior of filter assembly.
2. Unscrew vent plug (1, Fig 10 (c) ) by two or three turns and drain filter by releasing drain plugs (2, Fig. 10 (c) ).
3. Unscrew filter bowl securing setscrews at top of filter (3, Fig. 10 (c)) remove bottom covers and transparent bowls and discard elements. Ensure, when removing elements, that no fuel is allowed to leak onto the engine.
4. Thoroughly clean filter head, bottom covers and transparent bowls in a suitable cleaning fluid.
5. Inspect sealing rings and renew, if damaged in any way.
6. Place bottom covers, transparent bowl and new elements together, position these assemblies squarely under the filter head and secure with their retaining setscrews.
7. Reinstall drain plugs in bottom covers.
8. Unscrew priming pump handle (4, Fig. 10 (c)) from filter head and operate pump until fuel, free from air bubbles, issues from filter vent point.
9. Tighten vent plug and screw pump handle into filter head.

**IDLING SPEED SETTING**

C.A.V. Rotary Type Pumps

D.P.A. pumps have three types of adjustment. The first type is a spring loaded screw (6.354). The second is on the reversible governor head and consists of a setscrew and locknut. The third is on the governor housing (mechanically governed type pump) and consists of a nut and setscrew.

For the first type, turn the screw clockwise to increase engine speed or anti-clockwise to decrease (see Fig. 11 (a) ).

For the second type, undo the locknut and set the speed (see Fig. 11 (c) and 11 (d) ). This must be done in conjunction with the setting of the anti-stall device (see page 51).

For the third type, undo the locknut and set the required speed.

S.I.G.M.A. Rotary Type Pumps (TV8.510 (M) )

The idle speed adjustment screw is shown in Fig. 9 (d).

In-Line Pumps

The idle adjustment screw is the upper of the two adjustable stop screws situated at the right hand rear of the fuel injection pump (V8.510 (M) engines, Fig. 11 (b)).

The idling speed will vary according to application. For details, inquire at the nearest Perkins. C.A.V. or Simms distributor. (Or Perkins Engines Service Department: Farmington, Michigan or Rexdale, Ontario).

*Fig. 11 (a)*


*Fig. 11 (b)*

**ANTI-STALL DEVICE**

S.I.G.M.A. Rotary Type Pump (TV8.510 (M))
There is no anti-stall device incorporated in this type of fuel injection pump.

C.A.V. DPA Rotary Type Pumps
Refer to Fig. 11 (c) (d)

1. Slacken locknut (2 or 7 ) sufficiently to enable the anti-stall adjusting screw (1 or 6) to be unscrewed two complete turns.

2. Adjust idling speed to 625 rpm* with idling adjustment screw (4 or 2).

3. Screw down anti-stall adjusting screw (1 or 6) until there is a very slight increase in engine speed, bring back half a turn and lock with lock nut (2 or 7).

4. Accelerate engine to maximum no load rpm and immediately return to idle (See page 32).

Should the period of return from maximum rpm to idle exceed three seconds, the device has been turned too far.

*This idle speed may vary according to application. If in doubt, refer to your nearest Perkins Distributor.

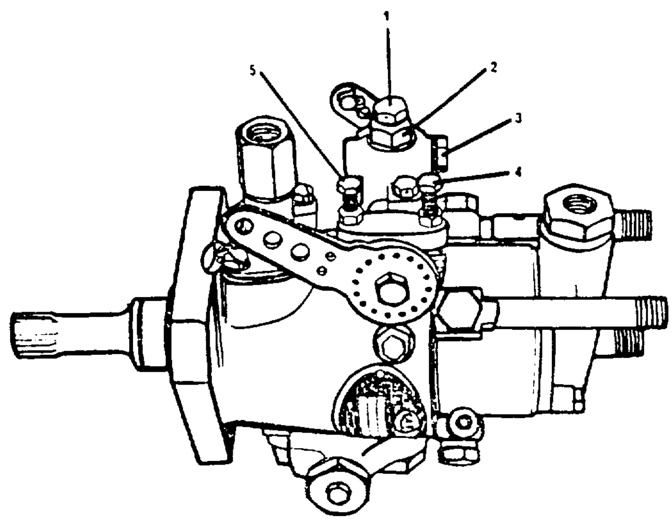



*Fig. 11 (c) Earlier Fuel Pump*

1. Anti-stall adjusting screw
2. Anti-stall locknut
3. Air vent screw
4. Idle adjustment screw
5. Maximum speed screw

If the engine stalls out, the device has not been turned in far enough. The necessary adjustment should be made to overcome either situation.

**Do not attempt to adjust the maximum speed screw (5). This is a factory adjusted setting that requires special test equipment. If the setting is altered, the result may be severe engine damage.**

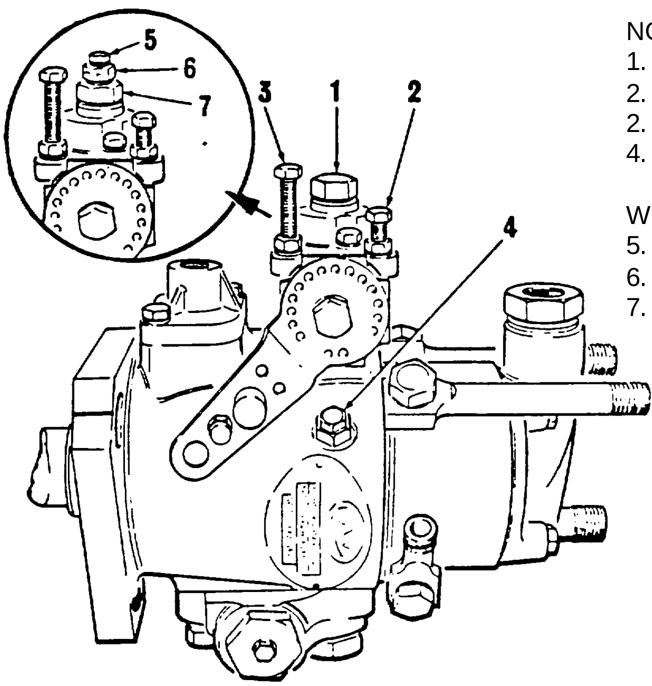



Fig. 11 (d) Later Fuel Pump

NO ANTI-STALL DEVICE
1. Governor Housing Bleed Screw
2. Idle Adjustment Screw
2. Maximum Speed Screw
4. Hydraulic Head Bleed Screw

WITH ANTI-STALL DEVICE
5. Governor Housing Bleed Screw
6. Anti-stall Adjusting Screw
7. Locknut

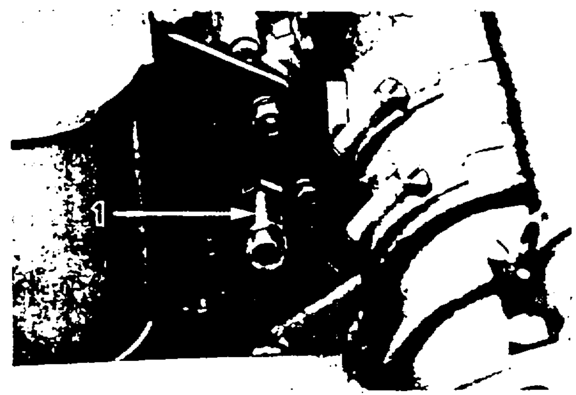



Fig. 11 (e)

In-Line Pumps

1. Screw out anti-stall device by two or three turns (refer to Fig. 11 (e) for V8.510 engines).

2. With engine warmed up. adjust idle speed adjustments for 500 rpm.

3. Screw in the anti-stall device until it just affects idle speed. Back out 3/4 turn and lock with locknut.

4. Operate speed control lever and check to ensure that the anti-stall device is not influencing the idle speed setting and that the engine does not stall out when the lever is quickly closed.

C.A.V. Thermostart Device

Two different types of C.A.V. Thermostarts are installed on Perkins engines. The discontinued type, Mark I, s still in use with older engines while the current type, Mark III, is widely used with newer engines.

Bleeding the Thermostart:

The Mark Ill device incorporates a heat sensitive bi-metallic element to open and close the fuel inlet valve. If the device is used "dry" (i.e., without fuel) the bi-metallic element will become distorted because of the excessive heat and thereafter will not function properly to shut off the fuel. The result of unmetered fuel entering the combustion chambers will be difficult starting, black exhaust smoke and additional engine noise. Also, it can cause hydraulic lockup, which can, in turn, cause the connecting rods to be bent.

In consideration of the consequences described above, it is imperative that before attempting to start a new engine or an engine having any part of its low pressure fuel system dismantled, the fuel system and the fuel line to the Thermostart device must be "bled" to ensure fuel availability.

To "bleed" the fuel system-

1. Loosen the air vent screw on the injection pump governor control housing.
2. Loosen the hydraulic head vent screw on the side of the injection pump body.
3. Loosen the vent plug on the top of the primary fuel filter.
4. Operate the fuel transfer pump priming lever until fuel free from air bubbles issues from each venting location. While continuing to operate the lever, tighten the screws in the following order.
   a) Primary fuel filter vent screw.
   b) Hydraulic head vent screw.
   c) Governor vent screw.
5. Loosen the fuel line connection at the inlet to the Thermostart device.
6. Operate the fuel lift pump priming lever until fuel free from air bubbles issues from the loosened connection. While continuing to operate the lever, tighten the connection.

**INJECTOR TESTING AND REPLACEMENT**

Normally, defective injectors can be isolated by loosening the pipe union nut on each injector in turn while the engine is running at approximately 800 rpm. As each nut is loosened, fuel will not be injected into the associated cylinder and, as a result, the engine rpm will decrease if the injector was previously functioning normally. If the engine rpm remains constant, the injector is probably defective.

When installing a replacement injector remember to also include a new copper seating washer. These are special washers and ordinary washers can not be used for this purpose. The recess in the cylinder head, the faces of the washer and the corresponding face of the nozzle holder cap must be perfectly clean to ensure a leak proof seal. The importance of injectors being seated squarely and secured with the correct torque cannot be emphasized too strongly. Even a slight "canting" of the injector can result in fouling and distortion of the nozzle and needle valve. This canting can also result in leakage between injector and cylinder head, with a resultant engine mis-fire.

TORQUE - To ensure squareness and free entry of the nozzle into its bore, the securing nuts must be tightened evenly until a torque of 12 Ib ft (1.7 kgf m) is attained. Overtightening of these securing nuts can result in a fractured injector flange and/or a fouled nozzle needle valve.

**TIGHTENING HIGH PRESSURE FUEL PIPE NUTS**

Fuel leakage from high pressure pipe unions will result if the nuts are over-tightened. Excessive torque can cause the ferrule (olive) and/or the collar of the nut to be damaged. The correct torque is 12/15 Ibf ft. (1.7 - 2.0 kgf m)

If a high pressure pipe union leaks fuel because the nut has not been tightened sufficiently, the nut should only be tightened enough to stop the leak.

## COOLING SYSTEM

Two types of cooling systems are employed on Perkins marine engines, i.e., indirect and keel cooling.

Indirect Cooling: This system incorporates a heat exchanger, coolant in a closed circuit and raw (sea) water used as the cooling medium. The raw water discharge can be routed into the exhaust silencing system. A thermostat in the closed circuit system keeps the engine at an operating temperature of 150 - 200°F (65 - 93ºC) for 4.108 engines and 168 - 197°F (75 -91°C) for the remainder of the marine engine range. Two water pumps are used.

Keel Cooling: This is the same system as above except the dissipation of heat is accomplished by pipes located outside the hull, usually at an angle between the keel and the garboard strake. The length and diameter will be determined by the engine requirements.

Coolant Capacities: Heat Exchanger System

| | |
|---|---|
| 4.108 (M)<br>2 U.S. Gallons (7.57 Litres) | 4.154 (M)<br>3 U.S. Gallons (11.36 Litres) |
| 6.354 (M) All<br>5.4 U.S. Gallons (20.44 Litres) | V8.510 (M), TV8.510 (M)<br>9.3 U.S. Gallons (35.2 Litres) |
| 4.236<br>3.5 U.S. Gallons (13.25 Litres) | |

## COOLING SYSTEM MAINTENANCE

Rubber Impeller Type Water Pump

This type of pump is used for raw water circulation.

The pump should never be run in a dry condition (impeller blades will tear) and, if the engine is not to be operated for any length of time, it will be necessary to pack the water pump with MARFAK 2HD grease. (If this is not available, glycerine may be used). This is effected by removing the pump end plate' to give access to the interior of the pump. Insert the grease, or glycerine, through the top-most pipe connection (after removing the rubber hose). Turn the engine over to spread the lubricant. This treatment is usually effective for about three months and should be repeated if stored for a longer period of time.

*Refer to Page 43.

With 4.154 marine engines, the raw water pump will have to be removed from the engine to gain access to the end plate.

**NOTE: ALWAYS KEEP A SPARE IMPELLER ON BOARD**

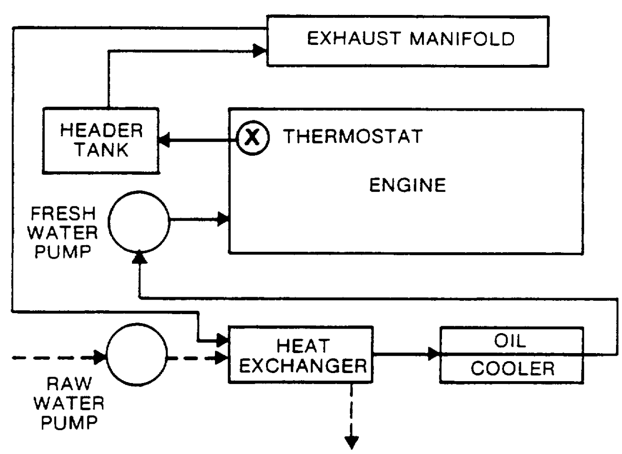



*Fig. 12. Typical Heat Exchanger Cooling System Using Separate Heat Exchanger and Engine Oil Cooler.*

Heat Exchangers, Oil Coolers and Air Charge Coolers

A heat exchanger usually consists of a casing with a core (tube stack), which is the actual heat exchanger. The oil cooler usually has a smaller core and is sometimes an integral part of the engine heat exchanger.

The heat exchanger and coolers should be serviced every season. However, it is stressed that, depending on operating conditions, this period may have to be reduced. Although the coolant temperatures of new engines cease to fluctuate after a short period of operation, the stabilized (normal operating) temperatures will vary slightly from engine to engine because of design tolerances, installation and hull variations. once the normal operating temperature has been established for a particular engine, any excessive rise in temperature should be considered abnormal and immediately investigated. If a cooling system problem is suspected (or confirmed) the following guidelines will provide a means for isolating the cause.

1. Check the coolant level in the header tank and ensure the proper pressure cap is being used (7 psi or .492 kgf/cm2). The coolant in an operating or recently stopped engine is very hot and under pressure. If the filler pressure cap is suddenly removed the liquid may spurt and cause injury by scalding. Always stop an engine and allow it to cool before removing the cap. Once cool, loosen the cap slowly to relieve the pressure.

2. Check the sea cock and strainer for obstructions - clean where necessary.

3. Check the sea water pump impeller-renew if damaged. Ensure that no pieces of the impeller (if broken) have passed into the connecting pipes (i.e., inlet and outlet) because, if so, they could restrict water flow.

4. Check all heat exchangers (coolers) for obstructions within the cooling core tubes on the sea water side. Once the end cap and/or plates are removed, any minute scaling within the core tubes can be removed by passing a rod (slightly smaller than the internal bore) through the tubes. Do not use excessive force when pushing the rod through the tubes.

   If the tubes are so clogged that a rod can not be passed through them, the core will have to be removed from its casing and boiled in a caustic soda solution. Commercial cooling system cleaners can be used for this purpose, providing they are recognized as being acceptable by the heat exchanger manufacturer. Reassemble with new gaskets, seals and "O" rings.

   If a reduced power and/or excessive smoke condition exists in addition to an Increase in coolant temperature with a turbo charged engine having an air charge cooler (Inter cooler), check the inter cooler and, if necessary, clean as described for heat exchangers.

5. Check - especially if the engine was operated in muddy or silty water- the exhaust manifold outlet elbows and the exhaust water injection connections for mud or silt restrictions.

6. Oil Coolers - both engine and gear box - can also effect engine coolant temperatures. Oil coolers should be checked and cleaned as described for heat exchangers.

7. It is particulary important for TV8.510 marine engines to check the last cooler in the sea water system - usually the gear box oil cooler - for water flow restrictions. This cooler should be checked any time there is suspicion of a higher than normal temperature and, in addition, it should be checked at least yearly with seasonal weekend cruising and twice yearly with extended cruises.

Water Pump Drive Belts

Check the tensions of the sea (4.154 M) and fresh water pump drive belts. When correctly adjusted, the depression of the belt by the thumb between water pump and crankshaft pulley should be approximately 3/8" (10 mm).

Seacocks and Strainers

Ensure that seacocks are open prior to starting the engine and that, after the engine has started, there is a flow of water from the discharge pipe. The interval between the cleaning of the strainer is left to the discretion of the operator but regular checks should be made to ensure there are no restrictions. Fig. 13 depicts a typical seacock.

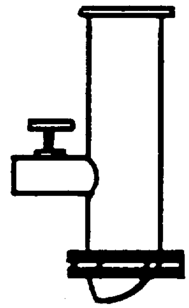


*Fig. 13*

Thermostats

The thermostat, by controlling engine operating temperature within a given range, plays an important part in the operating efficiency and life of an engine. Therefore it is essential that it functions correctly at all times.

**LUBRICATING SYSTEM**

The importance of correct and clean lubrication cannot be stressed too highly. Care should be taken in the selection of oil to ensure that it is correct for the climatic conditions. The oil pan should be filled to the correct level but DO NOT overfill above the full mark.

Because of the variance in delivery of the lubricating oil pump and scavenge pump, the following procedure is recommended for horizontal 6.354 engines when changing the lubricating oil.

1. Fill engine oil pan to full mark on the dipstick.
2. Run the engine until at normal operating temperature, idle engine for two minutes and shut down.
3. Top up oil pan to full mark on dipstick. This replaces residual oil remaining in the crankcase.

For routine oil level checks, horizontal engines should be idled for two minutes before reading the dipstick. The oil level should not be checked with the engine running at speeds in excess of 1000 rpm, or if the engine has been shut down from speeds of over 1000 rpm without the two minutes idling period.

Oil Pressure

Engine oil pressure should be 30/60 psi (2.1/4.2 kgf/cm2) at normal operating speed and temperature. It is normal for the pressure to drop while the engine is idling and when the oil is hot.

Oil Filters
The lubricating oil filter installed on most Perkins marine engines is the screw-on canister type. The canister is secured to the filter head by a threaded adaptor.

Perkins diesel engines require the use of high quality lube oil filters made to Perkins original equipment standards. To protect our customers from filters that do not meet Perkins specifications, we have established minimum performance standards based on SAE oil filter test procedures SAE J806a. The Perkins Farmington Engineering Department maintains a list of filter manufacturers who have supplied test data to SAE J806a and have met Perkins minimum standards. These standards in general preclude the use of low quality, low cost filters.

Renewing Oil Filter
1. Clean exterior of filter.

2. Unscrew and discard the oil canister.

3. Clean the filter head and threaded spigot.

4. Pour (slowly) clean engine lub oil into the center of the replacement canister until full'.

5. Using clean engine lub oil, lightly oil the top seal of the replacement canister.

6. Screw replacement canister onto filter head until the seal just touches head and then tighten by hand a further half turn. If the canister is overtightened, difficulty may be experienced in removal.

7. Run the engine and check for leaks. Do not run the engine at high idle until oil pressure has built up. Recheck oil level and top up as necessary.

*It is recommended that before installing a new screw-on filter canister, it should be primed with oil. Clean lubricating oil should be poured slowly in the center threaded orifice, allowing time for the oil to fill the canister through the filter medium. When attaching a canister to a filter head not in the straight-up position, a small quantity of oil in the stack pipe may be spilled before the canister is screwed home onto its seal.

**RECOMMENDED ENGINE LUBRICANTS**

The recommended engine lubricating oil for naturally aspirated Perkins marine engines is a reputable brand of oil meeting the minimum requirements of U.S. Military Specification MIL-L-46152 when a fuel having a maximum sulfur content of 1.3% by weight is used. This was formerly known as MIL-L-2104B and can be identified by API Service Classification "CC" Lubricating oil for turbocharged engines should meet the requirements of MIL-L-2104C. which can be identified by API Service Classification "CD".

Should questions arise concerning a particular brand of lub oil, consult the supplier. Synthetic Lubricating Oils

As the result of continuing requests for Perkins approval of synthetic lubricating oils, the following policy is announced:

1. General Policy

   Perkins Engines does NOT recommend the use of synthetic lubricating oil for the following reasons:

   a. General experience to date shows the potential for excessive engine wear, particularly with reference to piston rings, cams and gears.

   b. Experience to date shows the potential for premature seal and other elastomer deterioration.

   c. Synthetic oils have been found to be subject to critical quality control requirements. Critical compounding is required and small deviations result in greater than expected performance variations.

   d. No major name brands currently have acceptable compounds. The other than name brand suppliers are difficult to identify and evaluate as dependable suppliers.

2. Exceptions to General Policy

Some products on the market are not true synthetic lubricating oils. Instead, they are man-made hydrocarbons (sometimes referred to as "synthesized hydrocarbon"). This type of man-made fluid is the only available oil with a molecular structure having good high temperature properties and yet not containing the waxy materials that interfere with low temperature flow. Because of the properties of these fluids, Perkins makes the following exceptions to its "no synthetic" rule:

a. The fluid must meet or exceed MIL-L-46167 or MIL-L-46152 quality levels.

b. It must be synthesized hydrocarbon oil versus synthetic oil.

c. The customer must request in writing approval for use in a specific geographical location.

d. If lubrication connected wear and/or failure problems develop, the approval may be rescinded.

LUBE OIL SPECIFICATIONS:
(Minimum Viscosity Index of 80)

| ALL ENGINES | |
|---|---|
| NATURALLY ASPIRATED | TURBOCHARGED |
| MIL-L-46152 (API "CC") with 200 hr. Oil Change Period | MIL-L-2104C (API "CD") with 200 hr. Oil Change Period |
| | MIL-L-46152 (API "CC") with 100 hr. Oil Change Period |

VISCOSITY REQUIREMENTS: All engines except 4.108

| TEMPERATURE RANGES DEGREES F | ENGINE OIL VISCOSITY'* |
|---|---|
| Zero to 30 | SAE 10W |
| 30 to 80 | SAE 20W20 |
| 80 and over | SAE 30 |
| 4.108 ENGINES | |
| Zero to 45 | SAE 10W |
| 45 to 80 | SAE 20W20 |
| 80 and over | SAE 30 |

'Multi-viscosity oils may be used providing the viscosity range is compatible with the specified viscosity (e.g., 10W/30 may be used in lieu of 10W oil).

**GEARBOXES (TRANSMISSIONS)**

The following gearboxes are attached to Perkins engines when supplied from production, but other boxes may be attached by certain boat builders.

| | |
|---|---|
| 4.108 | Borg-Warner 71 CR or Paragon |
| 4.154 | Borg-Warner 71 CR |
| 4.236 | Borg-Warner 71 CR or Borg-Warner 72 CR |
| 6.354 | Borg-Warner 72 CR/C or Borg-Warner 71 CR/C |
| T6.354* | Borg-Warner 72 CR/C |
| HT6.354 | Borg-Warner 72 CR/C |
| V8.510 | Borg-Warner 72 CR, 73 CR or Twin Disc MG-502 |
| TV8.510 | Borg-Warner 73 CR or Twin Disc MG-506 |

*Also T6.354 MGT

**BORG-WARNER - Procedure for checking fluid level**

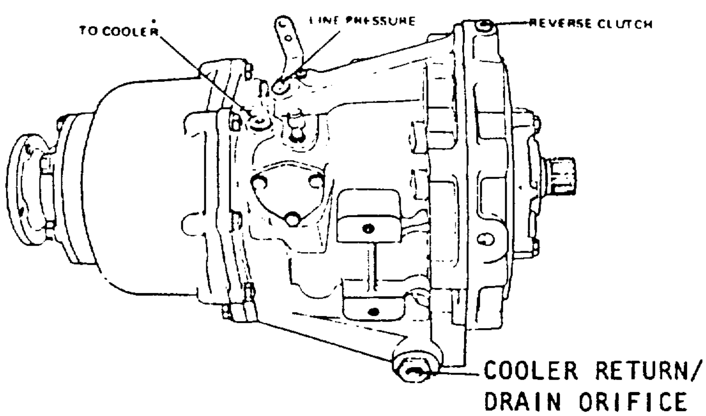
The fluid level should be checked immediately after shut-down and sufficient fluid added to bring the level to the full mark on the dipstick. The dipstick assembly need not be threaded into the case to determine fluid level. Newer gearboxes have plug type dipsticks.

Filling - Transmission fluid (Type "A") should be added until it reaches the full mark on the dipstick. The unit should be rotated at idling speed for a short time to fill all circuits.

The maximum interval between fluid changes for Borg Warner "Velvet Drive" marine transmission is 400 hours operating time or 12 months (each boating season), whichever occurs first.

The condition of the fluid filter (if equipped) screen should be checked and cleaned if necessary prior to refilling the transmission.

**NOTE:** **Vee Drive, 2.1:1 reduction units and CR-2 Drop Center transmissions do not have filter screens. The filter screen for all other units is located within the cooler return/ transmission fluid drain orifice.**




Fluid Pressures and Temperatures (71CR/C and 72CR/C)
Fluid Pressures should be 110-150 PSI (7.53-10.55 kgf/cm2) at normal operating temperatures of 150-165ºF (65.55-73.8°C). At low temperatures or excessive speeds, pressure may rise to 200-250 PSI (14.06-17.58 kgf/cm2). The maximum recommended fluid temperature is 190ºF (87.6°C).

Fluid Pressures and Temperatures (73CR)
Fluid Pressure should be 115-140 PSI (8.08 - 9.84 kgf/cm2) at 2000 rpm engine speed with a fluid temperature of 140-190ºF (60-88ºC).

Fluid Capacities

| GEARBOX | LEVEL U.S. QUARTS | LEVEL LITRES | INCLINED U.S. QUARTS | INCLINED LITRES |
|---|---|---|---|---|
| 71C & CR 1:1 | 1.8 | 1.71 | 1.3 | 1.2 |
| 1.50:1 | 2.5 | 2.36 | 2.7 | 2.56 |
| 1.91:1 | 2.5 | 2.36 | 2.7 | 2.56 |
| 2.10:1 | 2.5 | 2.36 | 2.7 | 2.56 |
| 2.57:1 | 2.5 | 2.36 | 2.7 | 2.56 |
| 2.91:1 | 2.5 | 2.36 | 2.7 | 2.56 |
| 72C & CR 1:1 | 2.1 | 2.00 | 1.7 | 1.55 |
| 1.50:1, 1.91:1 | | | | |
| 2.10:1 | 2.7 | 2.56 | 2.8 | 2.55 |
| 2.57:1, 2.91:1 | 2.7 | 2.56 | 2.8 | 2.55 |
| 73C 1:1 | 2.6 | 2.38 | 1.5 | 1.42 |
| 1.51:1, 2.1:1 | | | | |
| 2.9:1 | 2.0 | 1.89 | 2.2 | 2.04 |

**BORG-WARNER MODEL DESIGNATIONS**

Recently Borg-Warner changed the means for identifying their various transmissions. The following cross reference is being included for identification convenience.

| RATIO | PREVIOUS MODEL DESIGNATION | PREVIOUS MODEL DESIGNATION | NEW DESIGN MODEL DESIGNATION |
|---|---|---|---|
| 1:1 | AS1-71C | 10-04-000-036 | 10-17-000-001 |
| 1:1 | AS1-71CR | 10-04-000-037 | 10-17-000-002 |
| 1:1 | AS1-71CB | 10-04-000-038 | 10-17-000-003 |
| 1:1 | AS1-71CBR | 10-04-000-039 | 10-17-000-004 |
| 1.52:1 | AS2-71C | 10-04-000-042 | 10-17-000-005 |
| 1.52:1 | AS2-71CR | 10-04-000-043 | 10-17-000-006 |
| 1.91:1 | AS7-71C | 10-04-000-050 | 10-17-000-007 |
| 1.91:1 | AS7-71CR | 10-04-000-051 | 10-17-000-008 |
| 2.10:1 | AS3-71C | 10-04-000-044 | 10-17-000-009 |
| 2.10:1 | AS3-71CR | 10-04-000-045 | 10-17-000-010 |
| 2.57:1 | AS14-71C | 10-04-000-046 | 10-17-000-011 |
| 2.57:1 | AS14-71CR | 10-04-000-047 | 10-17-000-012 |
| 2.91:1 | AS 15-71C | 10-04-000-048 | 10-17-000-013 |
| 2.91:1 | AS15-71CR | 10-04-000-049 | 10-17-000-014 |
| 1:1 | AS11-72C | 10-05-000-034 | 10-18-000-001 |
| 1:1 | AS11-72CR | 10-05-000-035 | 10-18-000-002 |
| 1.52:1 | AS12-72C | 10-05-000-038 | 10-18-000-003 |
| 1.52:1 | AS12-72CR | 10-05-000-039 | 10-18-000-004 |
| 1.91:1 | AS17-72C | 10-05-000-046 | 10-18-000-005 |
| 1.91:1 | AS17-72CR | 10-05-000-047 | 10-18-000-006 |
| 2.10:1 | AS13-72C | 10-05-000-040 | 10-18-000-007 |
| 2.10:1 | AS13-72CR | 10-05-000-041 | 10-18-000-008 |
| 2.57:1 | AS14-72C | 10-05-000-042 | 10-18-000-009 |
| 2.57:1 | AS14-72CR | 10-05-000-043 | 10-18-000-010 |
| 2.91:1 | AS15-72C | 10-05-000-044 | 10-18-000-011 |
| 2.91:1 | AS15-72CR | 10-05-000-045 | 10-18-000-012 |

**TWIN DISC MG-502 & MG-506 GEARBOXES**

Oils used in this gearbox type must conform with API Service Classification "SD". Any oil that conforms with this specification is suitable. The correct S.A.E. designation to be used will depend upon the temperature of the cooling water at the inlet to the gearbox oil cooler.

| S.A.E. DESIGNATION | |
|---|---|
| Cooling Water Temp. Below 85ºF (29°C) | Cooling Water Temp. Above 85ºF (29°C) |
| 20w/20 | 30 |

PROCEDURE FOR CHECKING OIL LEVEL
The gearbox oil level should always be checked with the engine running at idle speed.

FILLING
Stop the engine. Fill gearbox to "full" mark on the dipstick with API "SD" engine lub oil.
OIL CAPACITY: 4.8 U.S. Quarts (4.55 Litres)
4.8 U.S. Quarts (4.55 Litres)

OIL PRESSURE
Normal pressure is 300-320 psi (21.1 - 22.5 kgf/cm2) at 1,800 rpm and 1800F (830C).
Minimum pressure is 270 psi (18.98 kgf/cm2) at cruising speed.

**PARAGON GEARBOXES**
Procedure for Checking Fluid Level - When the engine is first started, allow it to idle for a few moments. Stop the engine and check the transmission fluid level. Add type "A" transmission fluid, if necessary, to bring the level up to the mark on the transmission dipstick.

Oil Pressure - Normal pressure is 60 psi (4.22 kgf/cm2) at normal operating temperature.

**PROPELLER SHAFT TRAILING (FREE WHEELING)**
Borg Warner have determined through practical experience that sail boats having Borg Warner transmissions (auxiliary engine installations) can sail with the propeller trailing (free wheeling) at unlimited speeds without risking damage to the transmission, providing the unit is filled with fluid (to full mark on dipstick).

Twin engine power boats having one engine inoperative (shut down) with its propeller free-wheeling are also no longer restricted to a maximum speed or rpm, providing the fluid level is maintained at the full mark on the dipstick.

**CHECKING VALVE TIP CLEARANCES**

When rotating engines, they should always be turned in their normal direction of rotation, i.e., anti-clockwise when viewing from the gearbox end. The exception is contra-rotating engines, which is clockwise from the gearbox end.

<u>4.108, 4.154 and 4.236 Engines</u>
The clearance is set between the top of the valve stem rocker and arm and should be 0.012 in. (0.30 mm) cold. Refer to Fig. 14 (a).

When setting valve clearances the following procedure should be adopted:

1. With the valves rocking on No. 4 cylinder (i.e., the period between the opening of the intake valve and the closing of the exhaust valve), set the valve clearances on No. 1 cylinder.
2. With the valves rocking on No. 2 cylinder, set the valve clearances on No. 3 cylinder.
3. With the valves rocking on No. 1 cylinder, set the valve clearances on No. 4 cylinder.
4. With the valves rocking on No. 3 cylinder, set the valve clearances on No. 2 cylinder.

<u>6.354, T6.354 MGT, T6.354 and HT6.354 Engines</u>
The clearance is set between the top of the valve stem and rocker arm and should be 0.012 in. (0.30 mm) cold. Refer to Fig. 14 (a)

When setting valve clearances the following procedure should be adopted.

1. With the valves rocking on No. 6 cylinder (i.e., the period between the opening of the intake valve and the closing of the exhaust valve), set the valve clearances on No .1 cylinder.
2. With the valves rocking on No. 2 cylinder, set the valve clearances on No. 5 cylinder
3. With the valves rocking on No. 4 cylinder, set the valve clearances on No. 3 cylinder.
4. With the valves rocking on No. 1 cylinder, set the valve clearances on No. 6 cylinder.
5. With the valves rocking on No. 5 cylinder, set the valve clearances on No. 2 cylinder.
6. With the valves rocking on No. 3 cylinder, set the valve clearances on No. 4 cylinder.

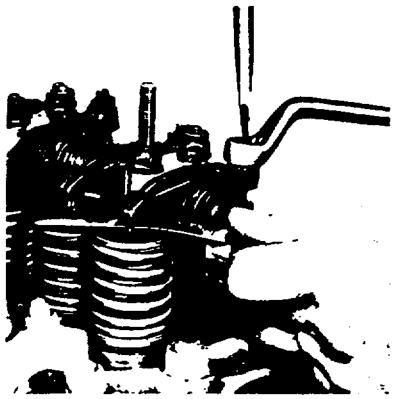


*Fig. 14 (a).*

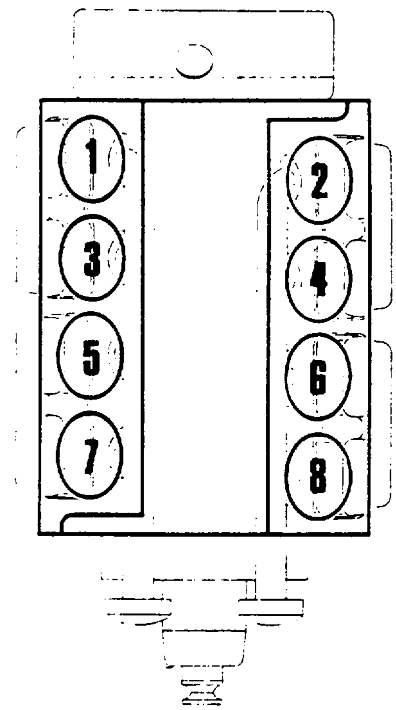



*Fig. 14 (b)*

<u>TV8.510 and V8.510 Engines</u>
The clearance is set between the top of the valve stem and rocker arm and should be 0.012 in. (0.30 mm) cold.

When setting valve clearances the procedure below should be followed. Refer to Fig. 14 (b) for cylinder numbering.

LEFT BANK

1. With the valves rocking on No. 4 cylinder (i.e., the period between the opening of the intake valve and the closing of the exhaust valve), set the valve clearances on No. 1 cylinder.
2. With the valves rocking on No. 6 cylinder, set the valve clearances on No. 7 cylinder.
3. With the valves rocking on No. 2 cylinder, set the valve clearances on No. 5 cylinder.
4. With the valves rocking on No. 8 cylinder, set the valve clearances on No. 3 cylinder.

RIGHT BANK

1. With the valves rocking on No. 3 cylinder, set the valve clearances on No. 8 cylinder.
2. With the valves rocking on No. 1 cylinder, set the valve clearances on No. 4 cylinder.
3. With the valves rocking on No. 7 cylinder, set the valve clearances on No. 6 cylinder.
4. With the valves rocking on No. 5 cylinder, set the valve clearances on No. 2 cylinder.

## ELECTRICAL SYSTEM

### Alternator

The alternator has two generating parts, a stator and a rotor. When the rotor rotates inside the stator windings, alternating current (AC) is induced into the stator. This is unsuitable for charging the battery, therefore, a rectification unit comprised of diodes is also built into the alternator. These are connected in such a manner that they provide an output of direct current (DC) for the battery. The alternator output amplitude is controlled by a fully transistorized integral regulator that requires no servicing and is non-repairable. The alternator type and output rating (42 or 61 amp) can be found stamped on the alternator body or identification plate (e.g., 10SI 42A)

**GENERAL PRECAUTIONS FOR ALTERNATORS**
NEVER disconnect the battery or the starter switch while the alternator is running. This will cause a voltage surge in the system and damage the diodes and transistors.

NEVER disconnect any electrical lead without first stopping the engine and turning all switches to the "OFF" position. ALWAYS identify a lead as to its correct terminal before disconnection. A short circuit or reversed polarity will destroy diodes and transistors.

NEVER connect a battery into the system without checking for correct polarity and correct voltage.

NEVER "Flash" connections to check for current flow. No matter how brief the "Flash", the transistors may be destroyed.

NEVER experiment to try to adjust or repair the system unless you have had proper training on alternators, and you have the correct test equipment and technical data.

NEVER ground the field circuit.

NEVER run the alternator if the output circuit is open, (i.e., without an electrical load).

NEVER attempt to polarize an alternator. When using a battery charger disconnect battery cables.

NEVER apply a battery voltage direct to the regulator or alternator field terminals because this will damage the transistors.

ALWAYS disconnect the alternator terminals before carrying out any electrical welding on the boat because the intense magnetic field created by the "make" and "break" of the arc may cause damage to the diodes.

DO NOT check for continuity of the alternator or regulator with insulation testers such as a "Megger", etc.

ALWAYS disconnect the battery before connecting test instruments (except voltmeter) or before replacing any unit or wiring.

**STARTER MOTOR**
The starter motor has a centrifugally operated mechanical overspeed protection device that releases the pinion from the flywheel when it reaches a predetermined excessive speed.
The solenoid and main switch assemblies are mounted on top (external) of the starter motor housing.

Normally, scheduled maintenance is not required.

The starter motor type is stamped on the housing or nomenclature plate.

**BATTERY MAINTENANCE**

**WARNING: Batteries being charged give off explosive gas. Do not smoke or produce any means for spark ignition. Always ensure that batteries are properly and securely located in an area with adequate ventilation and access for maintenance. In addition, the following guidelines should be adopted:**

1. Batteries should be isolated (with isolation switch) when not in use.

2. Maintain correct electrolyte level (just above the top of the separators).

3. Keep batteries clean and dry to avoid possible corrosion and current leakage.

4. Ensure battery connections are clean and tight and, to avoid overheating, that the cable size is adequate for the current load.

5. Ensure that no current conducting components or attachments are located in close proximity to the battery.

## ELECTROLYTIC CORROSION

Corrosion can occur when two dissimilar metals are in contact in the presence of sea water. Care is taken to avoid this in the design of an engine, but different metal types are necessary. Brass or bronze pipe fittings attached to aluminum parts (for example) will result in rapid corrosion. A zinc pencil is inserted into the heat exchanger to assist in the prevention of electrolytic action.

Particular care is necessary when an engine is installed in an aluminum hull. Zinc anodes can be attached to hulls where corrosion cannot be entirely avoided and specialist firms will advise on their use.

Corrosion can also be caused by current leaking from the battery (and other parts of the electrical system) to the hull via the engine or metal attachments.

## RADIO INTERFERENCE SHIELDING

Radio interference in the form of noise can be caused by the alternator, starter motor and other engine-driven equipment. In addition, many boats have electronic equipment aboard (e.g., radar) that could create radio interference. To prevent this interference, adequate shielding must be provided, if possible. Stray electronic radiation shielding is a very complex task and for severe problems it is suggested that a specialist in the field of electronics be consulted.

## EMERGENCY MAINTENANCE AND OPERATING TIPS

If the engine stops the first thing to do is check that the fuel supply is ON. If the fuel valves or taps are all open, check the fuel level in the tank. If the engine has been run until the fuel tank is completely empty there is a very good chance that there is a lot of dirt in the fuel lines. Change the fuel filter and, after refueling, bleed the system and re-start the engine.

If the engine slows down or loses power, the cause could be something wrapped around the propeller. Always check this first. Check the air intake for obstruction and the engine compartment for a good supply of air. Also, the air intake mesh may be clogged with foreign matter sucked from a dirty engine compartment.

If the engine coolant boils, ease down the throttle and try to ascertain the cause. The first check is the sea cock to ensure an adequate cooling water supply. If satisfactory, check raw water pump operation, the impeller may have failed. If so, replace with the spare impeller. A spare should always be carried on board.

If a serious leak occurs on a high pressure fuel pipe, disconnect and direct the flow into a can or other receptacle, and run on the remaining cylinders. DO NOT attempt to flatten and pipe because this will ruin the fuel injection pump. Leaks in low pressure fuel pipes can be temporarily repaired by the use of heavy duty adhesive tape, hose and clamps.

If an auxiliary engine is required to run while the boat is beating to windward, the boat may heel (see chart) without adverse effect on the lubrication system providing the boat is righted occasionally so that the valve gear can be lubricated.

Maximum Continuous Angle of Heel

| Heel | 4.108 | 4.154 | 4.236 | 6.354 | HT6.354 |
|---|---|---|---|---|---|
| To Port | 250 | 300 | 300 | 300 | 360 |
| To Starboard | 250 | 300 | 300 | 300 | 23° |

Coolant leaks can normally be temporarily repaired with heavy duty adhesive tape, hose and clamps.

If a serious oil leak occurs, shut down the engine immediately and try to find the cause. Oil leaks are a lot harder to repair temporarily because of the pressure involved. However, if the main flow can be stopped to a drip or dribble, place a can underneath the leak and replenish the engine with new oil (from a spare oil can) at the same rate as the loss.

Drip trays of metal or glass fiber should be used beneath the engine to stop lubricating oil or fuel oil dripping into the bilges. Care must be taken to avoid galvanic action between the drip tray and engine (e.g., a copper tray should not be used under an aluminum alloy oil pan). Remember to keep the drip tray clean because this provides an early indication of leaks.

**OPERATING PARAMETERS**

Maximum Engine Compartment Temperature (all engines): 140°F (60ºC)

Maximum Battery Compartment Temperature (all engines): 122°F (50º)

Volume of Air Required Per Engine

| VOL. | 4.108 | 4.154M | 4.236M | 6.354M | T6.354M | T6.354MGT | V8.510M | TV8.510M |
|---|---|---|---|---|---|---|---|---|
| ft$^3$/MIN | 105 | 110 | 157 | 250 | 300 | 406 | 365 | 550 |
| M$^3$/MIN | 3 | 3.1 | 4.45 | 7 | 8.5 | 11.5 | 10.5 | 15.5 |

Maximum Exhaust Back Pressure (measured within 12 inches/305mm of engine manifold)

| Press. | 4.108M | 4.154M | 4.236M | 6.354M | T6.354M | T6.354MGT | V8.510 | TV8.510 |
|---|---|---|---|---|---|---|---|---|
| in. Hg | 3 | 3 | 3 | 3 | 1.5 | 1.5 | 3 | 1.5 |
| mm Hg | 76 | 76 | 76 | 76 | 38 | 38 | 76 | 38 |

**ON-BOARD TOOLS AND SPARE PARTS**

An "on board" tool kit for emergency repairs should be supplemented by:

- Hose clamps, assorted
- Hose, assorted (flex type useful)
- Wire (20 AWG or 12-14 AWG Stranded)
- Insulating (electrical) tape
- Gasket Compound
- Magnet (keep away from compass)
- Mechanical fingers
- Self-gripping (pipe) wrench
- Asbestos Lagging
- Low pressure fuel pipe olives (ferrules)
- Small hacksaw with spare blade
- Assorted files
- Heavy duty adhesive tape

The two kits listed below on page 66 are applicable to any Perkins marine engine. The part numbers for these parts are listed in the applicable parts book for each engine. These kits are strictly guidelines and may be varied at the discretion of the owner/operator.

MAJOR KIT

| QTY. | DESCRIPTION |
|---|---|
| 1 | Zinc Pencil (Plug) |
| 1 | Injector (6 cyl. engines: 2) |
| 1 pkg. | Injector or Seating Washers |
| 1 | Water outlet Gasket |
| 2 | Fuel Oil Filter Elements |
| 2 | Lub Oil Filter Elements |
| 1 | Water Pump Belt |
| 1 | Alternator Belt |
| 1 | Thermostat |
| 1 pkg. | Leak-Off Washers |
| 1 pkg. | Leak-Off Olives (Ferrules) |
| 1 set | Injection Lines |
| 1 | Transfer Pump and Gasket |
| 1 | Sea Water Pump Kit |
| 1 | Top Gasket Set |
| 1 | Water Pump Kit |
| 4 qts. | Type "A" Transmission Fluid' |
| 8 qts. | Engine Lub Oil |

MINOR KIT

| QTY. | DESCRIPTION |
|---|---|
| 1 | Transfer Pump and Gasket |
| 1 | Injector (6 cyl. engines: 2) |
| 1 pkg. | Injector Seating Washers |
| 1 | Water Outlet Gasket |
| 2 | Fuel Oil Filter Elements |
| 2 | Lub Oil Filter Elements |
| 1 | Water Pump Belt |
| 1 | Thermostat |
| 1 pkg. | Leak-Off Washers |
| 1 pkg. | Leak-Off Olives (Ferrules) |
| 1 | Sea Water Pump Impeller |
| 4 qts. | Type "A" Transmission Fluid' |
| 8 qts. | Engine Lub Oil |

The parts listed above are also offered in kit form by Perkins Engines. Please order from your distributor. Lub oil and transmission fluid must be purchased separately.

*Borg-Warner and Paragon Gearboxes. Twin Disc: Substitute with "SD" engine lub oil.

TROUBLESHOOTING CHART

| TROUBLE | POSSIBLE CAUSE |
|---|---|
| Low cranking speed | 1, 2, 3, 4 |
| Will not start | 5, 6, 7, 8, 9, 10, 12, 13, 14, 15, 16, 17, 18, 19, 20, 22, 31, 32, 33 |
| Difficult Starting | 5, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 18, 19, 20, 21, 22, 24, 29, 31, 32, 33 |
| Lack of power | 8, 9, 10, 11, 12, 13, 14, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 31, 32, 33 |
| Misfiring | 8, 9, 10, 12, 13, 14, 16, 18, 19, 20, 25, 26, 28, 29, 30, 32 |
| Excessive fuel consumption | 11, 13, 14, 16, 17, 18, 20, 22, 23, 24, 25, 27, 28, 29, 31, 32, 33 |
| Black exhaust | 11, 13, 14, 16, 18, 19, 20, 22, 24, 25, 27, 28, 29, 31, 32, 33 |
| Blue/white exhaust | 4, 16, 18, 19, 20, 25, 27, 31, 33, 34, 35, 45, 56 |
| Low oil pressure | 4, 26, 37, 38, 39, 40, 42, 43, 44, 58 |
| Knocking | 9, 14, 16, 18, 19, 22, 26, 28, 29, 31, 33, 35, 36, 45, 46, 59 |
| Erratic running | 7, 8, 9, 10, 11, 12, 13, 14, 16, 20, 21, 23, 26, 28, 29, 30, 33, 35, 45, 59 |
| Vibration | 13, 14, 20, 23, 25, 26, 29, 30, 33, 45, 48, 49 |
| High oil pressure | 4, 38, 41 |
| Overheating | 11, 13, 14, 16, 18, 19, 24, 25, 45, 47, 50, 51, 52, 53, 54, 57 |
| Excessive crankcase pressure | 25, 31, 33, 34, 45, 55 |
| Poor compression | 11, 19, 25, 28, 29, 31, 32, 33, 34, 46, 59 |
| Starts and stops | 10, 11, 12 |

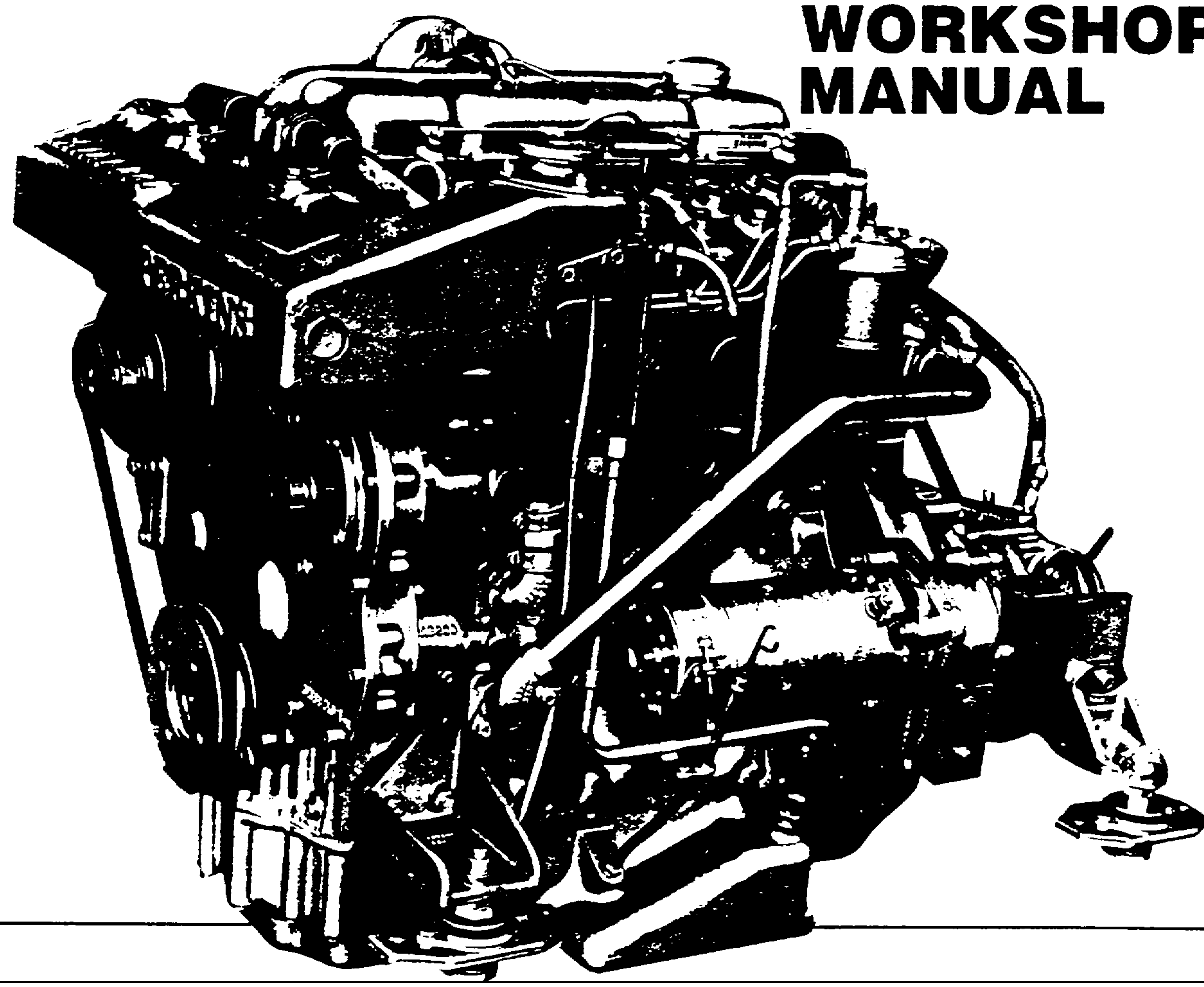
KEY TO TROUBLESHOOTING CHART

1. Battery capacity low
2. Bad electrical connections
3. Faulty starter motor
4. Incorrect grade of lubricating oil
5. Low cranking speed
6. Fuel tank empty
7. Faulty stop control operation
8. Blocked fuel feed pipe
9. Faulty fuel lift pump
10. Choked fuel filter
11. Restriction in air cleaner
12. Air in fuel system
13. Faulty fuel injection pump
14. Faulty injectors or incorrect type
15. Incorrect use of cold start equipment (if equipped)
16. Faulty cold starting equipment
17. Broken fuel injection pump drive
18. Incorrect fuel pump timing
19. Incorrect valve timing
20. Poor compression
21. Blocked fuel tank vent
22. Incorrect type or grade of fuel
23. Sticking throttle or restricted movement
24. Exhaust pipe restriction
25. Cylinder head gasket leaking
26. Overheating
27. Cold running
28. Incorrect tappet adjustment
29. Sticking valves
30. Incorrect high pressure pipes
31. Worn cylinder bores
32. Pitted valves and seats
33. Broken, worn, or sticking piston ring (s)
34. Worn valve stems and guides
35. Overfull air cleaner or use of incorrect grade of oil (oil bath cleaner)
36. Worn or damaged bearings
37. Insufficient oil in oil pan
38. Inaccurate gauge
39. Oil pump worn
40. Pressure relief valve sticking open
41. Pressure relief valve sticking closed
42. Broken relief valve spring
43. Faulty suction pipe
44. Choked oil filter
45. Piston seizure/pick up
46. Incorrect piston height
47. Open circuit strainer or week strap blocked
48. Faulty engine mounting (housing)
49. Incorrectly aligned flywheel housing or flywheel
50. Faulty thermostat
51. Restriction in water jacket
52. Loose water pump drive belt
53. Gearbox or engine oil cooler choked
54. Faulty water pump
55. Choked breather pipe
56. Damaged valve stem oil deflectors (if equipped)
57. Coolant level too low
58. Blocked oil pan strainer
59. Broken valve spring

INDEX

Perkins
Engines

# WORKSHOP MANUAL



4.236M

PRINTED IN U.S.A.

**workshop manual for 4.236 marine diesel engines**



**Perkins Engines, Inc.**
32500 Van Born Road
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1982

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This publication is written for world wide use. In territories where legal requirements govern engine smoke emission, noise, safety factors, etc., then all instructions, data and dimensions given must be applied in such a way that, after servicing (preventive maintenance) or repairing the engine, it does not contravene the local regulations when in use.

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**PERKINS COMPANIES**

| | |
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## SAFETY PRECAUTIONS

THESE SAFETY PRECAUTIONS ARE IMPORTANT. Reference must also be made to the local regulations in the country of operation.

Do not change the specification of the engine.

Do not smoke when you put fuel in the tank.

Clean away any fuel which has fallen and move material which has fuel contamination to a safe place.

Do not put fuel in the tank during engine operation (unless really necessary).

Never clean, lubricate or adjust the engine during operation (unless you have had the correct training when extreme caution must be used to prevent injury).

Do not make any adjustments you do not understand.

Ensure that the engine is not in a position to cause a concentration of toxic emissions.

Persons in the area must be kept well clear during engine and equipment operation.

Do not permit loose clothing or long hair near parts which move.

Keep away from parts which turn during operation. Note that water pump/alternator drive belts can not be seen clearly while the engine is run.

Do not run the engine with any safety guards removed.

Do not remove the header tank filler cap while the engine is hot and the coolant is under pressure as dangerous hot coolant can be discharged.

Do not use salt water in the closed circuit cooling system or any other coolant which can cause corrosion. Keep sparks or fire away from batteries (especially while during charge) or combustion can occur. The battery fluid can burn and is also dangerous to the skin and especially the eyes.

Disconnect the battery terminals before you make a repair to the electrical system.

Only one person must be in control of the engine/s.

Ensure the engine is only operated from the control panel or operators position.

If your skin comes into contact with high pressure fuel. get medical assistance immediately.

Diesel fuel can cause skin damage to some persons. Use protection on the hands (gloves or special skin protection solutions).

Ensure that the transmission drive control is in "Out of Drive" position before the engine is started.

Extreme care must be taken if emergency repairs have to be made at sea or in adverse conditions.

Fit only correct Perkins Parts.

## POWERPART Consumable Products

To give assistance in the correct operation, service and maintenance of your engine and machine, Perkins Engines. Ltd., have made available the products shown below.

The instructions for the use of each product are given on the outside of each container.

These products are available from your Perkins distributor.

**POWERPART Antifreeze**
Gives corrosion protection and also a more efficient coolant in hot conditions. See Page C.5

**POWERPART Lay-Up 1**
A diesel fuel additive for protection against corrosion. See Page C.4

**POWERPART Lay-Up 2**
Gives inside protection to the engine and other closed systems. See Page C.4

**POWERPART Lay-Up 3**
Gives outside protection to any metal parts. See Page C.4

**POWERPART De-Icer**
To remove frost.

**POWERPART Silent Spray**
Silicone lubrication to lubricate and prevent noise from hinges, slide doors, etc.

**POWERPART Damp Displacer**
To make electrical equipment dry and to give future protection.

**POWERPART Hylomar**
Universal sealing compound to seal joints.

**POWERPART Hylosil**
Silicone rubber sealant to prevent leakage.

**POWERPART Impact Adhesive**
To keep joints in position during installation and other general attachment purposes.

**POWERPART Solvent**
To thoroughly clean metal faces before assembly.

**POWERPART Locking Agent.**
Used to securely install fasteners, sleeves, etc.

## Foreword

This workshop manual has been compiled for use in conjunction with normal workshop practice. Mention of certain accepted practices, therefore, has been purposely omitted in order to avoid repetition.

Reference to renewing joints and cleaning off joint faces, has to a great extent been omitted from the text, it being understood that this will be carried out where applicable.

Similarly, it is understood that in reassembly and inspection, all parts are to be thoroughly cleaned and where present, burrs and scale are to be removed.

It follows that any open ports of high precision components, e.g., fuel injection equipment, exposed by dismantling, will be blanked off until reassembled, to prevent the ingress of foreign matter.

When fitting setscrews into "through" holes into the interior of the engine. a suitable sealant should be used.

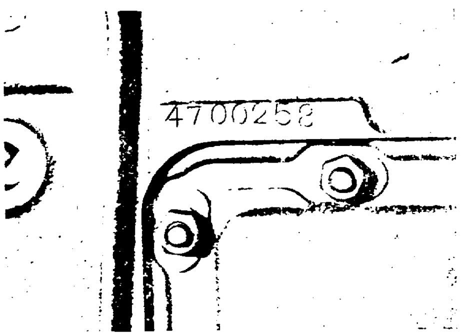
## Engine Number

Three systems of engine numbering have been used.

On very early engines, the serial number consisted of seven digits commencing with the figure 4.

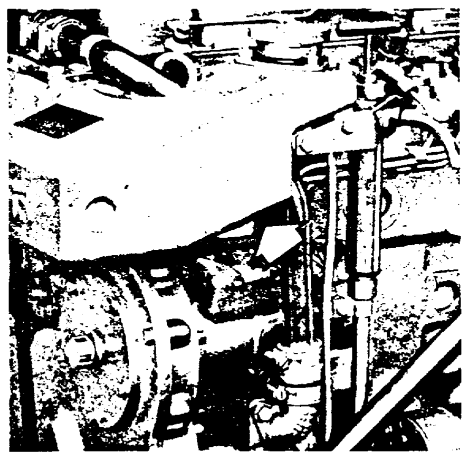
With later engines, the number consisted of figures and letters, e.g., 236:251. The first three figures represent the capacity of the engine in cubic inches. The letter "1 " denotes the online was built in the United Kingdom and the last group of figures comprises the engine serial number.

On current engines, the number can consist or up to fifteen letters and figures a typical number being LD14739U510336D and will be found stamped on the cylinder block just above the fuel pump




Engine Number Location
(Earlier 4.236 engines)


Engine Number Location
(Later 4.236 engines)



Engine Number Location
(Current 4.236 Engines)

**Contents**

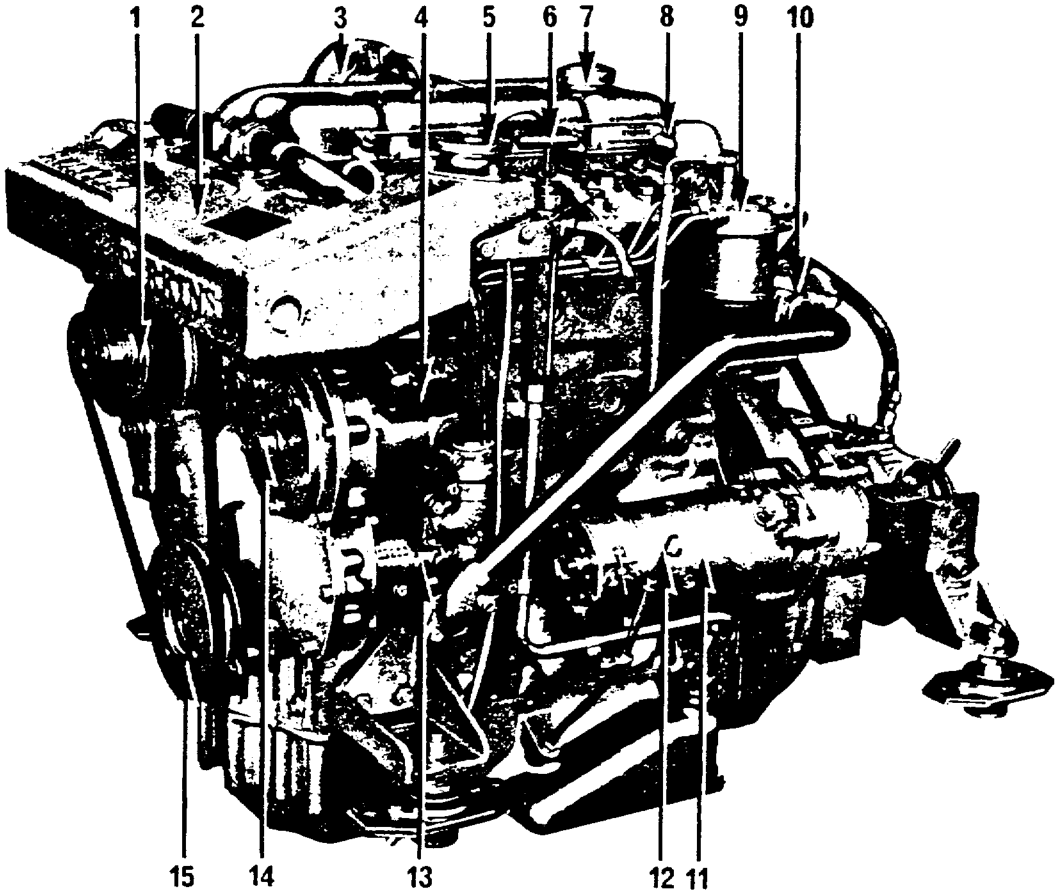
This publication is produced by the Technical Publications Department of Perkins Engines Ltd. and every endeavour is made to ensure that the information contained in this manual is correct at the time of publication. but due to continuous developments. the manufacturers reserve the right to make alterations without notice.

This engine manual is to guide you in dismantling and re-assembly - for information regarding the **application** of the engine, the reader should refer to the Perkins **"MARINE INSTALLATION MANUAL"** Publication No. 801SER 11811157.

## SECTION A
## Engine Views

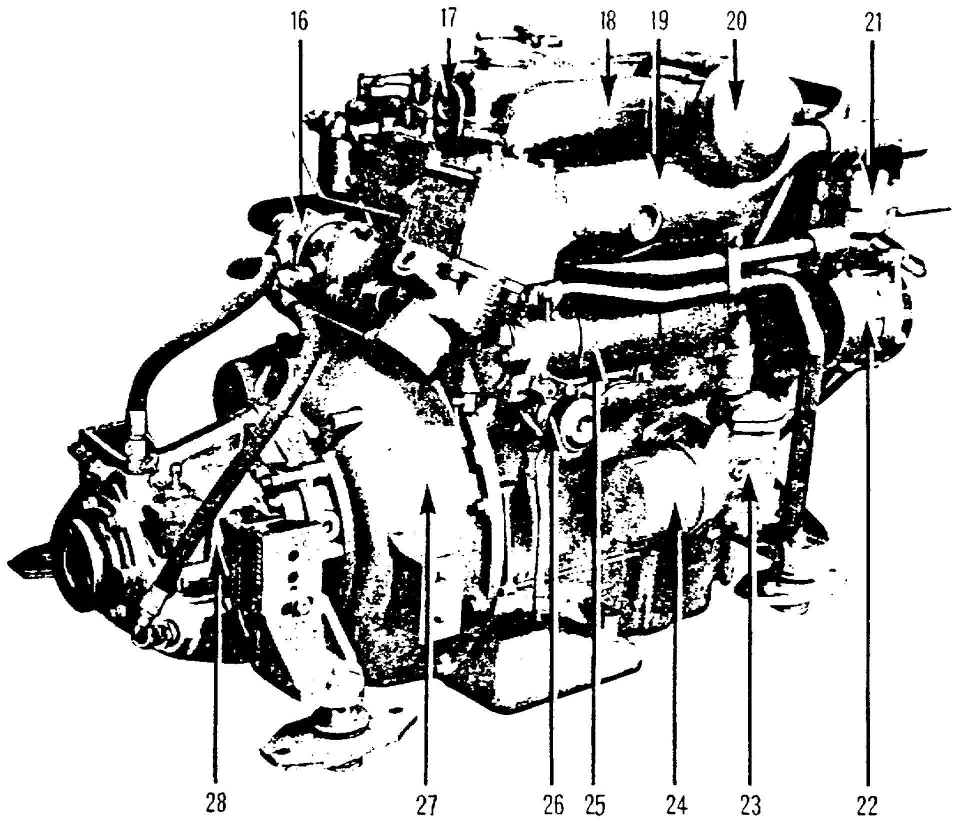
Perkins Engines are built to individual requirements to suit the applications for which they are intended and the following engine views do not necessarily typify any particular specification.

## ENGINE VIEWS-A.2




Lowline 4.236M Engine

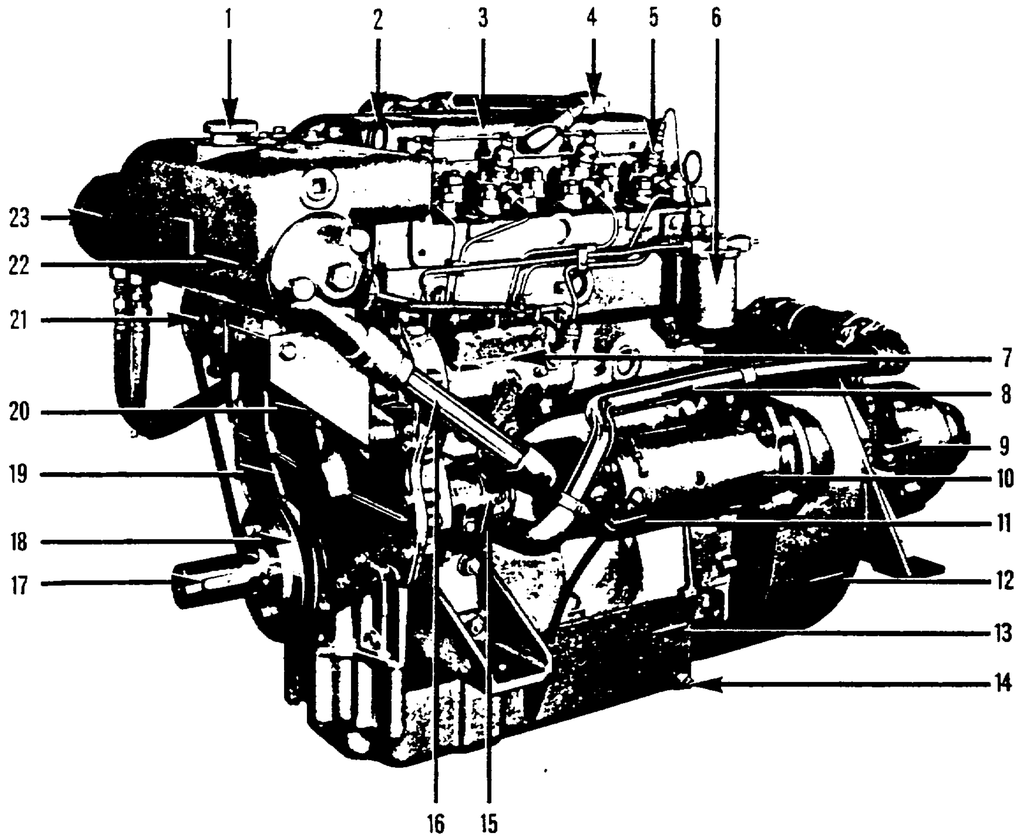
1. Fresh Water Pump Pulley.
2. Fresh Water Header Tank.
3. Air Filter.
4. Fuel Injection Pump.
5. Fresh Water Filler Cap.
6. Lubricating Oil Drain Pump.
7. Lubricating Oil Filler Cap.
8. Atomiser.
9. Fuel Oil Filter.
10. Gearbox Oil Cooler.
11. Starter Motor.
12. Lubricating Oil Dipstick
13. Sea Water Pump.
14. Tachometer Drive Connection.
15. Crankshaft Pulley.




Lowline 4.236M1 Engine

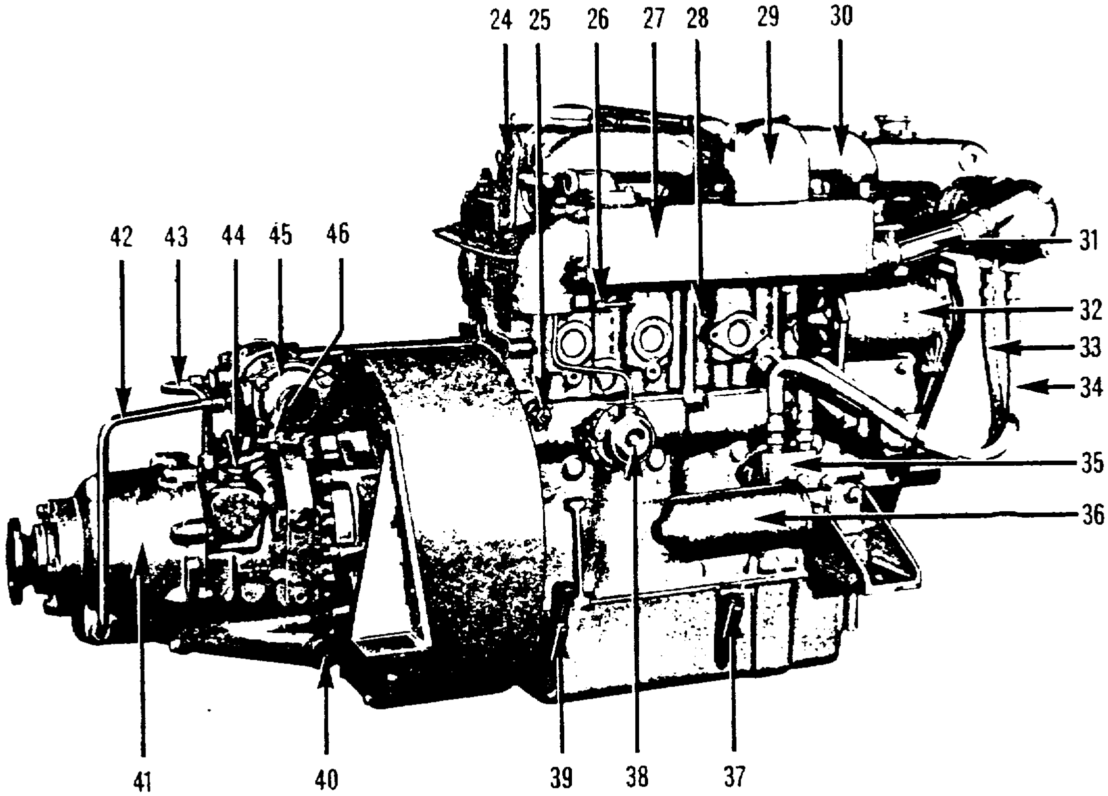
16. Gearbox Oil Cooler.
17. Engine Rear Lifting Eye.
18. Induction Manifold.
19. Water Cooled Exhaust Manifold.
20. Air Filter.
21. Thermostat Housing.
22. Alternator.
23. Engine Oil Cooler.
24. Spin-on Lubricating Oil Filter.
25. Heat Exchanger.
26. Fuel Oil Lift Pump.
27. Flywheel Housing.
28. Borg Warner 71CR Gearbox.

**ENGINE VIEWS-A.4**




4.236M Engine

1. Coolant Filler Cap
2. Front Lifting Eye
3. Rocker Cover
4. Lubricating Oil Filler Cap
5. Atomiser
6. Fuel Oil Filter
7. Fuel Injection Pump
8. Water Pipe from Gearbox Oil Cooler to Sea Water Pump.
9. Gearbox Filler Plug and Dipstick
10. Starter Motor.
11. Engine Oil Dipstick
12. Flywheel Housing
13. Lubricating Oil Sump.
14. Lubricating Oil sump Drain Plug.
15. Sea Water Pump.
16. Water Pipe Sea from Sea Water Pump to Heat Exchanger.
17. Power Take Oil from Front of Crankshaft.
18. Crankshaft Pulley
19. Timing Case Cover
20. Engine Tachometer Drive
21. Dynamo Pulley
22. Heat Exchanger
23 Engine Oil Cooler




4.236M Engine

24. Rear Lifting Eve.
25. Cylinder Block Drain Tap.
26. Exhaust Manifold Drain Tap.
27. Exhaust Manifold.
28. Cylinder Block.
29. Air Filter.
30. Induction Manifold.
31. Water Pipe from Heat Exchanger to Exhaust Manifold.
32. Dynamo.
33. Oil Pipe to Cooler.
34. Oil Pipe from Cooler.
35. Oil Filter Adaptor
36. Lubricating Oil Filter.
37. Alternative Dipstick Position.
38. Fuel Lift Pump.
39. Sump Draining Connection.
40. Gearbox Oil Drain Cap.
41. Reduction Gear Housing.
42. Oil Inlet Pipe from Cooler.
43. Oil Pipe to Cooler.
44. Gearbox Breather.
45. Gearbox Oil Cooler.
46. Gearbox Oil Cooler Water Drain Tap.

**Engine Date**

| | |
|---|---|
| Type ...... ...... ...... ...... ...... | Four Stroke - Direct Injection |
| Nominal Bore (see Page B.2) ...... ...... ...... | 3.875 in (98,43 mm) |
| Stroke ...... ...... ...... ...... ...... | 5 in (127 mm) |
| No. of Cylinders .. ...... ...... ...... ...... | 4 |
| Cubic Capacity .... ...... ...... ...... ...... | 236 in' (3,86 litres) |
| Compression Ratio ...... ...... ...... ...... | 16: 1 |
| Firing Order ...... ...... ...... ...... ...... | 1, 3. 4, 2 |
| Rotation ...... ...... ...... ...... ...... | Left Hand (viewed from rear) |
| Valve Tip Clearance ...... ...... ...... ...... | 0.012 in (0.30 mm) cold |
| Engine Weight ..... ...... ...... ...... ...... | 1100 lb (499 kg) with Borg Warner D.D. |
| ...... ...... ...... ...... ...... | 1145 lb (519 kg) with Borg Warner Reduction |
| ...... ...... ...... ...... ...... | Gear |

**Details of Ratings**

| | |
|---|---|
| Pleasure (High Speed) ...... ...... ...... ...... | 84 bhp (62.6 kW) at 2800 rev/min |
| Pleasure ...... ...... ...... ...... ...... | 76 bhp (56.6 kW) at 2503 rev/min |
| Commercial ...... ...... ...... ...... ...... | 69 bhp (50.7 kW) at 2250 rev/min |
| Commercial (Heavy Duty).... ...... ...... ...... | 54 bhp (40.3 kW) at 1800 rev/min |

**De-Rating for Altitude**

This is not usually necessary for the 4.236 marine engine. A small loss of power will occur when temperature and humidity conditions are particularly adverse and allowance for this should be made when designing the propeller.

When the engine is required to operate on a lake more than 4,000 feet above sea level, contact Technical Services Department, Perkins Engines Ltd., Peterborough or one of those Overseas Companies listed on Page 11.

| Recommended Torque Tensions | lbf ft | kgf m | Nm |
|---|---|---|---|
| Cylinder Head Nuts or Setscrews ... ... | 100 | 13,8 | 136 |
| Connecting Rod Nuts | | | |
| Cadmium Plated (silver finish) ... ... ... | 75 | 10,4 | 102 |
| Phosphated (black finish)... ... ... ... | 95 | 13,1 | 129 |
| Main Bearing Setscrews | | | |
| (prior to Eng. No. 236U82408) ... ... ... | 150 | 20,7 | 203 |
| Main Bearing Setscrews | | | |
| (commencing Eng. No. 236U82408) ... ... | 180 | 2,8 | 244 |
| Idler Gear Hub Setscrews. ... ... ... | 30 | 4,1 | 41 |
| Flywheel Setscrews | 80 | 11 | 108 |
| Camshaft Gear Retaining Setscrew ... ... ... | 50 | 6,9 | 68 |
| Crankshaft Dog Nut or Retaining Screw | 300 | 42 | 406 |
| Lub. Oil Filter Setscrews ... ... ... | 30 | 4,2 | 41 |
| Atomiser Securing Nuts | 12 | 1.7 | 16 |
| Dynamo Pulley Retaining Nut ... ... ... | 20 | 2.8 | 27 |
| Alternator Pulley Retaining Nut (7/16 in) | 30 | 4,1 | 41 |
| Alternator Pulley Retaining Nut (9/16 in) ... ... ... | 30 | 4,1 | 41 |
| Alternator Pulley Retaining Nut (5/8 in) ... ... ... | 42 | 5,8 | 57 |
| Balancer Retaining Setscrews ... ... ... | 36 | 5,0 | 49 |
| High Pressure Fuel Pipe Nuts ... ... ... | 15 | 2,1 | 20 |
| Thermostart... ... ... ... ... | 10 | 1,4 | 14 |
| Thermostart Adaptor ... ... ... ... | 10 | 1,4 | 14 |

## TECHNICAL DATA -B.2

### Manufacturing Data and Dimensions

All threads used, except perhaps on proprietary equipment are Unified Series and America Pipe series. The crankshaft and pulley retaining setscrew are thread 7/8 in U.N.F. of T.P.I.

The following data of clearances and tolerances are given as a guide for personnel engaged upon major overhauls and the figures are those used in the factory for production methods.

The figure quoted in the dimensions column represent the minimum and the maximum sizes to which parts may be accepted when new.

The difference between these maximum and minimum figures is know as the manufacturing tolerance and this is necessary as an aid to manufacturing and its value is an expression of the desired quality of manufacture.

For example, where the outside diameter of a crankshaft main journal is quoted as 2.9985/2.999 in (76,16/76,18 mm) then the manufacturing tolerance is 0.0005 in (0.0127 mm).

During the overhaul of an engine it is reasonable to expect the use of personal initiave. It is obviously uneconomical to return worn component parts into service to involve labour cost again at an early date.

**Cylinder Block**

| | |
|---|---|
| Total Height of Cylinder Block between Top and Bottom Faces | 17.367/17.375 in (441,12/441,33 mm) |
| Parent Bore Dia. for Cylinder Liner (Cast Iron) | 4.0615/4.0625 in (103,16/103,19 mm) |
| Main Bearing Parent Bore Dia. | 3.166/3.167 in (80,42/80,44 mm) |
| Camshaft Bore Dia. No. 1 for Bush (where fitted) | 2.1875/2.1887 in (55,56/55.59 mm) |
| Camshaft Bearing Bush Internal Dia. fitted | 2.0000/2.0017 in (50.8/50.84 mm) |
| Camshaft Bore Dia. No. 1 | 2.00/2.001 in (50,80/50,83 mm) |
| Camshaft Bore Dia. No. 2 | 1.990/1.9918 in (50,55/50,59 mm) |
| Camshaft Bore Dia. No. 3 | 1.970/1.9718 in (50,04/50,08 mm) |

**Cylinder Liners (Cast Iron)**

| | |
|---|---|
| Type | Dry-Interference Fit |
| Interference Fit of Liner | 0.003/0.005 in (0,08/0,13 mm) |
| Inside Dia. of Liner after finish boring | 3.877/3.878 in (98,48/98.50 mm) |
| Height of Liner above Cylinder Block Face | 0.028/0.035 in (0.71/0.89 mm) |
| Maximum Oversize (Rebore) | +0.030 in (0,76 mm) |
| Overall Leneth of Liner | 9.005/9.015 in (228.7/229,0 mm) |

**Pistons**

| | |
|---|---|
| Type | Cavity in Crown |
| Overall Height (Skirt to Crown) | 4.767 in (121.08 mm) |
| Piston Skirt Dia. (Across Thrust) | 3.8699/3.8707 in (98,29/98,32 mm) |
| Piston Crown Dia. (Across Thrust) | 3.8508/3.8528 in (97.80/97.85 mm) |
| Piston Height in Relation to Cylinder Block Top Face (prior to Engine Nos. 236U135765 or 236U147150L) | 0.003/0.010 in (0,08/0,25 mm) ABOVE |
| Piston Height in Relation to Cylinder Block Top Face (commencing Engine Nos. 2361'135765 or 236U1147150L | 0.016/0.024 in (0.41/0.61 mm) ABOVE |
| Bore Dia. for Gudgeon Pin | 1.37485/1.37505 in (34.92/34.93 mm) |
| Compression Ring Groove Width-Numbers 1, 2,. 3 | 0.0057 0.0967 in (2.43/2.46 mm) |
| Scraper Ring Groove Width-Numbers 4 and 5 | 0.2525 0.2535 in (6.41/6.44 mm) |
| Weight of Piston | 2 lb 9 1/8, oz. - 1/4 oz (1.165 kg - 7 g) |

**Piston Rings**

| | |
|---|---|
| Top-Compression ...... ...... ...... ...... | Chromium Plated-Parallel Face |
| Second and Third-Compression ...... ...... ...... | Internally Stepped |
| Fourth-Scraper .... ...... ...... ...... ...... | Conformable Scraper |
| Fifth-Scraper ...... ...... ...... ...... ...... | Maxigroove |
| Compression Ring Width..... ...... ...... ...... | 0.0928/0.0938 in (2,36/2,.38 mm) |
| Groove Width ...... ...... ...... ...... ...... | 0.0957/0.0967 in (2,43/2,46 mm) |
| Ring Clearance in Groove.... ...... ...... ...... | 0.0019/0.0039 in (0,05/0,10 mm) |
| Scraper Ring Width ...... ...... ...... ...... | 0.249/0.250 in (6,33/6,35 mm) |
| Ring Clearance in Groove.... ...... ...... ...... | 0.0025/0.0045 in (0,06/0,11 mm) |
| Ring Gap-Chrome Compression...... ...... ...... | 0.016/1.024 in (0,41/0,61 mm) |
| Ring Gap-Internally Stepped Compression... ...... | 0.012/0.020 in (0,30/0,51 mm) |
| Ring Gap-Maxigroove Scraper ...... ...... ...... | 0 012/0.020 in (0,30/0,51 mm) |

**Gudgeon Pin**

| | |
|---|---|
| Type ...... ...... ...... ...... ...... | Fully Floating |
| Outside Dia. of Gudgeon Pin ...... ...... ...... | 1.3748/1.3750 in (34,92/34,93 mm) |
| Length of Gudgeon Pin ...... ...... ...... ...... | 3.297/3.312 in (83,74/84,12 mm) |
| Fit in Piston Boss. ...... ...... ...... ...... | Transition |

**Small End Bush**

| | |
|---|---|
| Type ...... ...... ...... ...... ...... | Steel backed, Lead Bronze Lined |
| Length of Small End Bush ... ...... ...... ...... | 1.316/1.336 in (33,43/33,93 mm) |
| Outside Dia. of Small End Bush...... ...... ...... | 1.535/1.5365 in (38,99/39,02 mm) |
| Inside Dia. before Reaming. ...... ...... ...... | 1.359/1.363 in (34,52/34,62 mm) |
| Inside Dia. after Reaming ...... ...... ...... | 1.37575i1.3765 in (34,94/34,96 mm) |
| Clearance between Small End Bush and Gudgeon Pin | 0.00075:0.0017 in (0,02/0,04 mm) |

Connecting Rod

| | |
|---|---|
| Type ...... ...... ...... ...... ...... | "H" Section |
| Cap Location to Connecting Rod...... ...... ...... | Serrations |
| Big End Parent Bore Dia. ...... ...... ...... | 2.6460/2.6465 in (67,21/67,22 mm) |
| Small End Parent Bore Dia. ...... ...... ...... | 1.53125/1.53225 in (38,90/38,92 mm) |
| Length from Centre Line of Big End to Centre Line of Small End.. ...... ...... ...... ...... | 8.624/8.626 in (219,05/219,10 mm' |
| Big End Bolt Dia... ...... ...... ...... ...... | 0.500 in (12,7 mm) |
| Thread of Bolt ...... ...... ...... ...... | U.N.F. |

**TECHNICAL DATA-B.4**

**Connecting Rod Alignment**

Large and small end bores must be square and parallel with each other within the limits of ±0.010 it (0,254 mm) measured 5 in (127 mm) each side of the axis of the rod on test mandrel as shown in Fig. B.1 With the small end bush fitted, the limit of ±0.010 in (0.254 mm) is reduced to ±0.0025 in (0,06 mm).

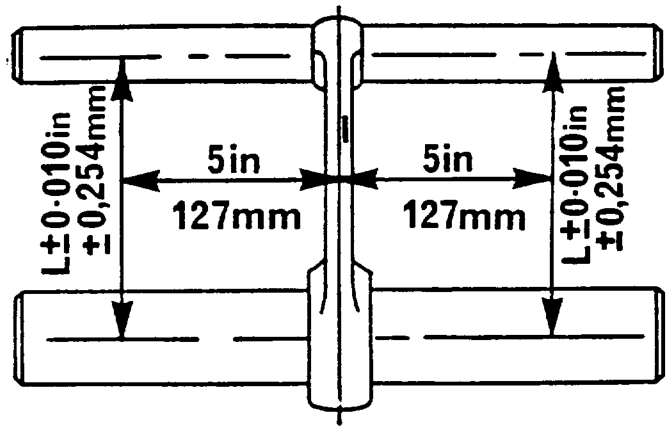



*Fig. B.1.*

**Crankshaft**

| | |
|---|---|
| Overall Length ...... ...... ...... ...... | 24.01/24.04 in (609,85/610,62 mm) |
| Main Journal Dia.. ...... ...... ...... ...... | 2.9984/2.9992 in (76,16/76,18 mm) |
| Main Journal Length-Nos. 1 ...... ...... ...... | 1.453/1.473 in (36,91/37,41 mm) |
| Main Journal Length Nos. 2, 4 and 5 ...... ...... | 1.545/1.549 in (39,24/39.34 mm) |
| *Main Journal Length-Nos. 3 ...... ...... ...... | 1.738/1.741 in (44.15/44.22 mm) |
| *Main Journal Fillet Radii ...... ...... ...... | 0.145/0.156 in (3,68/3,96 mm) |
| Crankpin Dia ...... ...... ...... ...... | 2.4988/2.4996 in (63,47/63,49 mm) |
| Crankpin Length.. ...... ...... ...... ...... | 1.5885/1.5915 in (40,35/40,42 mm) |
| *Crankpin Fillet Radii ...... ...... ...... | 0.145/0.156 in (3,68/3,96 mm) |
| *Surface Finish-All Journals ...... ...... ...... | 16 micro inches (0,4 microns)- maximum |
| Main Journal and Crankpin Regrind Undersizes ...... | 0.010, 0.020 and 0.030 in (0,25, 0,51 and 0,76 mm) |
| Oil Seal Helix Dia. (rope seal only) ...... ...... | 3.124/3.125 in (79,35/79,38 mm) |
| Oil Seal Helix Width (rope seal only) ...... ...... | 0.050/0.080 in (1,27/2,03 mm) |
| Oil Seal Helix Depth (rope seal only) ...... ...... | 0.004/0.008 in (0,10/0.20 mm) |
| Flange Dia. ...... ...... ...... ...... | 5.247/5.249 in (133.27/133.32 mm) |
| Flange Width ...... ...... ...... ...... | 0.500 in (12,70 mm) |

**Crankshaft (Contd.)**

| | |
|---|---|
| Spigot Bearing Recess Depth ...... ...... ...... | 0.781 in (19,84 mm) |
| Spigot Bearing Recess Bore ...... ...... ...... | 1.849/1.850 in (46,98/47,00 mm) |
| Crankshaft End Float ...... ...... ...... ...... | 0.004/0.015 in (0,102/0,38 mm) |

*Fillet radii and surface finish must be maintained during crankshaft regrinding. Length of No. 3 main journal not to exceed 1.759 in (44,68 mm) after regrinding. Width of crankpins must not exceed 1.5965 in (40,55 mm) after regrinding. Where necessary use oversize thrust washers to bring crankshaft end float within the correct limits.

**Crankshaft Thrust Washers**

| | |
|---|---|
| Type ...... ...... ...... ...... ...... | Steel Backed, Lead Bronze Faced |
| Position in Engine ...... ...... ...... ...... | Centre Main Bearing |
| Thrust Washer Thickness (STD) ...... ...... | 0.089/0.091 in (2,26/2,31 mm) |
| Thrust Washer Thickness (O/S) ...... ...... ...... | 0.0965/0.1005 in (2,45/2,55 mm) |
| Thrust Washer Outside Dia. ...... ...... ...... | 4.088/4.098 in (103,84/104,90 mm) |
| Thrust Washer Inside Dia. ...... ...... ...... | 3.420/3.430 in (86,87/87.12 mm) |

**Main Bearings**

| | |
|---|---|
| Type ...... ...... ...... ...... ...... | Pre-Finished, Steel Backed,<br>Aluminum Tin Faced |
| Shell Width-Nos 1, 2, 4 and 5 ...... ...... | 1.245/1.255 in (31,62/31,88 mm) |
| Shell Width-Nos. 3 ...... ...... ...... ...... | 1.435/1.445 in (36,45/36,70 mm) |
| Outside Dia. of Main Bearing ...... ...... ...... | 3.167 in (80.41 mm) |
| Inside Dia. of Main Bearing. ...... ...... ...... | 3.0010/3.0026 in (76,23/76,27 mm) |
| Main Bearing Running Clearance ...... ...... | 0.0018/0.0042 in (0,05/0,11 mm) |
| ! Shell Thickness.. ...... ...... ...... ...... | 0.0822/0.0825 in (2,088/2,096 mm) |

**Connecting Rod Bearings**

| | |
|---|---|
| Type ...... ...... ...... ...... ...... | Pre-Finished, Steel Backed,<br>Aluminum Tin Faced |
| Shell Width ...... ...... ...... ...... ...... | 1.245/1.255 in (31,62/31,88 mm) |
| Outside Dia. of Con. Rod Bearing ...... ...... | 2.6465 in (67,22 mm) |
| Inside Dia. of Con. Rod Bearing ...... ...... | 2.5008/2.5019 in (63,52/63,55 mm) |
| Con. Rod Bearing Running Clearance ...... ...... | 0.0012/0.0031 in (0,03/0,08 mm) |
| Shell Thickness ...... ...... ...... ...... | 0.0723/0.0726 in (1,836/1,844 mm) |

**Camshaft**

No. 1 Journal Length ...... ...... ...... ...... 1.2055/1.2155 in (30,62/30,87 mm)
No. 1 Journal Dia. ...... ...... ...... ...... 1.9965/1.9975 in (50,71/50,74 mm)
No. 1 Cylinder Block Camshaft Bore Dia...... ...... 2.000/2.001 in (50,8/50,83 mm)
No. 1 Journal Running Clearance.... ...... ...... 0.0025/0.0045 in (0,06/0,11 mm)
No. 2 Journal Length ...... ...... ...... ...... 1.625 in (41,27 mm)
No. 2 Journal Dia. ...... ...... ...... ...... 1.9865/1.9875 in (50,46/50,48 mm)
No. 2 Cylinder Block Camshaft Bore Dia. ... ...... 1.990/1.992 in (50,55/50.60 mm)
No. 2 Journal Running Clearance.... ...... ...... 0.0025/0.0053 in (0,06/0,14 mm)
No. 3 Journal Length ...... ...... ...... ...... 1.15625 in (29,37 mm)
No. 3 Journal Dia. ...... ...... ...... ...... 1.9665/1.9675 in (49,95/49,98 mm)
No. 3 Cylinder Block Camshaft Bore Dia...... ...... 1.970/1.972 in (50,04/50,09 mm)
No. 3 Journal Running Clearance.... ...... ...... 0.0025/0.0053 in (0,06/0,14 mm)
Cam Lift ...... ...... ...... ...... ...... 0.3045 in (7,73 mm)
Oilways for Rocker Shaft Lubrication ...... ...... No. 2 Journal

**Camshaft Thrust Washer**

Type ...... ...... ...... ...... ...... 360º
Thrust Washer Outside Dia.. ...... ...... ...... 2.872/2.874 in (72,95/73,00 mm)
Cylinder Block Recess Dia. for Thrust Washer ...... 2.875/2.885 in (73,03/73,28 mm)
Clearance Fit of Washer in Recess .. ...... ...... 0.001/0.013 in (0,03/0,33 mm)
Thrust Washer Inside Dia. ...... ...... ...... 1.750 in (44,45 mm)
Thrust Washer Thickness ...... ...... ...... 0.216/0.218 in (5,47/5,54 mm)
Cylinder Block Recess Depth for Thrust Washer
(Earlier Type). ...... ...... ...... ...... 0.152/0.154 in (3,86/3,91 mm)
Thrust Washer Protrusion beyond Cylinder Block
Face (Earlier Type) . ..... ...... ...... ...... 0.062/0.066 in (1,53/1,68 mm)
Cylinder Block Recess Depth for Thrust Washer
(Later Type) ...... ...... ...... ...... 0.187/0.190 in (4,75/4,83 mm)
Thrust Washer Protrusion beyond Cylinder Block
Face (Later Type) ...... ...... ...... ...... 0.026/0.031 in (0.66/0,79 mm)
Camshaft End Float ...... ...... ...... ...... 0.004/0.016 in (0,10/0.41 mm)

**Valve Timing**

Refer to Page K.7.

**Cylinder Head**

Cylinder Head Length ...... ...... ...... ...... 19.875 in (454,02 mm)
Cylinder Head Depth ...... ...... ...... ...... 4.0625 in ± 0.015 in (103,20 mm ± 0,38 mm)
Skimming allowance on Cylinder Head Face ...... 0.012 in (0,31 mm)
Min. Cylinder Head Depth after Skimming.... ...... 4.0355 in (102,51 mm)*
Max. Nozzle Protrusion after Skimming ...... ...... 0.175 in (4,44 mm)
Leak Test Pressure ...... ...... ...... ...... 30 lb/in$^2$ (2,11 kgf/cm$^2$) - 207 kN/m$^2$
Valve Seat Angle . ...... 45°
Valve Bore in Cylinder Head ...... ...... ...... 0.37425/0.37525 in (9,51/9,53 mm)

*Minimum Cylinder Head Depth quoted is nominal and Skimming Allowance must be governed by the Maximum Nozzle Protrusion Permissible.

**Exhaust Valves**

| | |
|---|---|
| Valve Stem Dia. . ...... ...... ...... ...... | 0.372/0.373 in (9,45/9,47 mm) |
| Clearance Fit of Valve in Head ...... ...... ...... | 0.00125/0.00325 in (0,03/0,08 mm) |
| Valve Head Dia. ...... ...... ...... ...... | 1.438/1.442 in (36,54/36,64 mm) |
| Valve Face Angle. ...... ...... ...... ...... | 45° |
| Valve Head Depth below Cylinder Heal Face (prior to Eng. Nos. 236U135765 or 236U147150L) | 0.029/0.039 in (0,74/0,99 mm) |
| Valve Head Depth below Cylinder Head Face (commencing.Engine Nos. 236U135765 or 236U147150L) ...... ...... ...... ...... | 0.042/0.052 in (1,07/1,32 mm) |
| Valve Head Depth below Cylinder Head Face (all types) Service* ...... ...... ...... ...... | 0.055 in (1,40 mm) maximum |
| Overall Length of Valve ...... ...... ...... | 4.847/4.862 in (123,11/123,49 mm) |
| Service Valve Stem Oversizes ...... ...... ...... | 0.003, 0.015 and 0.030 in (0,08, 0,38 and 0,76 mm) |
| Sealing Arrangement ...... ...... ...... | Rubber Deflectors |

*Where engines conform to the BSAU141a 1971 regulations, then the valve depth production limits should not be exceeded.

**Inlet Valves**

| | |
|---|---|
| Valve Stem Dia. ...... ...... ...... ...... | 0.3725/0.3735 in (9,46/9,48 mm) |
| Clearance Fit of Valve in Head ...... ...... ...... | 0.00075/0.00275 in (0,02/0,07 mm) |
| Valve Head Dia. ...... ...... ...... ...... | 1.742/1.746 in (44,25/44,36 mm) |
| Valve Face Angle. ...... ...... ...... ...... | 45° |
| Valve Head Depth below Cylinder Head Face ...... | 0.035/0.045 in (0.89'1,14 mm) |
| Valve Head Depth below Cylinder Head Face - Service* ...... ...... ...... ...... ...... | 0.061 in (1,55 mm) |
| Overall Length of Valve , ...... ...... ...... | 4.831/4.846 in (122,71/123,09 mm) |
| Service Valve Stem Oversizes ...... ...... ...... | 0.003, 0.015 and 0.030 in (0.08. 0.38 and 0.76 mm) |

'Where engines conform to the BSAU141a 1971 regulations, then the valve depth production limits should not be exceeded.

**Inner Valve Springs**

| | |
|---|---|
| Fitted Length ...... ...... ...... ...... | 1.5625 in (39,7 mm) |
| Load at Fitted Length ...... ...... ...... ...... | 15.4 lbf ± 2 lbf (7 kgf ± 0,91 kgf) |
| Fitted Position ...... ...... ...... ...... | Damper Coils to Cylinder Head |

**Outer Valve Springs**

| | |
|---|---|
| Fitted Length ...... ...... ...... ...... | 1.780 in (45,22 mm) |
| Load at Fitted length ...... ...... ...... ...... | 40 lbf ± 2 Ibf (18,1 kgf ± 0,91 kgf) |
| Fitted Position ...... ...... ...... ...... | Damper Coils to Cylinder Head |

**Tappets**

| | |
|---|---|
| Overall Length ...... ...... ...... ...... | 2.96875 in (75,41 mm) |
| Outside Dia. Tappet Shank . ...... ...... ...... | 0.7475/0.7485 in (18,99/19,01 mm) |
| Cylinder Block Tappet Bore Dia. ...... ...... | 0.750/0.7512 in (19,05/19,08 mm) |
| Tappet Running Clearance in Bore ...... ...... | 0.0015/0.0037 in (0,04/0,09 mm) |
| Outside Dia. of Tappet Foot ...... ...... ...... | 1.1875 in (30,16 mm) |

**Rocker Shaft**

| | |
|---|---|
| Overall Length of Shaft ...... ...... ...... | 16.78125 in (426,24 mm) |
| Outside Dia. of Shaft ...... ...... ...... ...... | 0.7485/0.7495 in (19,01/19,04 mm) |

**Rocker Levers**

| | |
|---|---|
| Inside Dia. of Lever Bore ...... ...... ...... | 0.7505/0.7520 in (19,06/19.10 mm) |
| Lever Clearance on Rocker Shaft .... ...... ...... | 0.001/0.0035 in (0,03 /0,09 mm) |

## TECHNICAL DATA-B.8

### Valve Clearances

Clearances between Valve Stem and Rocker Lever.. 0.012 in (0,300 mm) Cold

## TIMING GEARS

### Camshaft Gear

| | |
|---|---|
| Number of Teeth.. ...... ...... ...... | 56 |
| Inside Dia. of Gear Boss ...... ...... ...... | 1.375/1.376 in (34,93/34,96 mm) |
| Outside Dia. of Camshaft Hub ...... ...... ...... | 1.3751/1.3757 in (34,93/34,95 mm) |
| Transition Fit of Gear on Camshaft Hub ...... ...... | 0.0007/0.0009 in (0,017/0,022 mm) |

### Fuel Pump Gear

| | |
|---|---|
| Number of Teeth.. ...... ...... ...... | 56 |
| Inside Dia. of Gear Bore ...... ...... ...... | 1.750/1.751 in (44,45/44,47 mm) |
| Fuel Pump Hub Dia ...... ...... ...... | 1.748/1.7488 in (44,40/44,42 mm) |

### Idler Gear and Hub

| | |
|---|---|
| Number of Teeth.. ...... ...... ...... | 63 |
| Inside Dia. of Gear (bushes fitted) ... ...... ...... | 1.9998/2.0007 in (50,79/50,82 mm) |
| Outside Dia. of Gear Hub ...... ...... ...... | 1.996/1.9975 in (50,70/50.72 mm) |
| Running Clearance of Gear on Hub.. ...... ...... | 0.0023/0.0047 in (0,06/0,12 mm) |
| Idler Gear Width Including Bushes ... ...... ...... | 1.1865/1.1875 in (30,14/30,16 mm) |
| Hub Width ...... ...... ...... ...... | 1.1915/1.1945 in (30,26/30,33 mm) |
| Idler Gear End Float ...... ...... ...... | 0.004/0.008 in (0,10/0,20 mm) |

### Crankshaft Gear

| | |
|---|---|
| Number of Teeth.. ...... ...... ...... | 28 |
| Gear Bore ...... ...... ...... ...... | 1.875/1.876 in (47,63/47,65 mm) |
| Crankshaft Dia. for Gear ...... ...... ...... | 1.875/1.8755 in (47,63/47,64 mm) |

### Timing Gear Backlash

All gears ...... ...... ...... ...... 0.003 in (0.08 mm) minimum

## LUBRICATION SYSTEM

Lubricating Oil Pressure Normal oil pressure at max. engine speed and normal operating temperature 30/60 lbf/in- (2,1/4.2 kgf/cm:) - 207/414 kN/$m^2$

Lubricating Oil Capacities

| | |
|---|---|
| Sump ...... ...... ...... ...... | 14.5 IMP pints - 8.2 litres - 8.7 US quarts |
| Total ...... ...... ...... ...... | 16.5 IMP pints -9.4 litres -9.9 US quarts |

Sump

| | |
|---|---|
| Dipstick Position .. ...... ...... ...... | Direct into sump, port side below fuel injection pump. |
| Strainer Location.. ...... ...... ...... | On Suction Pipe of Lubricating Oil Pump. |

### Lubricating Oil Pump Clearances

**Pump Part No. 41314054 (Concentric)**

| | |
|---|---|
| No. of Lobes on Inner Rotor ...... ...... ...... | Three |
| No. of Lobes on Outer Rotor ...... ...... ...... | Four |
| Inner Rotor to Outer Rotor ...... ...... ...... | 0.001/0.003 in (0,03/0,08 mm) |
| Inner Rotor End Clearance ...... ...... ...... | 0.0015/0.003 in (0,04/0,08 mm) |
| Outer Rotor End Clearance ...... ...... ...... | 0.0005/0.0025 in (0,01/0,06 mm) |
| Outer Rotor to Pump Body ...... ...... ...... | 0.011/0.013 in (0,28/0,33 mm) |

**Pump Part No. 41314061 (Hobourn Eaton)**

| | |
|---|---|
| No. of Lobes on Inner Rotor ...... ...... ...... | Four |
| No. of Lobes on Outer Rotor ...... ...... ...... | Five |
| Inner Rotor to Outer Rotor ...... ...... ...... | 0.001/0.006 in (0,03/0,15 mm) |
| Inner Rotor and Outer Rotor End Clearance . ...... | 0.001/0.005 in (0,03/0,13 mm) |
| Outer Rotor to Pump Body ...... ...... ...... | 0.0055i0.010 in (0,14/0,25 mm) |

**Oil Pump Drive Gear**

| | |
|---|---|
| Number of Teeth.. ...... ...... ...... ...... | 19 |
| Inside Dia. of Gear Bore ...... ...... ...... | 0.497/0.4978 in (12,62/12,64 mm) |
| Outside Dia. of Oil Pump Shaft ...... ...... ...... | 0.4990/0.4995 in (12,67/12,69 mm) |
| Interference Fit of Gear on Shaft ...... ...... | 0.0012/0.0025 in (0,03/0,06 mm) |
| Clearance between Drive Gear and Pump Body ...... | 0.003/0.007 in (0,08/0,18 mm) |

**Oil Pump Idler Gear**

| | |
|---|---|
| Number of Teeth.. ...... ...... ...... ...... | 20 |
| Inside Dia. of Gear Bore ...... ...... ...... | 1.000/1.0012 in (25,40/25,43 mm) |
| Outside Dia. of Gear Bush ...... ...... ...... | 1.000/1.0008 in (25,40/25,42 mm) |
| Inside Dia. of Gear Bush ...... ...... ...... | 0.8750/0.8763 in (22,23/22,26 mm) |
| Outside Dia. of Idler Gear Shaft ...... ...... | 0.8737/00.8742 in (22,19/22,20 mm) |
| Running Clearance of Gear on Shaft ...... ...... | 0.0008/0.0026 in (0,02/0,07 mm) |
| Idler Gear End Float ...... ...... ...... ...... | 0.002/0.016 in (0,05,/0,41 mm) |

**Relief Valve**

| | |
|---|---|
| Type ...... ...... ...... ...... | Spring Loaded Plunger |
| Pressure Setting.. ...... ...... ...... ...... | 50/60 Ib/in- (3,5/4.2 kgf, cm$^2$:) - 345/414 kN/m$^2$ |
| Length of Plunger. ...... ...... ...... ...... | 0.9375 in (23.81 mm) |
| Outside Dia. of Plunger ...... ...... ...... | 0.5585/0.5595 in (14,19/14,21 mm |
| lnside Dia. of Valve Housing Bore ... ...... ...... | 0.5605/0.5625 in (14,23/14.30 mm) |
| Clearance of Plunger in Bore ...... ...... ...... | 0.001 /0.004 in (0,03.0,10 mm) |
| Outside Dia. of Spring ...... ...... ...... ...... | 0.368./0.377 in (9,35/9,58 mm) |
| Spring-Free Length ...... ...... ...... ...... | 1.5 in (38,10 mm) |
| Spring-Solid Length ...... ...... ...... ...... | 0.745 in (18,92 mm) Maximum |

**Lubricating Oil Filter**

| | |
|---|---|
| Type of Filter ...... ...... ...... ...... ...... | Full Flow |
| Element Type ...... ...... ...... ...... | Paper or Spin-on Canister |
| By-Pass Valve Setting ...... ...... ...... ...... | Opens between 8/17 lbf/in$^2$ (0.5/1.2 kgf. cm 55,117 kN :m pressure differential |

**COOLING SYSTEM**

| | |
|---|---|
| Type ...... ...... ...... ...... | Indirect Fresh/Sea Water Cooling utilizing Heat Exchanger |
| Engine Fresh Water (Closed Circuit Capacity) ...... | 26 pt (14,8 litre) Including Heat Exchanger |

**Thermostat**

| | |
|---|---|
| Type ...... ...... ...... ...... | Wax Capsule |
| Opening Temperature ...... ...... ...... ...... | 177º-183°F (80°-84°C) |
| Fully Open at ...... ...... ...... ...... | 208°F (980C) |
| Valve Lift ...... ...... ...... ...... | 0.312/ 0.469 in (7,94/11,91 mm) |

## TECHNICAL DATA-B.10

### Water Pump (Fresh Water)

| | |
|---|---|
| Type ...... ...... ...... ...... ...... | Centrifugal |
| Outside Dia. of Shaft for Pulley ...... ...... ...... | 0.7492/0.7497 in (13,03/13,04 mm) |
| Inside Dia. of Pulley Bore ...... ...... ...... | 0.7508/0.7516 in (19,07/19,09 mm) |
| Transition Fit of Pulley on Shaft ...... ...... ...... | 0.0011/0.0024 in (0,03/0,06 mm) |
| Outside Dia. of Shaft for Impeller..... ...... ...... | 0.6262/0.6267 in (15,90/15,92 mm) |
| Inside Dia. of Impeller Bore ...... ...... ...... | 0.6249/0.6257 in (15,87/15,89 mm) |
| Interference Fit of Impeller on Shaft ...... ...... | 0.0005/0.0018 in (0,01/0,05 mm) |
| Outside Dia. of Impeller ...... ...... ...... | 3.094/3.096 in (78,58/78,63 mm) |
| Impeller Blade to Body Clearance ...... ...... | 0.027/0.035 in (0,68/0,89 mm) |
| Water Pump Seal Type ...... ...... ...... | Synthetic Rubber, Carbon Faced |
| Outside Dia. of Water Pump Seal for Pump Bore .... | 1.435/1.436 in (36,45/36,47 mm) |
| Inside Dia. of Seal for Impeller Shaft ...... ...... | To suit 0.625 in (15,875 mm) Dia. shaft |
| Bearing Seal Type ...... ...... ...... ...... | Felt, impregnated with Water Repellent Oil |
| Bearing Seal Thickness ...... ...... ...... ...... | 0.219 in (5,56 mm) |
| Outside Dia. of Seal ...... ...... ...... ...... | 1.375 in (34,93 mm) |
| Inside Dia. of Seal ...... ...... ...... ...... | 0.922 in (23,41 mm) |

### Water Pump (Sea Water)

| | |
|---|---|
| Type ...... ...... ...... ...... ...... | Centrifugal |

## FUEL SYSTEM

### Fuel Oil Specifications

| | | |
|---|---|---|
| United Kingdom | BS.2869:1967 | Class A. or A.2 |
| United States | V-F-800a | Grades DF-A, DF-1 or DF-2. |
| | A.S.T.M./D975-66T | Nos. 1-D or 2-D |
| France J.O. 14/9/57 | | Gas Oil or Fuel Domestique |
| India IS: 1460/1968 | | Grade Special or Grade A |
| Germany | DIN-51601 (1967) | - |
| Italy | CUNA-Gas Oil NC 630-01 (1957) | - |
| Sweden | SIS. 15 54 32 (1969) | - |
| Switzerland | Federal Military Spec. 9140-335-1404 (1965) | - |

Fuel oils available in territories other than those listed above which are to an equivalent specification may be used.

### Fuel Lift Pump

| | |
|---|---|
| Type of Pump ...... ...... ...... ...... | A.C. Delco V.P. Series |
| Method of Drive ...... ...... ...... ...... | Eccentric on Camshaft |
| Delivery Pressure ..... ...... ...... ...... ...... ...... ...... ...... | 2 3/4 to 4 1/4 lbf/in$^2$ (0.19/0,30 kgf/cm$^2$) - 19/29 kN/m$^2$: |
| Pump to Cylinder Block Gasket Thickness ...... | 0.025 in (0,64 mm) |
| Spring Colour Code ...... ...... ...... ...... | Green |

### Fuel Filter (Final)

| | |
|---|---|
| Element Type ...... ...... ...... ...... | Paper |
| Valve Type ...... ...... ...... ...... ...... | Gravity Vent Valve |

**Fuel Injection Pump**

| | |
|---|---|
| Make ...... ...... ...... ...... ...... | C.A.V. |
| Type ...... ...... ...... ...... ...... | D.P.A. (Mechanically Governed) |
| Pump Rotation ...... ...... ...... ...... | Clockwise |
| Plunger Dia. ...... ...... ...... ...... ...... | 8,5 mm |
| Timing Letter (Mechanical) ...... ...... ...... | "C" |
| No. 1 Cylinder Outlet ...... ...... ...... ...... | "W" |

**Engine Checking and Fuel Pump Marking Angles, Static Timing**

The correct marking angles and static timing can be found by reference to the prefix letters and figures of the setting code adjacent to the word "set" on the fuel pump identification plate. Engine checking and fuel pump marking angles are for use with timing tool MS67B and adaptor PD67B—1.

| **Prefix Letters** | **Engine Checking Angle (Degrees)** (with engine at TDC compression) | **Fuel Pump Marking Angle (Degrees)** | **Static Timing** (BTDC-Degrees) | **Piston Displacement** |
|---|---|---|---|---|
| AS62 | 279 | 292 | 26 | 0.322 in (8,18 mm) |
| BS44 | 281 | 296 | 30 | 0.425 in (10,79 mm) |
| BS49 | 281 | 292 | 22 | 0.230 in (5,84 mm) |
| BS34 | 281 | 292 | 22 | 0.230 in (5,84 mm) |
| BS62 | 281 | 292 | 22 | 0.230 in (5,84 mm) |
| BS64 | 281 | 292 | 22 | 0.230 in (5,84 mm) |
| LS43 | 284 1/2 | 296 | 30 | 0.230 in (6.35 mm) |
| LS44 | 281 | 296 | 23 | 0.425 in (10,79 mm) |
| LS45 | 284 1/2 | 296 | 23 | 0.250 in (6.35 mm) |
| LS49 | 284 1/2 | 296 | 23 | 0.250 in (6.35 mm) |
| LS50 | 284 1/2 | 296 | 23 | 0.250 in (6.35 mm) |
| LS52 | 284 1/2 | 296 | 23 | 0.250 in (6.35 mm) |
| LS55 | 284 1/2 | 296 | 25 | 0.250 in (6.35 mm) |
| LS57 below 2160 rev/min | 284 1/2 | 296 | 23 | 0.250 in (6.35 mm) |
| LS57 above 2160 rev/min | 283 1/2 | 296 | 25 | 0.295 in (7,49 mm) |
| LS61 | 284 1/2 | 296 | 23 | 0.250 in (6.35 mm) |
| LS62 | 283 1/2 | 296 | 25 | 0.295 in (7.49 mm) |
| LS63 | 284 1/2 | 296 | 23 | 0.250 in (6.35 mm) |
| LS66 | 281 | 292 | 22 | 0.230 in (5.84 mm) |
| LS67 | 284 1/2 | 296 | 23 | 0.250 in (6.35 mm) |
| MS67 | 279 | 292 | 26 | 0.322 in (8,18 mm) |
| PS45 | 281 | 292 | 22 | 0.230 in (5,84 mm) |
| PS48 | 281 | 292 | 22 | 0.230 in (5,84 mm) |
| PS51 | 281 | 292 | 22 | 0.230 in (5,84 mm) |
| PS54 | 281 | 292 | 22 | 0.230 in (5,84 mm) |
| PS55 | 283 | 292 | 18 | 0.156 in (3,96 mm) |
| PS61 (Exceptions below) | 281 | 292 | 22 | 0.230 in (5,84 mm) |
| PS61/850/4/3120 | 280 1/2 | 292 | 23 | 0.250 in (6.35 mm) |
| PS61/850/7/3120 | 280 1/2 | 292 | 23 | 0.250 in (6.35 mm) |
| PS61/850/9/2400 | 280 1/2 | 292 | 23 | 0.250 in (6.35 mm) |
| PS62 | 281 | 292 | 22 | 0.230 in (5,84 mm) |
| PS66 | 281 | 292 | 22 | 0.230 in (5,84 mm) |
| WS62 | 280 | 292 | 24 | 0.275 in (6,98 mm) |
| WS66 | 280 | 292 | 24 | 0.275 in (6,98 mm) |
| XS55E | 281 | 293 | 24 | 0.275 in (6,98 mm) |
| ZS51E | 278 1/4 | 291 | 25 1/2 | 0.311 in (7,90 mm) |

**TECHNICAL DATA—B.12**

**Atomisers**

| | |
|---|---|
| Make ...... ...... ...... ...... ...... | C.A.V. |
| Atomiser Body ...... ...... ...... ...... | BKBL 67S5151 |
| Atomiser Nozzle ...... ...... ...... ...... | BDLL 150S6556 |
| Minimum Working Pressure ...... ...... ...... | 170 atmospheres (176 kgf/cm2 - 2500 lbf/in$^2$) |
| Setting Pressure ...... ...... ...... ...... | 175 atmospheres (181 kgf/cm2 -2570 lbf/in$^2$) |
| Identification Code ...... ...... ...... ...... | "CU" |

| | |
|---|---|
| Make ...... ...... ...... ...... ...... | C.A.V. |
| Atomiser Body ...... ...... ...... ...... | BKBL 67S5299 |
| Atomiser Nozzle ...... ...... ...... ...... | BDLL 150S6649 |
| Minimum Working Pressure ...... ...... ...... | 195 atmospheres (201 kgf/cm$^2$ - 2870 lbf/in$^2$) |
| Setting Pressure ...... ...... ...... ...... | 210 atmospheres (217 kgf/cm$^2$ - 3090 lbf/in$^2$) |
| Identification Code ...... ...... ...... ...... | "FC" |

**ELECTRICAL SYSTEM**

**Dynamo**

| | |
|---|---|
| Make ...... ...... ...... ...... ...... | Lucas |
| Type ...... ...... ...... ...... ...... | C40A. 2 Pole, 2 Brush<br>Shunt Wound. Voltage Control |
| Rotation ...... ...... ...... ...... ...... | Clockwise Positive Earth |
| Output ...... ...... ...... ...... ...... | 11 A maximum |
| Dynamo Cut-in Speed ...... ...... ...... ...... | 525—625 rev/min |

**Alternator**

| | |
|---|---|
| Make ...... ...... ...... ...... ...... | C.A.V. or Lucas |
| Type ...... ...... ...... ...... ...... | AC5 or 11AC |
| Maximum Output AC5 12 volt (hot) ...... ...... | 55A at 13.5 volts |
| Maximum Output AC5 24 volt (hot) ...... ...... | 31A at 27.5 volts |
| Maximum Output 11AC 12 volt (hot) ...... ...... | 43A at 13,5 volts |
| Cutting in Speed 12 and 24 volts AC5 ...... ...... | 1125 rev/min |
| Cutting in Speed 11AC ...... ...... ...... ...... | 1000 rev/min |

**Starter Motor**

| | |
|---|---|
| Make ...... ...... ...... ...... ...... | C.A.V. |
| Type ...... ...... ...... ...... ...... | CA 45 D12-2M |
| Max. Current ...... ...... ...... ...... ...... | 900 A |
| Starter Cable Resistance ...... ...... ...... | 0.0017 ohms |
| No. of Teeth on Pinion ...... ...... ...... ...... | 10 |
| Rotation ...... ...... ...... ...... ...... | Clockwise |

**Starting Aid**

| | |
|---|---|
| Make ...... ...... ...... ...... ...... | C.A.V. |
| Voltage ...... ...... ...... ...... ...... | 12 Volt |
| Maximum Current Consumption ...... ...... ...... | 12.5/13.5 A at 1 1.5 V |
| Flow Rate through Thermostart ...... ...... ...... | 3.5/5.0 ml/min |
| Height of Reservoir above center of Thermostart ..... | 4.5—10 in (12—25 cm) |

NOTE: The Manufacturers reserve the right to alter this specification without notice.

**BALANCER UNIT**

| | |
|---|---|
| Front Dia. of Shafts (Driving and Driven)...... ...... | 1.2484/1.2490 in (31,71/31.73 mm) |
| Inside Dia. of Front Balance Frame Bushes ...... | 1.2510/1.2526 in (31.78/31.82 mm) |
| Running Clearance of Shafts in Bushes ...... ...... | 0.002/0.0042 in (0.05/0.11 mm) |
| Rear Dia. of Shafts (Driving and Driven)...... ...... | 0.9987/0.9992 in (25,37/25.38 mm) |
| Inside Dia. of Rear Balance Frame Bushes ...... | 1.001/1.0022 in (25.43/25,46 mm) |
| Running Clearance of Shafts in Bushes ...... ...... | 0.0018/0.0035 in (0,05/0,09 mm) |

| | |
|---|---|
| Shaft Dia. for Balance Weights | 1.0622/1.0630 in (26,98/27,00 mm) |
| Bore Dia. of Balance Weights | 1.0625/1.0637 in (26,99/27,02 mm) |
| Fit of Balance Weights on Shafts | —0.0005/+0.0015 in (—0,01/+0,04 mm) |
| Spigot Dia. of Balance Weights | 2.4988/2.500 in (63,47/63,50 mm) |
| Recess Dia. in Balance Weight Gears | 2.500/2.501 in (63,50/63,53 mm) |
| Fit of Gear on Balance Weight | —0.000/+0.0024 in (—0.00/+0,06 mm) |
| Dia. of Shaft for Lub. Oil Pump Gear | 0.4215/0.4235 in (10,71/10,76 mm) |
| Bore Dia. of Lub. Oil Pump Drive Gear | 0.425/0.426 in (10,79/10,82 mm) |
| Clearance Fit of Gear on Shaft | 0.0015/0.0045 in (0,04/0.11 mm) |
| Depth of Lub. Oil Pump Body | 0.999/1.002 in (25,38/25,45 mm) |
| Width of Lub. Oil Pump Drive Gears | 0.998/1.000 in (25,35/25,40 mm) |
| End clearance of Lub. Oil Pump Gears when 0.004 in (0,102 mm) joint is fitted | 0.003/0.008 in (0,08/0,20 mm) |
| Shaft Dia. for Lub. Oil Pump Driven Gear | 0.4382/0.4386 in (11,13/11,14 mm) |
| Bore Dia. of Lub. Oil Pump Driven Gear | 0.4389/0.4396 in (11,15/11,17 mm) |
| Running Clearance of Oil Pump Driven Gear | 0.0003/0.0015 in (0,01/0,04 mm) |
| Hub Dia. for Idler Gear | 1.4984/1.4990 in (38,06/38,08 mm) |
| Bore Dia. of Idler Gear Bush | 1.500/1.5016 in (38,10/38,14 mm) |
| Running Clearance of Idler Gear on Hub | 0.001/0.0032 in (0,03/0,08 mm) |
| Idler Gear End Float | 0.008/0.014 in (0,20/0,36 mm) |

Note: Later balancer units have needle type bearings and all current balancer units have reversed weight roller bearings.

## Service Wear Limits

The following "wear limits" indicate the condition when it is recommended that the respective items should be serviced or replaced.

| | | |
|---|---|---|
| Cylinder Head Bow | Transverse | 0.003 in (().08 mm) |
| | Longitudinal | 0.006 in (0.15 mm) |
| Maximum Bore Wear (when reboring or new liners are necessary).. | | 0.008 in (0,20 mm) |
| Crankshaft Main and Big End Journal, Wear, Ovality | | 0.0015 in (0,04 mm) |
| Maximum Crankshaft End Float | | 0.015 in (0,38 mm) |
| Valve Stem to Bore/Guide Clearance | Inlet | 0.005 in (0,13 mm) |
| | Exhaust | 0.006 in (0,15 mm) |
| Valve Head Thickness at outer edge | | 1/32 in (0,79 mm) |
| Rocker Clearance on Rocker Shaft | | 0.005 in (0,13 mm) |
| Camshaft Journals, Ovality and Wear | | 0.002 in (0,05 mm) |
| Camshaft End Float | | 0.020 in (0,51 mm) |
| Idler Gear End Float | | 0.010 in (0,25 mm) |

### Preparation for Starting

Check the radiator water level.

Check the engine sump oil level.

See that there is fuel oil in the tank.

Check that the starter battery is fully charged and that all electrical connections are properly made and all circuits in order.

### Starting the Engine

**If the engine is warm,** turn starter switch in a clockwise direction to the "HS" position (see Fig. C.1).

As soon as the engine starts. release the switch to the "R" position.

Be sure that the starter pinion and engine have stopped rotating before re-engaging the starter motor, otherwise damage may result.

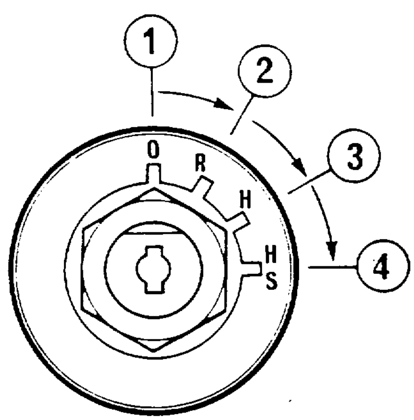



*Fig. C.1*

1. Off Position.
2. Run Position.
3. Heat Position.
4. Heat and Start Position.

If weather is cold, turn starter switch to the "H" position (see Fig. C.1) and hold it there for fifteen to twenty seconds.

Then turn the starter switch to the "HS" position, thereby engaging the starter motor.

If the engine does not start after twenty seconds, return the switch to the "H" position for ten seconds and then re-engage the starter motor by switching to the "HS" position.

As soon at the engine starts, release the switch to the "R" position.

### Earlier Heat Start Switch

The cold start switch supplied with earlier engines is shown in Fig. C.2.

With this type of switch, starting a warm engine is effected by turning the switch in a clockwise direction to the "S" position.

In cold weather, the switch should be turned to the "H" position for fifteen to twenty seconds and then to the "HS" position in order to engage the starter motor.

As soon as the engine starts, the switch should be returned to the "0" position.

When this type of switch is used, it was sometimes customary to have a separate switch for the electrical circuits and this should be turned on before starting the engine and turned off after stopping the engine.

### Starting the Engine (Alternative Method)

With some engines. a different starter switch may be found and the cold start aid operated by means of a separate push button switch.

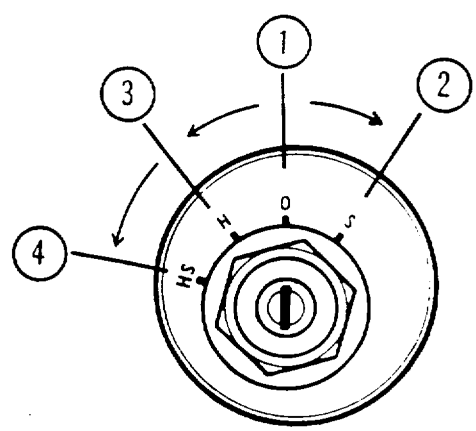



*Fig. C.2*

Earlier Heat/Start Snitch.

1. Off Position.
2. Start Position
3. Heat Position.
4. Heat and Start Position.

The cold starting procedure is however the same, i.e.,

Switch on by turning the starter switch in a clockwise direction to the first position.

Press the heater button for fifteen to twenty seconds and then, with the heater button still pressed, turn the starter switch in a further clockwise direction to engage the starter motor. As soon as the engine starts. release both starter switch and heater button.

**Cold Starting Aid**

The cold start unit comprises a tubular valve body carried in a holder which screws into the inlet manifold, and surrounded by a heater coil, an extension of which forms an igniter coil. The valve body houses a needle, the stem of which holds a ball valve in position against its seating.

The whole is surrounded by an open perforated shield. Fuel oil from the container enters through an adaptor.

When the unit is cold, the ball valve is held closed. On switching on the coil, the valve body is heated and expands. opening the ball valve and permitting the entry of fuel. The fuel is vaporized be the heat of the valve body and when the engine is cranked and air is drawn into the manifold, the vapor is ignited by the coil extension and continue to burn, thus heating the inlet air.

When the coil is switched off, the flow of air in the manifold cools the valve body rapidly and the valve closes.

The cold start aid is a sealed unit and cannot be dismantled. If the unit ceases to function, it must be renewed.

**To Stop the Engine**

A spring loaded stop control i. located near the engine controls and functions by cutting off the fuel at the fuel injection pump.

To operate, pull (he knob and hold in this position until the engine ceases to rotate. Ensure that the control returns to the run position, otherwise difficulty may be experienced in restarting the engine Some engines, may have an electric solenoid stop control on the fuel injection pump operated by a switch on the control panel

Turn start switch to the “O” position.

**Things to Note**

Always be sure that the starter pinion has stopped revolving before re-engaging the starter, otherwise the ring or pinion may be damaged.

Ensure that the electrical connection to the cold starting aid is correctly made.

Always ensure that, if a reservoir is used to feed fuel to the starting aid, it is fully primed and is not leaking. On later engines, the starting aid fuel feed is taken directly from the fuel filter.

In the event of difficult starting, check that fuel is reaching the cold starting aid in the induction manifold by unscrewing the inlet fuel connection.

If fuel is reaching it satisfactorily, then it may be that the cold starting aid itself is not working correctly. This can be checked by removing the air cleaner and watching the cold starting aid whilst the equipment is used. When the starting switch is turned to the "heat" position, the element should become red hot, and on engagement of the starter motor, it should burst into flame.

4.236 Marine engines are fitted with efficient cold starting equipment and no responsibility can be accepted for any damage caused by unauthorized starting aids.

To present thermostart damage, it is essential that the thermostart is not operated **DRY.** After any operation which allows fuel to drain from the thermostart feed pipe, the pipe must be disconnected at the thermostart and all air bled from the pipe before the thermostart is operated.

Where a thermostart starting aid has to be replaced, care must be taken not to exceed the torque figure quoted on Page B.1. Excessive torque loading can crack the insulator adaptor causing an electrical short and hard starting characteristics.

**Running-in Procedure**

It is not necessary to gradually run-in a new or factory rebuilt engine and any prolonged light load running can in fact prove harmful to the bedding in of piston rings and liners.

Full load can be applied on a new or factory rebuilt engine as soon as the engine is used, **provided that the engine coolant is first allowed to reach a temperature of at least 140°F 160°C).**

## Preventive Maintenance

If a Perkins marine diesel engine is to give long and trouble free service, it is imperative that it be maintained in accordance with the following Periodical Attentions :—

It is good engineering practice to check for water, fuel and lubricating oil leaks and the tightness of nuts, setscrews and hose clips at each servicing period.

It should be noted that the maintenance periods given are on the assumption that the fuel and lubricating oils used are to the specifications given in this workshop manual.

**Daily or Every 8 hours**
**(whichever occurs first)**

Check coolant level.
Check sump oil level.
Check gearbox oil level.
Check oil pressure.

**Every 125 hours or 2 months**
**(whichever occurs first)**

Clean air intake gauzes or screens.
Grease tachometer angle drive connections (where nipple fitted).

**Every 250 hours or 4 months**
**(whichever occurs first)**

Drain and renew engine lubricating oil using an approved oil — see appendix.
Renew lubricating oil filter element or canister.
Check drive belt tension.
Clean water trap.
Lubricate dynamo rear bush (where fitted).

**Every 500 hours or 12 months**
**(whichever occurs first)**

Renew final fuel filter element.
Clean lift pump sediment chamber.
Drain and clean fuel tank.
Renew gearbox lubricating oil (Borg Warner).

**Every 2,500 hours**

Arrange for examination of proprietary equipment, i.e., Starter motor, dynamo, alternator, oil cooler, etc.
Service atomisers.
Check and adjust valve clearance (see Page E.8).

**Note:** Whilst a lubricating oil drain plug is fitted, it is not normally possible to drain the oil in the Marine installation. Instead, a sump draining connection is fitted, to which a hand operated pump (supplied as an optional extra) can be attached, for the purpose of pumping out the lubricating oil when necessary.

The sump draining connection is situated on the starboard side of the engine.

With 4.236 low-line engines, the sump drain pump is a standard fitment.

**POST-DELIVERY CHECKOVER**

After a customer has taken delivery of his Perkins Marine Diesel engine. it is advisable. in his own interest. that a general checkover of the engine be carried out after the first 25/'50 hours in service.

It is also recommended that the following procedure be adopted where an engine has been laid up for a considerable period before it is again put into service.

The checkover should comprise the following points :—

1. Drain lubricating oil sump and re-fill up to the full mark on the dipstick with new clean oil (Do not overfill). When the sump is drained and it is possible to gain access to the sump strainer, it should be removed and cleaned.

2. Renew clement or canister of lubricating oil filter.

3. Check external nuts for tightness.

4. Warm up engine and then shut down : remove rocker assembly. Retighten cylinder head nuts setscrews in the correct sequence as given in Fig. E.11 and to the correct torque as given on Page B.1. The correct procedure for retightening of the cylinder head nuts, setscrews is given on Page E.8. Replace rocker assembly.

5. Check and adjust valve clearances (0.012 in or 0,30 mm cold) see Page E.8.

6. Check fuel pipes from tank to fuel injection pump for leaks.

7. Check for lubricating oil leaks, and rectify if necessary.

8. Check cooling system for leaks and tighten

hose clips where necessary and inspect header tank water level.

9. Check water pump belt for tension.

10. Carry out test to check general performance of engine.

11. Check engine mounting bolts for tightness.

Thereafter maintenance periods should be in accordance with the instructions given on this page.

It is assumed that electrical equipment will have already been checked for such points as dynamo rate of charge, effectiveness of connections and circuits, etc.

## PROTECTION OF AN ENGINE NOT IN SERVICE

The recommendations given below are to ensure that damage is prevented when an engine is removed from service for an extended period. Use these procedures immediately the engine is removed from service. The instructions for the use of POWERPART products are given on the outside of each container.

1. Thoroughly clean the outside of the engine.

2. Where a preservative fuel is to be used. drain the fuel system and till with the preservative fuel. **POWERPART Lay-Up 1** can be added to the normal fuel to change it to a preservative fuel. If preservative fuel is not used, the system can be kept charged with normal fuel, but this will have to be drained and discarded at the end of the storage period together with the fuel filter element.

3. Run the engine until it is warm. Correct any fuel, lubricating oil or air leakage. Stop the engine and drain the lubricating oil sump.

4. Renew the lubricating oil filter canister or element.

5. Fill the sump to the full mark on the dipstick with clean new lubricating oil or with a correct preservative fluid. **POWERPART Lay-Up 2** can be added to the lubricating oil to give protection against corrosion during the period in storage. If a preservative fluid is used, this must be drained and normal lubricating oil used when the engine is returned to service.

6. Drain the cooling system, see Page C.5. To give protection against corrosion, it is better to fill the cooling system with a coolant that has a corrosion inhibitor. If frost protection is needed, use an antifreeze mixture. If no frost protection is needed, use water with an approved corrosion inhibitor mixture.

7. Run the engine for a short period to send the lubricating oil and coolant around the engine.

8. Remove the atomisers and spray **POWERPART Lay-Up 2** into each cylinder bore. If this is not available, clean engine lubricating oil will give a degree of protection. Spray into the cylinder bores 140 ml (1/4 pint) of lubricating oil divided evenly between the four cylinders.

9. Slowly turn the crankshaft one revolution and then install the atomisers complete with new seat washers.

10. Remove the air filter and spray **POWERPART Lay-Up 2** into the induction manifold. Replace air filter and seal with waterproof tape.

11. Remove the exhaust pipe Spray **POWERPART Lay-Up 2** into the exhaust manifold. Seal the manifold with waterproof tape.

12. Remove the lubricating oil filler cap. Spray **POWERPART Lay-Up 2** around the rocker shaft assembly. Fit the filler cap.

13. Disconnect the battery and put it into safe storage in a fully charged condition. Before the battery is put into storage, give the battery terminals protection against corrosion**.** **POWERPART Lay-Up 3** can be used on the terminals.

14. Seal the vent pipe of the fuel tank or the fuel filler cap with waterproof tape.

15. Remove end plate from sea water circulating pump and lubricate the interior with glycerine or MARFAK 2HD grease, or remove the impeller for the lay-up period. Always use a new joint when refitting backplate.

16. Remove the drive belt and put into storage.

17. To prevent corrosion, spray the engine with **POWERPART Lay-Up 3.** Do not spray inside the alternator cooling fan area.

**NOTE:**
**Before the engine is started after a period in storage, operate the starter motor with the engine stop control in the "off" position until oil pressure shows on the gauge or the oil warning light goes out. If a solenoid stop control is used, this will have to be disconnected for this operation.**

If the engine protection is done correctly according to the above recommendations, no corrosion damage will normally occur. Perkins Engines Ltd., are not responsible for any damage that occurs in relation to a service storage period.

**ENGINE COOLANT**

The quality of the coolant used can have a large effect on the efficiency and life of the cooling system. The recommendations given below can be of assistance in the maintenance of a good cooling system with frost and/or corrosion protection.

1. Where possible, use clean soft water.

2. If an antifreeze mixture is used to prevent frost damage, it must have an ethylene glycol (ethanediol) base. An antifreeze that is to one of the standards given below or to an equal standard is acceptable if the pH value is kept within the range of 7.0-8.5 when diluted.
   U.K. BS 3151:1959
   ‘Ethanediol Antifreeze Type B with Sodium Benzoate and Sodium Nitrate Inhibitors'.
   U.S.A. ASTM 03306-74
   ‘Ethylene Glycol Base Engine Coolant'.
   Australia AS 2108-1977
   ‘Antifreeze Compounds and Corrosion Inhibitors for Engine Cooling Systems'.

When Perkins POWERPART Antifreeze is used, the correct mixtures of antifreeze and water are as given below. Perkins POWER PART Antifreeze fully passes the above standards.

| Lowest Temp. of Protection Needed | % Volume of POWERPART Antifreeze | Mixture-Ratio by Vol. POWERPART Antifreeze: Water |
|---|---|---|
| -12°C( 10°F) | 25 | 1:3 |
| -18°C( 0°F) | 33 | 1:2 |
| -25°C (-13°F) | 40 | 1:1.5 |
| -37°C (-34°F) | 50 | 2:1 |
| -60°C (-76°F) | 66 | 2:1 |

The quality of the antifreeze coolant must be checked at least once a year, for example, at the start of the cold period.

3. When frost protection is not necessary, it is still an advantage to use an approved antifreeze mixture as this gives protection against corrosion and also raises the boiling point of the coolant. A minimum concentration of 25% by volume of antifreeze is necessary, but it is our recommendation that a 33% concentration by volume is used.

   If an antifreeze is not used, add a correct corrosion inhibitor mixture to the water.

   Change the water/corrosion inhibitor mixture every six months or check according to the inhibitor manufacturer's recommendations.

   **Note: Some corrosion inhibitor mixtures contain soluble oil which can have an adverse effect on some types of water hose.**

If the correct procedures are not used, Perkins Engines Ltd. can riot be held responsible for any frost or corrosion damage.

To Drain the Cooling System

1. Remove filler cap from header-tank.

2. Drain water from header tank and engine cylinder block by opening all drain cocks and plugs. The cylinder block may be flushed back through the drain points with the thermostat removed. If it is decided to refill the fresh water system with antifreeze or corrosion inhibitor, see this page.

3. If the engine is to be layed up for the winter season, the raw water system should also be drained. Before commencing draining, the sea cock should be turned off and then all drain cocks opened and plugs removed. The removal of the sea water hose at the lowest point of the engine will assist in complete drainage of the raw water.

4. If the engine is to be left drained during freezing conditions, 1/2 pint (250 ml) of undiluted antifreeze should be added to the oil coolers to prevent freezing should any water drain into the coolers if the boat is moved.

**fault finding chart**

| Fault | Possible Cause |
|---|---|
| Low cranking speed | 1, 2, 3, 4. |
| Will not start | 5, 6, 7, 8, 9, 10, 12, 13, 14, 15, 16, 17, 18, 19, 20, 22, 31, 32, 33. |
| Difficult starting | 5, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 18, 19, 20, 21, 22, 24, 29, 31, 32, 33. |
| Lack of power | 8, 9, 10, 11, 12, 13, 14, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 31, 32, 33. |
| Misfiring | 8, 9, 10, 12, 13, 14, 16, 18, 19, 20, 25, 26, 28, 29, 30, 32. |
| Excessive fuel consumption | 11, 13, 14, 16, 18, 19, 20, 22, 23, 24, 25, 27, 28, 29, 31, 32, 33. |
| Black exhaust | 11, 13, 14, 16, 18, 19, 20, 22, 24, 25, 27, 28, 29, 31, 32, 33. |
| Blue/white exhaust | 4, 16, 18, 19, 20, 25, 27, 31, 33, 34, 35, 45, 56. |
| Low oil pressure | 4, 36, 37, 38, 39, 40, 42, 43, 44, 53, 58. |
| Knocking | 9, 14, 16, 18, 19, 22, 26, 28, 29, 31, 33, 35, 36, 45, 46, 59. |
| Erratic running | 7, 8, 9, 10, 11, 12, 13, 14, 16, 20, 21, 23, 26, 28, 29, 30, 33, 35, 45, 59. |
| Vibration | 13, 14, 20, 23, 25, 26, 29, 30, 33, 45, 48, 49. |
| High oil pressure | 4, 38, 41. |
| Overheating | 11, 13, 14, 16, 18, 19, 24, 25, 45, 47, 50, 51, 52, 53, 54, 57. |
| Excessive crankcase pressure | 25, 31, 33, 34, 45, 55. |
| Poor compression | 11, 19, 25, 28, 29, 31, 32, 33, 34, 46, 59. |
| Starts and stops | 10, 11, 12. |

**KEY TO FAULT FINDING CHART**

1. Battery capacity low.
2. Bad electrical connections.
3. Faulty starter motor.
4. Incorrect grade of lubricating oil.
5. Low cranking speed.
6. Fuel tank empty.
7. Faulty stop control operation.
8. Blocked fuel feed pipe.
9. Faulty fuel lift pump.
10. Choked fuel filter.
11. Restriction in air cleaner or induction system.
12. Air in fuel system.
13. Faulty fuel injection pump.
14. Faulty atomisers or incorrect type.
15. Incorrect use of cold start equipment.
16. Faulty cold starting equipment.
17. Broken fuel injection pump drive.
18. Incorrect fuel pump timing.
19. Incorrect valve timing.
20. Poor compression.
21. Blocked fuel tank vent.
22. Incorrect type or grade of fuel.
23. Sticking throttle or restricted movement.
24. Exhaust pipe restriction.
25. Cylinder head gasket leaking.
26. Overheating.
27. Cold running.
28. Incorrect tappet adjustment.
29. Sticking valves.
30. Incorrect high pressure pipes.
31. Worn cylinder bores.
32. Pitted valves and seats.
33. Broken, worn or sticking piston ring/s.
34. Worn valve stems and guides.
35. Overfull air cleaner or use of incorrect grade of oil.
36. Worn or damaged bearings.
37. Insufficient oil in sump.
38. Inaccurate gauge.
39. Oil pump worn.
40. Pressure relief valve sticking open.
41. Pressure relief valve sticking closed.
42. Broken relief valve spring.
43. Faulty suction pipe.
44. Choked oil filter.
45. Piston seizure/pick up.
46. Incorrect piston height.
47. Sea cock strainer or heat exchanger blocked.
48. Faulty engine mounting (Housing).
49. Incorrectly aligned flywheel housing or flywheel.
50. Faulty thermostat.
51. Restriction in water jacket.
52. Loose water pump drive belt.
53. Choked gearbox or engine oil cooler.
54. Faulty water pump.
55. Choked breather pipe.
56. Damaged valve stem oil deflectors (if fitted).
57. Coolant level too low.
58. Blocked sump strainer.
59. Broken valve spring.

## CYLINDER HEAD MAINTENANCE

The number of hours run has no bearing on when to overhaul the cylinder head on the 4.236 marine engine as carbon beyond a superficial coating does not form and accumulate on the cylinder head and pistons as is the case with a petrol engine.

Ease of starting and performance are the determining factors, therefore the cylinder head should only be removed when it is absolutely necessary.

Before commencing to overhaul the cylinder head ensure that all joints, gaskets and parts expected to be required are available.

### To Remove the Cylinder Head

1. Drain coolant from heat exchanger, cylinder block and exhaust manifold jacket (See engine photographs for location of drain points).

2. Disconnect the battery terminals to eliminate the possibility of a short circuit.

3. Disconnect the exhaust pipe from the exhaust manifold. Blank off the end of the exhaust pipe to prevent objects being dropped into it.

4. Disconnect sea water inlet and outlet connections from heat exchanger and exhaust manifold jacket, and connection between heat exchanger and fresh water pump.

5. Disconnect the lub. oil pipes from the lub. oil cooler.

6. Remove the heat exchanger securing setscrews and withdraw the heat exchanger.

7. Disconnect and remove the atomiser leak-off pipe assembly. Blank off the ports on the top of the atomisers.

8. Remove the fuel pipe from the fuel filter to the fuel injection pump inlet, also the fuel pipe from the fuel filter to the fuel injection pump outlet. Blank off the exposed parts.

9. Disconnect the fuel pipe from the fuel lift pump outlet to the fuel filter. Remove the two setscrews which secure the fuel filter to the cylinder head and withdraw the filter from the engine.

10. Remove the breather pipe from between the cylinder head cover and the induction manifold.

11. Disconnect and remove the high pressure fuel pipes from the fuel injection pump and atomisers. Blank off the exposed ports. Release and remove the nuts securing the atomisers and carefully extract the atomisers from the cylinder head (see Fig. E.1).

12. Disconnect the fuel pipe and electrical lead at the thermostart unit.

13. Remove the air filter. Remove the induction and exhaust manifolds.

14. Detach the rocker cover from the engine by removing the four screws which secure it to the cylinder head.

15. Remove the four rocker bracket securing nuts and washers, and remove the rocker assembly from the cylinder head (see Fig E.2). Remove the push rods.

16. Release and remove the cylinder head nuts or setscrews in the reverse order of the tightening sequence shown in Fig. E.1).

17. Remove the cylinder head. Do not insert a screwdriver or any other sharp instrument between the cylinder head and block. When removed place the cylinder head on a flat surface, preferably wood, to avoid damage.

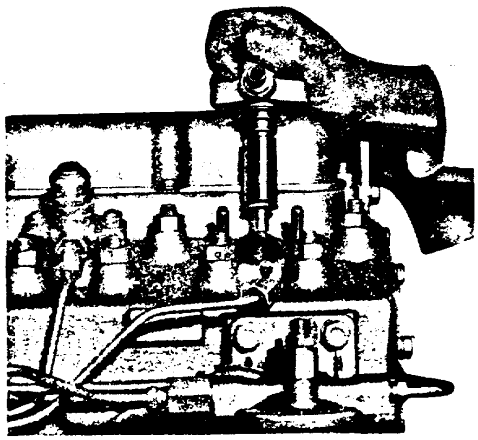


*Fig. E.1.*
*Removing an Atomiser.*

**To Remove the Valves**

Originally, all valves were numbered 1.1, 2.2, 3.3, and 4.4 with a corresponding number adjacent to each valve face (see Fig. E.3). This practice has now ceased and where these valves are to be used again. Then they should be suitably marked to ensure that they are replaced in their respective positions.

1. Place the cylinder head on the bench with the gasket face downwards.

2. Compress the spring caps and springs with a suitable valve spring compressor as shown in Fig. E.4 and remove the two half conical collets from each valve.

3. Remove the spring caps, springs and rubber oil deflectors from the valve stems, thus liberating the valves which can be taken out when the cylinder head is turned over.

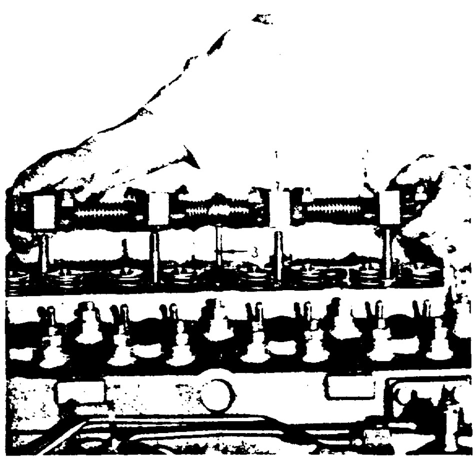


*Fig. E.2.*
*Removing the Rocker Shaft Assembly.*
1. Rocker Shaft Bracket.
2. Rocker Lever.
3. Oil Feed Connection.

**Cleaning**

It is essential that absolute cleanliness is observed during the following instructions to prevent the possibility of damage resulting from particles of hard carbon falling into the engine, thereby causing damage to cylinder liners, pistons and bearings, etc.

1. Carefully remove all traces of carbon from the cylinder head taking care not to scratch or burr the machined faces.

2. If the water jacket of the cylinder head shows signs of excessive scale, a proprietary brand of descaling solution should be used.

3. Blank off the rocker oil feed oil-way between numbers 2 and 3 cylinders to prevent the ingress of carbon particles and carefully remove the carbon from the pistons and cylinder block face again taking care not to scratch or burr the machined surfaces.

4. After valve seat machining and valve grinding operations have been carried out, all parts should be thoroughly washed in a suitable cleaning fluid.

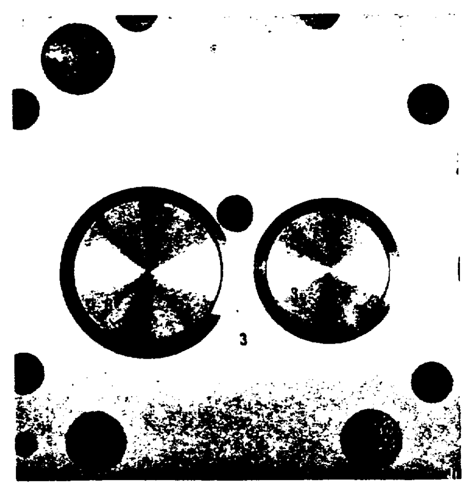



*Fig. E.3.*
*Numbering of Valves*

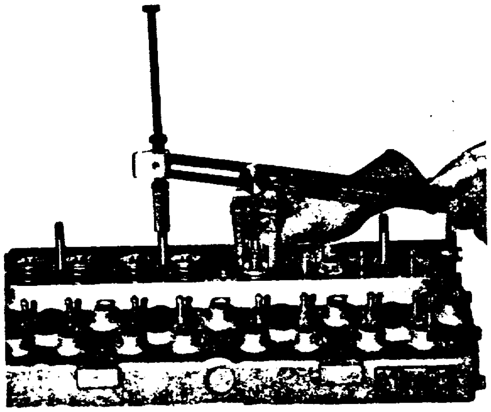


*Fig. E.4.*
*Removing the Valve Collets.*

**Valve Guides**

Detachable valve guides are not fitted, the valve bores being machined direct into the cylinder head.

When wear takes place in the valve bores restoration of the original clearance between the valve stem and its accommodating bore is accomplished by fitting valves with oversize stems. Three service valves are available, for both inlet and exhaust, with oversize stems of 0.003, 0.015 and 0.030 in. (0.08, 0.38 and 0.76 mm) respectively.

In order to fit the 0.015 and 0.030 in oversize valves, the bores in the cylinder head must be reamed with a piloted reamer to ensure that the valve position relative to the valve seat is maintained. Suitable reamers for carrying out this operation can be obtained from Messrs. V. L. Churchill and Co. Ltd.

When the above operation has been completed, check to ensure that the clearance between the valve bore in the cylinder head and the valve stem is within the limit of 0.0015 in to 0.0035 in (0.038 to 0.089 mm).

**Valves and Valve Seats**

There will be little wear of the valve stems provided that lubrication has always been adequate.

Check the valve stems for wear and their fit in the bores. If the stems are worn fit new valves.

Examine the valve faces for pitting or distortion. Valve refacing should be carried out on a suitable grinding machine to an angle of 45°.

When fitting new valves ensure that the valve head depth relative to the cylinder head face is not less than that quoted on Page B.7. Maximum depth should not exceed 0.061 in (1,55 mm) for inlet and 0.055 in (1,4 mm) for exhaust. Check this measurement by placing a straight edge across the face of the cylinder head and with feeler gauges measure the distance between the straight edge and valve head (see Fig. E.5).

The valve seats in the cylinder head should be reconditioned in the orthodox way, by means of cutters or specialized grinding equipment, to an angle of 450.

As narrow a valve seat as possible should always he maintained, therefore, care should be taken to ensure that a minimum of metal is removed.

*Fig. E.5.*
*Checking Valve Depths.*

### Hand Grinding

The efficiency of a diesel engine depends largely on the maintenance of good compression, therefore when grinding in valves, make certain that no signs of pitting are left on the seatings. At the same time care should be taken to avoid unnecessary grinding away of the valve seat.

1. With the valve removed apply a thin coating of medium or fine grinding paste according to the surface condition of the seat and replace the valve in its guide.
2. Lightly rotate the valve using a suitable suction tool in alternate directions, raising the valve from its seat from time to time and turning it continuously to ensure a concentric seat.
3. Add more grinding paste if necessary and continue the operation until an even grey matt finish is obtained.
4. After grinding operations have been completed. check the valve head depths relative to the cylinder head face to ensure that they are within the specified limit below the head face (see Page B.7).
5. Thoroughly wash off the cylinder head with cleaning fluid and ensure that all traces of grinding paste have been removed.

### Valve Seat Inserts

Valve scat inserts are not fitted to 4.236 marine engines during production. It is, however. permissible to fit inserts to valve seats where it is considered necessary, i.e. if the existing seat is damaged or worn to such an extent that recutting and lapping would place the valve depth relative to the cylinder head face beyond the maxi mum limits as given on Page B.7.

When fitting inserts ensure that genuine Perkins Parts are used.

1. Using the appropriate size piloted reamer 0.015 in (0,38 mm), or 0.030 in (0,76 mm) according to the condition of the valve bores in the cylinder head-ream out the valve bores.

**NOTE**

**It is well to remember that the appropriate oversize stem replacement valves will be needed when this operation has been carried out on guideless cylinder heads.**

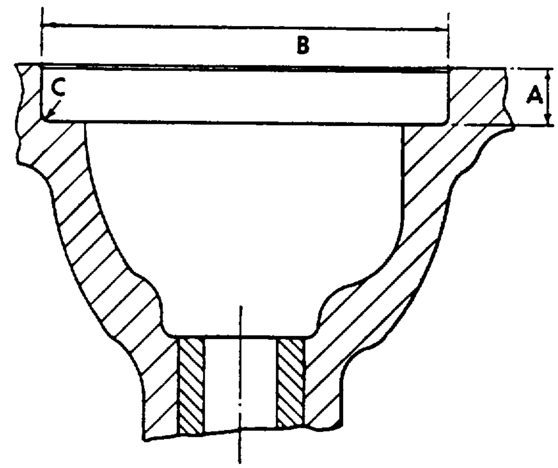



*Fig. E.6.*
*Valve Seat Cutting Dimensions.*

**Inlet**
A.—0.283/0.288 in (7,19/7,31 mm)
B.—2.0165/2.0175 in (51,22/51,24 mm)
C —Radius 0.015 in (0,38 mm) max

**Exhaust**
A.—375 to .380 in
B.—1.678 to 1.679 in
C.—Radius 015 in (max.)

2. Using the new valve bore as a pilot, machine the recess in the cylinder head face to the dimensions shown in Fig. E.6.
3. Remove all machining swarf and thoroughly clean the insert recess (removing any burrs which may be present), and once more using the valve bore as a pilot, press the insert home using the inserting tool (see Fig. E.7) using a steady pressure with either a hand or hydraulic press.

   This tool will ensure squareness which is essential whilst the insert is being pressed home.

   The insert must not, under any circumstances. be hammered in, neither should any lubrication be used.
4. Visually inspect to ensure that the insert has been pressed fully home, i.e. is flush with the bottom of the recess.
5. Once again using the valve bore as a pilot, machine the "flare" to the dimensions given in Fig. E.8.
6. Remove all machining swarf and any burrs which may be present.

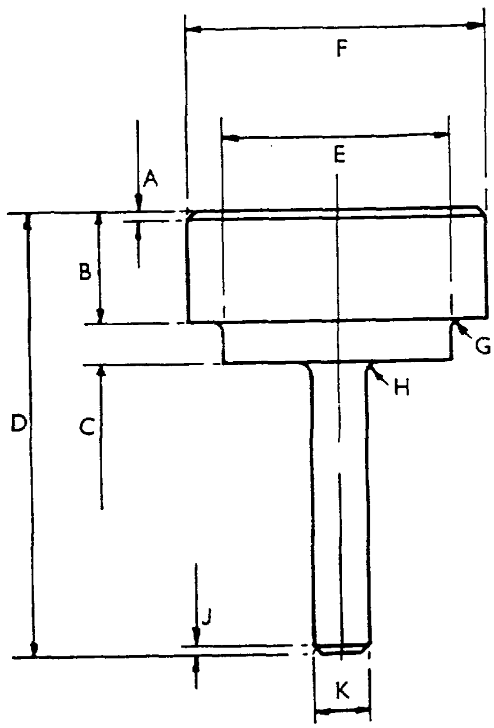



*Fig. E.7. Press Tool for Valve Seat Inserts.*

| **Inlet** | **Exhaust** |
|---|---|
| A— 1/16 in (1,59 mm) at 45° | A— 1/16 in at 45° |
| B— 3/4 in (19,05 mm) | B— 3/4 in |
| C— 0.250 in (6.35 mm) | C— 0.3125 in (7,29 mm) |
| D— 3 in (76.20 mm) | D— 3 In |
| E— 1.582 1.583 in (40,18:40,21 mm) | E— 1.248/1.249 in 31,70/31,72 mm) |
| F— 2.009'2.019 in (51,03/51,28 mm) | F— 1.670/1.680 in (43,32/43,76 mm) |
| G— 1/32 in (0,79 mm) radius | G— 1/32 in radius |
| H— 1/16 in (1.59 mm) radius | H— 1/16 in radius |
| J— 1/16 in (1,59 mm) at 45° | J— 1/16 in at 45° |
| K— 0.372:0.373 in (9,45i/9,47 mm) | K— 0.372/0.373 in |

7. Re-cut the valve seat at an included angle of 900 as in normal procedure, so that the valve head depth below the cylinder head face is within the production limits given on Page B.7.

**NOTE**

**If the cylinder head face has been skimmed since the fitting of valve seat inserts, then the following action is permitted :**

**(a) If the insert is in a serviceable condition, machine to the dimensions given in Fig. E.8 and continue as in stages 6 and 7.**

**(b) If the insert is damaged or unserviceable through wear, remove the insert and replace with a new one, but before fitting, the back of the insert should be surface ground, removing the equivalent depth of material to that removed by the skimming of the cylinder head face. Do not forget to re-chamfer the insert as it was prior to grinding, i.e. 0.020/0.030 in (0,508/0,762 mm) at 45°. Then proceed as in stages 3 - 7.**

### Valve Springs

Valve springs deteriorate because of fatigue resulting from the combined effect of heat and the normal working of the springs. After a period the spring becomes weak and is then prone to failure. This, of course, applies to all types of engines.

A new set of springs should be fitted whenever the engine undergoes a major overhaul.

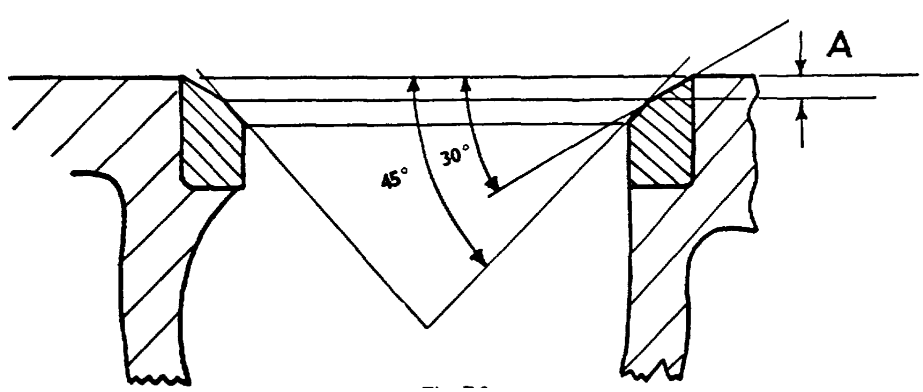



*Fig. E.8.*
*Showing Flare to be cut at 30°.*
*A-0.100 to 0.105 in (inlet), 0.094 to 0.099 in (exhaust).*

When carrying out a top overhaul only, examine the valve springs carefully with particular regard to squareness of ends and pressures developed at specified lengths, the details of which can be found in the Technical Data Section.

**Rocker Shaft Assembly**

To Dismantle:—

1. Remove the circlips and washers from each end of the rocker shaft.
2. Withdraw the rocker levers, springs and support brackets from the shaft.
3. Remove the locating screw from the rocker oil feed connection and withdraw the connection from the shaft. Wash all parts thoroughly in cleaning fluid. Examine the rocker lever bores and shaft for wear. The rockers should be an easy fit on the shaft without excessive side play.

To Reassemble

1. Fit the oil feed connection to the rocker shaft and secure with the locating screw, ensuring that the screw enters the locating hole in the shaft.
2. Refit the support brackets, springs, and rocker levers to the shaft in the order shown in Fig. E.2. The support brackets are interchangeable and when fitting them ensure that the securing stud holes are to the right viewing the shaft from the front end, with each pair of rockers inclined away from each other at the valve end.
3. Fit the securing washer and circlip at each end of the rocker shaft.

**Push Rods**

Check the push rods for straightness. If any are bent, fit replacement push rods.

To fit a replacement push rod, (excepting numbers 1 and 8) with the rocker shaft assembly in position proceed as follows:—

1. Ensure that the valve concerned is closed.
2. Slacken off the valve adjusting screw and slide the rocker lever sideways until the push rod can be withdrawn from the engine.
3. Fit the new push rod and re-adjust the valve clearance.

To fit a replacement push rod to numbers 1 and 8 tappets proceed as follows :—

1. Ensure that the valve concerned is closed.
2. Slacken off the valve adjusting screw.
3. Remove the circlip and washer securing the rocker lever to the shaft and remove the lever from the shaft. The push rod can now be withdrawn from the engine.
4. Fit the replacement push rod. Refit the rocker lever, washer and circlip to the rocker shaft.
5. Re-adjust the valve clearance.

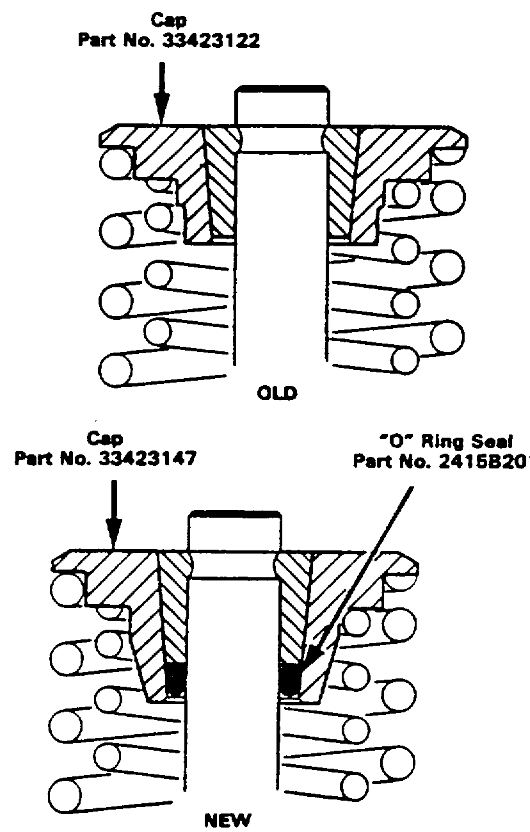



*Fig. E.9.*
*Valve Cap Sealing Arrangement*

To Re-Assemble the Cylinder Head

1. Ensure that the cylinder head and valves etc. are perfectly clean.
2. Lightly oil the valve stems to provide initial lubrication.
3. Insert each valve in its correct bore.
4. Fit the valve oil deflector rubbers with the open end towards the cylinder head.

5. Locate the spring seat locating washers, valve springs and spring retainers in their correct positions on the valve stems.

6. Using a suitable valve spring compressor (See Fig. E.4) compress each valve spring in turn and fit the valve collets.

**Note: As from Engine No. LD U778518H, 'O' ring seals have been fitted in the valve spring caps under the collets. The valve spring caps have been changed which have a deeper body so that the seal can be fitted as shown in Fig. E.9. The new caps are fitted to both valves, but the seals are fitted to exhaust valves only.**

### To Refit the Cylinder Head

Before assembling the cylinder head to the engine it is extremely important to ensure that the cylinder block and cylinder head faces are perfectly clean. Care must be taken to ensure that the rocker assembly oil feed passage in the cylinder head is free from obstruction.

Whenever the cylinder head is removed, it should **not** be refitted with the old gasket, whatever the gasket condition.

**IMPORTANT:** Always ensure the correct gasket is fitted. The thickness of gaskets varies according to the piston height as given on Page B.2 and exhaust valve depths as given on Page B.7 and if the correct gasket is not used, then piston/valve contact may result.

1. Current type cylinder head gaskets should be fitted DRY. On no account should jointing compound be used.

   Before placing gasket over cylinder head studs, ensure it is correctly positioned. Gaskets are marked to indicate how they should be fitted.

2. Place the cylinder head in position on the cylinder block. Lightly oil threads and tighten nuts/setscrews progressively (in 3 stages) in the order shown in Fig. E.11 to a torque of 100 lb ft (13,8 kgf m) — 136 Nm. The final stage should be repeated to ensure that no loss of tension has occurred earlier in the tightening sequence.

3. Fit the push rods in their respective positions and assemble the rocker shaft assembly to the cylinder head. Ensure that a new rubber sealing ring is fitted to the rocker oil feed connection and that it is correctly positioned before tightening down the rocker shaft assembly.

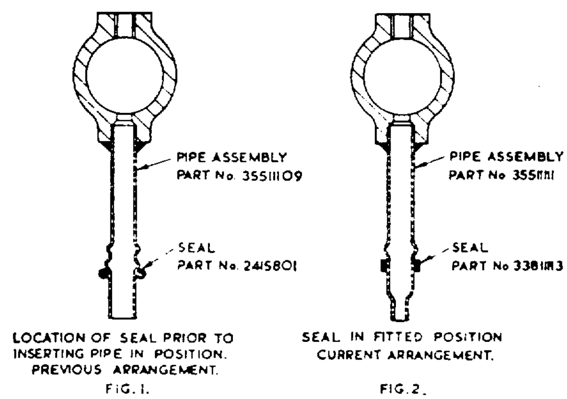



*Fig E.10*
*Showing location of "O" Ring prior to fitting Rocker Shaft.*

When fitting the seal to the rocker oil feed connection, the seal should be positioned immediately below the 'bottom convolution so that when the pipe is inserted into the cylinder head. the "O" ring will roll up and over the lower convolution and locate itself between the two convolutions. With current engines, the seal should be fitted to butt up against the lower convolution (see Fig. E.10).

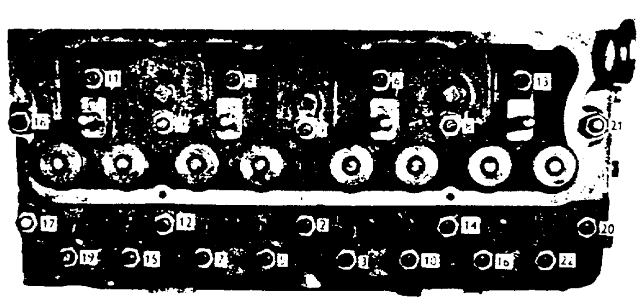


*Fig. E.11.*
*Cylinder Head Nut Tightening Sequence.*

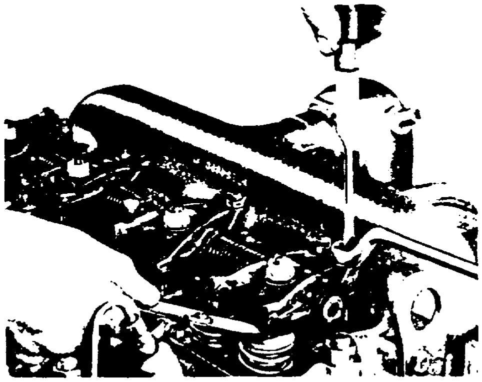


*Fig. E.12.*
*Adjusting Valve Clearance.*

4. Adjust valve clearances to 0.012 in (0.30 mm) in the following manner:—
   (a) With the valves rocking on No. 4 cylinder, set the clearances on No. 1 cylinder.

   (b) With the valves rocking on No. 2 cylinder, set the clearances on No. 3 cylinder.

   (c) With the valves rocking on No. 1 cylinder, set the clearances on No. 4 cylinder.

   (d) With the valves rocking on No. 3 cylinder, set the clearances on No. 2 cylinder.

Using a new joint, lit the rocker cover and secure with four plain washers, spring washers and screws.

5. Assemble the inlet and exhaust manifolds to the cylinder head using new joints and caskets. Connect the electrical lead and fuel feed pipe to the thermostart unit.

6. Refit the atomizers with new copper sealing washers and tighten down the securing nuts evenly ensuring the atomizer is squarely on its seat. Refit the high pressure fuel pipes to the injection pump and atomizer, (see Pages N.9 and N.13).

7. Fit the breather pipe assembly to the cylinder head cover.

8. Refit the fuel filter to the cylinder head securing it with the w(o setscrews and spring washers. Refit the fuel pipe connecting the lift pump outlet to the fuel filter.

9. Fit the fuel pipe connecting the fuel filter to the injection pump inlet also the pipe connecting the injection pump outlet to the fuel filter.

10. Refit the atomizer leak-off pipe assembly.

11. Fit the heat exchanger and secure with the setscrews.

12. Reconnect the lubricating oil pipes to the lubricating oil cooler.

13. Reconnect the water connection between the fresh water pump and the heat exchanger, also the sea water connections between the heat exchanger and exhaust manifold jacket.

14. Using a new gasket, connect the exhaust pipe to the exhaust manifold.

15. Refit the air filter and connections. Fit the water outlet hose. Re-connect the battery terminals.

16. Fill the cooling system with clean water ensuring that the drain taps are turned off. Check for water leaks.

17. Bleed the air front the fuel system as detailed on Page N.14 and start the engine.

18. Run the engine until normal operating temperature is attained and retighten the cylinder head nuts/setscrews, in sequence Fig. E.11, and to the correct torque as given on Page B.1.

**Note:**
**When retightening cylinder head nuts/setscrews, the engine coolant outlet temperature should not be less,, than 170° F (77° C). If the nut setscrew moves when retightened, then tighten up to the torque quoted on Page B.1. If the nut setscrew does not move before the correct torque is achieved. then slacken off 1/12 to 1/6 of a turn (30° to 60°) and retighten to the correct figure After retightening all the nuts/setscrews, the first 10 positions should be rechecked without further slackening off to ascertain they are still tightened to the torque quoted.**

19. Reset the valve clearance to 0.012 in (0.3,0 mm) cold (see item 4). Fit the cylinder head cover ensuring that there are no oil leaks at the joint.

**Note: After the first 25/50 hours running, the rocker assembly should be removed and the cylinder head nuts/setscrews again retightened to the correct torque and the sequence shown in Fig. E.11. Ensure the correct procedure is followed as in above 18. Replace rocker assembly and set valve clearance to 0.012 in (0.30 mm) with the engine cold.**

**As from Engine Nos. 236U135765 and 236U147150L. engines are built to conform to BSAU141a 1971 regulations and should only be fitted with the later cylinder head and cylinder head gasket. The valve depths should also conform to the Production limits as given on Page B.7.**

To Remove Pistons and Connecting Rod Assemblies

1. Remove the cylinder head (see Page E.1).

2. Remove the lubricating oil sump.

3. Turn the engine crankshaft until two big ends are at bottom center then remove the nuts from the big end bolts.

4. Remove the big end caps, bearing shells and big end bolts.

**Note: If the bearing shells removed are serviceable, care must be taken to refit them in their original positions.**

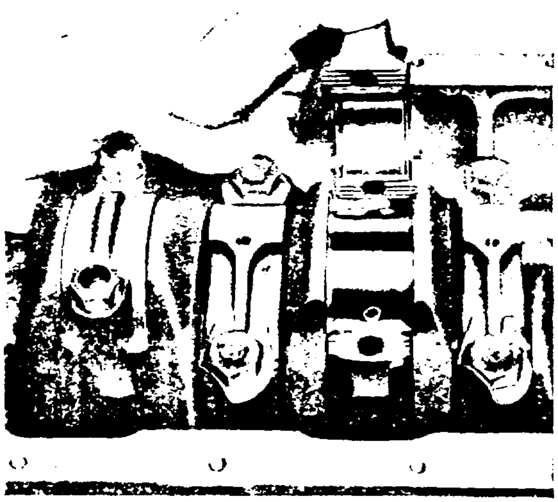


*Fig. F.1.*
*Removing a Big End Bearing Cap.*

5. Push pistons and connecting rods out of the top of the cylinders (Refer Fig. F.2).

6. Turn the engine crankshaft until the next two big ends are at bottom center and repeat removal operations.

**Note: Carbon deposits around the top of the cylinder bores should be removed before**

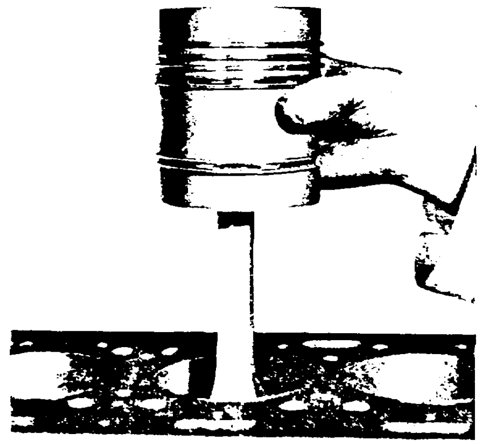


*Fig. F.2.*

*Removing Piston and Connecting Rod Assembly from Cylinder Bore.*

**attempting to remove the pistons. Keep each piston and connecting rod assembly separate, each to each as marked.**

**To Remove Pistons and Rings from Connecting Rods**

1. Remove the three compression rings and the two scraper rings from each piston.

2. Remove tile circlips retaining the gudgeon pin. using circlip pliers, and withdraw the gudgeon pin. If the gudgeon pin is tight in the piston bore, warm the piston in clean liquid to a temperature of 100°/120°F (40°/50°C) and the gudgeon pin will then he easily pushed out.

**Inspection**

1. Thoroughly clean all the dismantled components.

2. Examine the pistons for scoring. Check the clearance of the piston rings in their respective ring grooves (see Technical Data).

3. Check the fitted gap of the compression and scraper rings. In worn cylinders the gap should be checked at the bottom of the cylinder. For details of ring gap dimensions (see Technical Data).

4. Check the fit of the gudgeon pin in the piston bore and in the small end bush of the connecting rod. The pin is a transition fit in the piston, i.e. within the limits of —0.00015 in (0.004 mm) to +0.00025 in (0,006 mm). The clearance dimension between the gudgeon pin and the small end bush of the connecting rod is between 0.00075 in (0.01q mm) and 0.0017 in (0,04.3 mm). For details of piston bore, gudgeon pin and small end bush bore diameters see Technical Data. To renew the small end hush, press out the old bush using a suitable tool. Remove any sharp edges around the small end parent bore. Press in the new bush, ensuring that the oil hole in the hush coincides with the hole in the connecting rod. Ream out the

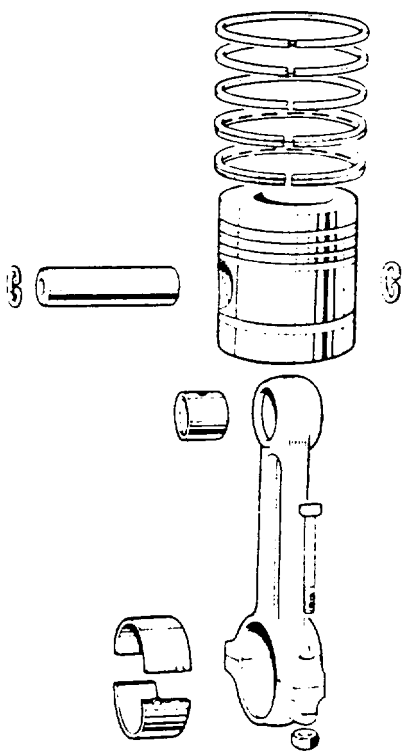


*Fig. F.3.*
*Exploded view of Piston and Connecting Rod Assembly.*

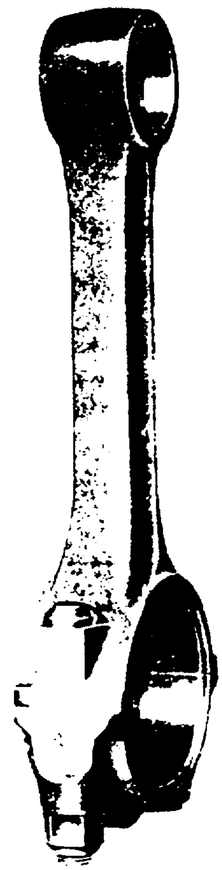


*Fig. F.4.*
*Numbering of Connecting Rods and Caps.*

new bush to suit the gudgeon pin and check the connecting rod for parallelism (see Technical Data).

5. Examine the big end bearing shells for wear and scoring. Also examine the crankpins and if necessary, remove the crankshaft, regrind the crankpins and fit undersize bearing shells. These are available in undersizes of 0.010 in (0,25 mm), 0.020 in (0,51 mm) and 0.030 in (0,76 mm). For details of crankshaft removal see Page H.31.

6. If the engine has been in service for a lengthy period, it is advisable to fit new piston circlips even if the old ones do not appear to be strained or damaged.

**To Assemble the Pistons and Rings to the Connecting Rods**

If the original pistons are being used they must be assembled to the same connecting rods, i.e. the piston stamped 1 on the crown must be fitted to the rod marked 1. For markings of pistons and connecting rods see Figs. F.4 and F.6.

1. Warm the piston in clean liquid to a temperature of 100°/120°F (40°/50°C). It will he noted that the cavity in the piston crown is off-set towards one side of the piston. Therefore, place the piston on the connecting rod with the cavity towards the side of the rod which carries the rod and cap identification numbers. Insert the gudgeon pin and fit the retaining circlips ensuring that they are seating correctly in the piston grooves.

2. Check the fitted ring gap of the compression and scraper rings (see Technical Data).

   **Note: Then checking fitted ring gap in worn cylinders, the ring should be checked at the bottom of the cylinder.**

3. Fit the piston rings to the piston in the following order:

   Slotted Scraper—
   below the gudgeon pin.
   Spring Expanded Oil Control—
   above the gudgeon pin.
   Internally Stepped Compression—
   third groove.
   Internally Stepped Compression—
   second groove.
   Chromium Plated Compression—
   top groove.

   **Note: When fitting internally stepped compression rings, ensure that the "step" is towards the piston crown.**

**To Fit the Pistons and Connecting Rods to the Cylinder Bore**

1. Before fitting the piston and connecting rod assemblies to their respective cylinder bores, thoroughly clean and liberally coat each bore with clean engine oil.

2. Using a suitable ring guide (see Fig. F.5), insert the pistons and connecting rods into the top of the cylinder bores, ensuring that

*Fig. F.5.*
*Piston Fitting with the aid of an adjustable ring clamp.*

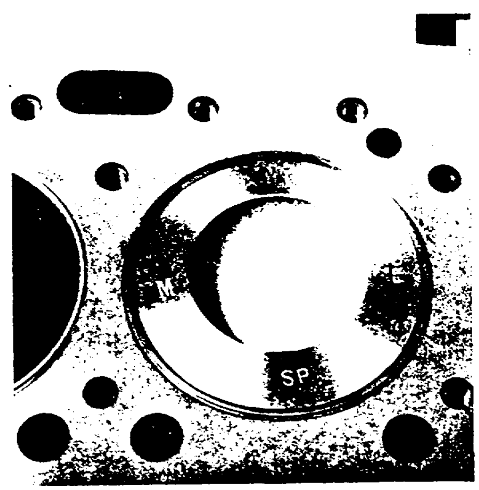



*Fig. F.6.*
*Showing markings on Piston*

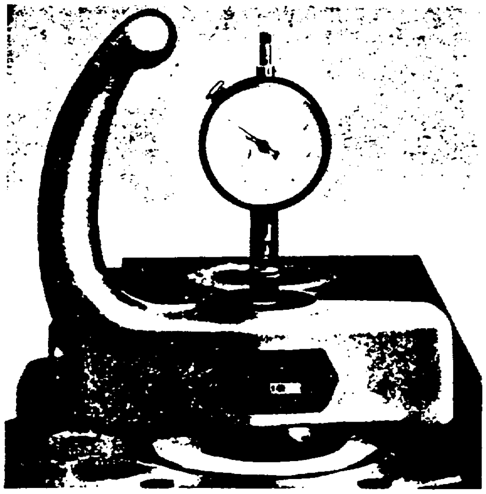


*Fig. F.7.*

*Checking Piston Height In relation to Cylinder Block Top Face*

the piston and rod numbers relate to the cylinder into which they are being fitted. Ensure that with the rod identification number opposite to the camshaft, the word "Front" marked on the piston crown is towards the front of the engine. If not, remove the piston from the connecting rod and refit correctly as previously detailed.

3. Turn the crankshaft until the appropriate crankpin is at bottom center, draw the connecting rod to the bearing shell, locating it in the tag slot.

4. Refit the other correct half bearing shell to the cap, again locating it in the tag slot, and refit the cap and bearing shell ensuring that the numbers stamped on the rod and cap coincide. Refit the two connecting rod bolts with the flat on the head of each bolt located against the milled shoulder on the rod. Secure with two new nuts to a torque wrench setting as given on Page B.1.

5. Refit the lubricating oil sump (see Page L.5).

6. Refit the cylinder head (see Page E.6).

**Fitting New Pistons**

When fitting new pistons it is essential to see that the piston and connecting rod are assembled correctly before fitting them to the engine, see "To Assemble the Pistons and Rings to the Connecting Rod."

Ensure that genuine Perkins parts are used, so that the new piston height will, when assembled, in the engine, comply with the tolerances as listed in "Technical Data" - Page B.2.

**NOTE: As from Engine Nos. 236U135765 and 236U147150L, the pistons must be topped to the correct height above the cylinder block face as given on page B.2.**

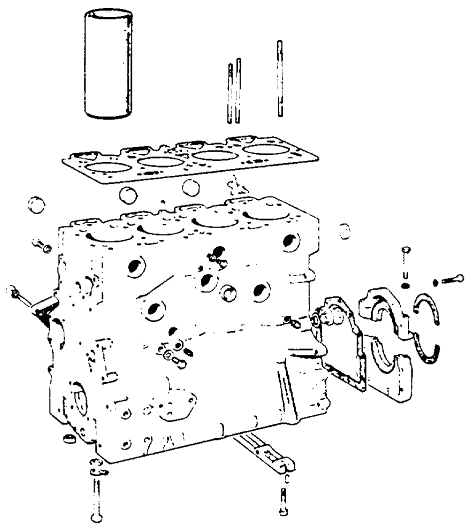


*Fig. G.1.*
*Exploded view of Cylinder Block Assembly.*

**To Renew Bush in No. 1 Camshaft Bore**

Current 4.236 marine engines have a bush fitted into No. 1 camshaft bore in the cylinder block.

A prefinished bush is available to replace a worn bush.

The worn bush may be extracted and replaced by a new one.  making sure that the oil holes in the bush and cylinder block correspond.

**CYLINDER LINERS**

Cast iron interference fit dry liners are fitted to the 4.236 marine engine.  These liners may be rebored to 0.030 in (0,76 mm) oversize, but during this operation it is most important to ensure that the true alignment of the bores relative to the crankshaft axis is maintained.

**To Renew Cylinder Liners**

1. Remove all engine components from the cylinder block (see appropriate sections for removal of these).

2. Remove the cylinder head studs from the cylinder block.

3. The liners are pressed out through the top of the cylinder block using a shouldered metal disc slightly smaller on the outside diameter than the parent bore size.  Ensure that no damage is caused to the parent bore.

4. Ensure that the cylinder bores are perfect, clean and free from burrs etc.

5. Thoroughly wash oil any grease etc. from the new liner with cleaning fluid, and dry thoroughly.  When fitting replacement liners ensure that the correct type is used.

6. Lubricate the outside diameters of the liner with clean oil and press them in until 0.028  0.035 in (0,71/0,89 mm) of the liner Is protruding above the cylinder block face.  Shin washers or a solid stop washer 0.028  0.035 in (0,71/0,89 mm) thick should be used when pressing the liners into the cylinder block In order to give the necessary protrusion

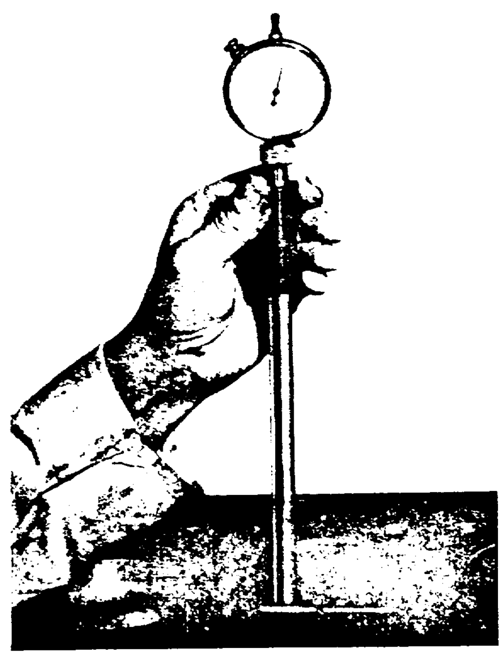


*Fig. G.2.*
*Dimensional check of Cylinder Bore*

*Fig. G.3.*
*Checking Cylinder Liner Protrusion above top face of Cylinder Block.*

7. Bore and finish hone the liners to the dimension given in "Technical Data." The above liner protrusion may create difficulties where boring equipment is mounted on the top face of the cylinder block. This may be overcome by making a parallel plate to fit between the boring bar and cylinder block face. Such a plate should be thicker than .035 in (0,89 mm) and have holes bored in it to give clearance around the protruding liners.

8. Assemble the engine components to the cylinder block (see the appropriate sections for assembly of these).

**Oversize Cylinder Liners**

Oversize outside diameter cylinder liners are available for fitment in service where the standard parent bore is enlarged to remove damage.

They are available as follows:-

| Oversize | Description |
|---|---|
| 0.005 in (0,13 mm) | Cast Iron Flangeless-bore and hone |
| 0.010 in (0.25 mm) | Cast Iron Flangeless-bore and hone |

Where a parent bore is reclaimed in service, it should be machined to the dimension by adding the appropriate liner oversize to the parent bore diameter given on Page B.2. The top of the parent bore must be re-chamfered after machining.

Where 0.005 in and 0.010 in oversize liners are fitted, the liner oversize should be stamped on the cylinder block top face between the liner and the edge of the cylinder block.

## CRANKSHAFT AND MAIN BEARINGS

The crankshaft runs in fi ve pre-finished replaceable shell bearings lined with aluminum tin.

Crankshaft end float is controlled by four thrust washers which are located on both sides of the center main bearing housing. 0.0075 in (0,19 mm) oversize thrust washers are available which may he combined with standard thrust washers to give an adjustment of 0.0075 in (0.19 mm) or when used on both sides of the bearing housing, give an adjustment of 0.(15 in (0.,38 mm).

The main bearings are located in position by tabs fitting into slots machined in the bearing housings.

> **Note: Main bearing cap setscrew tabwashers have been deleted on later engines. It is therefore no longer necessary to replace these tabwashers when fitting main hearing cap setscrews. The tightening torque for these setscrews remains unchanged.**

### To Remove Main Bearings and Thrust Washers

Under normal circumstances, by the time the main bearings, require renewing the crankshaft will need to be removed for regrinding. However,

*Fig. H.1.*
*Removing a Main Bearing Cap.*

*Fig. H.2*
*Removing a Main Rearing Shell with the Crankshaft "in situ."*

removal of main bearing and thrust washers can he carried out without withdrawn the crankshaft. Proceed as follows : —

1. Remove the sump. sump strainer and the oil pump suction and delivery pipes (see page L.3).

2. Remove the two setscrews securing the main bearing cap. Only remove one bearing cap at a time.

3. Slacken the setscrews on the remaining bearing caps. To gain access to the rear main bearing setscrews, the rear main bearing bridge piece must be removed. This is secured by two recessed setscrews to the cylinder block and the two lower rear main oil seal housing securing setscrews. Access to the front main bearing setscrews can be achieved by removing the lubricating oil pump (see Page L.3).

4. Remove the lower half of the bearing from the bearing cap and with a suitable piece of thin hard wood push out the top half of the bearing by rotating it on the crankshaft, apply the wooden strip to the opposite side

of the one with the tag (see Fig. H.2).

**Note: If the original bearings are to be refitted, identify each bearing half to its respective position.**

5. If the thrust washers require removal, it is necessary to remove the center main bearing cap. Remove the two bottom half thrust washers from the recesses in the center main bearing cap. The two top half thrust washers should be removed by sliding round from one side, using a suitable piece of thin hard wood, until withdrawal can be effected. Identify each thrust washer half to its relative position.

### To Refit Main Bearings and Thrust Washers

1. Refit the main bearing half to the bearing cap locating it in the tag slot. Liberally oil the other half of the bearing, insert it plain end first and slide it around the crankshaft journal until the locating tag locates in its slot. Oil the cap half of the bearing and refit the cap securing with the two setscrews and shim washers. Tighten the setscrews to a torque setting as given on Page B.1.

   **Note: Make sure that the bearing caps are fitted to their original positions. Each cap is numbered to correspond with its engine position commencing with No. 1 at the front of the engine. Each cap is also marked with a serial number as stamped on the cylinder block bottom face. These should read in line (see Fig. H.3).**

2. Tighten the setscrews on the remainder of the bearing caps, which were slackened off, ensuring they are tightened to the correct torque setting.

3. To refit the thrust washers, liberally oil the two upper halves with lubricating oil and slide them into the recesses provided on either side of the main bearing housing. The steel side of the thrust washers should be towards the bearing housing and the cap. Position the two lower halves on either side of the bearing cap and refit the cap. Secure with the setscrews tightened to the torque setting given on Page B.1.

4. Check the crankshaft end float to ensure that a clearance of 0.004/0.015 in (0.102/0,38 mm) exists.

5. Refit the rear main bearing bridge piece together with new joints between the cylinder block and bridge piece and new sealing rubbers at the bridge piece ends (see Fig. H.6). Secure the bridge piece to the cylinder block with the two recessed screws and fit the two setscrews securing the rear main bearing oil seal housing to the bridge piece.

6. Refit the oil pump as detailed on Page L.5.

7. Refit the oil delivery and suction pipes to the oil pump.

8. Refit the sump strainer and sump.

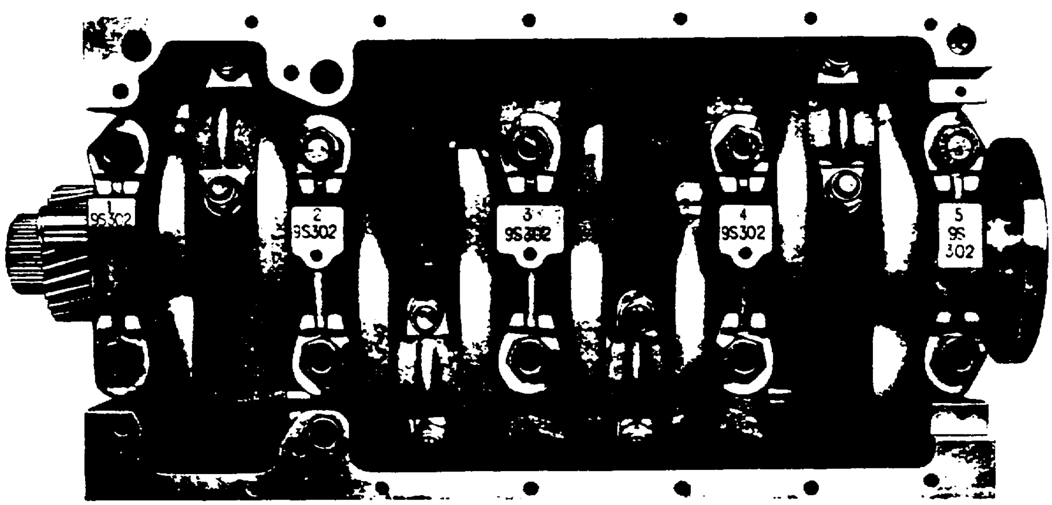



*Fig. H.3.*
*View of Crankcase showing Serial Numbers and Identification Numbers.*

## To Remove the Crankshaft

To carry out this operation, it will be necessary to remove the engine from the application and mount it in a suitable dismantling stand.

If the original components are to be refitted they should be suitably marked for re-assembly to their original positions.

1. Remove the sump, sump strainer and the oil pump suction and delivery pipes.
2. Remove the timing gears and timing case. (See Page K.3).
3. Remove the starter motor, flywheel and flywheel housing.
4. Remove the connecting rod caps and big end bearings (See Page F.1).
5. Remove the rear main oil seal housing.
6. Take off the rear main bearing bridge piece.
7. Remove the oil pump from the front main bearing cap (See Page L.3).
8. Remove main bearing cap setscrews.
9. Remove the main bearing caps and half bearings.
10. Lift out the crankshaft and remove the other half bearings.

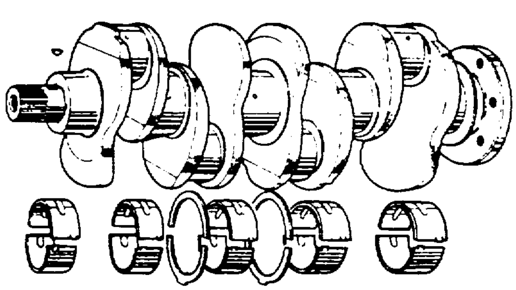


*Fig. H.4.*
*Exploded view of Crankshaft and Main Bearings.*

## Regrinding the Crankshaft (see Data, Page H.8)

Before regrinding the crankshaft, the following points should be checked to ensure it is suitable for further machining.

(a) The crankshaft should be crack-detected before regrinding. It must, of course, be remembered to demagnetize the crankshaft after crack detecting, in order to remove any polarization which may be present.

(b) The main journal and crankpin diameters should be checked to ascertain the next appropriate size to which the crankshaft can be reground, i.e., —0.010 in (—0.25 mm), —0.020 in (—0,51 mm) or —0.030 in ( —0.76 mm). If the crankshaft requires to be reground below -0.030 in (-0,76 mm) it is recommended that a new crankshaft be fitted. See "Technical Data" for crankshaft regrind dimensions.

(c) The dimensions given in "Technical Data' for the crankpin width apply only to a standard crankshaft. It will be appreciated that this dimension may increase as the crankpins are reground. but after regrinding the maximum width should not exceed 1,635 in (41,53 mm). During regrinding, all the limits must be adhered to, and the main journals and crankpins must be free from grinding marks.

After regrinding, the sharp corners on the oil holes should be removed and the crankshaft crack detected again and demagnetized.

**Note: It is important that the radii on the main journals and crankpins are maintained. If these are neglected, a fracture is liable to occur.**

## To Refit the Crankshaft

1. Ensure all oilways are free from obstruction.
2. Check the main bearing setscrews for stretch or damage to the threads. In no case should setscrews other than those supplied by the engine manufacturer be used as they are of a special heat treated high grade steel.

3. Clean the bearing housings and place the top half bearings in position. Liberally oil the bearings with clean oil.

4. Place the crankshaft in position.

5. Oil the two upper thrust washer halves and slide them into the recesses provided on either side of the center main bearing housing.

6. Fit the lower halves of the main hearings to the hearing caps. Oil the hearings and place the caps in their respective positions ensuring that the lower halves of the thrust washers are correctly positioned on either side of the center main bearing cap. When replacing the main bearing caps, ensure that they are fitted in their respective positions, also that they are fitted the correct way round. The caps are numbered, No. I commencing at the front of the engine. Each cap is also marked with a serial number as stamped on the cylinder block bottom face. These should read in line (See Fig. H.3).

7. Examine main bearing setscrews for damage of threads, etc., replace where necessary. It is no longer necessary to fit tab washers to main bearing setscrews.

8. Evenly tighten the main hearing setscrews to a torque wrench setting as given on Page B.1.

9. Check the crankshaft end float to ensure that a clearance of 0.002/0.015 in (0,05/0,38 mm) exists. Oversize thrust washers may be fitted (see Fig. H.5)

10. Refit the connecting rod caps and big end bearings (See Page F.4).

11. Refit the rear main bearing bridge piece to the cylinder block together with new joints and sealing rubbers (see Fig. H.6). Ensure that the rear face of the bridge piece is in alignment with the rear face of the cylinder block (see Fig. H.7).

12. Fit new sealing strips to the rear main bearing oil seal housings and refit the housings as described in Rope Type Crankshaft Rear End Oil Seal. With lip type seals, refit oil seal housing as described in Lip Type Crankshaft Rear End Oil Seal.

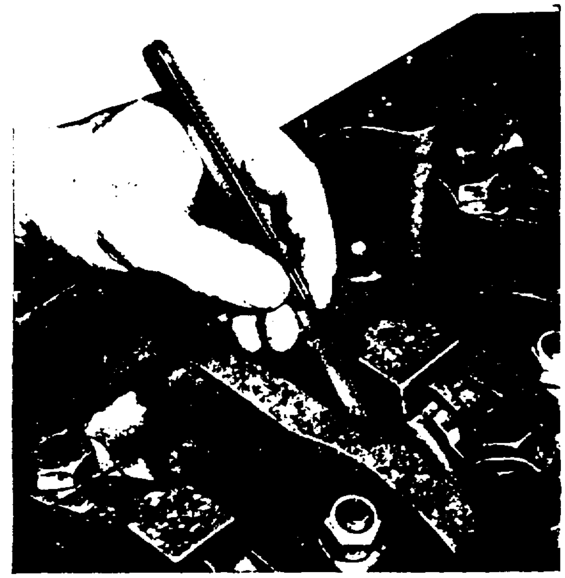


*Fig. H.5*
*Checking the Crankshaft End Float.*

13. Refit and correctly align tile flywheel housing as described on Page P.3. Refit the flywheel and starter motor.

14. Refit the oil pump, timing case and timing gears (see Page L.5 and K.3)

15. Refit the sump, sump strainer and the oil pump suction and delivery pipes.

**ROPE TYPE CRANKSHAFT REAR END OIL SEAL**

The housing consists of two halves bolted around the rear of the crankshaft which has a shallow spiral oil return groove machined in it to a depth of 0.004/0.008 in (0,10/0,20 mm). The bore of the housing is machined to accommodate a rubber cored asbestos strip. The strip consists of two sections, one for each half of the oil seal housing.

When fitting the seal the following procedure should be adopted:—

1. Set up a half housing in the vice with the seal recess uppermost.

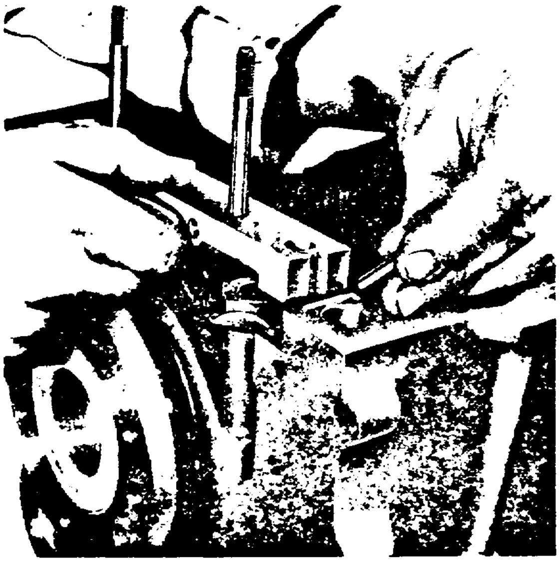


*Fig. H.6.*
*Refitting the Cylinder Block Bridge-Piece.*

2. Settle approximately 1 in (25 mm) of the strip, at each end, into the ends of the groove ensuring that each end of the strip projects 0.010/0.020 in (0,25/0,50 mm) beyond the half housing joint face. Allow the middle of the seal to bulge out of the groove during this operation.
3. With the thumb or Linger press the remainder of the strip into the groove, working from tile centre, then use any convenient round bar to further bed in the strip by rolling and pressing its inner diameter as shown in Fig. H.8. This

*Fig. H.7.*
*Aligning Bridge-Piece to Block Face.*

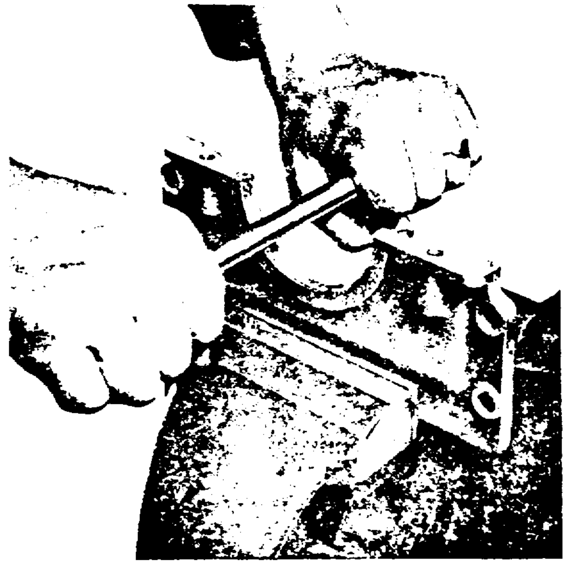


*Fig. H.8.*
*Bedding in the Rear Main Oil Seal.*

procedure takes advantage of the friction between the strip and the groove at the ends, to compact the rope whilst ensuring that the projections of the end faces of the rope remain as set.

4. Fit the sealing strip to the other half housing in a similar manner.
5. Remove all traces of the old joint from the cylinder block rear face and tit a new joint treated with a suitable jointing compound.
6. Lightly coat the faces of the housing with a suitable jointing compound.

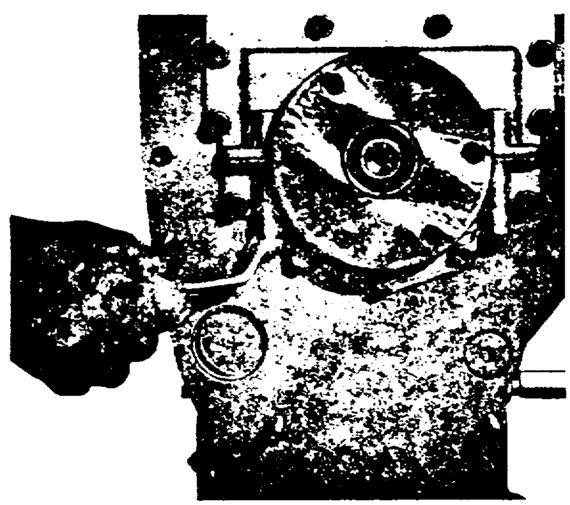


Fig. H.9. Oil Seal Housing securing Setscrews.

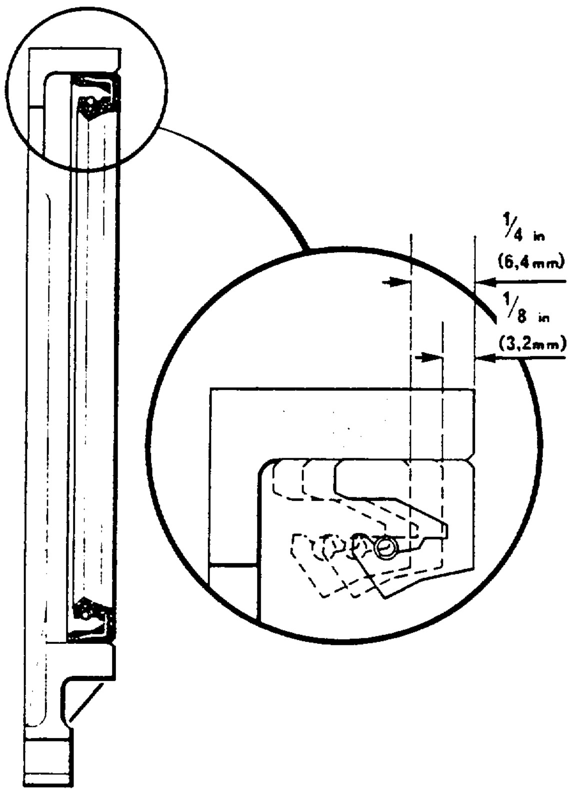



*Fig. H.10.*
*Three Positions for Lip*
*Type Rear Main Oil Seal.*

7. Spread a film of graphite grease over the exposed inside diameter surface of the strip.
8. Assemble the half housings around the crankshaft rear journal and fasten together by the two setscrews (see Fig. H.9).
9. Swivel the complete seal housing on the shaft to bed in the strips, and to establish that the assembly turns on the shaft.
10. Bolt the seal housing in position on the block and the rear main bearing cap bridge piece and finally tighten with setscrews and spring washers.

## LIP TYPE CRANKSHAFT REAR END OIL SEAL

On some engines, a circular, spring loaded, lip seal is fitted, which locates on the periphery of the flange of the crankshaft. On production, this seal is fitted with its rear face flush with the rear face of the single piece housing.

This type of seal is easily damaged and extreme care should be taken when handling and fitting it to its housing or to the crankshaft. Any visual damage across the lip of a new seal will cause leakage and prevent bedding in of the new seal.

The seal is designed to function correctly with the direction of rotation of the engine and for identification purposes, the seal is marked with an arrow.

On production the seal is fitted with its rear face flush with the rear face of the housing. In service, when a new seal is to be fitted to a worn crankshaft, it should be pressed further into the housing, in the first instance to 1/8 in (3,2 mm) or, if this position has been used, to 1/4 in (6,4 mm) from the rear face of the housing — see Fig. H.10.

If all three positions have been used, it may be possible to machine the worn sealing area of the crankshaft flange, but not the spigot area on which the flywheel locates — see Fig. H.11. When a new seal is fitted to a new or reconditioned crankshaft, it should be fitted with its rear face flush with the housing.

Before fitting the seal in the housing, carefully examine the seal for damage, especially on the lip and outside diameter.

Using clean engine lubricating oil, lubricate the outside diameter of the seal and the inside diameter of the housing.

Press the seal into the housing to the required position, taking care that the seal is entered and pressed in squarely, otherwise damage to the outside diameter of the seal may occur, or if it is not square in the housing when fitted to the engine it may leak.

The seal and housing should be fitted, using seal guide PD 145 (Churchill Tool) as follows: —

Clean the faces of the cylinder block and oil seal housing, and the outside diameter of the crankshaft flange.

Check that the seal and the outside diameter of the crankshaft flange are not damaged. Where a new seal has been fitted, check that it is in the correct position as previously detailed.

Ensure that the two dowels are fitted in the cylinder block. Coat both sides of the housing with Perkins (Hylomar) Jointing Compound and position the joint over the dowels in the block.

Using clean engine lubricating oil, lubricate the crankshaft flange, the seal and the seal guide. The lubrication of the seal is necessary to prevent damage that may be caused by initial dry running.

Position the seal and housing on the seal guide, locate and guide on the crankshaft flange and gently press the seal and its housing into position on the flange, locating the housing on its dowels.

Withdraw the guide and secure the housing with setscrews and washers.

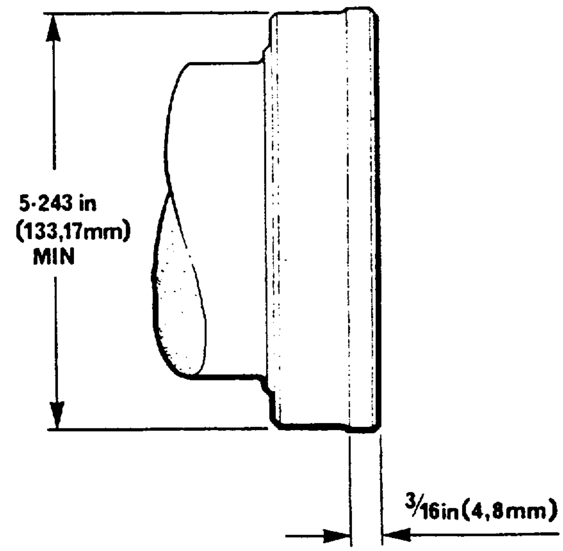



*Fig. H.11.*
*Regrinding of Crankshaft Flange for Lip Type Rear Oil Seal.*

**FOR CRANKSHAFT REGRINDING DATA SEE NEXT PAGE (H8).**

## Crankshaft Regrinding Data

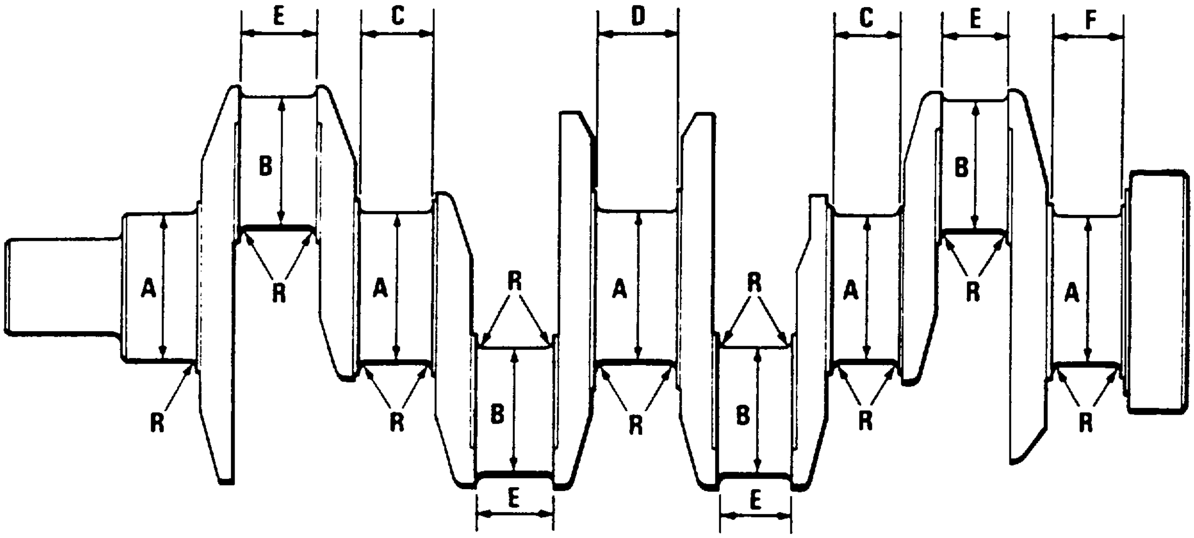



*Fig. H.12.*

| | 0.010 in (0.25 mm) Undersize | 0.020 in (0.51 mm) Undersize | 0.030 in (0.76 mm) Undersize |
|---|---|---|---|
| A | 2.9884/2.9892 in (75,91/75.93 mm) | 2.9784/2.9792 in (75.65/75.67 mm) | 2.9684/2.9692 in (75.40/75.42 mm) |
| B | 2.4888/2.4896 in (63,22/63,24 mm) | 2.4788/2.4796 in (62.96/62.98 mm) | 2.4688/2.4696 in (62.70/62.72 mm) |

C 1.554 in (39,47 mm) maximum
D 1 759 in (44,68 mm) maximum
E 1.5965 in (40.,55 mm) maximum
F 1.554 in (39,47 mm) maximum
R 0.145/0.156 in (3,68/3,96 mm) all journals and crankpins.
Surface finish, journals and crankpins 16 micro inches (0.4 microns) maximum C.L.A.
Surface finish, fillet radii 32 micro inches (0,8 microns) C.L.A.

Magnetic crack detection — D.C. Flow - 2 amps — A.C. Current - 1600 amps.

Limits of taper and out of round of pins and journals:
Taper 0.00035 in (0,009 mm) — Out of Round 0.0004 in (0.010 mm)

Maximum Run-out with the crankshaft mounted on the end main journals.

Independent readings:

| Crankshaft pulley Diameter T.I.R. | Rear Oil Seal Diameter T.I.R. | Flywheel Flange Diameter T.I.R. |
|---|---|---|
| 0.002 in (0.05 mm) | 0.002 in (0.05 mm) | 0.002 in (0,05 mm) |

Journals T.I.R. - Run-out must not be opposed

| Number 1 | Number 2 | Number 3 | Number 4 | Number 5 |
|---|---|---|---|---|
| Mounting | 0.003 in (0.08 mm) | 0.006 in (0,15 mm) | 0.003 in (0.08 mm) | Mounting |

On certain applications a balancer unit is incorporated in the engine sump, from which the lubricating oil pump is driven.

It is important to note that, on some of these applications, a crankshaft is fitted which has no balance weights, as distinct from the crankshaft on other applications which incorporates balance weights which are forged in the manufacturing process.

When replacing a crankshaft, the correct type should be fitted as determined by the displaced crankshaft.

It is also important to note that balancer units vary according to which side of the engine, the lubricating oil filter is fitted. When replacing a balancer unit, always ensure that the correct type is being fitted.

**To Remove**

Remove the lubricating oil sump.

Remove the balancer unit assembly, complete with the lubricating oil pump.

**To Dismantle**

Remove the seven setscrews and washers securing the lubricating oil pump to the balancer unit.

Remove the oil pump complete with backplate and driving gear, if possible. Should the backplate and driving gear remain in position on the balance unit they must be removed separately.

From the front of the balancer unit, remove the idler gear hub retaining nut or setscrews.

Remove the idler gear hub, idler gear and thrust plate.

Remove the two socket headed grubscrews in each of the balance weights.

Press out each of the shafts in turn, towards the drive end, taking care that the keys in the shafts do not foul the bushes in the drive end of the balancer frame. Insufficient care could result in the bushes being damaged and this would mean replacement of the complete frame assembly.

Both balance weights may now be lifted from the balancer frame, complete with their respective gears.

Should it be necessary to renew either the balance weights or coupling gears, remove the three socket headed capscrews in each balance weight assembly and take off the coupling gears.

Remove the two thimbles which locate between the frame and cylinder block.

Remove the seven plugs from the oilways in the balance frame and clean out the oilways.

**Important**

**When refitting the socket headed capscrews which secure the coupling gears to the balance weights, also the socket headed grubscrews in the balance weights and the idler gear and hub securing stud, "Loctite" grade A, should be used on the threads in the following manner: —**

**Use of "Loctite"**

Thoroughly clean both male and female threads with a suitable degreasing fluid (not kerosene), allowing 15 minutes for it to dry. It is recommended that, where possible. "Locquic" Q Activator be used for this purpose as it will considerably reduce the curing time.

Apply a light coating of "Loctite" grade A, to both male and female threads, fit the stud or screw and tighten to the .specified torque.

A curing period of 24 hours (1 hour if "Locquic" Q Activator has been used) at room temperature must now be allowed before the engine is started.

**To Re-assemble the Unit**

**Note**

**Replacement bushes for the balancer frame are not serviced separately and if wear is evident, a replacement balancer frame assembly must be obtained, complete with bushes already line-bored. Some later balancer units may have needle bearings fitted in place of bushes and are not interchangeable with bushes.**

Where needle race bearings are fitted, then the balancer unit drive and driven shafts, needle bearings, keys and oil pump gears must be changed after 5,000 hours operation.

Current balancer units have reversed balance weights where the gears are fitted to the rear of the weights instead of the front as shown in Fig. J.1. and thicker section roller race bearing are fitted.

**BALANCER UNIT - J.2**

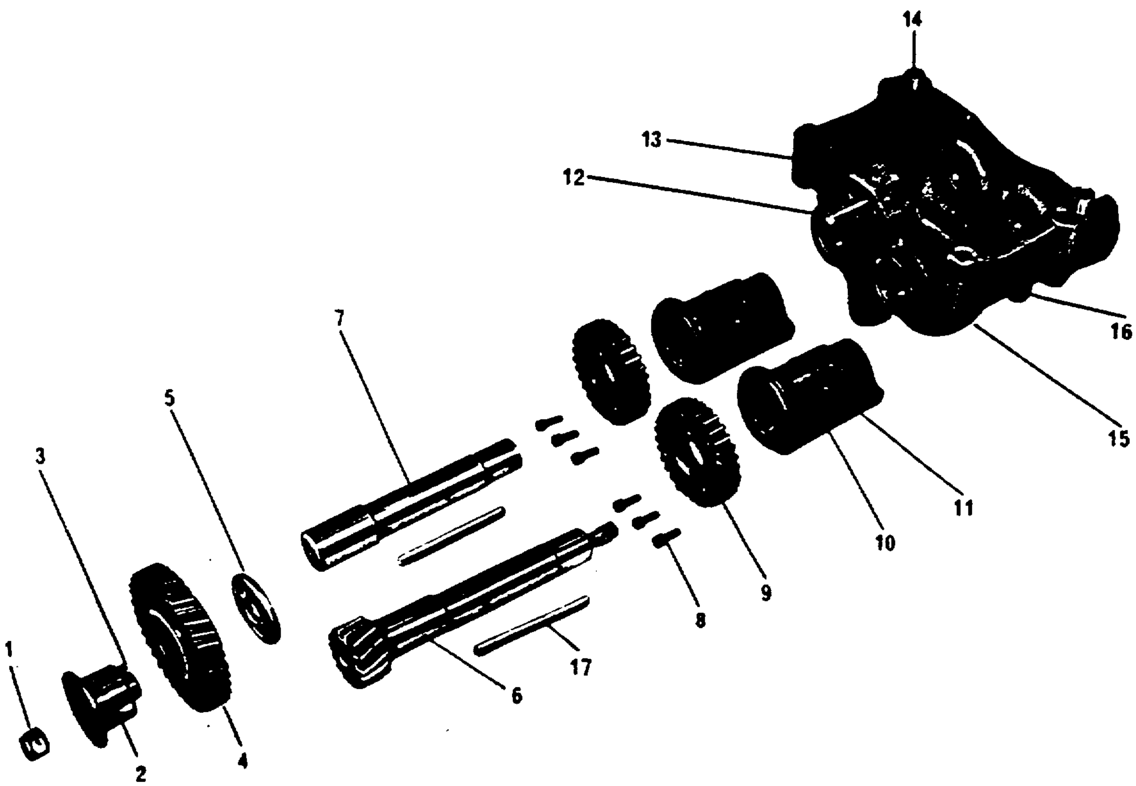



*Fig. J.1.*
*Exploded View of Balancer Unit*

| | | |
|---|---|---|
| 1. | Idler Gear Hub Retaining Nut or Setscrew (later engines) | 1 |
| 2. | Idler Gear Hub | 1 |
| 3. | Idler Gear Hub Dowel | 1 |
| 4. | Idler Gear Assembly (complete with bush) | 1 |
| 5. | Idler Gear Thrust Plate | 1 |
| 6. | Driving Shaft | 1 |
| 7. | Driven Shaft | 1 |
| 8. | Balance Weight Gear Retaining Screws | 6 |
| 9. | Balance Weight Gear | 2 |
| 10. | Balance Weight | 2 |
| 11. | Balance Weight Locating Screw | 4 |
| 12. | Idler Gear Hub Stud | 1 |
| 13. | Balance Weight Frame Plug | 5 |
| 14. | Frame to Cylinder Block Thimble | 2 |
| 15. | Frame Assembly (complete with bushes) | 1 |
| 16. | Balance Weight Frame Plug | 2 |
| 17. | Balance Weight Locating Key | 2 |

When replacing needle or roller race bearings, they should not be hammered in, but pressed in using a suitable dolly. Needle race bearings should be pressed in to a minimum of 0.008 in (0,20 mm) from the end of the housing. Thicker section roller race bearings should be pressed in so that a clearance of 0.030/0.040 in (0,76/1,02 mm) is left between the end faces of all bearings and inside face of the frame bosses.

Having renewed any part showing signs of wear, proceed as follows:—

Replace the seven plugs in the oil drillings of the balancer frame.

Should it have proved necessary to renew the idler gear and hub securing stud, fit the new stud, using "Loctite".

Should it have been necessary to remove the coupling gears from the balance weights, using "Loctite", re-assemble. finally tightening the socket headed capscrews to a torque of 11 Ibf ft (1.52 kgf m) - 15 Nm.

Where necessary, renew the shaft keys.

Stand the balancer unit on its lubricating oil pump end face.

Place the two balance weights complete with gears into the frame, coupling the gears so that when the shafts are partially entered, the keys are in the same relative position, i.e., both at top dead centre or both at bottom dead centre.

Ensure that each shaft is related dead centre to the bushes at the front end rear of the frame and press in until the drive shaft (with integral gear) is fully home and the end of the driven shaft is flush with the drive end face of the balancer frame.

Extreme care must be taken when pressing in the shafts, to prevent the keys from touching the drive end bushes (where fitted) or the needle bearings as they pass through. The slightest damage caused this way could result in seizure of the unit and severe consequential damage to the engine.

Using "Loctite", fit the two grubscrews to each balance weight and tighten to a torque of 7-1/2 Ibf ft (1,03 kgf m) - 10 Nm. Do not omit degreasing before using "Loctite".

Fit thrust plate, idler gear and hub so that the single centre punch mark on the idler gear registers between the two punch marks on the integral balance shaft gear. Ensure that the dowel in the hub locates in the corresponding hole in the balancer frame.

Fit the idler gear and hub retaining nut or setscrew and tighten to a torque of 40 Ibf ft (5.53 kgf m) - 54 Nm.

Revolve the unit by means of the idler gear to ensure that the action is quite free.

Place the oil pump back plate in position at the rear of the balancer unit.

Fit the oil pump drive gear onto the end of the balancer drive shaft.

Fit the oil pump idler gear onto the idler shaft in the pump and refit the pump housing to the balancer unit, securing with seven setscrews and washers to a torque of 21 lbf ft (2.90 kgf m) 29 Nm.

Revolve the balancer unit idler gear once more to ensure freedom.

Continue revolving the idler gear until the punch marks once more coincide. This may take several revolutions.

To Replace

Place the two locating thimbles into their bores and refit the balancer unit to the cylinder block, ensuring that the single centre punch mark on the crankshaft gear registers between the two punch marks on the idler gear of the balancer unit.

The balancer unit is now timed to the engine. When fitting the balancer unit to an engine where the front end has not been stripped, it will not be possible to observe the punch mark on the crankshaft gear for the purposes of timing the unit to the engine.

In this case, the engine should firstly be rotated so that either the piston of No. 1 or No 2 cylinder is at top or bottom dead centre. Bottom dead centre is preferable as any error greater than one gear tooth will cause a foul between the weights and the connecting rod in this position, making it obvious that the balancer unit has been timed wrongly.

Revolve the idler gear until the single centre punch mark on the idler gear registers between the two punch marks on the balancer shaft drive gear.

Suitably mark with chalk, a tooth of the drive to align with another chalk mark on the frame.

In this position, fit the balancer unit to the engine, checking that the weights have not moved by observing alignment of the chalk marks.

As a further check, observe that the single punch mark on the idler gear still registers between the two punch marks on the balancer shaft gear, **in alignment with the gear centres**. Accuracy in timing the balancer unit to the engine is essential as an error will cause serious consequential damage to the engine.

The ability to turn the engine over by hand is not necessarily proof that the balancer unit is correctly timed.

Secure the balancer unit to the cylinder block with four setscrews and washers, tightened to a torque of 36 lbf ft (4,98 kgf m) - 49 Nm.

After fitting the balancer unit to the cylinder block and especially in the case where a new balancer unit frame has been incorporated,. check to see that there is clearance between the balancer unit frame and No. 1 main bearing cap.

Refit the sump in the normal manner, as described in the relevant service literature.

**Running-In**

After renewing any parts, the balancer unit must be carefully run-in and this should be effected by firstly running the engine at fast idle for a period of half an hour, followed by a further half hour at 1,000 rev/min.

**NOTE**

**Replacement bushes are not serviced separately for the idler gear. A replacement idler gear, complete with pre-finished bush must be fitted.**

**The stud which secures the idler gear and hub to the balancer frame is available as a spare part but need not be removed from the balancer frame unless it requires replacing**.

## TIMING CASE AND DRIVE

### To Remove the Timing Case Cover

1. Slacken the dynamo/alternator mounting bolts, release the adjusting arm and ease the driving belt from the pulleys.
2. Remove the four setscrews which secure the power take-off shaft to the crankshaft pulley front face and remove the power take-off shaft.
3. Remove the tachometer drive and heat exchanger support bracket which are mounted on the face of the timing cover.
4. Remove the crankshaft pulley retaining setscrew and washer, and withdraw the pulley. Remove the setscrews and nuts which secure the timing case cover to the timing case. Withdraw the timing case cover taking care not to damage the crankshaft front oil seal which is located in the cover.

### To Renew the Crankshaft Front Oil Seal

1. Using a suitable dolly and press, remove the oil seal from the timing case cover.
2. Locate the new seal in the bore of the cover from the front.
3. Press the new seal into position until the front face of the heal is 1 in (6.35 mm) below the front face of the cover.

   The seal is designed to function correctly with the direction of rotation of the engine and for identification purposes, the seal is marked with an arrow.

   Earlier engines were fitted with a black nitrile seal and a crankshaft oil thrower.

   Current engines have a red silicone seal and ,the oil thrower is replaced with a distance piece. Under no circumstances should the latest red seal be fitted with an oil thrower.

### Tachometer Drive

The tachometer angle drive mounted on the timing case front cover should be greased with a high melting point grease in accordance with Preventive Maintenance given on Page C.3.

Grease starvation of the angle drive gears can result in overloading and subsequent failure, but overloading is more frequently caused by the flexible drive itself due to its corrosion resulting from the drive cable lying in bilge water or being allowed to arc on battery terminals etc. No bend in the flexible drive should be less than one foot radius.

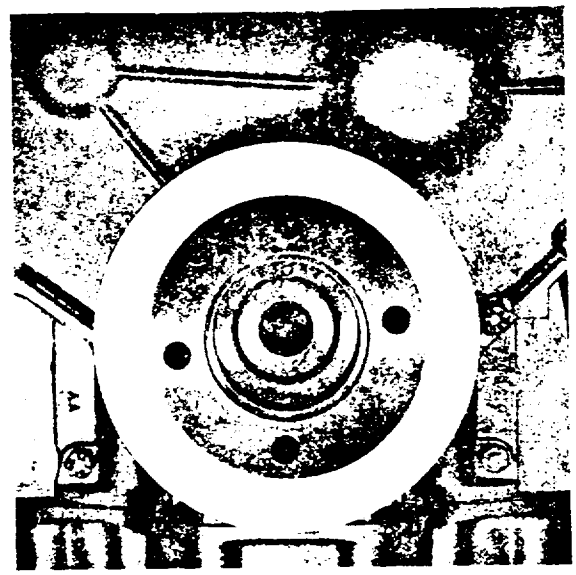


*Fig. K.1.*
*Showing markings for correct positioning of Crankshaft Pulley in relation to Crankshaft.*

With earlier engines. failure of the angle drive could result in fragments of the drive tag falling into the timing gear train and as a protective measure, a sleeve shield was introduced around the tachometer drive shaft and tag. It would be of advantage to introduce this safety shield on early engines whenever it becomes necessary to remove the timing case cover.

### To Refit the Timing Case Cover

1. Thoroughly clean the faces of the timing case front cover and timing case.
2. Position the timing case cover on the timing case by means of two opposite setscrews fitted loosely. Centralise the cover by locating the centralising tool PD.162 on the crankshaft and in the seal housing and tighten the assembly by means of the crankshaft pulley setscrew and washer — do not overtighten.

   Tighten all the timing case cover setscrews and remove the tool. If the centralising tool is not available, the crankshaft pulley can be used to centralise the cover but, as this method utilizes the inside diameter of the seal and the latest seal is soft, the cover may not be truly central and leaks may occur.

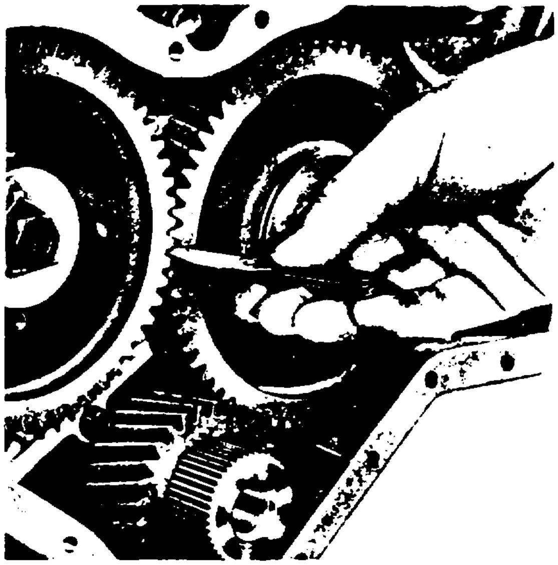


*Fig. K.2.*
*Checking Timing Gear Backlash.*

3. Refit the heat exchanger support bracket and tachometer drive.
4. Refit the crankshaft pulley ensuring that the centre punch mark on the pulley coincides with the line on the front face of the crankshaft (see Fig. K.1). Fit the retaining setscrew and washer and tighten to a torque setting of 300 lbf ft (42 kgf m) 410 Nm.
5. Refit the power take-off shaft to the crankshaft pulley and secure with the four setscrews.
6. Replace the dynamo/alternator and water pump driving belt over the respective pulleys and adjust as instructed on Page M.1.

**Checking the Timing Gear Backlash**

1. Remove the timing case cover as detailed on Page K.1.
2. Check the timing gear backlash as shown in Fig. K.2 using a clock gauge or feeler gauges. The backlash should be 0.003 in (0,08 mm) minimum.

**To Remove the Idler Gear and Hub**

1. Remove the timing case front cover as previously described in this Section.
2. Slacken and remove the three nuts securing the idler gear retaining plate to the idler hub and withdraw the retaining plate from its studs.
3. Remove the idler gear from the hub. The hub can now be withdrawn from its location in the timing case.

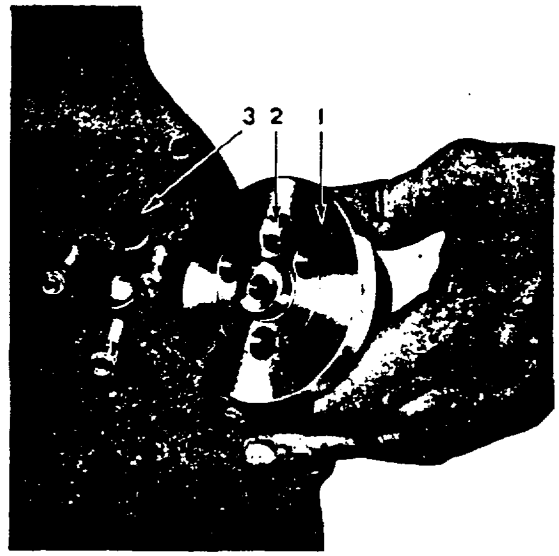



*Fig. K.3.*
*Idler Gear Hub Location.*
*1. Idler Gear Hub.*
*2. Oil Passage.*
*3. Oil Pressure Rail.*

4. Clean and thoroughly examine the gear and hub for wear, cracks, and pitting, etc.
**NOTE: - Replacement gears are supplied with the bushes fitted and machined to the dimensions given on Page B.8.**

**To Refit the Idler Gear and Hub**

1. After ensuring that the oilways in the hub are perfectly clean, refit the hub to its location in the timing case. The studs, on which the hub is located, are positioned so that the hub will fit in one position only, and the boss at the rear of the hub locates in a recess machined in the front face of the cylinder block (see Fig. K.3).
2. Remove the top cover and slacken off the rocker assembly securing nuts.
3. Turn the crankshaft to T.D.C. No. 1 and 4 cylinders, i.e., with the crankshaft gear keyway at the top of its periphery.
4. Refit the idler gear to its hub ensuring that the timing marks on the crankshaft, camshaft, fuel pump and idler gears are correctly aligned as shown in Fig. K.4.
5. Assemble the idler gear retaining plate to its studs and secure with the three setscrews tightened to a torque setting of 30 lbf ft (4,1 kgf m).

Check idler gear end float as shown in Fig. K.5. The end float should be between 0.003/0.007 in (0,08/0,18 mm).

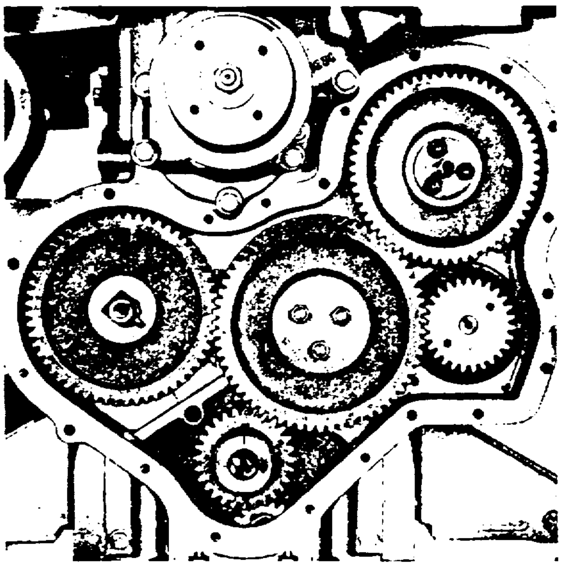


*Fig. K.4.*
*Showing Timing Marks on Drive Gear*

6. Tighten down the rocker assembly securing nuts and adjust the valve clearances to 0.012 in (0,30 mm) cold.
7. Refit the timing case front cover as previously detailed in this Section.

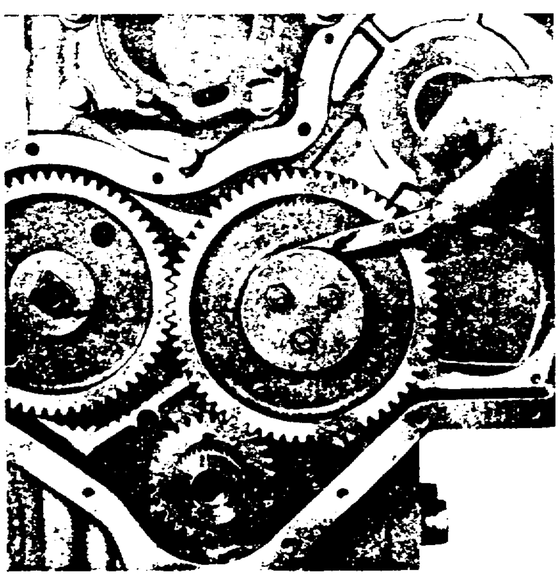


*Fig. K.5.*
*Checking Idler Gear End Float.*

**To Remove the Camshaft Gear**

1. Remove the timing case front cover as previously described in this Section.
2. Knock back the locking washer tab and remove the camshaft gear retaining setscrew, locking washer and camshaft gear retaining plate.

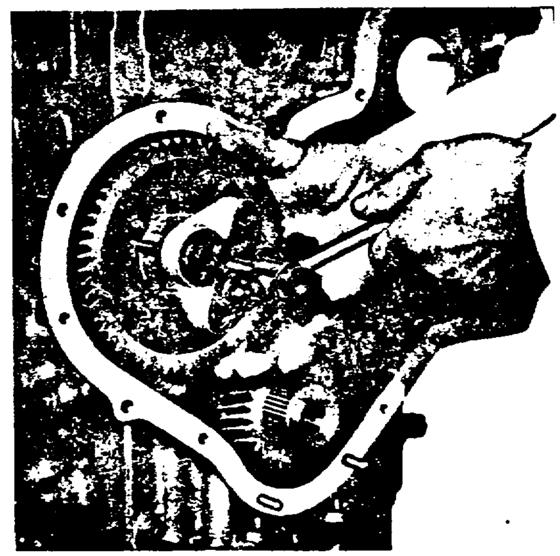


*Fig. K.6.*
*Camshaft Gear Removal*

3. Using a suitable extractor, remove the camshaft gear (see Fig. K.6).
4. Clean and thoroughly examine the gear for wear, cracks and pitting, etc.

**To Refit the Camshaft Gear**

1. Remove the idler gear as previously described in this Section.
2. Slacken off the rocker assembly securing nuts.
3. Refit the gear to the camshaft by drawing it onto the shaft with the retaining plate and setscrew.
4. Turn the engine until No. 1 piston is at T.D.C., i.e., with the crankshaft gear keyway at the top of its periphery.
5. Refit the idler gear to its hub ensuring that the timing marks on the crankshaft gear, fuel pump gear, camshaft gear and idler gear are correctly aligned as shown in Fig. K.4. Assemble the idler gear retaining plate to its studs, and secure with the three self locking nuts tightened to a torque setting of 30 lbf ft (4,1 kgf m)- 40 Nm.
6. Remove the camshaft gear retaining setscrew, fit a new lock washer, refit the setscrew,

tighten to a torque setting of 50 lbf ft 16.9 kgf m) - 68 Nm and secure the setscrew with the locking washer tab.

7. Refit the timing front case front cover as previously detailed in this Section.
8. Tighten down the rocker assembly securing nuts and adjust the valve clearances to 0.012 in (0,30 mm) cold.

**To Remove the Fuel Pump Gear**

1. Remove the timing case cover as previously described in this Section.
2. Turn the crankshaft until all the timing marks are correctly aligned (see Fig. K.4).
3. Remove the three setscrews and spring washers which secure the gear to the fuel pump.

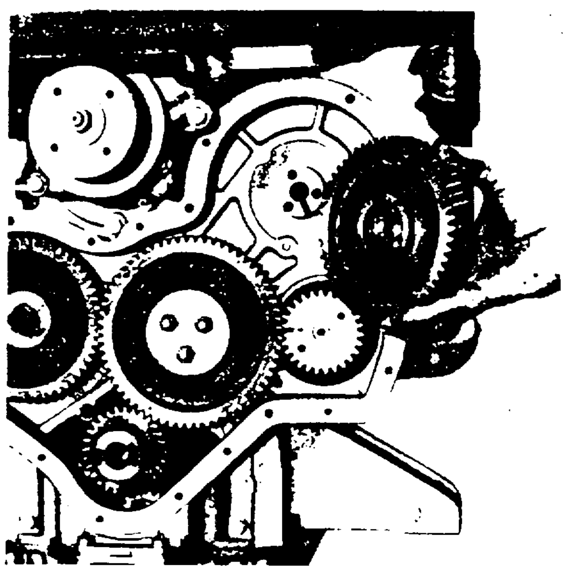


*Fig. K.7.*
*Removing the Fuel Pump Gear.*

4. Withdraw the gear from its dowelled location on the fuel pump.

**To Refit the Fuel Pump Gear**

1. Remove the idler gear from its hub.
2. Fit the fuel pump gear to the fuel pump drive shaft ensuring location of the dowel in the gear with the slot in the shaft.
3. Secure the gear with the three setscrews and spring washers.
4. Refit the idler gear to its hub as previously detailed ensuring that the timing marks are correctly aligned as shown in Fig. K.4.
5. Refit the timing case cover as previously detailed.

**To Remove the Timing Case**

1. Remove the timing case front cover and timing gears as previously described.
2. Remove the fuel and sea water pumps as described in the appropriate Sections.
3. Remove the nine setscrews and spring washers securing the timing case to the cylinder block.
4. Remove the four setscrews and washers securing the sump to the timing case.
5. Withdraw the timing case from the cylinder block taking care not to damage the sump joint.

**To Refit the Timing Case**

1. After ensuring that both the cylinder block and timing case faces are perfectly clean, fit the timing case to the cylinder block together with a new joint.
2. Secure the timing case with the setscrews and spring washers.
3. Secure the sump to the timing case with the four setscrews and spring washers.
4. Refit the fuel and sea water pumps as described in the appropriate sections.
5. Refit the timing gears and timing case front cover as previously described.

**Fitting New Timing Case**

In the event of a new timing case being fitted, this will not be marked with the scribed line for the correct alignment of the fuel injection pump.

To arrange this marking with the front cover, fuel pump and fuel pump gear removed, proceed as follows:—

1. Turn the engine to T.D.C.. number 1 cylinder compression stroke, with the timing marks on the camshaft gear, idler gear and crankshaft gear alined, crankshaft keyway upper-most.

   Remove collets, spring cap and spring from one of the valves from number 1 cylinder and allow the valve to rest on top of the piston. Care is necessary with this operation as the consequences of a valve dropping into a cylinder need not be described.

   With the aid of a clock gauge in contact with the tip of the valve stem now sitting on number 1 piston accurate T.D.C. can be established by rocking the piston over T.D.C. to obtain the highest clock reading. Zero the clock to the highest reading, rotate the engine anti-clockwise approx 0.100 in (2.54 mm), then rotate the engine in a clockwise direction until the clock gauge zeros. This

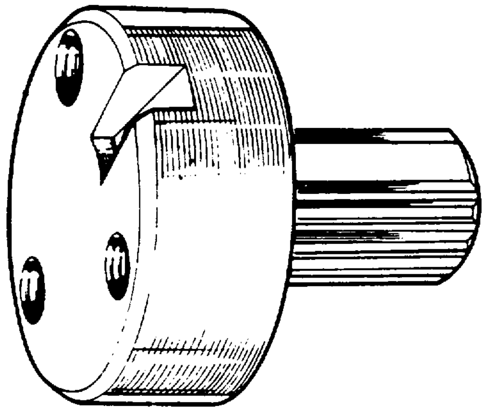


*Fig. K.8.*
*Adaptor PD67B-1.*

will ensure that all backlash is taken up at T.D.C. Refit valve spring cap and collets.

2. Fit adaptor PD67B-1 (see Fig. K.8) to the fuel pump gear so that dowel of gear locates in slot of adaptor and shaft of adaptor is towards rear of engine. Secure adaptor to gear using gear securing setscrews.

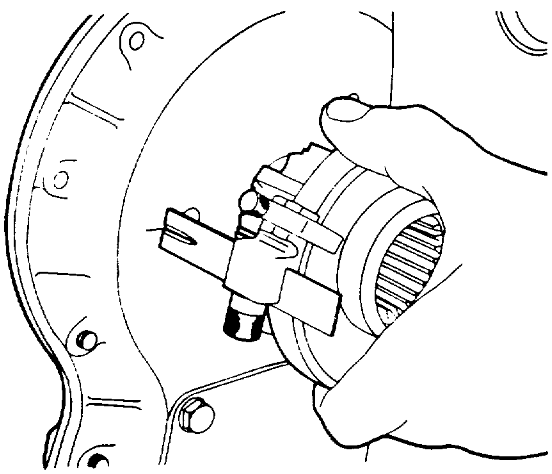


*Fig. K.9.*
*Marking Scribed Line on Rear of New Timing Case.*

3. Release screw (5) of timing tool MS67B (see Fig N.10) and remove splined shaft.
4. Ensure slotted pointer (2) of timing tool is positioned with slot to front of tool and chamfered sides of slot outwards. At this stage, slotted edge of pointer should be kept well back from front of body. Ensure that flat of washer fitted behind pointer securing screw (3) is located over pointer.
5. Release the bracket locking screw (4) and set bracket so that the chamfered edge is in line with the relevant engine checking angle (see Page B.11).
6. Pressing fuel pump gear and adaptor towards rear, with the fuel pump gear timing mark located correctly with the idler gear timing mark, locate splined shaft of adaptor into timing tool with master spline engaged and adaptor shaft in timing tool with rear face of adaptor abutting front face of timing tool.
7. Move tool forward, complete with gear so that register of tool locates in pump aperture of timing case. If pointer is 180° out, then engine is on wrong stroke and tool should be removed and engine set on correct stroke.

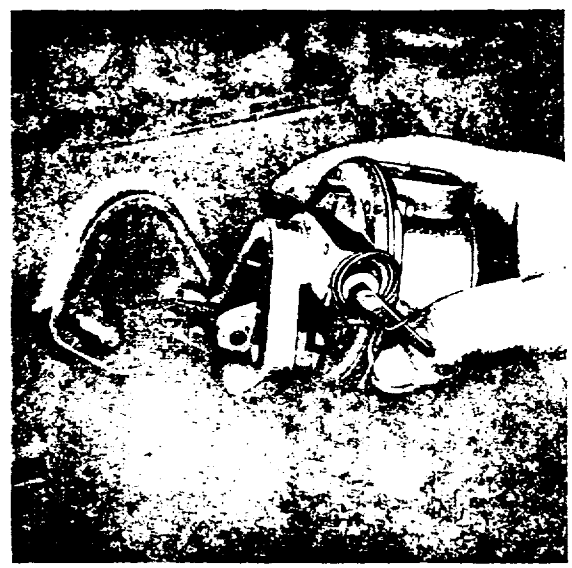


*Fig. K.10.*
*Removing the Fuel Lift Pump.*

8. Slide slotted pointer forward to reach rear face of timing case and lock in position.
9. Take up backlash by turning tool against normal direction of rotation (shown on pump nameplate) and mark the scribed line on the rear of the timing case to coincide with the centre of the slot in the pointer (see Fig. K.9).
10. Remove tool and adaptor from fuel pump gear and fit fuel pump to engine as detailed on Page N.6.

**To Remove the Camshaft and Tappets**

Camshaft end float is controlled by a thrust plate located in a recess machined in the front face of the cylinder block. The plate is dowelled to

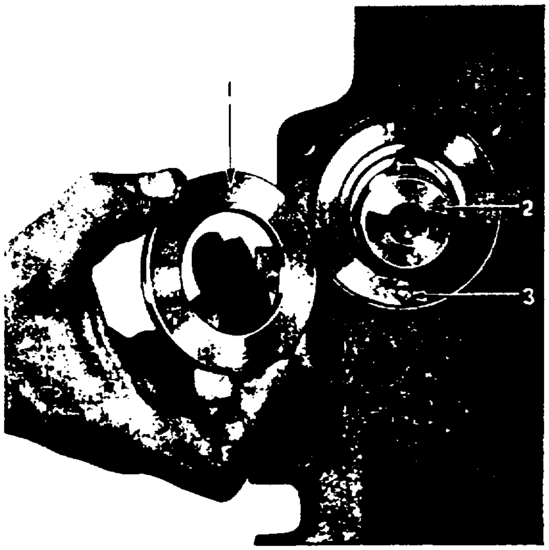



*Fig. K.11.*
*Removing Camshaft Thrust Washer.*
1. *Camshaft Thrust Washer.*
2. *Camshaft.*
3. *Thrust Washer Dowel Pin.*

prevent rotation and is held in position by the timing case.

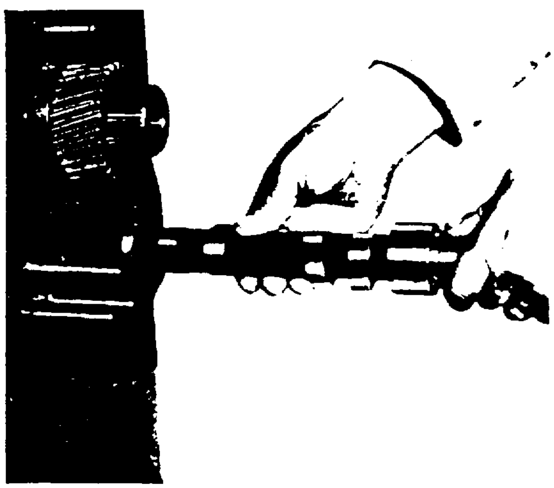


*Fig. K.12.*
*Removing the Camshaft.*

To remove the camshaft it is necessary to remove the engine from the application. After being removed the engine should be mounted in a suitable dismantling stand so that it can be turned upside down to prevent the tappets from falling into the sump when the camshaft is removed.

The removal procedure is as follows:—

1. Remove the engine from the application and mount in a suitable dismantling stand.
2. Remove the rocker cover, rocker assembly and push rods.
3. Remove the timing case front cover, timing gears and timing case as previously described.
4. Turn the engine over so that the sump is uppermost.
5. Remove the fuel lift pump (see Fig. K.10).
6. Remove the camshaft thrust plate from its location on the front of the cylinder block (see Fig. K.11).
7. Carefully withdraw the camshaft taking care not to damage the journals or cams (See Fig. K.12).
8. If desired the tappets may now be withdrawn after the sump has been removed (see Fig K.13).

**To Refit the Tappets and Camshaft**

1. If the tappets have been removed refit them in their locations (see Fig. K.13).

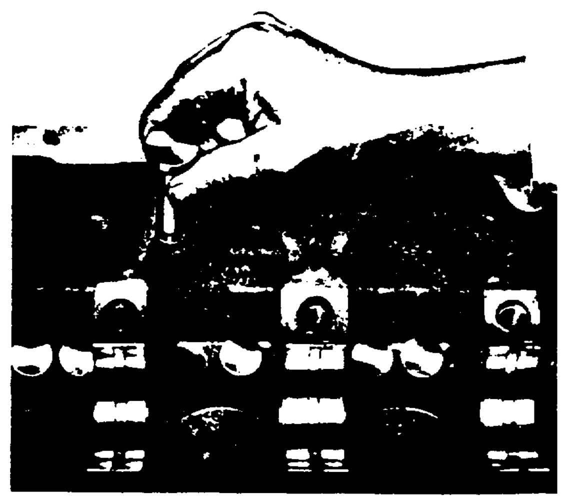


*Fig. K.13.*
*Removing a Tappet.*

2. Carefully refit the camshaft to the cylinder block taking care not to damage the journals or cams.
3. Fit the camshaft thrust plate to its location on the front face of the cylinder block ensuring that the plate is correctly positioned on the dowel. Check the thrust plate protrusion beyond the front face of the cylinder block. See "Technical Data."
4. Refit the sump, turn the engine upright and refit the fuel lift pump together with a new joint.
5. Using new joints, refit the timing case, timing gears and timing case front cover to the engine.
6. Refit the push rods and rocker assembly.

Adjust the valve clearances to 0.012 in (0,30 mm) cold. Refit the rocker cover together with a new joint.

7. Remove the engine from the dismantling stand and refit to the application.

## TIMING

### General

As timing gears are employed on the 4.236 marine engine, the factory setting remains constant. The following information is given as a general guide during an engine overhaul. It is well to remember that the removal of the cylinder head in no way affects either the fuel pump or valve timing.

### Timing Marks

When the engine is originally timed at the factory, certain marks are stamped on the gears, so that if for any reason the engine timing has to be disturbed, then to reset to the original timing is quite straight forward.

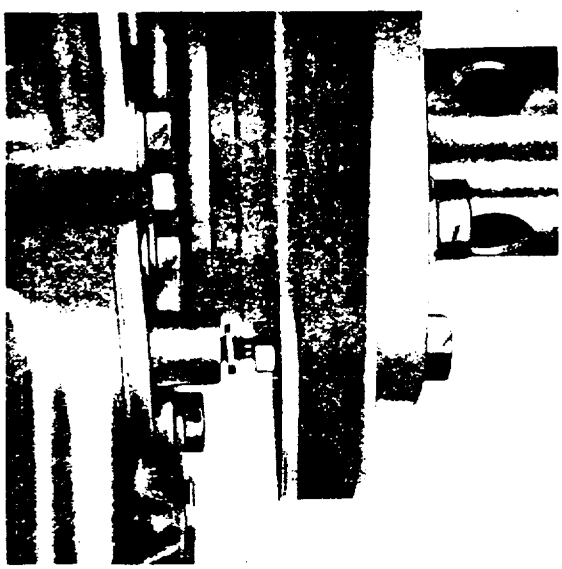


*Fig. K.14.*
*Showing Timing Pin located in Crankshaft Pulley.*

### Timing Pin

A timing pin is fitted at the bottom of the timing case cover on the starboard side. When it is unscrewed it locates in a hole machined in the rear face of the crankshaft pulley, when Nos. 1 and 4 pistons are at T.D.C. (see Fig. K.14).

Always return this pin. to its normal location immediately T.D.C. has been determined and before any attempt is made to turn or start the engine.

### To Reset Engine to the Original Timing

Before commencing the retiming procedure it is assumed that (a) the camshaft, fuel pump and idler gears have all been removed, and (b) the camshaft is free to turn by hand. (If the cylinder head assembly is still in position, it is advisable to remove the atomisers and rocker shaft to facilitate the retiming operations).

1. Turn the engine until the keyway in the front of the crankshaft is uppermost as shown in Fig. K.4. (This will bring Nos. 1 and 4 pistons to T.D.C.)
2. Fit the camshaft gear by drawing it onto its shaft using the retaining plate and setscrew. Lock the setscrew with the tabwasher.
3. Fit the fuel pump gear to the fuel pump drive shaft ensuring that the dowel is correctly located. Secure with the three setscrews and spring washers.
4. Replace the idler gear as previously detailed so that the timing marks are all correctly aligned as shown in Fig. K.4.
5. Check that the backlash between the timing gears is within the limits quoted on Page B.8.

**NOTE: When the timing has been reset, great care should be exercised when first turning the engine, for should the timing be incorrectly set, even by only one tooth, there is the possibility that a valve head will strike the piston crown.**

### For Checking Fuel Pump Timing, see Page N.6

### Checking Valve Timing

To check the valve timing proceed as follows:

1. Turn the crankshaft until the valves of No. 4 cylinder are 'on overlap'.
2. In this position set the valve clearance of No. 1 inlet valve to 0.047 in (1,2 mm).
3. Turn the engine slowly in the normal direction of rotation until the clearance of No. 1 inlet valve is just taken up. (In this condition it will just be possible to rotate No. 1 inlet valve push rod between the thumb and the forefinger).

4. Nos. 1 and 4 pistons will now be at T.D.C. if the timing has been correctly set.

   **NOTE: No adjustment is provided for valve timing, should the timing be incorrect and the camshaft gear has been correctly fitted to the camshaft hub, the error will probably be due to incorrect alignment of the original timing marks on the drive gears. Recheck as detailed on Page K.2.**

When valve timing is originally set and checked during production a timing tolerance of plus or minus 2-1/2 (flywheel) degrees is allowed for item (4) above. When the timing has been correctly set, do not forget to reset No. 1 inlet valve clearance to the correct figure also to return the timing pin to its correct location if it has been used to check T.D.C.

The importance of correct and clean lubrication cannot be stressed too highly and all references to engine oil should be taken to mean lubricating oil which falls within the specification given in the appendix. Care should be taken that the oil chosen is that specified for the climatic conditions under which the engine is operated.

The sump should be filled with a suitable grade of lubricant to the correct level but do not overfill above the full mark.

### Description

The lubrication is of the forced feed type, the oil being circulated, under pressure, by a lobed rotor type oil pump which is mounted on the front main bearing cap and driven through an idler gear by the crankshaft gear. The oil is drawn through a sump strainer and a suction pipe before entering the pump itself. Oil is then pumped via a pipe to the relief valve housing and then through an internal drilling in the cylinder block to an externally mounted adaptor onto which is fitted the full flow type lubricating oil filter. This adaptor channels the oil first to and from the oil cooler section of the heat exchanger, by means of flexible pipes, then through this full flow lubricating oil filter back into the cylinder block. The oil passes via drillings within the cylinder block to the pressure rail (main oil gallery).

With lowline engines, the oil cooler and lubricating oil filter are an integral component fitted on the starboard side of the engine.

From the pressure rail the oil is fed through oilways in the crankcase webs to the five main bearings and then from these through oilways drilled in the crankshaft webs the oil passes to the big ends. An oil seal prevents oil leaking along the crankshaft at the rear end and oil thrown from this seal returns to the sump.

The three camshaft bearings are lubricated through oilways in the crankcase webs from numbers one, three and five main bearings.

The camshaft centre bearing supplies a controlled feed of oil through an oilway, in the cylinder block and cylinder head, to the rocker shaft assembly. This controlled feed is achieved by allowing oil under pressure to be forced to the rocker shaft only when the oilways in the camshaft journal and camshaft centre bearing are in line, this occurring once per camshaft revolution. Oil from the rocker shaft escapes through a small bleed hole in each rocker lever and lubricates the valves and guides by splash, the surplus oil being returned to the sump by gravity.

The idler gear and hub are pressure lubricated direct from the pressure rail. Oil enters the rear of the hub and passes through drillings in the hub to lubricate the idler gear bush and gear retaining plate. Timing gear teeth are splash lubricated by surplus oil from the front camshaft bearing idler gear hub and fuel pump hub.

Pistons, cylinder liners and connecting rod small end bearings are lubricated by splash and oil mist, also the cams and tappets of the valve mechanism.

## THE OIL PUMP

The oil pump is secured to the front main bearing cap by three setscrews, a protrusion of the idler gear shaft locating in a hole in the bearing cap to give positive location.

The bushed idler gear which is free to rotate on its shaft transmits the drive from the crankshaft gear to the oil pump gear.

The oil pump drive gear is pressed and keyed on to the pump driven shaft on the other end of which is pressed and pinned a three lobed rotor. This rotor meshes with a four lobed driven rotor, which is free to rotate in the cast iron pump body.

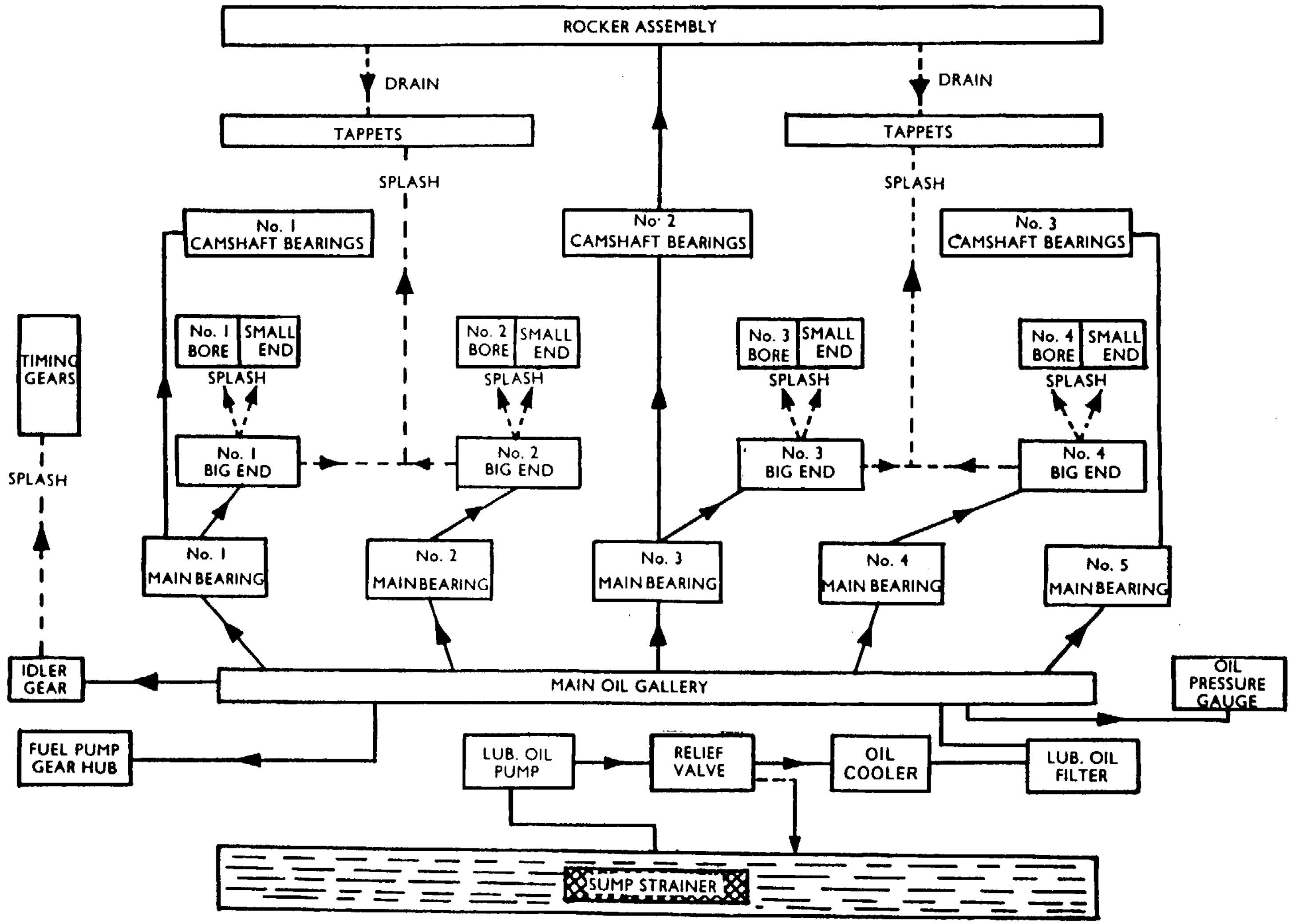



*Fig. L.1. Lubricating Diagram.*

As the pump rotors rotate, the pockets formed between the rotor lobes increase and then decrease in volume to propel the oil from the suction side to the pressure side of the pump.

**To Remove the Oil Pump**

1. Remove the sump securing setscrews and withdraw the sump from the engine. Remove the strainer from the suction pipe of the oil pump (see Fig. L.2). With lowline engines, the sump strainer is of a different pattern to that shown in Fig. L.2. but its removal is similar.
2. Disconnect and remove the suction pipe.
3. Disconnect and remove the oil delivery pipe between the pump and relief valve housing.
4. Remove the crankshaft pulley, timing case front cover, timing gears and timing case as described in the appropriate section.
5. Remove the idler gear circlip and idler gear (see Figs. L.3 and L.4).
6. Remove the three setscrews securing the pump to No. 1 Main bearing cap and with draw the pump from the cap (see Fig. L.5).

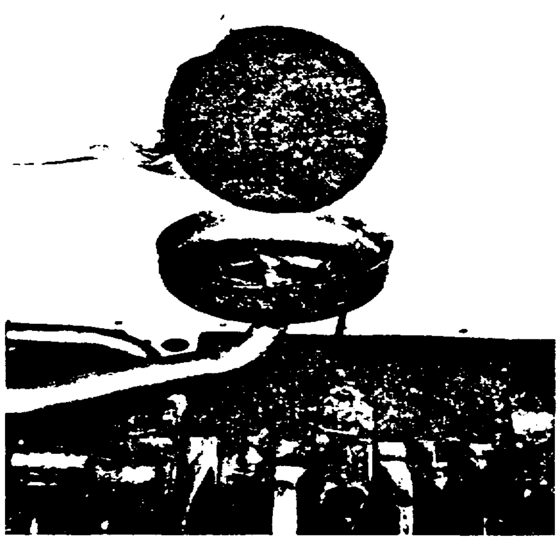


*Fig. L.2.*
*Removing Sump Strainer from Oil Pump Suction Pipe.*

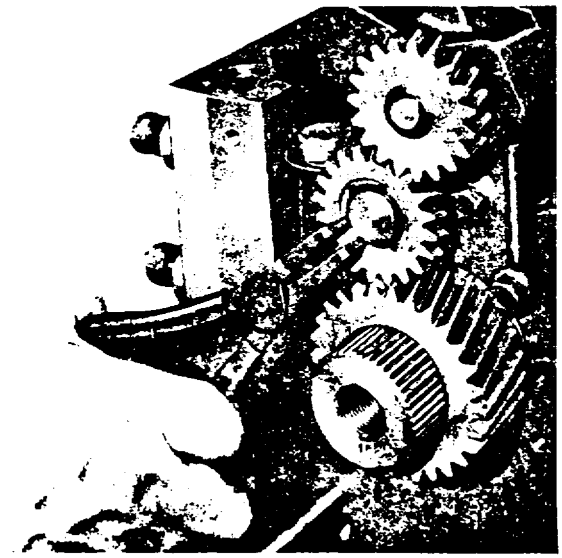


*Fig. L.3.*
*Removing the Oil Pump Idler Gear Retaining Circlip.*

**To Dismantle the Oil Pump**

1. With the pump assembly suitably held in a vice remove the oil pump drive gear retaining circlip (where fitted) and using a suitable extractor remove the drive gear.

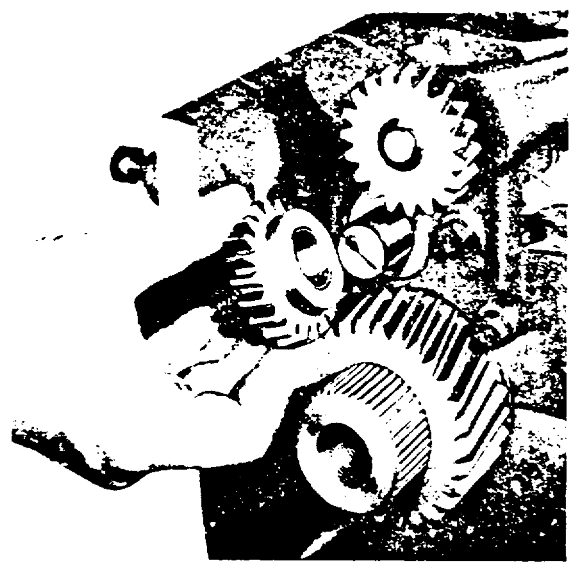


*Fig. L.4.*
*Removing the Oil Pump Idler Gear*

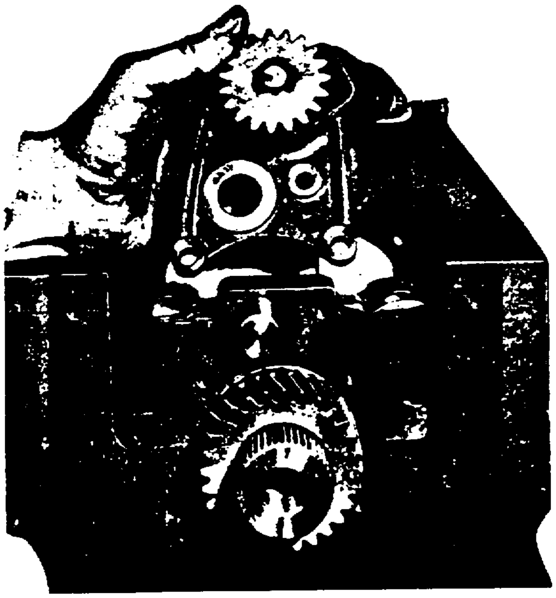


*Fig. L.5.*
*Removing the Lubricating Oil Pump.*

2. Remove the key from the keyway of the drive shaft.
3. Unscrew the three screws which secure the end plate to the pump and remove the plate.

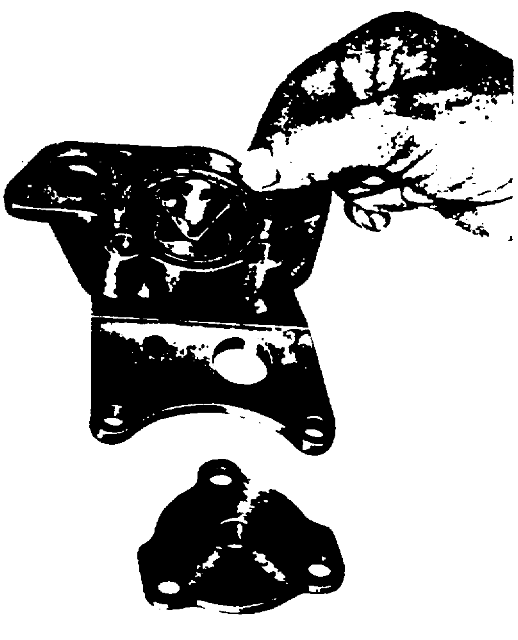


*Fig. L.6.*
*Removing the "O" Sealing Ring from the Oil Pump.*

4. Carefully remove the drive and driven rotors from the pump body.
5. Remove the "O" sealing ring from the pump body (where fitted). See Fig. L.6.

**Inspection**

1. After thoroughly cleaning all the parts they should be examined for signs of cracking, wear or corrosion.
2. Install the inner and outer rotors in the pump body, bearing in mind that the chamfered edge of the outer rotor enters the pump body first.
3. The clearances are checked as shown in Figs. L.7., L.8 and L.9.

**NOTE: The relevant clearances for these dimensional checks are given on Page B.8, they are the clearances applicable to a new pump and are intended to be used as a guide. Should a lubricating oil pump be worn to such an extent that it adversely effects the working oil pressure, then a replacement pump should be obtained. The component parts of the pump itself are not supplied individually,**

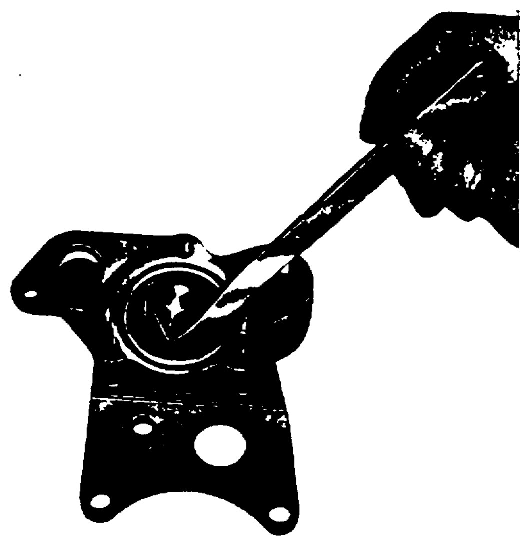


*Fig. L.7.*
*Checking Clearance between Inner and Outer Rotor.*

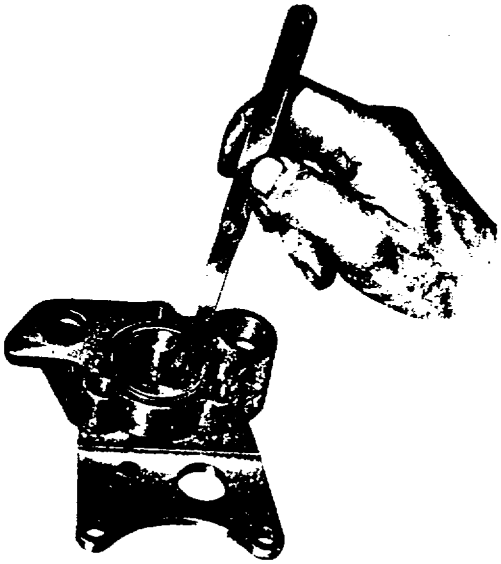


*Fig. L.8.*
*Checking the Clearance between the Outer Rotor and Oil Pump Body.*

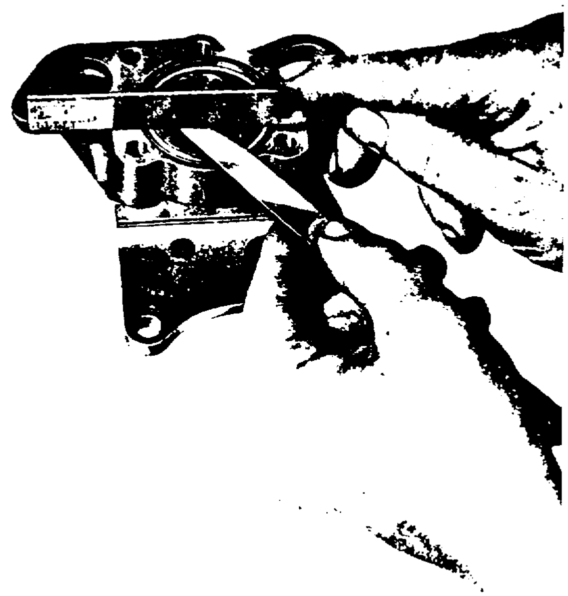


*Fig. L.9.*
*Checking Rotor End Clearance.*

therefore if any parts require renewing a replacement assembly should be fitted. It may be worth mentioning at this point that low oil pressure may not even be due to the oil pump, reference to the page covering Fault Diagnosis under the heading "Low Oil Pressure" may help to isolate the cause.

**To Assemble the Oil Pump**

1. Fit the drive and driven rotors to the pump body entering the chamfered end of the outer rotor to the body first. Refit end plate using a new "O" ring (where fitted). Secure the plate with the three screws.
2. Refit the key in the keyway of the drive shaft and refit the drive gear to the shaft. With earlier pumps, the boss on the drive gear was positioned towards the rear of the gear, the flat face of the gear being towards the circlip groove. The correct clearance for the gear was 0.003/0.007 in (0,08/0,18 mm) between the rear face of the gear and the pump body.
   With current pumps, the boss on the gear is positioned on the front of the gear and the correct clearance for the gear is 1.244/1.264 in (31.60/32,11 mm) when measured from the front face of the gear boss to the rear face of the pump mounting flange.
3. Fit the drive gear retaining circlip (where fitted).

**To Refit the Oil Pump**

1. Prime the oil pump with clean lubricating oil.
2. Fit the oil pump to No. 1 main bearing cap and secure with the t three setscrews.
3. Refit the idler gear to the shaft with the recessed face towards the front and secure with the circlip. Check the idler gear end float which should be within the tolerance of 0.002/0.016 in (0,05/0,41 mm). Check the idler gear backlash which should be within the limit of 0.00610.009 in (0,15/0,23 mm).
4. Using new joints refit timing case, timing gears, timing case front cover and crankshaft pulley as described in the appropriate section.
5. Refit the oil delivery pipe between the oil pump and pressure relief valve housing.
6. Refit the suction pipe to the oil pump using a new flange seal.
7. Fit the sump strainer to the pump suction pipe, and using new joints, refit the sump to the engine and secure with the retaining setscrews. Refill the sump with clean oil of an approved grade.

## OIL PRESSURE RELIEF VALVE

The oil pressure relief valve is contained in a housing bolted to the bottom face of the cylinder block and is set to operate at 50/60 lbf/in$^2$ (3,5/4.2 kgf/cm$^2$) - 345/414 kN/m$^2$.

### To Remove and Dismantle the Relief Valve Assembly

1. Remove the sump securing setscrews and withdraw the sump from the engine.
2. Disconnect the oil pump delivery pipe at the relief valve end.
3. Remove the one or two setscrews (according to housing type) which secure the relief valve housing to the cylinder block and take off the relief valve housing.
4. Remove the splitpin from the end of the relief valve housing and withdraw the cap, spring and plunger. An exploded view of the relief valve assembly can be seen in Fig. L.11.
5. Thoroughly clean all parts. Inspect them for wear or damage and renew where necessary.

### To Assemble and Refit the Relief Valve Assembly

1. Fit the plunger, spring and cap to the relief valve housing and secure with the split pin.

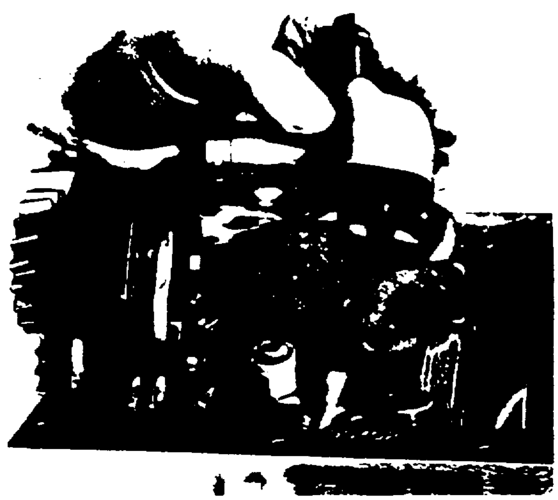


*Fig. L.10.*
*Removing the Oil Relief Valve Housing from the Cylinder Block.*

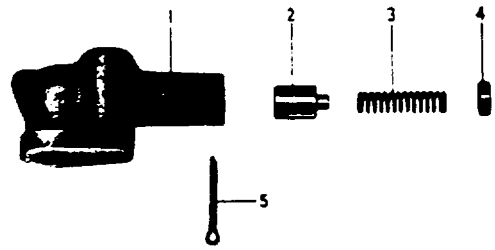



*Fig. L.11.*
*Exploded view of Oil Relief Valve.*
1. Relief Valve Body.
2. Plunger.
3. Spring.
4. Spring Retaining Cap.
5. Splitpin.

2. If a suitable test rig is available, check the pressure setting of the relief valve. The valve should lift between 50/60 lbf/in$^2$ (3,5/4.2 kgf/cm$^2$). If a test rig is not available, extreme caution is advised when starting the engine until it has been ascertained that the pressure relief valve is working correctly.
3. Using a new joint (where fitted) fit the relief valve housing to the cylinder block and secure with the setscrew(s).
4. Connect the oil pump delivery pipe to the relief valve housing.
5. Ensure that the sump strainer is correctly positioned on the oil pump suction pipe. Using new joints refit the sump to the engine and secure with the retaining setscrews. Refill the sump with clean oil of an approved grade.

## OIL PRESSURE

Always ensure that with the engine running, oil pressure is registering on the gauge or the oil pressure warning light is extinguished.

Pressures do vary according to climatic conditions and even between individual engines, but the oil pressure range at maximum working speed is given on Page B.8. The pressure will drop whilst the engine is idling and also a slight drop will be experienced when the oil is hot, this is quite normal. If, however, the oil pressure is suspected of being too high or too low then reference to the possible faults listed in Fault Diagnosis may prove helpful.

## LUBRICATING OIL FILTERS

To ensure cleanliness of the lubricating oil a sump strainer and a main full flow type of oil filter are fitted.

The sump strainer consists of a gauze wire container which is fitted over the end of the lubricating oil pump suction pipe. All oil must pass through this strainer before it reaches the oil pump, this ensures that no foreign matter reaches the pump which could cause any damage. It is recommended that this strainer is removed and thoroughly cleaned every time the sump is removed.

The main full flow type oil filter is mounted externally on the side of the cylinder block. All the oil passes through this filter after it leaves the pump, but before it reaches the bearings. This filter utilizes a replaceable paper filter element on earlier engines or a spin-on canister type having an integral element on later engines and no attempt should be made to clean it. It should be replaced by a new one in accordance with Preventive Maintenance recommended on Page C.3.

### To Renew Spin-on Oil Filter Canister

1. Unscrew filter canister from side of oil cooler (see Fig. L.12).
2. Discard old canister.
3. Clean head of oil cooler.
4. Using clean engine oil, liberally oil top seal of replacement canister.
5. Fill new canister with clean lubricating oil allowing time for the oil to filter through the element. Screw replacement canister on to end of the oil cooler until the seal just touches cooler head. Then tighten as per instructions on canister. Where a tool is available tighten to 15 lbf ft (2,07 kgf m) - 20 Nm.
6. Run engine and check for leaks.

**NOTE: Oil filter canisters have internal valves to prevent oil drain back and a special tube stack is fitted, so always ensure that the correct replacement is fitted.**

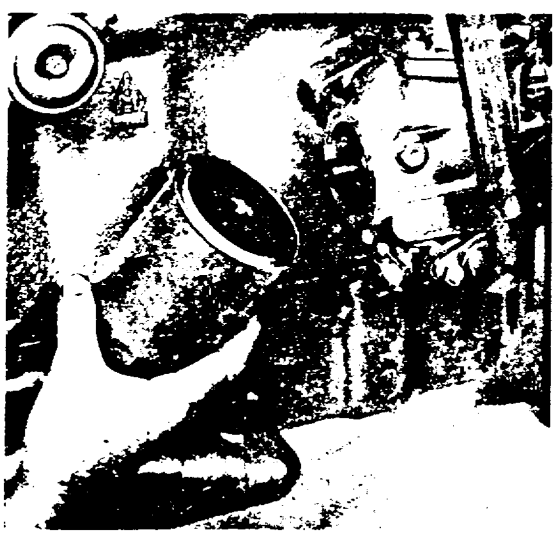


*Fig. L.12.*
*Removing Lubricating Oil Spin-on Canister.*
*(lowline engines)*

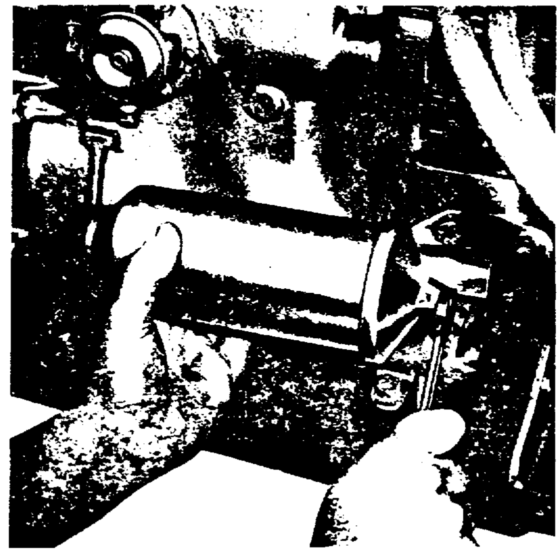


*Fig. L.13.*
*Removing the Lubricating Oil Filter Bowl Securing Screw.*
*(Replaceable element type)*

### To Remove the Filter Element (earlier engines)

1. Clean the exterior of tile filter bowl.
2. Unscrew the filter bowl securing bolt as shown in Fig. L.13. A suitable container should be placed beneath the filter to catch the oil in the bowl as the securing bolt is slackened.
3. Ease the filter bowl clear, lift out the old element and discard.

**NOTE: Ensure that the top edge of the filter bowl is not damaged in any way during handling, otherwise it may be difficult to obtain an oil tight seal when it is refitted, even when using a new sealing ring.**

### To Renew the Filter Element (earlier engines)

1. Clean out the filter bowl using cleaning fluid.
2. Fit the new element so that it locates correctly on the spring loaded guide in the base of the container.
3. Fit the new container seal in the filter head ensuring that it is correctly located in its groove.

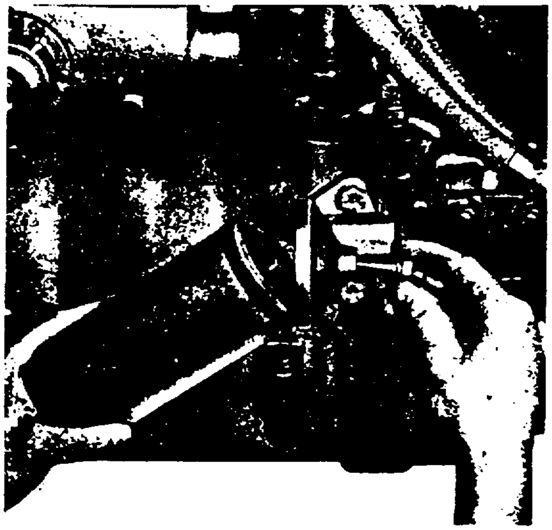


*Fig. L.14.*
*Removing the Lubricating Oil Filter Bowl.*
*(Replaceable element type)*

4. Offer the bowl to the head casting squarely and firmly, locate the securing bolt and tighten carefully. Ensure that the top edge of the filter bowl is central on the seal within the head casting recess.
5. Tighten the securing bolt. Do not overtighten.
6. After the engine has been run and the filter assembly checked for oil leaks, restore the oil in the sump to the correct level.

**To Remove the Oil Filter from the Engine (earlier engines)**

1. Withdraw the two setscrews securing the filter to the cylinder block and remove the filter assembly.

**To Refit the Oil Filter to the Engine (earlier engines)**

1. Ensure that the cylinder block face and filter mounting face are clean and that all traces of the old joint have been removed.
2. Using a new joint secure the oil filter to the cylinder block with the two setscrews and tighten to a torque wrench reading of 30 lbf ft (4.1 kgf m) - 41 Nm.
3. Check the sump level after running the engine and top lip as necessary.

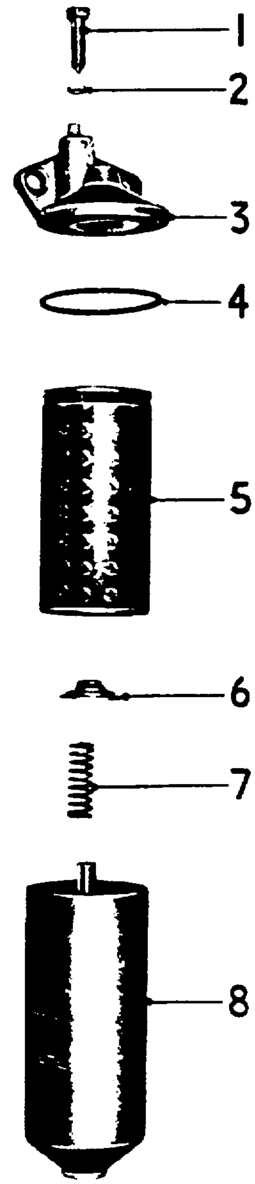



*Fig. L.15.*
*Exploded View of Lub. Oil Filter.*
*(Replaceable element type)*

1. Bowl Retaining Setscrew.
2. Retaining Setscrew Washer.
3. Filter Cover.
4. Bowl Sealing Ring
5. Element.
6. Element Seating Washer.
7. Spring.
8. Bowl.

The 4.236 Marine engine is indirectly cooled. This type of system employs two separate water circuits. One is a fresh water (closed) circuit which circulates within the cylinder block and head, the other is a sea or river water (open) circuit which circulates externally round the engine. Heat is interchanged between circuits via a heat exchanger unit.

**Lowline Engines**

A neoprene impeller type water pump is used to circulate the coolant on the open side of the system. The raw water is drawn in through the gearbox oil cooler to the water pump. From the pump, it is delivered to the heat exchanger mounted on the starboard side of the engine and then to the oil cooler where the engine oil passes over a series of tubes running the length of the unit. It is through these tubes that the coolant is passed. From the engine oil cooler, the raw water is finally discharged through the exhaust manifold water injection bend.

Circulation of the closed fresh water system is effected by a centrifugal water pump mounted on the front of the cylinder block and is belt driven from the crankshaft. Water is drawn from the header tank mounted on the front of the engine to the cylinder block where both the head and block are cooled by thermosyphon action. The water then passes to the thermostat. When the engine is cold and the thermostat fully closed, the water bypasses the thermostat to a double entry elbow mounted on the heat exchanger via a copper pipe. From the double entry elbow, the water passes to the rear of the exhaust manifold. As the engine warms up, the thermostat will start to open allowing the warm cooling water to bleed through the heat exchanger through the double entry elbow joining up with the bypass cooling water. The water then passes through the exhaust manifold to the header tank. As the water temperature rises to its allowed maximum, the thermostat gradually opens until it is in the fully open position, the bypass flow is cut off and the full cooling water flow passes through the heat exchanger and passes through the exhaust manifold and back to the header tank. The amount of water passing through the bypass and through the heat exchanger will depend on the opening position of the thermostat.

The header tank is fitted with a pressurized finer cap.

The water pumps for each circuit are described individually later in this section.

**Standard Engines**

With earlier standard engines, the header tank mounted at the front of the engine incorporates both the engine fresh water heat exchanger and the engine oil cooler. A pressurized filler cap is fitted.

The coolant on the open side of the system is drawn in through the gearbox oil cooler to the water pump. From the water pump, it is delivered to the combined heat exchanger and engine oil cooler in the header tank where fresh water and oil in their respective compartments pass over a series of tubes running the length of the unit. It is through these tubes that the coolant on the open side is passed. From the combined heat exchanger and oil cooler. the water is then passed to the water cooled exhaust manifold and is then finally discharged overboard.

Circulation of the closed fresh water system is effected by a centrifugal water pump mounted on the front of the cylinder block and is belt driven from the crankshaft. Water is drawn from the combined header tank heat exchanger and is delivered to the cylinder block where both the head and block are cooled by thermosyphon action. After circulation, the water is finally discharged at the front of the cylinder head through the thermostat housing to the header tank/heat exchanger.

The water pumps for each circuit are described individually later in this section.

The operating temperatures of the closed water system at the outlet should be in the region of 190$^{o}$F (88$^{o}$C).

A thermostat is fitted in the water outlet connection, which enables the engine to reach its most efficient working temperature in the shortest possible time by restricting coolant flow. When the correct temperature is reached, the thermostat valve opens and allows the water to circulate normally. Where a pressurized system is used, the coolant temperature will be slightly higher.

**To Adjust the Dynamo/Alternator and Water Pump Belt**

The belt tension should be adjusted so that it is possible to depress the belt, without undue pressure, approximately 3/8 in (10 mm) on the longest unsupported length of the belt (see Fig. M.1).

To prevent premature wear and eventual failure, correct tension of this belt should be maintained by periodical checking and adjustment every 250 hours.

Excessive belt tension, and consequent overloading of the dynamo/alternator and water pump bearings, is detrimental to both belt and bearings and may cause complete failure of one or both of these components.

Insufficient belt tension, allowing belt slip, will impair the efficiency of the engine cooling system and adversely affect dynamo/alternator output.

Belt adjustment is obtained by altering the position of the dynamo/alternator in the following manner.

1. Slacken off the dynamo/alternator adjusting lever setscrew, the adjusting lever to timing case setscrew and the dynamo/alternator to bracket support bolts.
2. The dynamo/alternator is now free to be moved on its support bracket towards or away from the engine to obtain the correct belt tension. Hold the dynamo/alternator in the desired position.
3. Tighten the adjusting lever setscrew, the lever to timing case setscrew and the dynamo/alternator to bracket support bolts.
4. Check that the tension is still correct.

**NOTE: When a new belt is fitted it is advisable to re-check the adjustment after a short running period. New belts are subject to initial stretch and early readjustment may be necessary.**

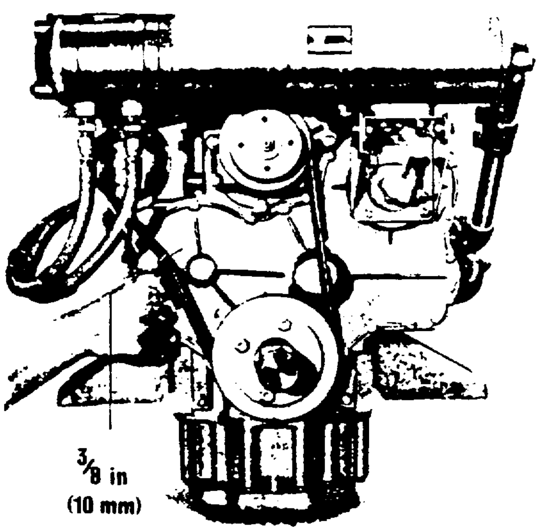



*Fig. M.1.*

**To Remove the Belt**

1. Slacken off the dynamo/alternator adjusting lever setscrew, the adjusting lever to timing case setscrew and the bracket support bolts. Pivot the dynamo/alternator towards the cylinder block.
2. Turn the engine by hand and work the belt off the water pump and dynamo/alternator pulleys.
3. Remove the belt from the crankshaft pulley.
4. Examine the belt for wear or fraying and renew as necessary.

**To Refit the Belt**

Refitting the belt is a reversal of the removal operations. Adjust the fan belt tension as detailed. If a new belt is fitted, check the tension after a few hours of running to ensure that any slackness due to initial stretching is corrected.

## FRESH WATER PUMP (Closed Circuit)

This is of the centrifugal type, the pump shaft which rotates within two bearings is belt driven by means of a pulley pressed onto one end and secured with a self locking nut. The drive is transmitted through the shaft to an impeller which is pressed onto the other end of this shaft.

The impeller assists the circulation of the coolant around the system. Water is contained within the impeller chamber by means of a spring

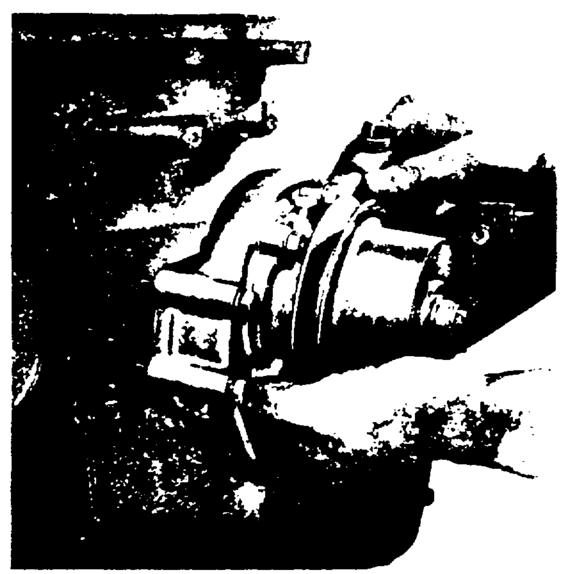


*Fig. M.2.*
*Removing the Water Pump.*

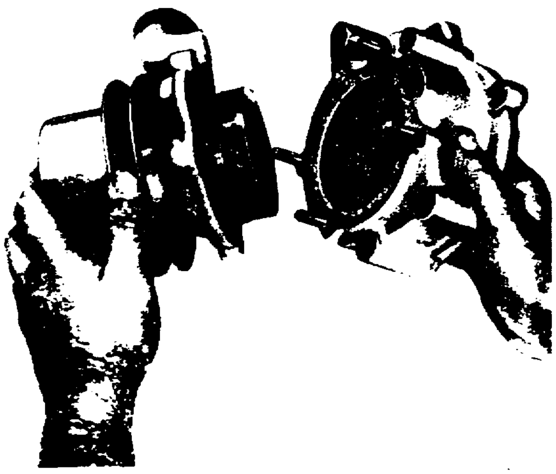


*Fig. M.3.*
*Separating the Front and Rear Pump Body Sections.*

loaded carbon-faced seal which registers against the inside (back) face of the impeller.

**To Remove and Refit Fresh Water Pump**

**Description**

1. Remove the dynamo/alternator and water pump driving belt.
2. Disconnect the inlet and outlet connections to the water pump.
3. Unscrew the five setscrews which pass through the pump and rear pump body into the cylinder block. Withdraw the pump from the engine (see Fig. M.2).
4. Separation of the front and rear pump body sections is achieved by removing the securing nuts and washers and gently tapping with a hide-faced hammer.
5. Refit the pump rear body and water pump in the reverse sequence ensuring that all joint faces are clean, and that new joints are fitted between the cylinder block and pump rear body, and between the rear body and water pump.
6. Refit the dynamo/alternator and water pump driving belt as detailed on Page M.1.

**Fresh Water Pump Seals**

Where ceramic counter face water pump seals are fitted, if the engine is run without coolant, even for a few seconds, the heat build-up between the carbon seal and ceramic counter face is very rapid, resulting in the cracking of the ceramic. This often creates the misunderstanding that the cause of leakage is due to the incorrect assembly of the sealing arrangement of the water pump.

*Fig. M.4.*
*Removing the Water Pump Pulley.*

**To Dismantle the Water Pump**

1. Unscrew the self locking nut securing the water pump pulley to the pump shaft and remove the nut with plain washer.
2. Using a suitable withdrawal tool, remove the pulley from the shaft (see Fig. M.4) and remove the pulley driving key from the shaft.
3. Press the water pump shaft, complete with impeller, out of the water pump body from the front of the pump.
4. Using a suitable press, remove the impeller from the pump shaft.
5. Remove the water seal from the pump shaft.
6. Remove the bearing retaining circlip from the front of the pump body using circlip pliers.
7. Press the two bearings and distance piece out of the pump body.
8. Finally, remove the front grease seal, seal retainer and flange from the pump body.

**Inspection**

1. Thoroughly wash all the water pump components in cleaning fluid and dry off.
2. Examine the pump body for cracks, damage or corrosion.
3. Examine the drive shaft for wear ensuring the inner diameters of the bearings are a perfect fit on the shaft. The shaft should be renewed if wear in this area is sufficient to allow the races to rotate on the shaft.

4. Remove rust and scale from the impeller and visually inspect for cracks or damage. Examine the impeller hub sealing face for excessive wear or scoring. Renew if unserviceable.
5. Examine the water seal for damage. Excessive wear, scoring or cracks in the carbon sealing face will necessitate renewal.
6. Inspect the bearings for pitting, corrosion or wear, and renew if necessary.

**To Re-Assemble the Water Pump**

1. Press the rear bearing on to the shaft, fit the bearing distance piece and then press on the front bearing. When fitting the bearings to the shaft, ensure that the shielded face of each bearing faces outwards towards the front and rear end of the shaft.
2. Fit the grease seal retaining plate in position against the back face of the rear bearing. This retaining plate is "dished" and when in position, the centre of the plate must not be in contact with the bearing.
3. Fit the felt seal and seal retainer housing so that these bear on the retaining plate.
4. Half fill the space between the two bearings with a high melting point grease and press the complete bearing and shaft assembly into the pump housing from the front end. Securely position the retaining circlip in the recess of the pump housing immediately forward of the front bearing.
5. Fit the water seal into the housing ensuring that the carbon face is positioned towards the rear. When fitted, the seal must rest squarely on its seat and not be canted in any way.
6. At this stage, the shaft should be turned by hand to ensure that no undue resistance to rotation exists.
7. Fit the driving pulley key and press on the pulley making sure that no rearward axial movement of the shaft is incurred.
8. Where ceramic counter face seals are fitted, fit seal to shaft with counter face towards water seal and rubber bonded holder towards impeller face.

*Fig. M.5.*
*Checking Impeller to Water Pump Body Clearance.*

9. Press the impeller onto the shaft ensuring that a clearance of 0.012/0.032 in (0,30/0.81 mm) is maintained between the impeller vanes and the pump body (see Fig. M.5).
10. Refit the plain washer and pulley retaining self locking nut, tightening to a torque of 60 lbf ft (8,5 kgf m) - 84 Nm.

## SEA WATER PUMP (Open Circuit)

**Description**

This type of pump consists basically of a shaft, gear driven from the rear of the timing case, which rotates within bearings in a water tight housing. The shaft transmits the drive to a neoprene impeller mounted on the other end. This impeller is offset slightly to the water chamber in which it rotates. The impeller blades, being flexible have a trailing action when the pump is turned in the normal direction of rotation. This flexibility permits the impeller to operate offset to the centre of the water chamber and has the action of drawing in water through the suction (inlet) side of the pump in the large pockets between the impeller blades, when the impeller turns, the blades become more flexed and consequently the volume of the pockets between the blades decreases forcing the water now under pressure to escape as the blades uncover the outlet port on the pressure side of the pump.

The pump is self priming, but it is advisable to prime it when first commencing service or after the engine has been laid up for any considerable length of time. This is effected by disconnecting the pipe between the water pump and the heat exchanger at its upper end, filling it with water and then reconnecting it to the heat exchanger.

This pump should never be run in a dry condition and if the engine is to be withdrawn from service for any length of time, it will be necessary to pack the water pump with MARFAK 2HD grease. (Where this is not available, Glycerine may be used instead). This may be effected by removing the water pump end plate, giving access to the interior of the pump, which can then be packed with grease.

This treatment is usually effective for about three months, and should be repeated prior to recommencement of service if laid up for a longer period than this.

N.B. Due to considerable suction created by this type of pump, it is essential that where rubber hose pipe is employed on this side of the pump any 'runs' of hose should be reinforced internally, likewise at junctions the pipe ends should almost butt together to prevent either partial or complete collapse with subsequent overheating.

**To Remove the Pump**

1. Uncouple the inlet and outlet water connections.
2. Remove the nuts securing the pump to the back of the timing case.
3. Withdraw the pump complete with its driving gear from the studs. The pump may be replaced by reversing the above procedure.

**Dismantling the Pump**

1. Remove the water pump end cover plate.
2. Remove the impeller by means of a pair of pliers. If it is tight on the shaft, loosen it by holding the impeller and twisting the shaft backwards and forwards.
3. Loosen the cam locking screw a few turns, then lightly tap screw downwards to loosen the cam in the water pump body.

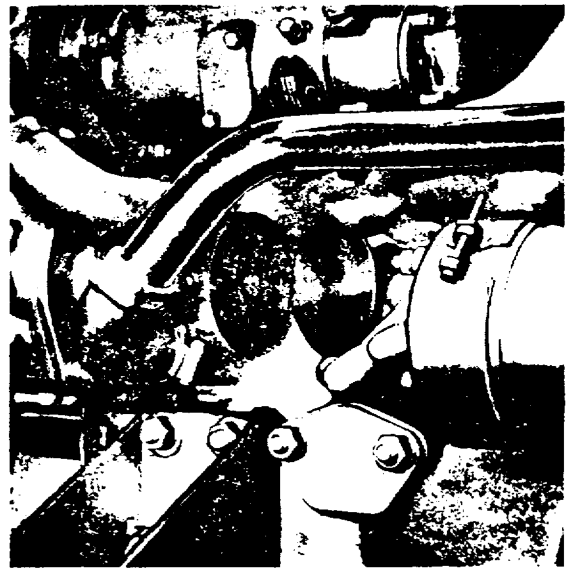


*Fig. M.6.*
*Removing Water Pump End Cover Plate*

4. Remove the cam locking screw and cam.
5. Remove wear plate from inside of impeller housing.
6. Remove the circlip on the water pump shaft and withdraw the spring loaded seal and seal seat.

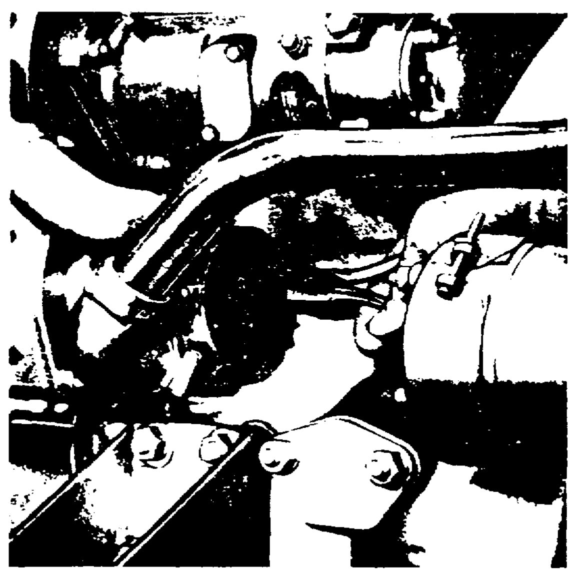


*Fig. M.7.*
*Removing Water Pump impeller*

*Fig. M.8.*
*Removing Sea Water Pump from back of Timing Case.*

It may be advisable to apply a soapy solution to the pump shaft in order to ease the seal past the circlip groove.

Should difficulty be experienced in gripping the seal with the fingers then two lengths of stiff wire or welding rod (3/64 in to 1/16 in dia.) with hooked ends (1/16 in to 3/32 in deep) can be utilized to secure the seal, one opposite the other, whereupon the seal can then be withdrawn.

Alternatively, slacken off the clamping device which secures the two halves of the pump together (bearing housing and impeller housing) and then proceed to separate them, thus exerting pressure on the seal from behind.

7. Remove the gear from the drive end of the pump shaft by means of a suitable puller.
8. Remove the outer retaining circlip from the bearing housing.
9. Withdraw the impeller housing from the bearing housing, firstly slackening off the clamping device.
10. Withdraw the slinger from the pump shaft.
11. A suitable press may then be used to press out the water pump shaft together with the water pump bearings.
12. Remove the bearings from the water pump shaft by means of a press. To re-assemble the water pump, the reverse order should be adopted.

When replacing the cam fitted in the impeller housing, be certain to coat the entire top surface, rear face and securing setscrew hole with a suitable jointing compound.

Note that the cam will go into position one way only.

Care should be taken, when replacing the rubber impeller, that all the blades lie in the same direction relative to rotation of the pump i.e., blades trailing.

When re-assembling, ensure that the rubber impeller is coated with MARFAK 2HD grease.

**NOTE:**

**If appreciable wear or scoring has taken place on the wear plate working face, it may be turned round so that the reverse side now becomes the working face. If this face in turn becomes worn, then a replacement wear plate should be fitted.**

**If appreciable wear or scoring has taken place on the end cover working face, it can be ground to restore flatness, providing that this operation is not carried out too many times. If a replacement end cover is fitted which does not carry the pump model number etc., then the original worn end cover should be fitted over the new part, utilizing longer setscrews.**

**The thickness of the end cover joint is critical. If it is damaged, it is important that the correct replacement joint, or one of similar thickness be fitted.**

**HEAT EXCHANGER AND OIL COOLER**
**(lowline engines)**

With lowline engines, the heat exchanger and oil cooler are two separate items both mounted on the starboard side of the engine. The oil cooler and spin-on lubricating oil filter are an integral unit.

Removal of both units is effected by removing the inlet and outlet water connections and removing the units from the cylinder block.

The dismantling of both units is similar. Remove the end covers and drive the tube stacks out of their respective housings. Cleaning of the tube stacks is the same as that recommended for the earlier combined heat exchanger and oil cooler as given on Page M.7.

When re-assembling, new "O" ring seals and joints should be fitted if they appear to be badly worn or deformed.

**HEAT EXCHANGER AND OIL COOLER**
**(earlier engines)**

The unit basically comprises: —

(a) An aluminum casing providing the header tank and a machined bore into which the heat exchanger tube stack is located.

(b) A smaller aluminum cylinder into which the oil cooler tube stack is located.

(c) Two tube stacks each comprising a multiplicity of small bore tubes running between two tube plates.

(d) Two sea water end covers.

(e) A tie rod which passes between the end covers and secures the assembly together.

**Dismantling**

When dismantling it is best to proceed in the order given below:

1. Remove the two sea water pipes from their respective end covers.

2. Disconnect the two oil pipes.

3. Remove the brass cap nut.

4. This end cover can now he removed.

5. The other end cover complete with tie rod can now be withdrawn. Care should be taken to support the oil cooler and the spacing ring after the tie rod has been removed, as this will not be attached in any way to the main casing.

6. The "O" seals can now be removed from the end of the tube stacks allowing the latter to be withdrawn from their respective casings.

7. The main aluminum casing can now be removed from the engine if necessary; this will entail disconnection of the fresh water flanges.

**Cleaning**

If the tube stack appears badly fouled up, the best method of cleaning is to use non caustic crystalline solvents approved by the manufacturers.

Usually, the fresh water side, i.e., the outside of the tubes are relatively clean as these are on the

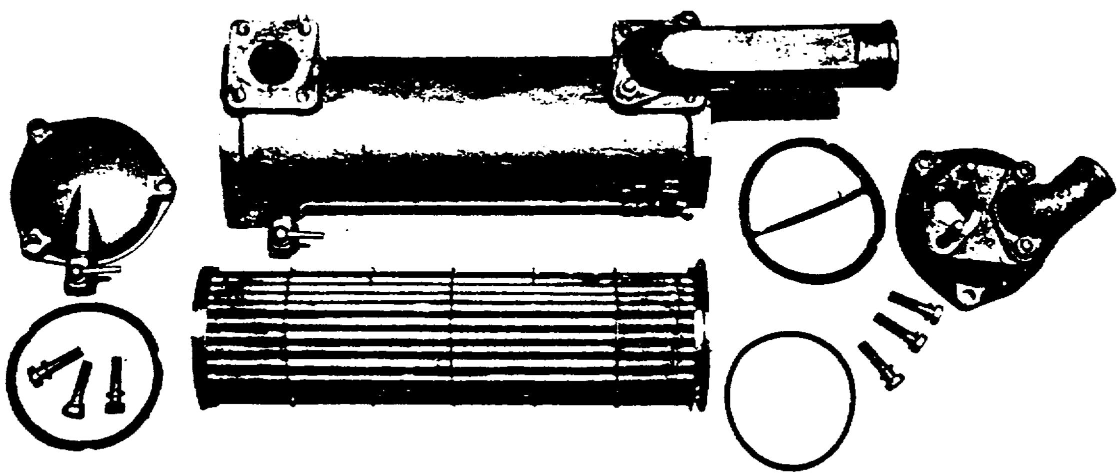


*Fig. M.9.*
*Exploded View of Heat Exchanger.*
*(lowline engines)*

closed water circuit. The inside of these tubes which have the raw water (sea water) passing through them are more likely to require cleaning.

If these are not badly scaled enough to require the solution treatment described above, they can be cleaned by pushing a length of 1/8 in (3.2 mm) diameter steel rod down the tubes to dislodge all foreign matter. It is important to note that when carrying out this exercise, the rod should be pushed through the tubes in the opposite direction to that in which the water flows. Do not use undue force to push the rod through the tubes.

The other components of the assembly should be cleaned before re-assembly and as these have no hidden features, no special instructions are considered necessary.

**Re-Assembly**

If the main aluminum casing has been removed from the engine it is best to refit this to the engine first before re-assembling the heat exchanger itself, although, if conditions are too cramped, it is quite possible to completely re-assembly the heat exchanger first, and then re-attach it to the engine.

1. Place the two tube stacks in their respective casing and fit the "O" seals over each end. It is advisable to renew these seals if they appear badly worn or deformed.

2. The complete oil cooler should now be slid along the tie rod, taking care that the tube stack is located in the end cover.

3. The spacing ring should be replaced in position and the tie rod complete with oil cooler assembly fitted to the main casing.

4. The other end cover can be replaced and the cap nut complete with its copper and asbestos washer refitted. This cap nut should be tightened to a torque not exceeding 25 Ibf ft (3,5 kgf m) - 34 Nm.

**GEARBOX OIL COOLER**

**To Remove**

1. Uncouple inlet and outlet water connections to the oil cooler.

2. Remove inlet and outlet oil pipes.

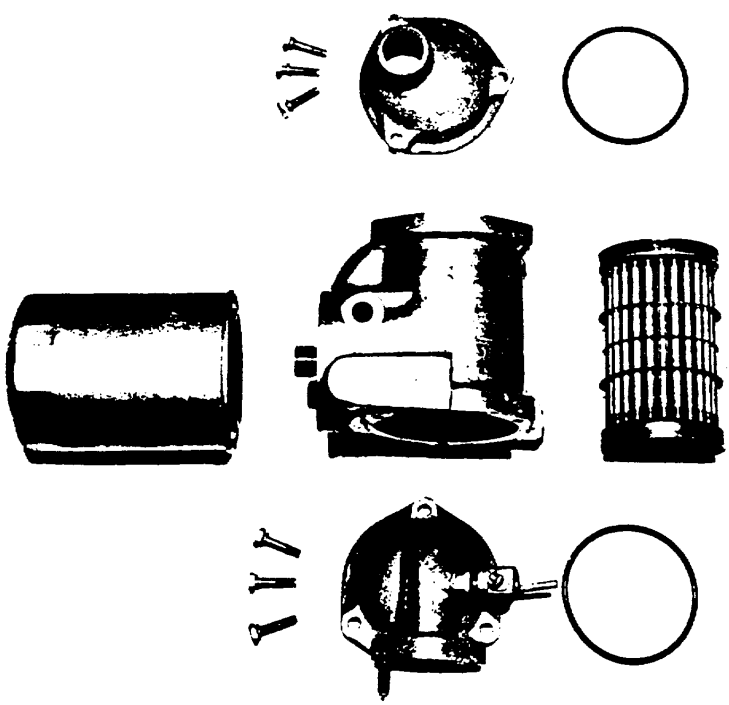


*Fig. M.10.*
*Exploded View of Lubricating Oil Cooler and Filter.*
*(lowllne engines)*

3. Remove oil cooler by unscrewing the two nuts on the ends of the oil cooler securing clamp.

   Replacement of the oil cooler is effected by reversing the above procedure.

**Dismantling**

1. Remove the oil cooler end covers by unscrewing the securing setbolts.
2. Remove the rubber "O" ring seals at each end of the cooler.
3. Drive tube stack out of oil cooler casing.

**Cleaning**

Under normal circumstances, the gearbox oil cooler will require little attention, providing the sea water strainer is efficient and is kept clean.

After a lengthy period of service, it may be necessary to clean the tube stack and this may be effected in a similar manner to that described for the combined heat exchanger and lub. oil cooler.

**Re-Assembly**

1. Place the tube stack in its casing and fit the "O" ring seals over each end cover. It is advisable to renew these seals if they appear to be badly worn or deformed.
2. The end covers and securing setscrews should now be replaced.
3. Tighten the securing setscrews.

## THERMOSTAT

**To Remove (lowline engines)**

1. Remove water connection between header tank and exhaust manifold. To effect this, it is necessary to slacken both hose clips and slide the hose towards the exhaust manifold. Removal of the two setscrews securing the water pipe to the header tank will then permit its removal.
2. Remove setscrews securing top cover of thermostat housing and remove cover.
3. Remove thermostat — see Fig. M.13.

**To Remove (earlier engines)**

1. Remove all water and lubricating oil connections to heat exchanger assembly.
2. Unscrew the four setscrews securing the heat exchanger assembly to the thermostat housing, thereby disclosing the thermostat.

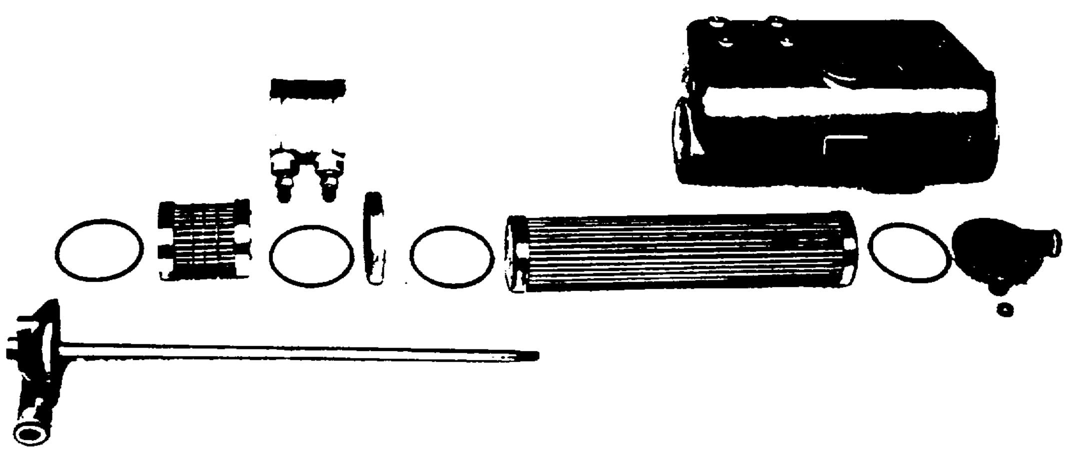


*Fig. M.11.*
*Exploded view of Heat Exchanger Assembly,*
*(earlier engines)*

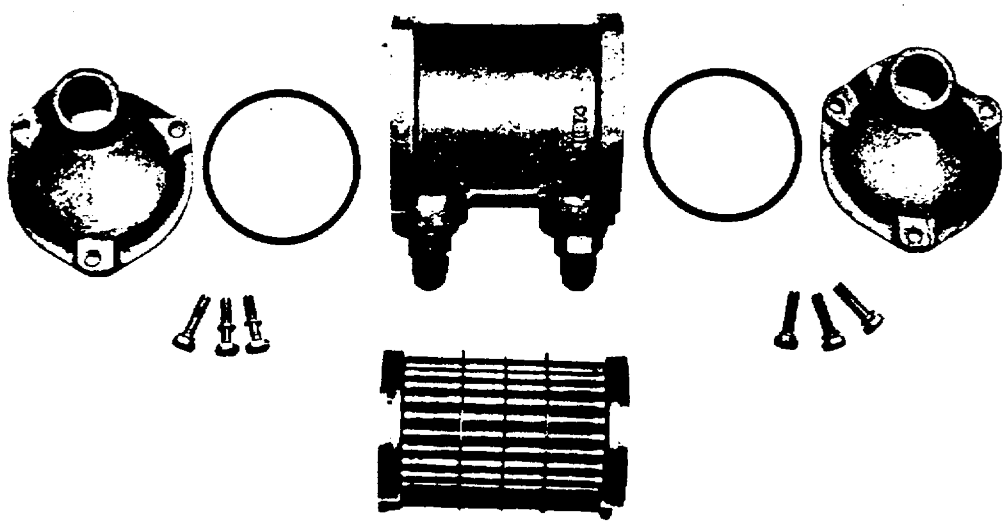


*Fig. M.12.*
*Exploded View of Gearbox Oil Cooler.*
*(lowline engines)*

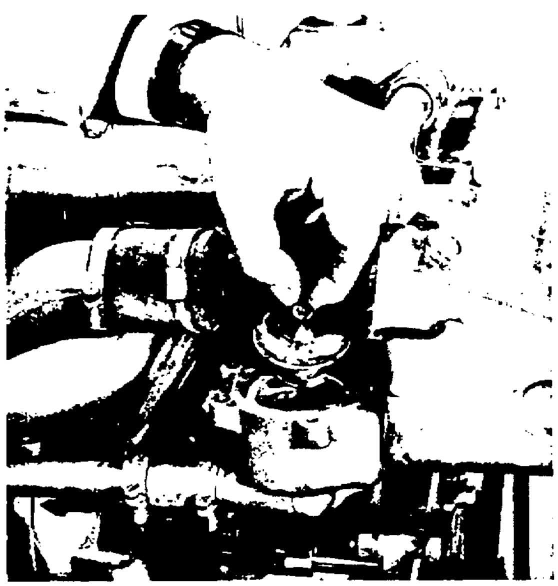


*Fig. M.13.*
*Thermostat Removal.*
*(lowline engines)*

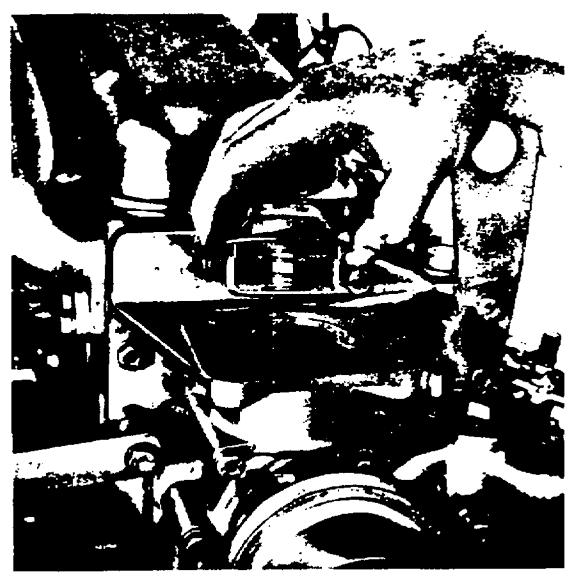


*Fig. M.14.*
*Thermostat Removal.*
*(earlier engines)*

3. Remove the thermostat — see Fig. M.14.

## Testing the Thermostat

If it is suspected that the thermostat is not operating correctly it should be tested in the following manner:—

1. Immerse the thermostat in a suitable container of water and gradually heat. Check the water temperature at frequent intervals with an accurate thermometer. The valve should commence to open at the temperature stamped on the top face of the thermostat adjacent to the valve seat.

2. If the thermostat does not function properly, no adjustment is possible. Replace with a new unit.

## Introduction

The equipment for the supply, filtration and delivery of fuel to the engine consists of a fuel tank, a diaphragm type fuel lift pump, fuel filters, a distributor type fuel injection pump and four injectors. There is also a small reservoir to provide a gravity feed to the cold starting aid in the air intake manifold.

Air drawn into the engine through the induction manifold is filtered by a perforated mild steel gauze.

This method of filtration is satisfactory for all applications except canal, river or dockside work where dust or other foreign matter may be present in the atmosphere. In this case a dry type air cleaner with cleanable element is preferable.

As with all diesel engines, particular stress is laid on the importance of clean, filtered fuel oil if longevity and trouble-free operation is to be obtained.

## AIR FILTERS

The time period for cleaning air filters should be governed by the conditions under which the engine operates.

The correct maintenance of the air filter will greatly assist in reducing bore wear, thereby extending the life of the engine.

## FUEL FILTER

The fuel filter is of the paper element type, therefore, no attempt should be made to clean the element. It should be renewed when periodical maintenance is being carried out.

The filters fitted to earlier engines have a separate element positioned inside a bowl whereas filters fitted to later engines have an encapsulated element held between the filter head and the filter base.

The period for changing the element will largely depend upon the quality and condition of the fuel available. Under normal conditions the element should be renewed every 1,000 hours. This period should be decreased accordingly if unavoidable contamination of the fuel is being experienced.

### To Renew Earlier Type Filter Element

1. Thoroughly clean the exterior of the filter bowl and cover.
2. Unscrew the bolt in the centre of the filter top cover (see Fig. N.1).
3. Take the filter bowl and element assembly away from the filter cover (see Fig. N.2).
4. Throw away the dirty element. Remove the lower element scaling washer, seal seating and spring from the bowl.
5. Thoroughly clean the inside of the bowl particularly the centre tube.
6. Fit the spring and seal seating to the bowl. Examine the lower seal, renew if necessary and refit to the bowl. Place the new element in position in the bowl.
7. Ensure that the element to top cover and the bowl to top cover seals are in good condition, if not, replace with new seals.
8. Bleed the fuel system as detailed on Page N.9.

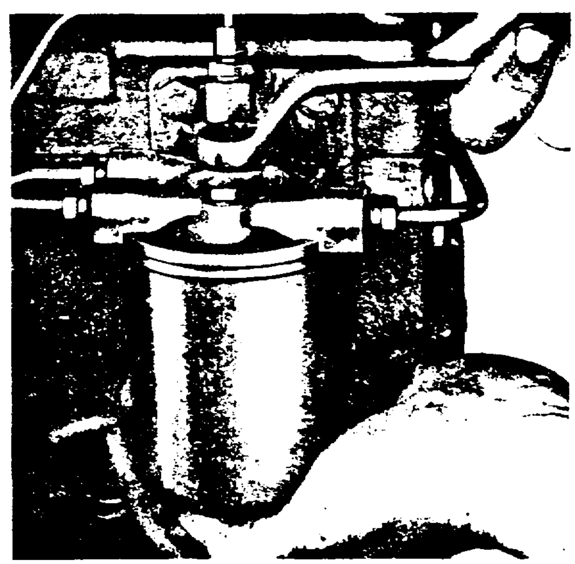


*Fig. N.1.*
*Removing the Fuel Filter Bowl Securing Bolt.*
*(Earlier Type)*

9. Refit the bowl to the top cover and secure with the centre bolt.

10. Vent the fuel system as detailed on Page N.15.

**To Renew Later Type Filter Element**

1. Thoroughly clean the exterior of the filter assembly.

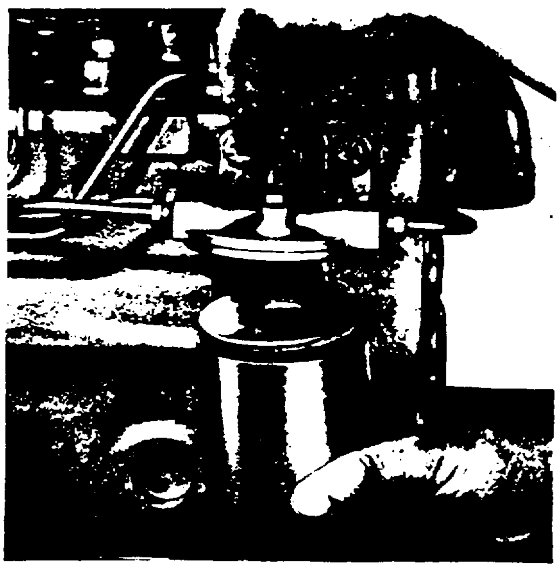


*Fig. N.2.*
*Removing the Fuel Filter Bowl.*
*(Earlier Type)*

3. Thoroughly clean the filter head and base.

4. Inspect the sealing rings and renew if damaged in any way.

5. Place the base squarely on the bottom of the new filter element and offer up the element squarely to the filter head so that the top rim of the element locates centrally against the sealing ring in the filter head.

6. Hold in this position whilst the securing setscrew is located and screwed home.

7. Bleed the fuel system as detailed on Page N.9.

*Fig. N.3.*
*Removing Fuel Filter Element*
*(Later Type)*

**FUEL LIFT PUMP**

**Testing the Pump in Position**

1. Disconnect the outlet pipe (lift pump to filter) leaving a free outlet from the pump.

2. Rotate the engine. There should be a well defined spurt of fuel from the outlet port once every two revolutions of the engine.

**Pressure Testing of Fuel Lift Pump in Position**

Fit a 0/10 lbf/in$^2$ (0/0,7 kgf/cm$^2$) - 0/70 kN/m$^2$ pressure gauge to the outlet of the pump. Ensure that there are no leaks at the connections between pump and gauge. Crank the engine for 10 seconds and note the maximum pressure on the gauge. If the pressure recorded is less than 75% of the minimum production static pressure shown below, then rectify the pump. Also observe the rate at which the pressure drops to half the maximum figure obtained when cranking has ceased. If less than 30 seconds, rectify the pump.

| | Min. Production Static Pressure | | | Min. Test Pressure (75% Min. Prod. Pres.) | | |
|---|---|---|---|---|---|---|
| | lbf/in$^2$ | kgf/cm$^2$ | kN/m$^2$ | lbf/in$^2$ | kgf/cm$^2$ | kN/m$^2$ |
| 4 bolt type | 6 | 0,42 | 41 | 4.5 | 0,31 | 31 |
| 2 bolt type | 2.75 | 0,19 | 19 | 2 | 0,14 | 14 |

**To Clean the Pump Chamber**

1. Remove the fuel lift pump cover and pulsator diaphragm by unscrewing and removing the cover screw (see Fig. N.4).

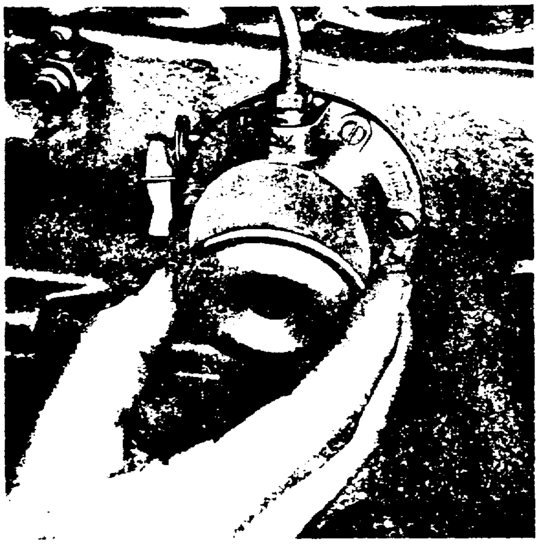


*Fig. N.4.*
*Fuel lift pump cover removal*

2. Clean the sediment chamber and check the pulsator diaphragm for condition. Renew if necessary.

3. Refit the pulsator diaphragm and cover. Tighten the securing screw just sufficiently to make a tight sealing joint.

4. Vent the fuel system as detailed on Page N.14.

**To Remove the Pump**

1. Disconnect the pipes from the inlet and outlet ports. Seal the ends of the pipes to prevent the entry of dirt, etc.

2. Remove the two setscrews securing the pump to the cylinder block and withdraw the pump and joint.

**To Dismantle the Pump**

1. Before dismantling, clean the exterior of the pump and make a file mark across the two flanges for guidance in re-assembling in the correct positions.

2. Remove the six securing screws and spring washers and separate the two halves of the pump.

3. Remove the diaphragm from the lower half of the body by unhooking it from the rocker arm link. The diaphragm spring can now be withdrawn from the body.

4. Drive out the rocker arm pivot pin from the body and withdraw the rocker arm, rocker arm spring and link from the body.

5. Dismantle the priming lever from the body by removing the lever retaining pin and withdrawing the lever and spring from the body.

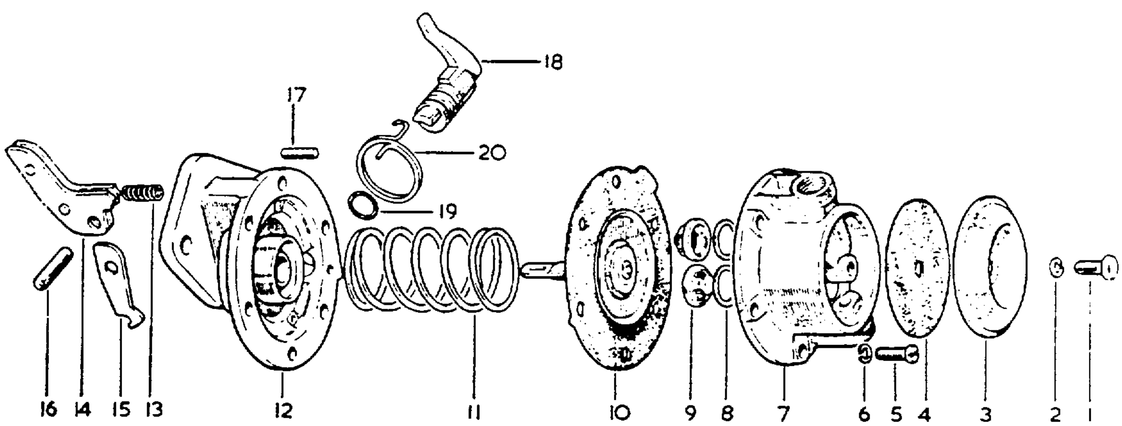



*Fig. N.5.*
*Exploded view of Fuel Lift Pump.*

1. Pulsator Cover Screw.
2. Pulsator Cover Washer.
3. Pulsator Cover.
4. Pulsator Diaphragm.
5. Cover Screw.
6. Cover Screw Washer.
7. Cover.
8. Valve Gasket
9. Valve Assembly.
10. Diaphragm Assembly.
11. Diaphragm Spring.
12. Body.
13. Rocker Arm Spring.
14. Rocker Arm.
15. Link.
16. Rocker Arm Pin.
17. Primer Pin.
18. Primer.
19. Sealing Ring.
20. Primer Spring.

6. Remove the valves from the upper body half by carefully levering from their locations. Remove the valve gaskets from the bottom of the recesses.

7. Remove the pump cover and pulsator diaphragm by unscrewing and removing the cover retaining screw.

**Inspection of Parts**

1. Thoroughly wash all parts in cleaning fluid.

2. Check the diaphragm for hardening or cracking and examine the pull rod for wear at the point where it connects with the rocker lever link. Renew the diaphragm and pull rod assembly if any of these signs are evident.

3. The diaphragm spring should be renewed if it is corroded or distorted. Ensure that if renewing the spring, the new spring has the same (green) colour identification.

4. The valves should be renewed unless in perfect condition. The two valves are identical and may be used for inlet or outlet (See Fig. N.5). It is advisable to renew the valve gaskets after dismantling.

5. Examine the rocker, arm, link, spring and pin for wear. If appreciable wear is evident new parts must be fitted.

6. Check the pulsator diaphragm for condition and renew if necessary.

7. Replace all gaskets and washers as routine procedure.

8. Examine the flanges of the two pump halves for distortion. If distorted lightly finish to restore flatness.

**To Re-Assemble the Pump**

1. Place the new valve gaskets in position in the valve recesses and fit the valves to the body. The inlet valve must be fitted so that the valve can open to admit fuel, i.e., the spring must protrude into pump chamber towards the diaphragm. The outlet valve must be fitted in the reverse position to the inlet valve, so that it allows flow of fuel out of the pump. To retain the valves in the casting, replace retaining plate or stake the casing in six places with a suitable punch.

2. Place the pulsator diaphragm in the pulsator cover and secure on the upper casting with the washer and screw.

3. Insert the rocker arm pin through its hole in the body, at the same time engaging the link and the rocker arm. During this operation ensure that the rocker arm spring is located properly in the pump body. Tap the rocker arm pin in until it is flush with the pump body. Stake the casting in three places each side to retain the pin.

4. Place the diaphragm spring in position in the pump body.

5. Place the diaphragm assembly over the spring, the pull rod being downwards, and centre the upper end of the spring in the lower diaphragm protector washer.

6. Press downward on the diaphragm and make sure that the downward tag on the lower diaphragm protecting washer is on the priming lever side of the body. This tag is required to be in the hole of the body ready for fitment of the priming lever. Engage the diaphragm pull rod with the link and at the same time permit the matching up of the holes in the diaphragm with those on the pump body flanges.

7. Push the rocker arm towards the pump until the diaphragm is level with the body flange. Place the upper half of the pump into its proper position as shown by the file mark on the flanges made prior to dismantling. Install the cover screws and washers and tighten only until the heads of the screws just engage the washer.

   Release the rocker arm and push on the spaded end of the rod so as to hold the diaphragm at the top of the stroke, and while so held tighten the securing screws diagonally and squarely.

   **NOTE: After assembling in the manner described, the edges of the diaphragm should be about flush with its two clamping flanges. Any appreciable protrusion of the diaphragm indicates incorrect fitting in which case especial care should be paid to maintaining pressure on the pull rod while the diaphragm screws are finally tightened.**

8. Fit primer to side of body and retain with the pin. Clip on priming lever spring.

9. Test the fuel lift pump to ensure that it is working correctly.

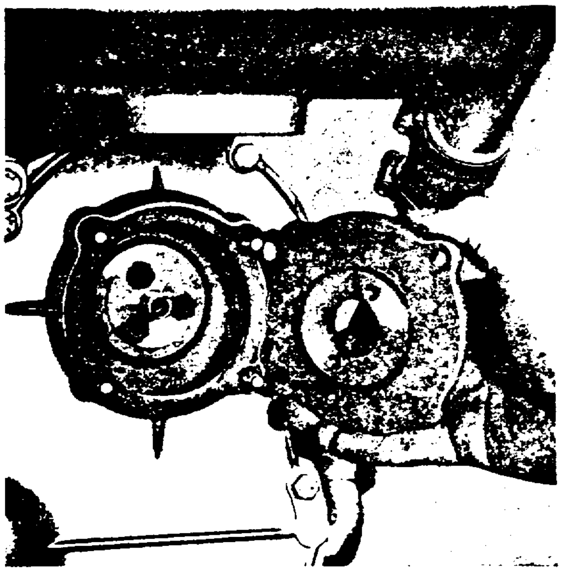


*Fig. N.6.*
*Inspection Cover removed to gain access to Fuel Pump Gear Securing Setscrews.*

**To Refit the Pump**

1. Using a new joint, refit the pump to the cylinder block and secure with the two nuts and spring washers.

2. Reconnect the fuel lines and vent the system of air as detailed on Page N.14

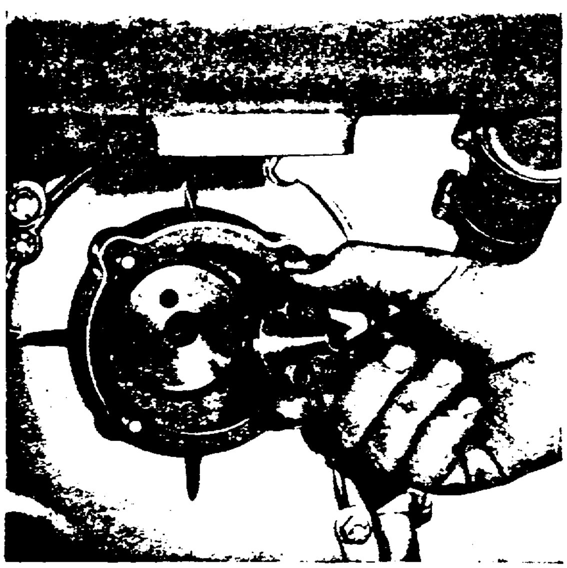


*Fig. N.7.*
*Removal of Fuel Pump Gear Setscrews and Tachometer Drive Shaft.*

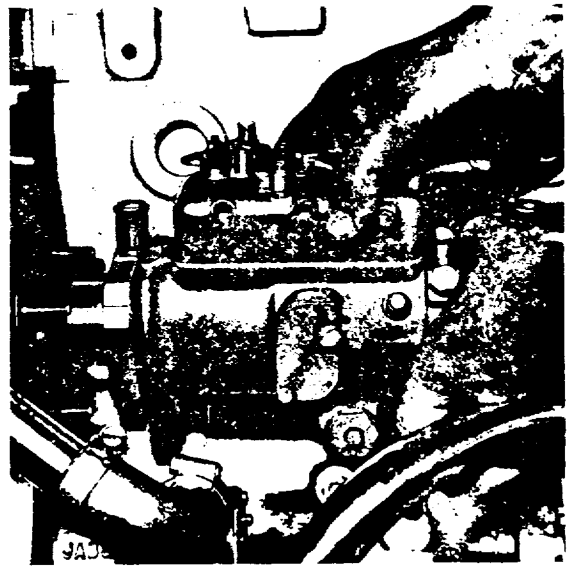


*Fig. N.8.*
*Removal of Fuel Pump.*

**FUEL INJECTION PUMP**

**Description**

The fuel injection pump is of the D.P.A. distributor type. It is a precision built unit incorporating a mechanical flyweight governor.

The pump is flange mounted and is driven front the engine timing case.

**IMPORTANT NOTE: Unless the necessary equipment and experienced personnel are available, dismantling of the fuel pump should not be attempted.**

**To Remove the Fuel Pump**

1. Remove the high pressure injection pipes from the pump and atomisers and blank off all ports to prevent the ingress of dirt.
2. Remove the low pressure pipes from the fuel pump inlet ports, again blanking off the open ports.
3. Disconnect the stop and throttle controls from the pump and remove the control return springs.
4. Remove the nuts and setscrews from the heat exchanger mounting bracket.
5. Remove the bracket complete with tachometer drive assembly and fuel pump gear cover plate.
6. Remove the three setscrews which secure the fuel pump gear to the fuel pump.

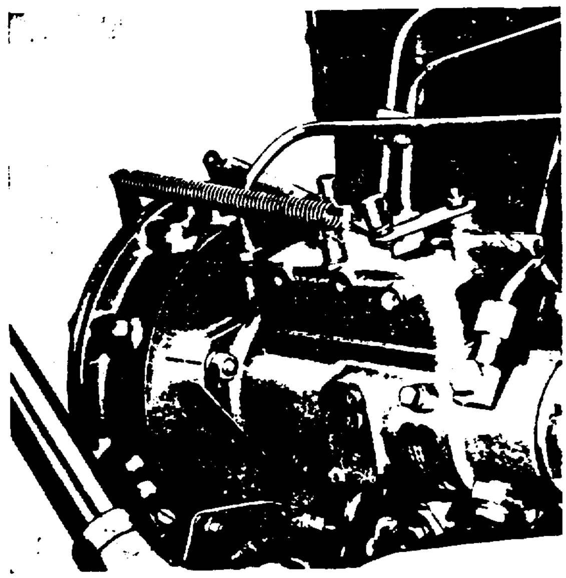


*Fig. N.9.*
*Timing Marks on Fuel Pump Flange and Timing Case.*

7. Remove the three nuts, spring washers and plain washers from the fuel pump securing studs. Withdraw the fuel pump from the timing case ensuring that when the fuel pump gear leaves the fuel pump shaft it stays in mesh with the idler gear otherwise the fuel pump timing will be affected.

**To Refit the Fuel Pump**

1. Offer up the fuel pump together with a new joint ensuring that the slot in the pump hub is aligned with the dowel in the fuel pump gear.
2. Position the pump so that the scribed line on the pump flange and the mark on the timing case are in alignment (see Fig. N.9). To check accuracy of scribed line on rear of timing case, this may be ascertained in accordance with the instructions for marking a new timing case as given on Page K.4. Fit the plain washers, spring washers and secure the pump to the timing case with the three nuts.
3. Secure the pump driving gear and tachometer drive adaptor to the fuel pump shaft with the three setscrews and spring washers, ensuring the dowel is properly located in its slot.
4. Using a new joint fit the fuel pump gear cover plate complete with tachometer drive assembly.
5. Refit the heat exchanger mounting bracket and secure with the setscrews and nuts.
6. Refit the low pressure pipes to the fuel pump inlet and outlet connections.
7. Refit the high pressure injection pipes between the atomisers and fuel pump.
8. Re-connect the throttle and stop lever controls and securely attach their respective return springs in position.
9. Vent the air from the fuel system as detailed on Page N.14.
10. Adjust the maximum speed and idling speed as detailed on Page N.8.
11. If the fuel pump timing is suspected of being inaccurate it should be checked and reset as follows:—

**To Check Marking Angle of Fuel Injection Pump using Tool MS67B**

1. Release screw (5, Fig. N.10) and position splined shaft with the small splined diameter to the rear to locate in the fuel pump drive shaft.
2. Ensure that the slotted pointer (2) is positioned with slot to rear of tool and chamfered sides of slot outwards. At this stage, slotted end of pointer should be kept well back towards the body of tool. Ensure that the flat in the washer fitted behind the pointer locating screw (3) is located over the side of pointer.
3. Release bracket screw (4) and set bracket so that the chamfered edge is in line with the relevant marking angle (see Page B.11).
4. Position timing tool, locating splined shaft in hub and slide tool towards pump to rest on end of hub and lock shaft in tool.

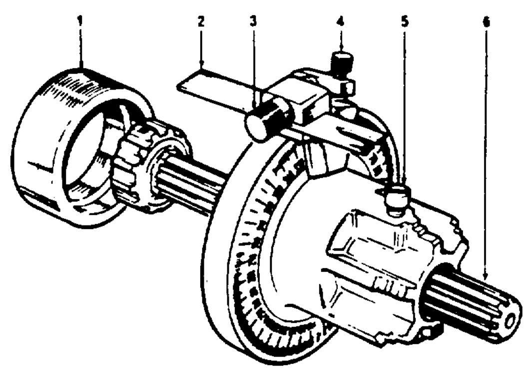



*Fig. N.10.*
*Fuel Pump Timing Tool MS67B.*

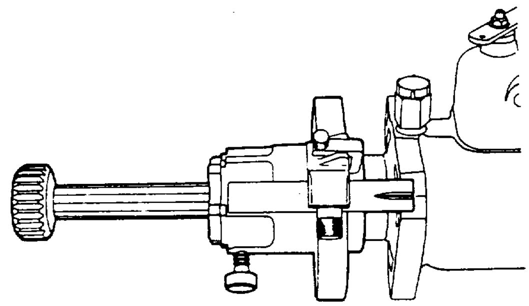


*Fig. N.11.*
*Checking Timing Mark on Fuel Pump Flange.*

5. Connect No. 1 outlet of pump body to an atomiser test rig and pump up to 30 atm (31 kgf/cm$^2$) or 440 lbf/in$^2$.
6. Turn pump in normal direction of rotation as shown on pump nameplate until it locks.
7. In this position, slide pointer forward until it is halfway over pump flange and check that timing mark is central to slot in pointer (see Fig. N.11).

Where no timing tool is available, the fuel pump timing may be checked as follows:—

On the fuel pump rotor, inside the fuel pump are a number of scribed lines, each one bearing an individual letter. A timing circlip with a squared end is positioned inside the pump and has to be set so that when the appropriate scribed line on the fuel pump rotor is aligned with the squared end of the timing circlip; this denotes the static point of injection.

To set the timing circlip, it is necessary to remove the pump from the engine and fix the position of the circlip by connecting No. 1 cylinder outlet connection (marked "W") to an atomiser tester and pump up to 30 atm (31 kgf,/cm$^2$ or 440 lbf/in$^2$). Turn the pump by hand

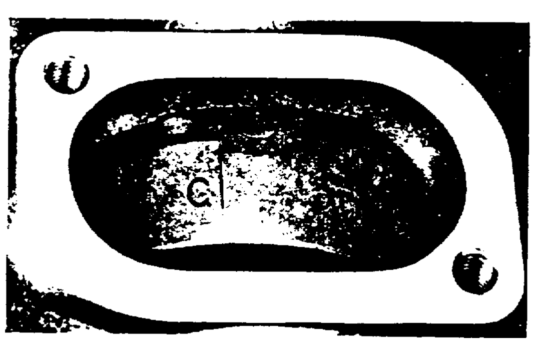



*Fig. N.12.*
*Timing Marks on Fuel Pump Rotor.*

in the normal direction of rotation until it "locks up". The squared end of the circlip should now be adjusted until it lines up with the letter "C" on the pump rotor.

To re-set the fuel timing the following procedure should be adopted:—

1. Ensure that the fuel pump circlip is correctly positioned as described previously.
2. Ensure that the fuel pump is correctly fitted with the scribed line on the mounting flange coinciding with the mark on the back of the timing case cover (see Fig. N.9).
3. Position the crankshaft so that No. 1 piston is at T.D.C. on compression stroke.
4. Remove the collets, spring cap and spring from one of the valves on No. 1 cylinder and allow the valve to rest on the top of the piston. Care is necessary with this operation as the consequences of a valve dropping into the cylinder need not be described.
5. With the aid of a clock gauge in contact with the end of the valve now sitting on the No. 1 piston it will be necessary to position the crankshaft so that the piston will be at the correct "Static Timing Position" (See Page B.11).
6. Remove the inspection plate on the fuel pump enabling the rotor to he seen.
7. With No. 1 piston at the static timing point In its compression stroke, the scribed line on the fuel pump rotor marked “C” should align with the squared end of the circlip (Refer to Fig. N.12).

   If it does not, then the necessary adjustment should he made by releasing the fuel pump, securing setscrews and turning the fuel pump on the slotted holes the required amount to bring the respective timing letter into alignment with the squared end of the timing circlip.
8. When the fuel pump timing is correct, refit the spring, spring cap and collets to the valve which has been used for the timing check and refit the pump inspection plate and timing case inspection plate. Re-seal the inspection plate.

**Maximum Speed Setting**

**IMPORTANT NOTE: The maximum speed screw seal of the original fuel pump must not be broken or tampered with in any way unless factory authority is first obtained. Failure to do so may result in the guarantee becoming void.**

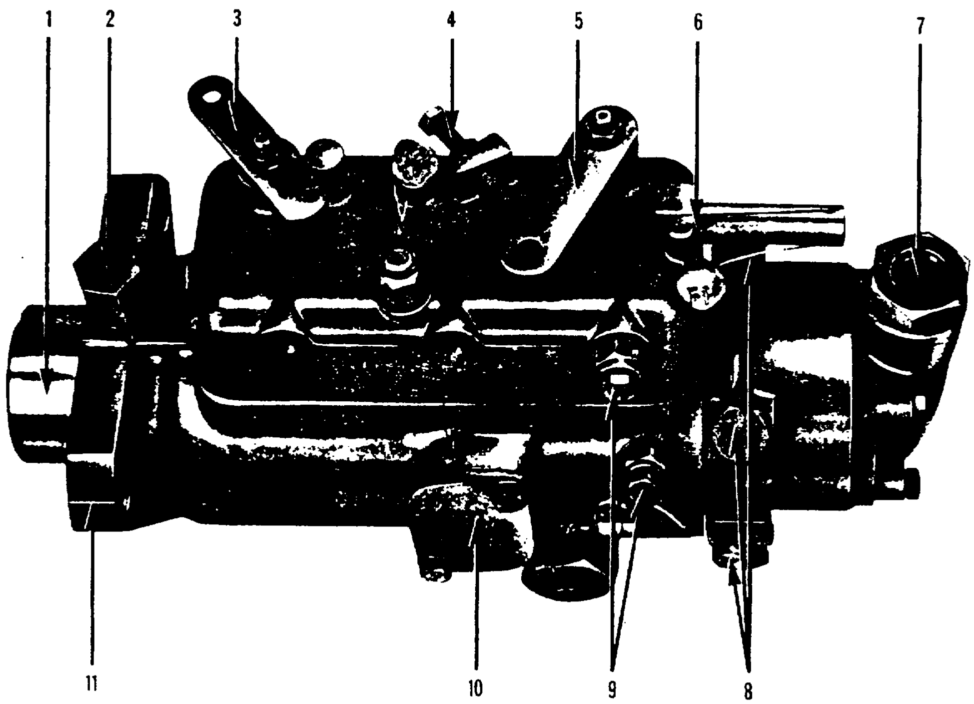



*Fig. N.13.*

1. Drive Shaft.
2. Fuel Outlet.
3. Stop Lever.
4. Idling Screw
5. Speed Control Lever.
6. Maximum Speed Screw.
7. Fuel Inlet.
8. Injector Pipe Connections
9. Bleed Screws.
10. Inspection Cover Plate.
11. Scribed Line.

When fitting a replacement fuel pump, or in the event of the maximum speed screw having been moved for any reason, the maximum no load speed must be checked and re-set as necessary.

The maximum no load speed will depend upon the type of application to which the engine is fitted, and for details of this, reference should be made to the code number stamped on the fuel pump data plate. The last four numbers in the code indicate the speed required, and in the case of the example quoted below, this would be 2660 rev/min.

**Code Example:—PS66/500/2/2660**

**NOTE: If the fuel pump data plate is damaged or defaced so as to make it impossible to read the code, or if the code is not stamped on the plate, you are advised to contact your nearest Perkins Distributor, or alternatively, Service Dept., Perkins Engines Limited, Peterborough, to obtain the correct maximum no load speed setting.**

To set the maximum no load speed the following procedure should be adopted:—

1. Check the fuel system for leaks and rectify as necessary. Ensure that no air is present in the system.
2. Run the engine at part throttle until full operating temperature has been reached.
3. Place a tachometer with a suitable extension and drive adaptor in the centre of the crankshaft pulley retaining screw.
4. Open the throttle until the maximum speed, given on the pump data plate, is obtained. If the speed will not reach this figure, turn the maximum speed screw anti-clockwise until the required speed is obtained. Should it be possible to obtain a higher speed, turn the maximum speed screw clockwise until the speed is reduced to the required figure. Re-seal the maximum speed screw.

**IMPORTANT.** Under no circumstances should the engine be allowed to operate at a higher speed than specified or severe damage to the engine may be the result.

### Idling Speed Setting

The engine idling speed is adjusted by the idling screw (see Fig. N.13).

With the engine warm, turn the screw clockwise to increase the engine speed and anti-clockwise to decrease.

The idling speed may vary, depending upon the type of craft to which the engine Is fitted. For details apply to the nearest Perkins Distributor, or alternatively, Service Dept., Perkins Engines Limited, Peterborough.

## ATOMISERS

### General

Each atomiser body consists of a steel body held to the cylinder head by means of a flange and two studs.

The joint between the atomiser and cylinder head is made by a copper washer between the lower face of the nozzle cap and the cylinder head.

When preparing to fit the atomiser into place in the cylinder head, care should be taken, that only the correct copper washer is used to make this joint. The metal of the cylinder head, the faces of the copper joint ring, and the corresponding face on the nozzle holder cap nut should be perfectly clean if a leak-proof joint is to result.

It is advisable to fit a new joint washer when the atomiser is replaced after having been removed for any reason.

Ensure that the old washer has been removed from atomiser or cylinder head.

This joint washer should be an easy, but not loose fit for the atomiser nozzle, and it is because this is such an important feature that the washers especially made for the purpose should be used and none other. On no account should ordinary sparking plug type washers be used.

The atomiser can now be fitted in place, care being taken to see that it is an easy fit in the cylinder head and on the holding-down studs, so that it can be placed down on the copper joint without force of any kind. The nuts on the flange should then be tightened down evenly in order to prevent the atomiser nozzle being canted and so "nipped" in the cylinder head.

The correct tightening torque for the atomiser securing nuts is 12 lbf ft (1,7 kgf m) - 16 Nm.

When fitting the leak-off pipes make sure new washers are used, and before tightening the banjo bolt make sure the washers are a good fit and are placed centrally, and remain central when tightening the bolt.

### MAINTENANCE

The following information is given for the guidance of those who wish to carry out their own atomiser maintenance using the basic test equipment, which would include an Atomiser Testing Pump and kit of tools. (Refer Figs. N.14 and N.17).

Atomisers should be taken out for examination at regular intervals. How long this interval should be is difficult to advise, because of the widely different conditions under which engines operate. When combustion conditions in the engine are good and the fuel tank and filtering system are maintained in first-class order, it is often sufficient if the atomisers are tested every 2,500 hours.

It is no use taking atomisers out of attention unless the equipment described above is available, or spare atomisers are at hand for substitution.

The nearer the ideal conditions of good fitting with adequate cooling and absolutely clean fuel are realized, the less attention the atomisers will need, and so the longer their efficient life. In this connection, since there is no other item of the equipment upon which the performance of an engine depends so much, it pays the user handsomely to see that the engine never runs with any of its atomisers out of order.

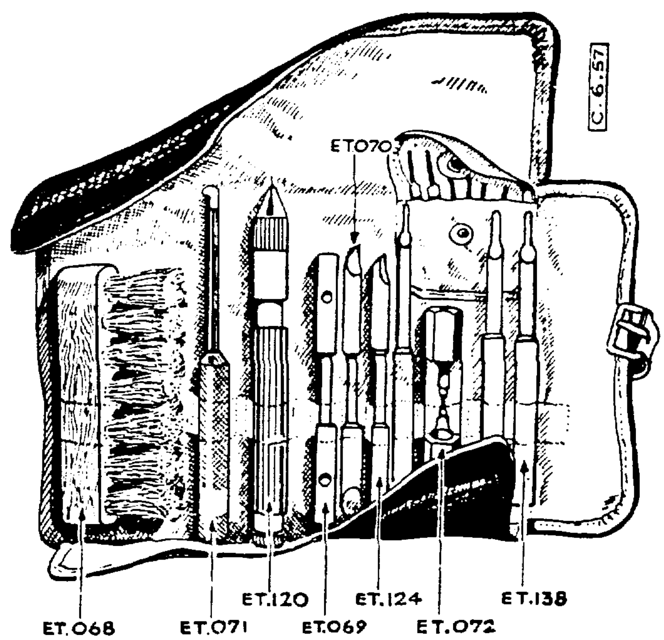



*Fig. N.14.*
*Complete Kit of Tools for use when cleaning and overhauling atomisers.*

## Troubles in Service

The first symptoms of atomiser troubles usually fail in one or more of the following headings:–

1. Misfiring.
2. Knocking in one (or more) cylinders.
3. Engine overheating.
4. Loss of power.
5. Smoky exhaust (black).
6. Increased fuel consumption.

Often the particular atomiser or atomisers causing trouble may be determined by releasing the pipe union nut on each atomiser in turn, with the engine running at a fast "tick-over." This will prevent fuel being pumped through the nozzle to the engine cylinder, thereby altering the engine revolutions. If after slackening a pipe union nut the engine revolutions remain constant, this denotes a faulty atomiser.

After stopping the engine the nuts from the flange of the doubtful atomiser should be removed and the complete unit withdrawn from the cylinder head and turned round, atomiser nozzle outwards and the unions retightened. After slackening the unions of the other atomiser pipes (to avoid the possibility of the engine starting), the engine should be turned until the nozzle sprays into the air, when it will be seen at once if the spray is in order. If the spray is unduly "wet" or "streaky" or obviously to one side, or the atomiser nozzle "dribbles," remove from the fuel pipe; the faulty atomiser should then be securely wrapped, preferably in grease-proof paper for attention on the maintenance bench.

**NOTE: Great care should he taken to prevent the hands or face from coming into contact with the spray, as the working pressure will cause the fuel oil to penetrate the skin with ease.**

## Preparation

The most suitable bench for atomiser maintenance is one that is zinc, linoleum or plastic covered, absolutely free from dust, dirt, filings, grease or acids, where no other work is done and where the use of cotton waste or fluffy rags is forbidden. It should also be provided with a small vice (the jaws being protected with clean soft copper or aluminum shields) and a dust-proof drawer for holding the nozzle cleaning tools.

An atomiser is good for service if, when operating the Atomiser Testing Pump at the recommended rate, it gives four effective sprays, each breaking into a very fine mist and the breaking pressure is not less than the working pressure, (refer page B.12) then the atomiser may be put back into service.

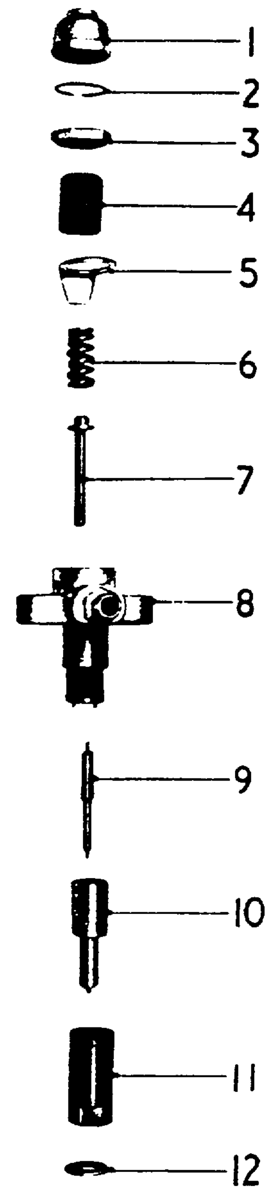



*Fig. N.15.*
*Exploded view of Atomiser.*

1. Nozzle Holder Cap Nut.
2. Cap Nut Washer.
3. Locknut.
4. Spring Cap.
5. Identification Tab Washer.
6. Spring.
7. Spindle.
8. Body.
9. Nozzle Needle.
10. Nozzle.
11. Nozzle Cap Nut.
12. Copper Washer.

An atomiser requires attention if (a), when proceeding as above it throws out "solid" wet jets and not broken up spray or, (b), if any of the holes are choked or partially choked so that the spray issues only from one or two holes in the nozzle, or (c), an irregular spray pattern is formed.

**Atomiser Dismantling**

The atomiser should be placed on a suitable holding plate, nozzle downwards, first remove the nozzle holder cap nut (1), slacken the locknut (3), release the nozzle spring tension by turning the spring cap (4) in an anti-clockwise direction. Reverse the position of the atomiser on the holding plate and remove the nozzle cap nut (11) and nozzle (10) taking care not to drop the nozzle needle onto the floor. Complete the dismantling by removing the spring cap, spring (6) and spindle (7). Inspect visually for signs of corrosion, distortion, etc. Keep all the dismantled parts together, if possible, in a tray to facilitate re-assembly after cleaning.

**NOTE: Do not lose the small steel shim washer fitted between the top of the spring and the spring cap.**

To hold the nozzle holder cap nut in a vice or to use badly worn or adjustable spanners is to invite trouble.

**Inspection**

The nozzle needle should be free from all traces of damage, it is important that it is not "blued" at the tip due to overheating. If the nozzle is "blued" or the seating has a dull circumferential ring indicating wear or pitting, the complete unit (nozzle and needle) should be set aside for attention by a depot or agent with specialized equipment available and a replacement nozzle assembly used

The stem of the nozzle needle should be clean and bright, free from high spots, bad scratches or dull patches, and the grooves free from foreign matter of any kind; similarly the nozzle needle bore in the nozzle body should be free from any of the above, the small drilled passages should be checked to see that they are clear.

**Cleaning**

Starting with the nozzle assembly, remove the needle from the nozzle body and by using the soft brass seat scraper (ET 070) any carbon which may be present on the nozzle body seat can be

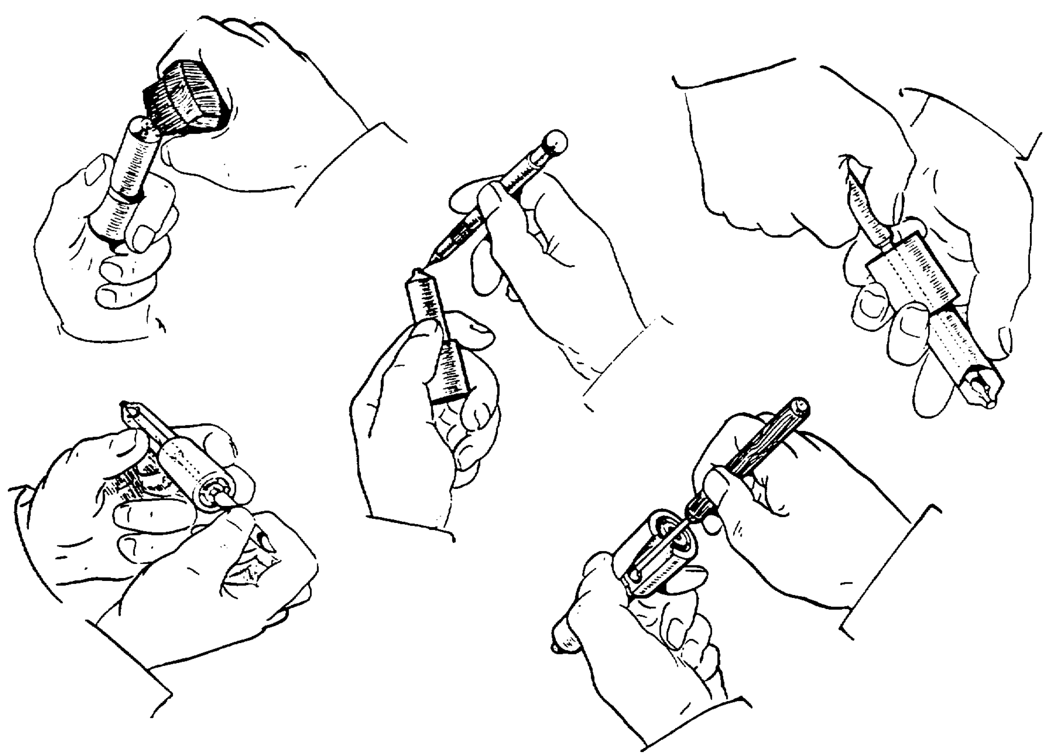


*Fig. N.16. Cleaning the Nozzle.*

removed. The gallery should now be cleaned with the aid of the special soft brass scraper (ET 071).

Brush all carbon from the nozzle tip using the brass wire brush contained in the recommended Nozzle Cleaning Kit shown in Fig. N.14. The four holes in the nozzle tip should be cleared by means of the probing tool (ET 120) fitted with the appropriate sized cleaning wire. If the size is not known, it can be ascertained by careful trial of wires in the holes. Extreme care must be taken, however, to obviate the danger of wire breaking off in the hole, as its removal is practically impossible and renders the nozzle unusable.

The cleaning wire should be fitted in the probe chuck so that there is approximately 1/16 in protrusion, thus giving maximum resistance to bending. Enter the wire into the hole, pushing and rotating gently until each hole in turn is cleared. Particular attention should be given to the nozzle needle seat. This and the smaller cylindrical portion above it, called the "stem" and "cone," can he cleaned with the fine brass wire brush. To ensure that the stem and cone in the nozzle body are free from carbon particles, the soft brass stem cleaner (ET 072) should be applied with a rotary action pressing between the fingers. After ensuring that the exterior of the atomiser nozzle is clean and free from carbon. the nozzle needle and nozzle body may be thoroughly washed in clean fuel oil, or an approved alternative, assembled together whilst submerged in the clean oil and left immersed until it is intended to re-assemble the atomiser. Should it be desired to store the nozzle assembly for any period of time, then the needle and nozzle should be lightly smeared with grease and stored away, preferably in a dust-proof drawer.

The atomiser body should now receive attention, it should be washed in clean fuel oil or an approved alternative. care being taken to ensure that the highly ground face is clean and free from scratches. This face must register with the atomiser nozzle flange cleanly and squarely to form a high pressure joint and must, therefore, be handled in such a way as to avoid damage to the surface. The exterior of the atomiser body, of course, should be cleaned thoroughly.

### Re-Assembly of Atomisers

The atomiser body and nozzle assembly may now be assembled carefully, after having immersed the pressure faces of each in clean fuel or an approved alternative, to ensure that these faces are absolutely clean. Place the atomiser body on the holding plate, pressure face uppermost, place the nozzle assembly in position (located by the dowel) and fit the nozzle cap nut, tighten carefully. Excessive tightening of this cap may result in distortion of the nozzle and its consequent failure; care should be exercised that the leverage applied is not excessive. Reverse the atomiser on the plate and refit the spindle, spring and spring cap (ensure that the steel shim washer is correctly located in the top of the cap). Transfer the atomiser from the holding plate and fit to the Atomiser Testing Pump. Pump up slowly until fuel spurts out of the four nozzle holes and whilst still pumping slowly turn the spring cap, using a suitable screwdriver, in a clock-wise direction increasing the spring tension until the breaking pressure is that quoted against Setting Pressure on Page B.12.

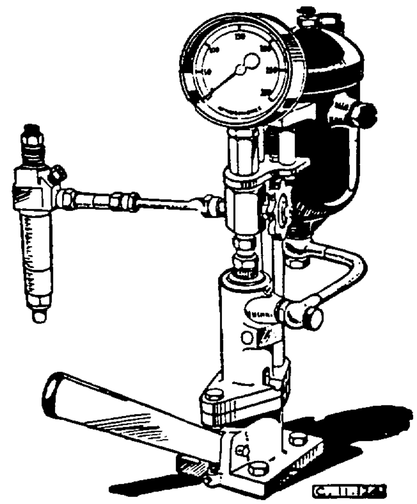


*Fig. N.17. Atomiser Testing Pump*

The atomiser is good for service if, as previously mentioned. when the Atomiser Testing Pump is operated at approximately twenty strokes per minute, four effective and even sprays breaking into a very fine mist are obtained.

**NOTE: When testing atomisers for spray formation, as opposed to setting the nozzle breaking pressure, always isolate the pressure gauge by means of the valve fitted, to prevent possible damage caused by rapid fluctuations in pressure.**

### Pressure Setting

To set the pressure at which the nozzle should open, slowly move the hand lever downwards and carefully watch the pressure gauge for the highest recorded pressure before the needle "flicks," indicating the needle lifting off its seat. Any necessary adjustment is effected by loosening the locknut (3) and turning the spring cap (4) clock-wise to increase or anti-clockwise to decrease the breaking pressure. Tighten the locknut and re-check the pressure before removing from the Atomiser Testing Pump.

When the atomiser has been cleaned, reassembled, the breaking pressure set to the recommended figure and the spray formation found to be satisfactory, the following two checks may be carried out on the Atomiser Testing Pump before returning the atomisers to service.

**(1) Back Leakage**

Pump up sufficient pressure to raise the nozzle needle from its seat, pump again slowly to just below this pressure (approximately 160-165 atmospheres), then upon releasing the hand lever and allowing the pressure to fall naturally, record the time (with the aid of a stop-watch) taken for the pressure shown on the gauge to fall from 150 to 100 atmospheres. For a nozzle in good condition this time should not be less than 6 seconds.

When carrying out this test observe that no leakage occurs at the lapped pressure faces of the nozzle holder and nozzle body. Leakage may be external, when it is visible at the nozzle cap nut screw thread, or internal, in which case it cannot be readily distinguished from excessive leakage past the lapped portion of the needle. If leakage past the lapped portion is suspected, do not overtighten the cap nut in an effort to cure such leakage, but remove the nozzle and re-examine the pressure faces for signs of dirt or surface imperfections. Clean thoroughly, and if all appears in order, replace components and re-test.

If the pressure drop time is still low, this indicates excessive leakage past the lapped portion of the nozzle needle.

**(2) Seat Tightness**

Wipe nozzle tip dry, pump up the pressure to approximately 10 atmospheres below the nozzle opening pressure, the nozzle tip must remain substantially dry and there must be no tendency for blobs of fuel to collect or drip. A slight dampness may be ignored.

**NOTE: If, after carrying out the aforementioned atomiser maintenance, satisfactory results are not obtained, the nozzle assemblies concerned may still be fit for further service after reconditioning. This, however, requires specialized equipment and the complete nozzle assemblies should be forwarded to the nearest depot or workshop capable of undertaking such work, and a replacement unit obtained.**

A perfect atomiser, when tested by pumping fuel through it in the open air gives a short "pinging" sound as the fuel emerges from the holes. After the atomiser has been in service for some time, the "pinging" changes to a crackling sound. It is not until the atomiser sounds "dead" that its condition is likely to affect the running of the engine.

When replacing the atomiser in the cylinder head follow carefully the instructions for fitting given on Page N.8.

**Atomiser Identification**

Later atomisers have the identification letters "CU" rolled on the atomiser body.

With earlier atomisers, the identification letters were stamped on the tab washer fitted under the spring cap locknut.

**Fuel Pipes**

No two of the pressure pipes, from the fuel pump to the atomisers are alike. Keep this in mind when replacing.

Examine the olives at each end of the pipe. If the union nuts have at any time been overtightened there is a risk that the olives will have cracked or been unduly compressed. If so, leakage will result and a new pipe should be fitted.

High pressure fuel pipes are now supplied with formed ends in place of olives. Earlier pipes were supplied with olives fitted as shown in Fig. N.18. Originally, the olives were fitted in the reverse position but both positions are still satisfactory if undamaged.

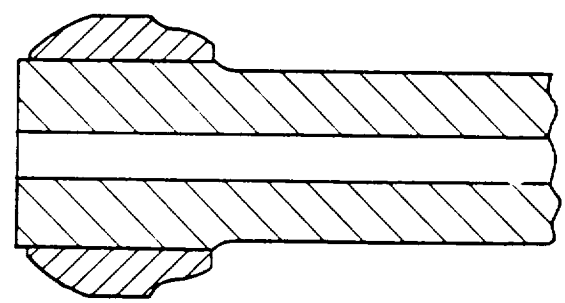


*Fig. N.18.*

In this connection bear in mind that the working pressure which these joints must sustain is several thousands pounds per square inch. Only a perfect joint is satisfactory.

Offer up the pipe to the fuel pump and atomiser unions to check that the pipe fits square at both ends. Do not fit one and then bend the pipe to square it with the other union.

When fitting the pipe tighten the unions alternately a little at a time, first one end and then the other.

The correct tightening torque for the high pressure fuel pipe nuts is 15 lbf ft (2,1 kgf m) - 20 Nm.

If the olives are in good condition, and the

*Fig. N.19*
*Unscrewing Vent Plug on lop of Filter Cover.*

pipe is square to the unions at each end as described previously, no force will be needed to make a good joint. Use only a standard open ended 5/8 in A.F. spanner.

If the union is tightened excessively the olive may collapse and split. The same danger exists if the pipe is not square to and central with the union.

When changing an atomiser always remove the pipe entirely. Never disconnect one end only, leaving the other end tight. Never bend the pipe.

## PRIMING THE FUEL SYSTEM

The air must be vented from the fuel system whenever any part of the system between the fuel link and injection pump has been disconnected for any reason, or when the system has been emptied of fuel.

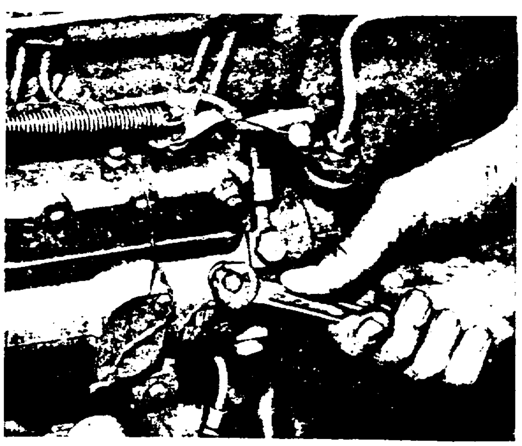


*Fig. N.20.*
*Slackening Vent Valve on Hydraulic Head Locking Screw.*

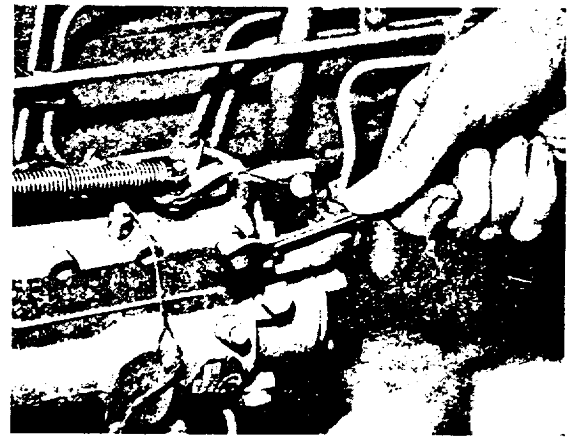


*Fig. N.21.*
*Slackening Air Vent Valve on Governor Control Cover.*

No attempt must be made to start the engine until the injection pump has been filled and primed as serious damage can be caused to the pump due to lack of lubrication.

The method of priming detailed below, ensures that only fuel which has passed through the paper filter element can reach the interior of the pump.

To bleed the system, proceed as follows:—

1. Unscrew by two or three turns, the vent plug on top of the fuel filter cover (not the return pipe to the tank). See Fig. N.1). Later type fuel filters are self venting and do not have a vent plug. Air vent the fuel filter by removing

*Fig. N.22.*
*Operating the Hand Priming Lever on the Fuel Lift Pump.*

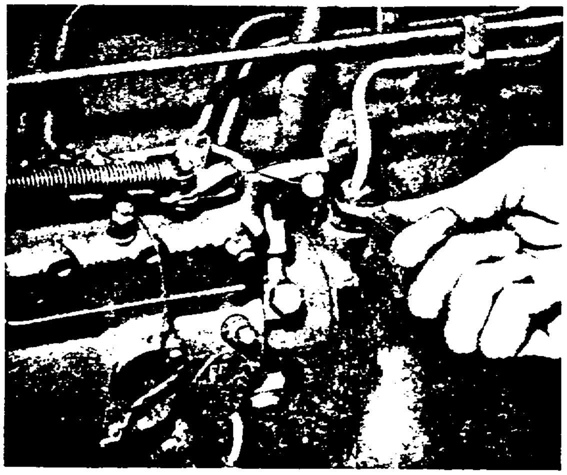


*Fig. N.23.*
*Slackening Union Nut at Pump Inlet.*

the excess fuel return pipe, to the fuel tank, from the filter head. Operate the fuel feed pump priming lever until fuel, free from air bubbles issues from the non return valve. Refit fuel return pipe.

2. Slacken the vent screw on the hydraulic head locking screw on the side of the fuel injection pump body. See Fig. N.20.
3. Slacken the air vent screw on the side of the governor control cover. See Fig. N.21.
4. Operate the priming lever of the fuel lift pump — see Fig. N.22 (note — if the cam on the engine camshaft driving the fuel lift pump is on maximum lift, it will not be possible to operate the hand primer and the engine should be turned one complete revolution) and when fuel, free from air bubbles issues from each vent point, tighten the connections in the following order.
   (a) Filter cover vent screw.
   (b) Head locking screw vent valve.
   (c) Governor cover vent valve.
5. Slacken the pipe union nut (see Fig. N.23) at the pump inlet, operate the priming device and retighten when oil, free from air bubbles issues from around the threads.
6. Slacken the unions at the atomiser ends of two of the high pressure pipes.
7. Set the accelerator at the fully open position and ensure that the "stop" control is in the "run" position.
8. Turn the engine until fuel oil, free from air bubbles, issues from both fuel pipes.
9. Tighten the unions on both fuel pipes, and the engine is ready for starting. If fuel has been drained from the thermostat feed pipe, the pipe must be disconnected at the thermostat and all air bled from the pipe before the thermostat is operated.

**Priming Procedure after changing a Filter Element**

1. With the vent plug on the filter cover removed, and the union at the filter end of the return pipe (filter to tank) slackened, operate the feed pump priming lever until oil, free from air bubbles, issues from the filter cover vent.
2. Replace the vent plug, and continue to operate the priming lever until oil, free from air bubbles, issues from around the threads of the return pipe union.
3. Tighten the return pipe union.
4. Slacken the union at the filter end of the filter to injection pump feed pipe, and operate the priming lever until oil, free from air bubbles, issues from around the union threads.
5. Tighten the feed pipe union. The pump and filter are now filled and primed and ready for further service.
6. Later type fuel filters may not have an air bleed plug. In this case remove the excess fuel return pipe, to the fuel tank, from the filter head. Operate the feed pump priming lever until fuel free from air bubbles issues from the non-return valve. Refit fuel return pipe. Continue from item 4.

## GEARBOX

The gearbox fitted to the 4.236 Marine engine is the earlier Borg Warner 71 CR or the later 10-17 type, hydraulically operated, direct drive type incorporating a reverse gear.

A Borg Warner 71 CR or the later 10-17 type gearbox with an epicyclic reduction gear can be supplied with the following ratios:– 1.523:1, 1.91:1, 2.1:1, 2.57:1, or 2.91:1. The output shaft of the gearbox or reduction gear is on the same centreline as the crankshaft.

For standard gearboxes and reduction gear, a left handed propeller is required, except with the 1.91:I reduction gear, which requires a right handed propeller. The 2.1:1 and 1.91:1 reduction gears can be used together in twin engined installations to give left and right handed propeller rotation.

The gearbox operating oil pressure should be 120/140 lbf/in$^2$ (8,4/9,8 kgf/cm$^2$) - 827/965 kN/m$^2$.

**IMPORTANT NOTE:**

**When filling the Borg Warner gearbox as fitted to the 4.236 Marine engine, Automatic Transmission Fluid Type 'A' must be used.**

The gearbox should be filled to the full mark on the dipstick and the unit turned over at low speed by idling the engine for a short period in order to fill all circuits including the cooler and cooler piping.

The oil level should then be checked immediately after shutting off the engine and sufficient oil added to bring the level to the full mark again.

When checking the gearbox oil level, the dipstick should be screwed fully home in order to obtain the correct reading.

## TO REMOVE THE GEARBOX

1. Remove lubricating oil pipes to and from gearbox oil cooler.
2. Remove water connections to and from gearbox oil cooler.
3. Remove gearbox oil cooler.
4. Uncouple propeller shaft from gearbox output shaft and move clear of box.
5. Remove nuts securing gearbox adaptor plate.
6. The gearbox can then be removed by withdrawing it to the rear.
7. Remove nuts securing gearbox adaptor plate to flywheel housing.
8. Remove adaptor plate.
9. The driving plate connecting the gearbox to the flywheel can now be removed. It should he noted that if either flywheel or flywheel housing .is removed, then it must be accurately aligned on replacement in accordance with the instructions on Pages P.2 and P.3.

## TO REFIT THE GEARBOX

Replacement of the gearbox is the reverse procedure to removal but the splines on the gearbox input shaft should be lubricated with anti-fretting grease before the unit is replaced.

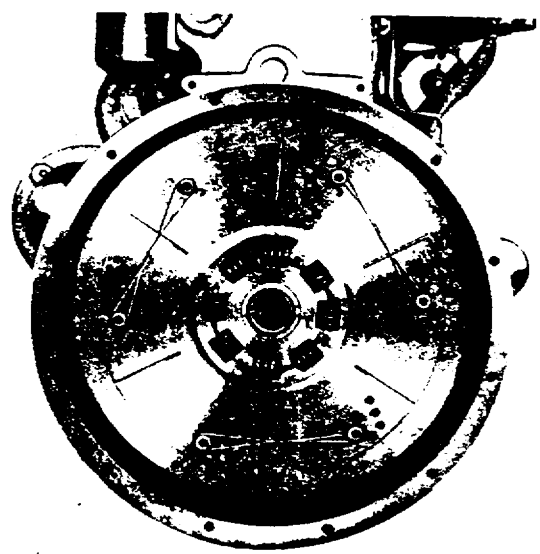


*Fig. P.1. Gearbox to Flywheel driving plate.*

## FLYWHEEL AND FLYWHEEL HOUSING

### To Remove the Flywheel

1. Remove the gearbox and adaptor plate.
2. Evenly unscrew the socket headed setscrews securing the driving plate assembly to the flywheel and detach the unit.
3. Knock back the tabs of the locking washers of the flywheel securing setscrews.
4. Remove the six setscrews and lift the flywheel from the crankshaft flange.

To facilitate the removal of the flywheel, it is recommended that two diametrically opposed securing setscrews are removed and in their place, screw in two suitably sized studs, finger tight only. The remaining setscrews can now be removed and the flywheel withdrawn under control.

### To Renew the Flywheel Ring Gear

1. Place the flywheel in a suitable container of clean cold water and support the assembly in the container by positioning four metal blocks under the ring gear. Arrange the flywheel assembly so that it is partly submerged in water with the ring gear uppermost. The complete ring gear must be above the water line and it is recommended that the bottom face of the ring be approximately 1/4 in (6.35 mm) above the water level. Heat the ring gear evenly around its circumference using oxy-acetylene welding equipment, thus expanding the ring, which will allow the flywheel to drop away from the ring gear. Lift out the flywheel and thoroughly dry it off.
2. Ensure that the registering faces of the flywheel and new ring gear are clean and free from burrs.
3. Heat the new ring gear to an approximate temperature of 475$^{o}$F (246$^{o}$C). Fit the gear over the flywheel with the lead-in on the teeth facing the front of the flywheel and allow the ring to cool in atmosphere.

### To Refit the Flywheel

1. It is most essential before fitting a flywheel that the crankshaft flange face and periphery are perfectly clean and free from burrs. The mating faces of the flywheel must also be absolutely clean and free from burrs.
2. It will be noted that there is a seventh untapped hole in the crankshaft flange, which is at bottom dead centre when the crankshaft is at T.D.C. Nos. 1 and 4 pistons. Mount the flywheel with the aid of guide studs to the crankshaft flange so that the untapped hole in the flange is in line with the seventh unused smaller hole in the flywheel. This ensures the flywheel timing marks are in a correct position in relation to the crankshaft.

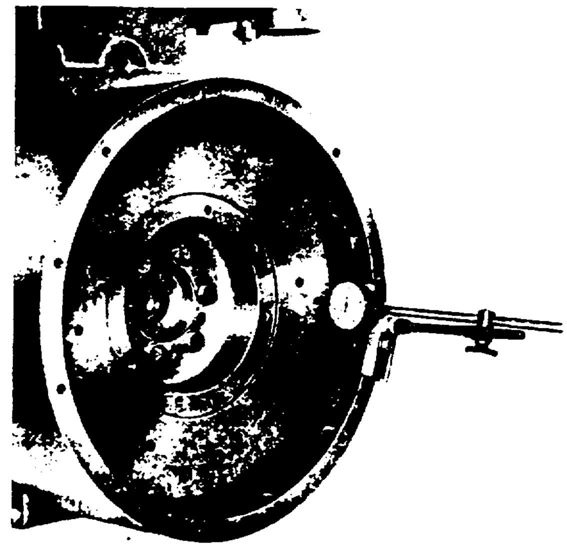


*Fig. P.2.*
*Checking Flywheel Back Face run-out.*

3. Engage the six securing setscrews with three new locking washers and tighten to a torque wrench reading of 74/80 lbf ft (10,3/11,0 kgf m) - 99/108 Nm.
4. Set up a clock indicator gauge with the base secured to the flywheel housing or cylinder block and adjust the clock so that the plunger is contacting the periphery of the flywheel. Turn the crankshaft and check the run-out. The flywheel should run truly within 0.012 in (0.30 mm) total indicator reading.
5. Now adjust the clock gauge so that the plunger is at right angles to the crankshaft flange and rests on the vertical machined face of the flywheel, at the outermost point of the face (see Fig. P.2).
6. Turn the crankshaft and check the run-out, shown on the clock gauge, of the flywheel face which should be within 0.0005 in (0,013 mm) per inch (25,4 mm) of flywheel diameter, total indicator reading at right angles to the crankshaft axis.
7. When the flywheel has been checked for alignment lock the setscrews with the tab washers.
8. Refit the adaptor plate and gearbox, etc.

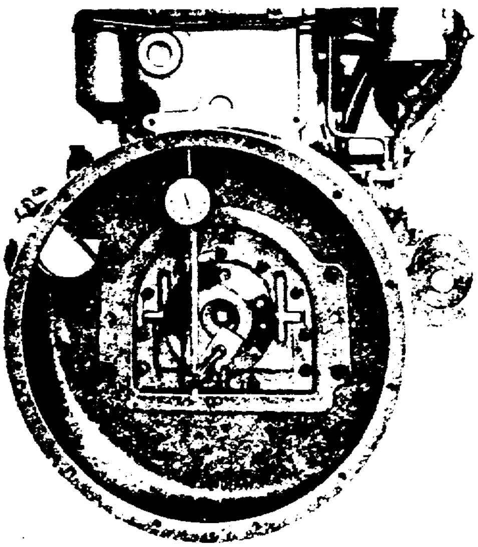


*Fig. P.3.*
*Checking Alignment of Flywheel Housing Bore.*

**To Remove the Flywheel Housing**

1. Remove the flywheel (see Page P.2).
2. Remove the starter motor.
3. Unscrew the nuts securing the flywheel housing to the cylinder block and tap the housing clear of the locating dowels.
4. Examine the housing for cracks or damage etc.

**To Refit the Flywheel Housing**

1. Ensure that the rear face of the cylinder block and the mating face of the flywheel housing are perfectly clean and free from burrs, etc.
   Check dowel location in block and housing, ream and fit oversize dowels where necessary.
2. Locate the flywheel housing carefully on the two dowels and refit the securing setscrews.
3. Mount a dial test indicator (clock) gauge with the base on the crankshaft flange and the gauge stylus on and perpendicular with the inner face of the housing aperture as shown in Fig. P.3. Rotate the crankshaft, the inner bore should be truly central with the crankshaft within the limits listed towards the end of this section.
4. With the gauge base still mounted in the same position adjust the stylus so that it is at right angles to tile vertically machined rear face of the flywheel housing as shown in Fig. P.4. Turn the crankshaft and check that this face is at right angles to the crankshaft axis to within the following limits.

| Diameter of Housing Bore | Max. Allowance |
|---|---|
| Up to 14 1/4 in (362 mm) | 0.006 in (0.15 mm) Total Indicator Reading |
| 14 1/4 to 20 1/8 in (362 to 511 mm) | 0.008 in (0.20 mm) Total Indicator Reading |
| 20 1/8 to 25 1/2 in (511 to 648 mm) | 0.010 in (0.25 mm) Total Indicator Reading |
| 25 1/2 to 31 in (648 to 787 mm) | 0.012 in (0.30 mm) Total Indicator Reading |

**NOTE: Any adjustments which may be necessary to bring the flywheel housing within the limits quoted must be carried out on the housing, under no circumstances may the rear face of the cylinder block be interfered with.**

5. When the housing is correctly aligned finally tighten the securing setscrews.
6. Refit the flywheel as previously described on Page P.2.

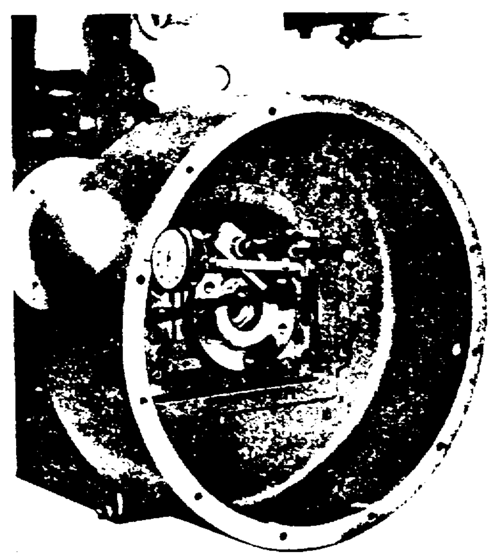


*Fig. P.4.*
*Checking Alignment of Flywheel Housing Face.*

## ALTERNATOR

### Models AC5 and 11AC

**1. General**

At the time of writing there are two types of alternator supplied with the 4.236 marine engine, namely the AC 5 with its associated 440 regulator, and the 11 AC with the 4 TR Control Box.

These are driven by the engine in the same manner as a D.C. Generator, namely, belt driven from the crankshaft pulley, but the advantage lies in their ability to provide higher maximum output at lower speeds, to cope with increased electrical load demanded by modem equipment. They are also much lighter in weight, output for output.

As opposed to the DC Generator in which the armature windings rotate inside a stationary field system, the alternator has a rotating field system inside a stationary generating winding. When the rotor rotates inside the stator, the output produced is alternating current (AC). This is unsuitable for charging the battery which requires direct current (DC), so it is rectified by means of diodes which converts it to uni-directional flow to the battery.

The alternator voltage output is maintained within close limits by means of a control box which is fully transistorized and functions as fast switches.

**2. Precautions**

As previously described the diodes in the alternator function as one-way valves and the transistors in the regulator/control box operate as fast switches. Both are accurate and sensitive.

They do not wear out and seldom require adjustment, but because they are sensitive to voltage changes and high temperature, the precautions are vital to prevent them from being destroyed.

(a) DO NOT disconnect the battery whilst the engine is running. This will cause a voltage surge in the alternator charging system that will immediately ruin the diodes or transistors.

(b) DO NOT disconnect a lead without first stopping the engine and turning all electrical switches to the off position.

(c) DO NOT cause a short circuit by connecting leads to incorrect terminals. Always identify a lead to its correct terminal. A short circuit or wrong connection giving reverse polarity will immediately and permanently ruin transistors or diodes.

(d) DO NOT connect a battery into the system without checking for correct polarity and voltage.

(e) DO NOT "flash" connections to check for current flow. No matter how brief the contact the transistors may be ruined.

**3. Maintenance**

The alternator charging system will normally require very little attention, but it should be kept free from build-up of dirt, and a check made if it fails to keep the battery charged.

(a) Regularly inspect the driving belts for wear and correct tension. It is important to ensure that all belts on a multiple belt drive have equal tension and are each carrying their share of the load. Slack belts will wear rapidly and cause slip which will not drive the alternator at the required speed. Drive belts which are too tight impose severe side thrust on the alternator bearings and shorten their life. Periodically ensure that the alternator is correctly aligned to the drive.

(b) Do not replace faulty belts individually in a multi-belt system. A complete matched set of drive belts must always be used.

(c) Keep the alternator clean with a cloth moistened in kerosene or cleaning fluids. Ensure that ventilation slots and air spaces are clear and unobstructed.

(d) Remove any dirt accumulated on the regulator/control box housing, and ensure that cooling air can pass freely over the casing.

## 4. Fault Finding on AC5

The AC 5 alternator is so designed that a flow of current indicated either by the extinguishing of the warning light, or as shown on the ammeter, is sufficient evidence that the system is in proper working order. Therefore, no open circuit, voltage or current output checks should be performed on the installation UNLESS:—

(a) The warning light fails to illuminate when the generator is stationary, and the switch is closed OR fails to become extinguished when the alternator is running.
(b) No charging current is shown on ammeter.
(c) The battery is flat.
(d) The battery is "boiling", indicating loss of voltage control.

If any of the above symptoms occur, the procedure indicated below should be followed.

(a) Connect a good quality moving coil voltmeter 0-50 volts range across the battery or regulator negative terminal, and one of the three positive terminals marked LO, MED, HI. Disconnect alternator output terminal. Fit a good quality moving coil 0-100 amp ammeter in series with the alternator terminal and output lead. The battery should be in a charged condition.
(b) Close the warning light switch (master electric switch on dashboard) when the warning lamp should light up.
(c) Switch on a 10-15 amperes load such as lights, fans, etc., for fifteen minutes.
(d) Start engine and run at fast idle speed when
    1. The warning light should go out.
    2. The ammeter records a small charge dc-pendant on engine speed.
(e) Increase engine speed momentarily to maximum speed, when the charging current should be about 30 Amperes for 24 Volt, and 53 Amperes for 12 volt systems.
(f) With the alternator running at approximately half speed, (engine speed about 1.500) rev/min) switch off electrical load. Depending on the connection selected for the positive sensing wire LO, MED or HI, the voltage should rise to between 26 and 28 volts on 24 volt systems and 13-14 volts on 12 volt systems and then remain constant. At the same time the current reading should drop appreciably.

Any variance in the above data could indicate a fault and the following procedure should be adopted before disconnecting any components.

The regulator is a sealed unit and is non-repairable and if found to be faulty it must be replaced.

**Warning Lamp does not light up when switched "On".**

Check the bulb.

If no fault

Check all wiring connections at regulator, alternator and battery.

If no fault

Switch off, disconnect “F” lead at regulator and connect it to the negative terminal.

Switch on. If warning lamp lights up, the regulator is faulty. If lamp fails to light up, the alternator is faulty.

**Warning Lamp does not go out and Ammeter shows no output when running.**

Check all regulator, alternator and battery connections.

If no fault

Switch off, disconnect “F” lead at regulator and connect to regulator negative terminal.

Switch on, and run at fast idle.

If no output, alternator is faulty.

If output appears, regulator is faulty.

**Warning Lamp does not go out when running and Ammeter shows reduced output with full output only at maximum speed or Warning Lamp goes out but Alternator delivers reduced output. Full output only at maximum speed.**

Alternator faulty. Remove from installation and apply open circuit diode check.

**Warning Lamp flashes intermittently and Ammeter needle oscillates when Battery is fully charged and no loads are switched in.**

Check for excessive resistance in regulator negative sensing lead.

If no fault, regulator is faulty.

**Batteries overcharging and Ammeter indicates high or full output all the time.**

Check regulator positive sensing lead and its connection at regulator.

If no fault, regulator is faulty.

## 5. Fault Finding on 11 AC

If the alternator does not produce its rated output of 43 amps for 12 volt and 23 amps for 24 volt circuit, the failure may be due to any unit or the associated wiring, and the following procedure should be followed.

**TEST 1.**

**Check the Field Isolating Relay**

Disconnect the earthed battery terminal and the cable from the alternator main output terminal. Connect a 0-60 DC ammeter between the terminal and disconnected cable. Link terminals 'C1' and 'C2' on the field relay. Reconnect the battery cable. Close the master switch and start engine and run at charging speed. If ammeter shows a charge the relay is faulty. or its wiring and connections.

If ammeter shows no charge, carry on with Test 2.

**TEST 2**

**Check the Alternator and Control Box**

Leave the test ammeter connected, and disconnect cables 'F' and '-' from control unit and join them together. Remove link from field relay terminals and ensure they are connected to 'C1' and 'C2'. Start engine and run at charging speed.

Ammeter should indicate current values of 35 amps or more for 12 volt circuit or 22 amps or more for 24 volt circuit. A zero or low reading indicates a faulty alternator.

If satisfactory output is recorded, a faulty control unit is indicated.

**TEST 3**

**Checking or Adjusting the Voltage Setting**

The regulator of the 4 TR control unit must be set on CLOSED CIRCUIT, when the alternator is under load. Also, the system must be stabilized before checking or resetting is carried out, and the battery must be in a well charged condition. Check the battery to control unit wiring, to ensure that the resistance of the complete circuit does not exceed 0.1 ohm. Any high resistance must be traced and remedied. Connect a test DC voltmeter (suppressed zero type) scale 12-15 volts for 12 volt installations or 24-30 volts for 24 volt installations, between the battery terminals, and note the reading with no electrical load. Disconnect battery earth cable and connect test ammeter between alternator main terminal and disconnected cable. Reconnect battery earth cable, and switch on an electrical load of approximately two amps. Start engine and run at about 2000 rev/min, for at least eight minutes. If the charging current is still greater than ten amps, continue to run engine until this figure is reached. Then compare the volt meter reading with the appropriate setting limits, as specified for the particular control unit as follows.

| | | |
|---|---|---|
| 12 V (37423)/(37449) | 13.9 | 14.3 volts |
| 24 V (37444)'(37502) | 27 9 | 28.3 volts |
| 12 V 37429 | 13.7 | 14.1 volts |

(Part no. marked on upper edge of the moulded cover of Control Unit).

If reading obtained is stable hut outside the appropriate limits the unit can be adjusted as follows.

ADJUSTMENT OF VOLTAGE SETTING

Stop the engine and remove the control unit from its mounting.. At the back of the unit is a sealed potentiometer adjuster. Carefully scrape away the sealing compound. Then start the engine, and while running the alternator at charging speed, turn the adjuster slot — CLOCKWISE to INCREASE the setting or ANTI-CLOCKWISE to DECREASE it — until the required setting is obtained.

Recheck the setting by stopping the engine, then start again and slowly "run-up" to charging speed. If setting is now correct, remount the control unit, disconnect test meters and restore original wiring connections. If, after adjustment, the voltmeter reading remains unchanged, or increases in an uncontrolled manner, then the control unit is faulty and a replacement must be fitted.

**TEST 4**

**Check of Alternator Output**

Disconnect battery earth cable, and connect test ammeter between the alternator main terminal and disconnected cables. Reconnect battery earth cable, and switch on the full electrical load and leave on for 3 or 4 minutes. Leave load on and start engine and run at approximately 2000 rev/min. The alternator output should balance the load, and at the same time show a charge to the battery.

**Check Warning Light Control**

If warning light does not function either by remaining "on" or "off", but the system is charging satisfactorily, connect voltmeter between the alternator "AL" terminal and earth. Reading should be 7.0-7.5 max (12 volt alternator) or 14.0-15.0 (24 volt alternator). Connect leads 'E' and 'WL' together. If warning lamp lights the warning light control is faulty and should be replaced.

**6. Fault Diagnosis Procedure for 11 AC**

**Alternator Fails to Charge**

(a) Check driving belt for correct tension and wear.
(b) Apply Tests 1 and 2.

**Low-Unsteady Charging Rate**

(a) Check driving belt for correct tension and wear.
(b) Check for high resistance at battery terminals and in the circuit wiring and connection. Check all connections made to earth.
(c) Apply Test 2.

**Flat Battery or Low State of Charge**

(a) CHECK condition of battery with hydrometer and high rate discharge tester.
(b) Check driving belt for correct tension and wear.
(c) Check that the field isolating relay contacts open when master switch is off; otherwise battery will discharge through rotor winding.
(d) Check that flat or low battery is not caused by insufficient alternator output caused by abnormal electrical loads by applying Test 4.

**Excessive Charge Rate to a Fully Charged Battery**

(a) Apply Test 3.

**Noisy Alternator**

(a) Alternator loose in mounting brackets.
(b) Worn, frayed or loose drive belt.
(c) Worn bearings, fully out of alignment.
(d) Rotor damaged or pulley fan loose on shaft.
(e) Open circuited, or short circuited rectified diodes, or stator winding open-circuit.
(f) Loose pulley.

## DYNAMO

### 1. General

The following information concerns the dynamo fitted as standard equipment to the earlier 4.236 marine engine, namely, the Lucas C40A model. If information concerning another type of dynamo is required, the relevant manufacturer should be contacted.

The C40A is a non-ventilated, shunt-wound two-pole two-brush machine arranged to work in conjunction with a compensated voltage control regulator unit. A hall bearing supports the armature at the driving end and a porous bronze bush at the rear supports the commutator end.

The output of the dynamo is controlled by the regulator unit and is dependent on the state of charge of the battery and the loading of the electrical equipment in use. When the battery is in a low state of charge, the dynamo gives a high output, whereas if the battery is fully charged, the dynamo gives only sufficient output to keep the battery in good condition without any possibility of overcharging. An increase in output is given to balance the current taken by lamps and other accessories when in use.

When fitting a new control box, it is important to use only an authorized replacement. An incorrect replacement can result in damage to the dynamo.

### 2. Routine Maintenance

**(a) Lubrication**

Every 250 running hours, inject a few drops of high quality S.A.E. 30 engine oil into the hole marked "OIL" at the commutator end bearing housing.

**(b) Inspection of Brushgear**

Every 2,500 running hours, the dynamo should be removed from the engine and the brushgear inspected by a competent electrician.

**(c) Belt Adjustment**

Occasionally inspect the dynamo driving belt, and if necessary, adjust to take up any slackness by turning the dynamo on its

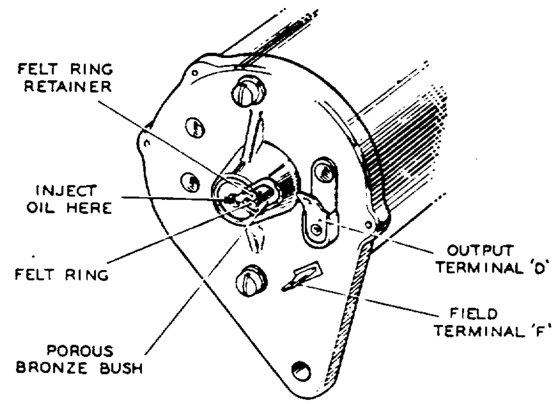



*Fig. Q.1.*
*Lubricator in Commutator End Bracket.*

mounting. Care should be taken to avoid overtightening the belt (see Page M.1).

### 3. Performance Data

The cutting in and maximum output speeds quoted below are production test figures and refer to cold machines with brushes only partly bedded.

Model C40A

Cutting-in Speed
1,100 rev/min (max.) at 13.0 dynamo volts.

Maximum Output:
11 amperes at 1,700 rev/min (max.) at 13.5 dynamo volts and a resistance load of 1.23 ohms.

Field Resistance:
6.0 ohms.

### 4. Servicing

**(a) Testing in Position to Locate Fault in**

**Charging Circuit**

1. Inspect the driving belt and adjust if necessary.

2. Check the connections on the commutator end bracket. The larger connector carries the main dynamo output, the smaller connector the field current.

3. Switch off all lights and accessories, take off the cables from the terminals of the dynamo and connect the two terminals with a short length of wire.

4. Start the engine and set to run at normal idling speed.

5. Clip the negative lead of a moving coil type voltmeter, calibrated 0 20 volts, to one dynamo terminal and the positive lead to a good earthing point on the yoke.

6. Gradually increase the engine speed, when the voltmeter reading should rise rapidly and without fluctuation. Do not allow the volt meter reading to reach 20 volts, and do not race the engine in an attempt to increase the voltage. It is sufficient to run the dynamo up to a speed of 1,000 rev/min. If the voltage does not rise rapidly and without fluctuation the unit must be dismantled for internal examination, see Para 4(b). Excessive sparking at the commutator in the above test indicates a defective armature which should be replaced.

**(b) To Dismantle**

1. Take off the driving pulley.

2. Unscrew and withdraw the two through bolts.

3. Withdraw the commutator end bracket from the yoke.

4. Lift the driving end bracket and armature assembly from the yoke. Take care not to lose the fibre thrust washer from the commutator end of the shaft.

5. The driving end bracket, which on removal from the yoke has withdrawn with it the armature and armature shaft ball bearing, need not be separated from the shaft unless the bearing is suspected and requires examination, or the armature is to be replaced; in this event the armature should be removed from the end bracket by means of a hand press, having first removed the shaft key.

**(c) Brush Gear (Checking with yoke removed)**

1. Lift the brushes up into the brush boxes and secure them in that position by positioning the brush springs at the sides of the brushes.

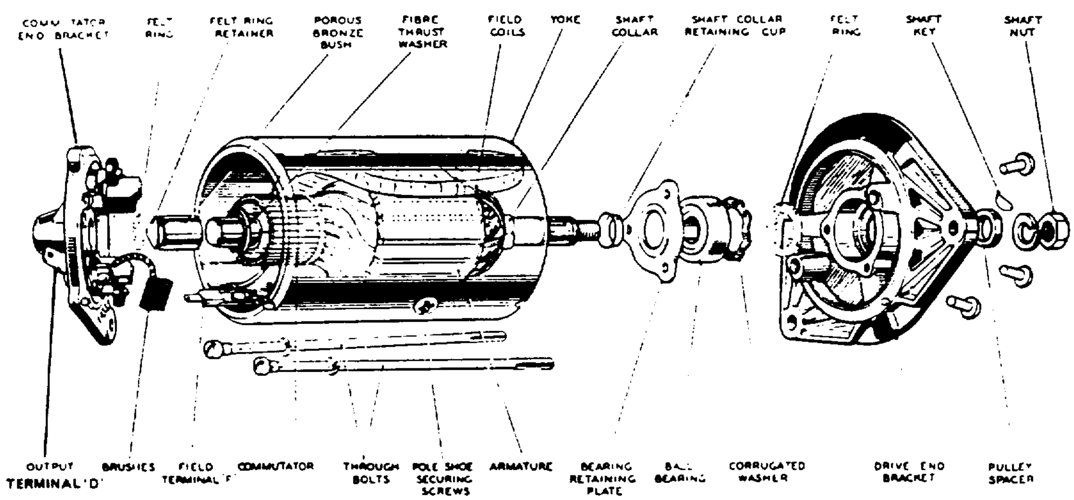



*Fig. Q.2.*
*Dynamo Dismantled.*

2. Fit the commutator end bracket over the commutator and release the brushes.

3. Hold back each of the brush springs and move the brush by pulling gently on its flexible connector. If the movement is sluggish, remove the brush from its holder and ease the sides by lightly polishing on a smooth file. Always refit the brushes in their original positions. If the brushes are badly worn, new brushes must be fitted and bedded to the commutator. The minimum permissible length of brush is 9/32 in (7,14 mm), i.e. when the spring arm reaches the brush box.

4. Measure the brush spring pressures, using a spring balance held radially to the commutator. The tension on the springs should be 30 ozf (0,85 kgf), maximum, when exerted on a new brush and 13 ozf (0,37 kgf), minimum, on a brush worn to 9/32 in (7,14 mm). Both pressures should be measured and defective springs replaced.

**(d) Commutator**

1. A commutator in good condition will be smooth and free from pits and burned spots. Two types of commutator, the moulded and the fabricated, will be found in service. Moulded commutators can be recognized by the exposed end being quite smooth, unlike that of the fabricated commutator from which a metal roll-over and an insulating cone protrude (see Fig. Q.3).

2. A moulded commutator can be re-skimmed during service but care must be exercised to ensure that the finished diameter is not less

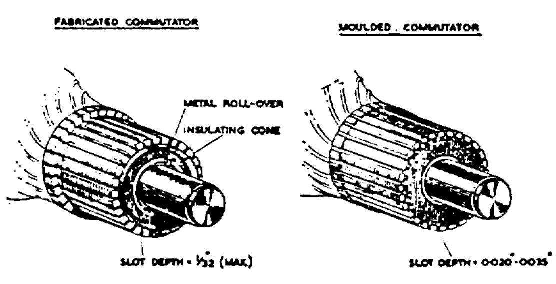



*Fig. Q.3.*
*Comparison of Fabricated and Moulded Commutators.*

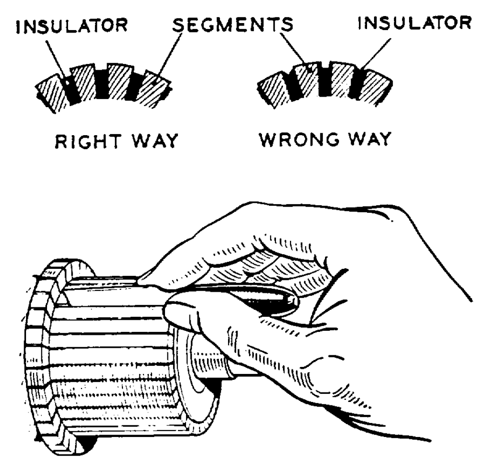



*Fig. Q.4.*
*Undercutting Insulators.*

than 1.450 in (36,83 mm). The process of re-skimming consists of rough turning (if necessary) followed by diamond turning. Whether or not rough turning is carried out depends upon the severity and unevenness of the wear which has taken place. A moulded commutator requires no undercutting in service, the production undercut being of sufficient depth to obviate any further need for this. The insulation slots, however, muss be kept clear of copper and carbon residue.

3. To remedy a worn fabricated commutator, undercut the insulators between the segments to a depth of 1,32 in (0,79 mm) using a hacksaw blade ground to the thickness of the insulator, then mount the armature, with or without the drive end bracket, in a lathe, rotate at high speed and take a light cut with a very sharp tool. Do not remove more metal than is necessary. Polish the commutator with very fine glass paper.

**(e) Armature**

Indication of an open-circuited armature winding will be given by burnt commutator segments. If armature testing facilities are not available, an armature can be checked by substitution.

To separate the armature shaft from the drive end bracket, press the shaft out of the drive end bracket bearing. When fitting the new armature, support the inner journal of the ball bearing, using a mild steel tube of suitable diameter, whilst pressing the armature shaft firmly home. See also Para 4 (h)1.

**(f) Field Coils**

Measure the resistance of the field coils, without removing them from the dynamo yoke, by means of an ohm meter connected between the field terminal and the yoke. The resistance is 6.0 ohms for the model C40A.

If an ohm meter is not available, connect a 12 volt d.c. supply between the field terminal and dynamo yoke with an ammeter in series. The ammeter reading should be approximately 2 amperes. Zero reading on the ammeter or an "Infinity" ohm meter reading indicates an open circuit in the field winding.

If the current reading is much more than 2 amperes, or the ohm meter reading much below 6 ohms, it is an indication that the insulation of one of the field coils has broken down.

In either event, unless a substitute dynamo is available, the field coils must be replaced. To do this, carry out the procedure outlined below, first noting to which end of the coil the field terminal is soldered.

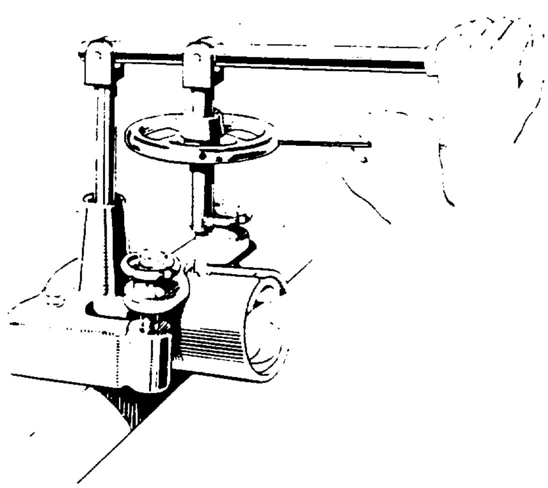


*Fig. Q.5.*
*Tightening Pole Shoe Retaining Screws.*

1. Drill out the rivet securing the field coil terminal assembly to the yoke and unsolder the field coil connections.
2. Remove the insulation piece which is provided to prevent the junction of the field coils from contacting with the yoke.
3. Mark the yoke and pole shoes so that the latter can be refitted in their original positions.
4. Unscrew the two pole shoe retaining screws by means of a wheel operated screw driver.
5. Draw the pole shoes and field coils out of the yoke and lift off the coils.
6. Fit the new field coils over the pole shoes and place them in position inside the yoke. Take care to ensure that the taping of the field coils is not trapped between the pole shoes and the yoke.
7. Locate the pole shoes and field coils by lightly tightening the fixing screws.
8. Fully tighten the screws by means of a wheel operated screwdriver.
9. Solder the original terminal and earthing eyelet to the appropriate coil ends.
10. Refit the insulating sleeve and re-rivet the terminal assembly to the yoke.
11. Refit the insulation piece behind the junction of the two coils.

**(g) Bearings**

Bearings which are worn to such an extent that they will allow side movement of the armature shaft must be replaced. To replace the bearing bush in a commutator end bracket proceed as follows:—

1. Remove the old bearing bush from the end bracket. The bearing can be withdrawn with a suitable extractor or by screwing a j inch tap into the bush for a few turns and pulling out the bush with the tap. Screw the tap squarely into the bush to avoid damaging the bracket.

2. Withdraw and clean the felt ring retainer and felt ring.

3. Insert the felt ring and felt ring retainer in the bearing housing, then press the new bearing bush into the end bracket, using a self-extracting tool of the type and in the manner shown in Fig. Q.6 the fitting pin or mandrel portion being of 0.5924 in (15,05 mm) diameter and highly polished. To withdraw the pin after pressing the bush fully home, turn the nut against the sleeve while gripping the squared end of the fitting pin. Porous bronze bushes must not be opened out after fitting, or the porosity of the bush may be impaired.

**NOTE:**
**Before fitting the new bearing bush it should be allowed to stand for 24 hours completely immersed in a good grade**

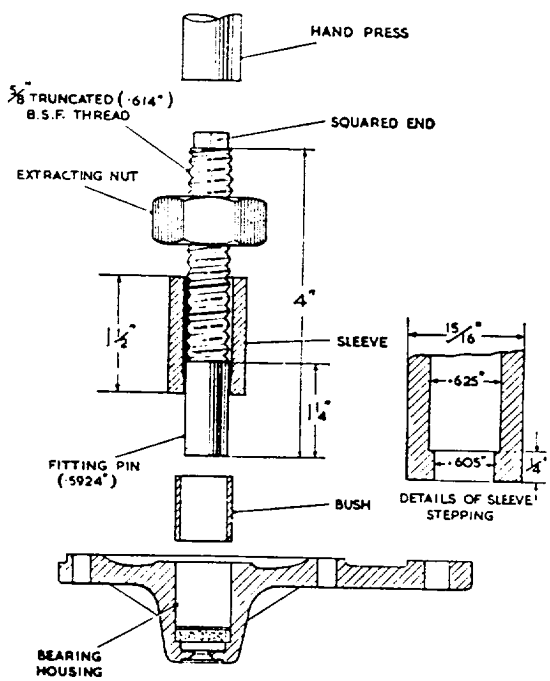



*Fig. Q.6.*
*Tool for fitting Commutator End Bracket Bush.*

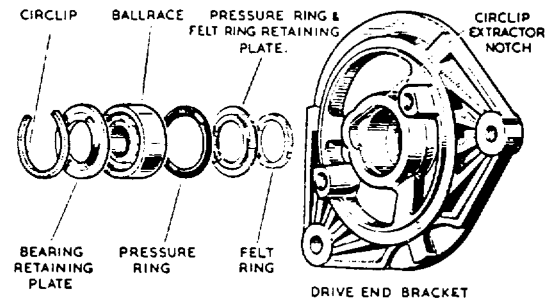



*Fig. Q.7.*
*Drive End Bracket with Circlip Retained Bearing.*

S.A.E. 30 engine oil: this will allow the pores of the bush to be filled with lubricant. The enclosed ball bearing at the driving end is replaced as follows:—

1. Drill out the rivets, or remove the screws whichever is applicable, which secure the bearing retaining plate to the end bracket and remove the plate.

2. Press the bearing out of the end bracket.

3. Remove and clean the corrugated washer and felt ring.

4. Before fitting the replacement bearing. See that it is clean and pack it with high melting point grease.

5. Place the felt ring and corrugated washer in the bearing housing in the end bracket.

6. Locate the bearing in the housing and press it home.

7. Fit the bearing retaining plate. Insert the new rivets from the pulley side of the end bracket and open the rivets by means of a punch to secure the plate rigidly in position. If secured by screws, fit the screws and tighten.

**Ball Race Bearing in Drive End Bracket**
**(Circlip Secured Assembly)**

This arrangement is shown in Fig. Q.7.

1. Insert the tip of a screwdriver in the extractor notch and prise free the circlip.

2. Remove the bearing retaining plate and press out the bearing.

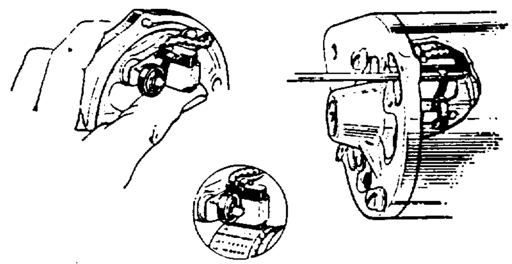



*Fig. Q.8.*
*Fitting Commutator End Bracket to Yoke.*

3. Ensure that the pressure and felt rings and the retaining plate do not fall out.

4. Check that the replacement bearing is clean and push it fully home with a hand press.

5. Replace the bearing retaining plate and after replacing the circlip in position, compress the whole assembly enough to allow the circlip to re-locate itself.

**(h) To Re-Assemble**

1. Fit the shaft collar retaining cup and drive end bracket to the armature shaft. The inner journal of the bearing must he supported by a tube, approximately 4 in (10,1 mm) long, 1/8 in (3 mm) thick and internal diameter 5/8 in (16 mm). Do not use the drive end bracket as a support for the bearing whilst fitting an armature.

2. Fit the yoke to the drive end bracket.

3. Push the brushes up into the brush boxes and secure them in that position by positioning each brush spring at the side of its brush.

4. Fit the commutator end bracket on the armature shaft until the brush boxes are partly over the commutator. Place a thin screwdriver on top of each brush in turn and press the brush down on the commutator. The brush springs should then position themselves on top of the brushes.

5. Fit the commutator end bracket to the yoke so that the projection on the bracket locates in the yoke.

6. Refit the two through bolts. After assembly lubricate the commutator end bearing.

## STARTER MOTOR

### Model - CA45

### GENERAL DESCRIPTION

Designed for flange mounting, the C.A.45 starter motor has a uniform cylindrical shape with no surface protrusions. This is because the solenoid and main switch assemblies are housed within the drive end-shield, around (i.e., co-axially with) the armature shaft.

The essential feature of the co-axial starter is that, the pinion alone moves axially to engage the engine flywheel. There is no longitudinal movement of the whole armature assembly, as in the axial types.

Smooth engagement of the pinion with the engine flywheel is constantly ensured by using two-stage operation of the solenoid and switch mechanisms. Thus the risk of damage to both pinion and flywheel, through faulty meshing. is practically eliminated.

In construction, the starter consists of three main sections into which it can he easily dismantled.

1. The solenoid switch-gear and pinion assembly housed in the drive end-shield.

2. The armature shaft and commutator assembly.

3. The yoke, pole-piece and field-coil assembly.

Ready access is possible therefore, to those parts most likely to require adjustment, such as the switchgear and commutator assemblies.

### OPERATING MECHANISM

The starter is designed for working off a 12 volt supply, with 17 amps solenoid current.

The starter operating mechanism consists of the following main parts, viz.:

The solenoid (10) and resistor (9) (Fig. Q.9).

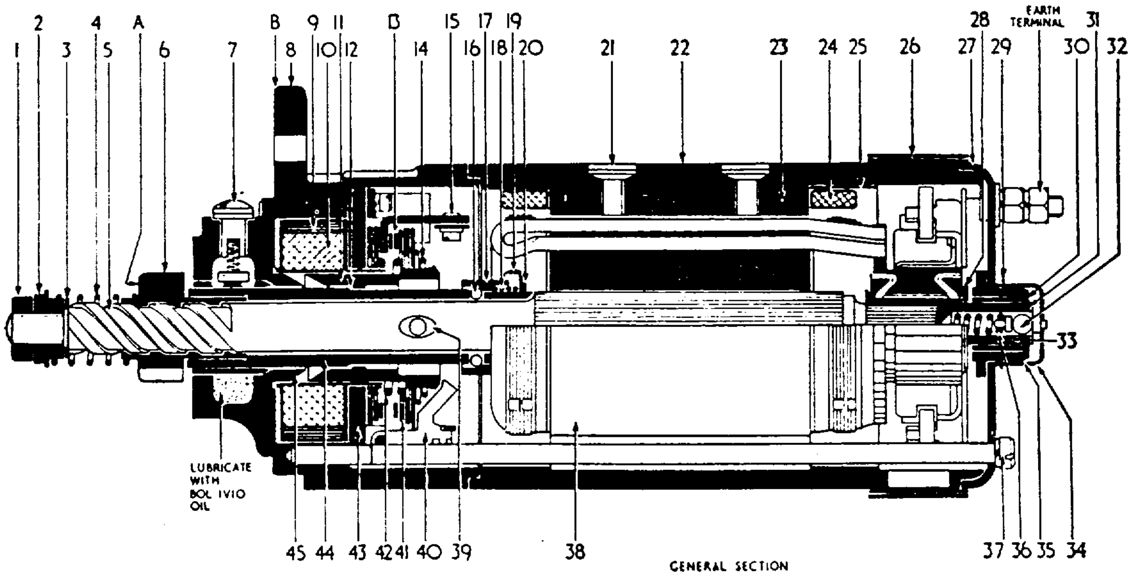



*Fig. Q.9.*
*Cross Section view of CA 45 Type Starter Motor.*

The pinion (6) and sleeve (44), mounted on the armature shaft (5).

The sliding plunger (11) mounted on the pinion sleeve.

First (13) and second (41) main switch contacts. The moving contacts are mounted on the plunger.

The contact trip-trigger (40).
The ball-locking collar (17) and trip-collar (19) both mounted on the pinion sleeve.

## OPERATION

Engagement of the pinion with the engine flywheel is made in two separate, but continuous stages.

### First Stage

When the starter switch-button is pressed, the solenoid (10), is energized. The magnetic field draws the sliding plunger (11) forward v, in (8 mm) to meet the shoulder (12), on the pinion sleeve (44).

The pinion, now pushed by the plunger, also moves forward, until the pinion nose commences to mesh with the engine flywheel.

Simultaneously, the moving contacts, mounted on the plunger, are also carried forward, causing the first set (13) to close. The second set (41) held by the trip-trigger (40) remain open until the first stage is completed. At this point, the plunger slides fully home against the stop (45) on the drive end shield.

The first pair of contacts having closed, battery current flows through the resistance (9) and armature field windings (24). Since the resistance allows a **limited** current only, to pass through the field windings. the armature rotates very slowly. The electrical circuit is shown schematically in Fig. Q.11. This completes the first stage of the operation.

### Second Stage

The pinion, already partially engaged and prevented from rotating by the engine flywheel will be gently pushed into full engagement by the helix on the slowly revolving armature shaft. However, just before complete engagement is reached, the trip-trigger (40) is lifted by the forward movement of the trip-collar (19) mounted on the pinion sleeve. This frees the second set of contacts (41), which now close. Closing of the contacts short circuits the resistor and allows full current to flow through the field windings. The armature now rotates under full power, with the pinion and engine flywheel fully engaged. This completes the second stage.

In order to avoid premature disengagement of the pinion before release of the starter button, a ball-locking device is positioned between the armature shaft and pinion sleeve. This consists of the following components:

> Four steel balls (16) located in holes in the pinion sleeve.
>
> A locking collar (17) mounted on the pinion sleeve.
>
> The collar loading spring (18).
>
> Four recesses (39) in the armature shaft.

The balls, set in holes in the pinion sleeve, are retained in position by the lock-collar, the inside bore of which, has a 450 chamfer, causing the balls to be pressed inwards against the armature shaft.

In the stationary position, the balls hold back the lock collar. When the pinion moves forward to the fully engaged position. the balls become opposite the recesses in the armature shaft sinking into them as the shaft revolves. Spring pressure pushes the collar over the top of the balls, locking them in the recesses. Thus any backward or forward movement of the pinion sleeve can no longer occur and the pinion is securely held in the fully engaged position as long as the starter button remains pressed.

Releasing the starter button cuts off the solenoid current. Under the combined pressure of the main contact and plunger springs (14) and (42). the plunger returns to its normal position. carrying with it the moving contact plate. Thus both sets of contacts open. With current cut, the rotation speed of the armature rapidly drops. The returning plunger pushes back the lock collar, releasing the balls and freeing the pinion sleeve. The engine flywheel speed now rapidly over-runs the pinion speed. This action, combined with the pressure of the return spring (4) throws the pinion out of mesh with the flywheel, returning the pinion to the disengaged position.

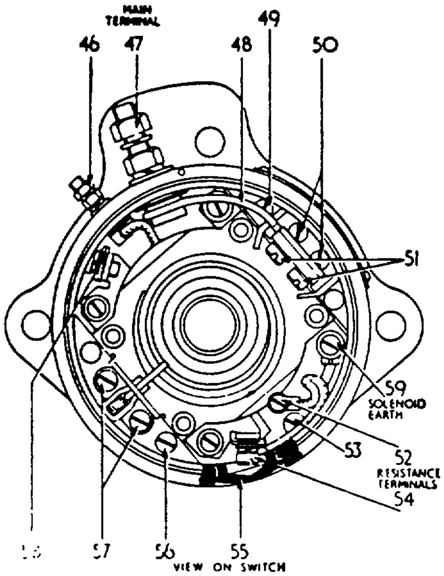



*Fig. Q.10.*

Any tendency of the pinion to wander forward under vibration resulting in damage to the contact and armature assembly, is prevented by pressure of the pinion return spring (4).

On rare occasions, badly worn pinion and flywheel teeth may meet face to face, preventing engagement and causing the pinion to remain stationary against the flywheel when the starter button is pressed. Special provision is made for overcoming this difficulty. At the commutator end of the armature, a steel ball thrust device is fitted.

This consists of a spring (36), guide (33), steel ball (32). and thrust-washer (30), against which the armature presses. The spring and ball are held in position by an end-cap (34) secured to the commutator end shield by a spring clip (29).

Should a face-to-face contact occur, the armature. under the influence of the helix, will be turned slightly and at the same time forced back against the spring: end movement of approximately 1/16 in (1,6 mm) is permitted. When the starter button is released the armature and pinion will come back to the normal disengaged position, but the radial position of the pinion will be slightly in advance of the previous position, so that the next engagement will be made quite smoothly. In order to maintain the required tolerances, shims (28) are fitted at the commutator end.

**Testing on the Application**

Ensure that the battery is in a charged condition.

Switch on the lamps and operate the starter button. If the starter fails to function, but the lights maintain full brilliance, check the switch and battery connections to the starter and all external leads. Sluggish action of the starter can be caused by a poor or faulty connection.

Difficulty in smooth engagement between starter and engine flywheel is probably due to dirt on the starter-shaft helices preventing free pinion movement. The shaft should be thoroughly cleaned with cleaning fluid followed by the application of a small quantity of Caltex Thuben 90 or SAE 90 oil.

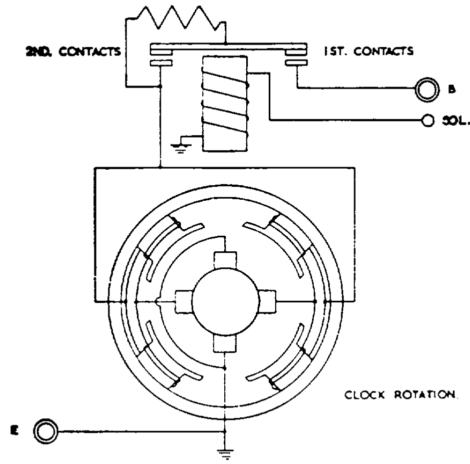



*Fig. Q. 11.*
*Internal Wiring Diagram.*

## OPERATING THE STARTER

**When starting the engine the following points should be rigidly observed**

1. Press the starter button firmly and release it **immediately** the engine fires.
2. If the engine does not fire at once, let it come to rest before pressing the switch again.
3. Do **not** run the battery down by keeping the starter switch pressed when the engine refuses to start. Ascertain the cause.
4. Do **not** operate the starter when the engine is running as serious damage may occur to both starter and flywheel.

## MAINTENANCE

**LUBRICATION**

The large oil reservoir in the drive end shield need only be replenished during overhaul periods, when a supply of BOLIVIO oil should be added through the oil plug (7).

An oil impregnated sintered bronze bush is fitted at the commutator end, and needs no further attention.

**BRUSH GEAR AND COMMUTATOR**

Inspect the brushes at intervals of approximately 2.500 hours. See that they are free in their guides and that the leads are quite free for movement, by easing back the brush springs and pulling gently on the flexible connections. If a brush is inclined to stick, remove it from its holder and clean the sides with a petrol moistened cloth.

Be sure to refit the brushes in their original positions to retain the "bedding." The brushes should he well bedded (i.e. worn to the commutator periphery) but if not, wrap a strip of very fine glass or carborundum paper firmly around the commutator with the abrasive side outwards. With the brushes in position, rotate the armature by hand in the normal working direction of rotation; until the correct brush shape is obtained. If the brushes are worn down so that the springs are no longer providing effective pressure, they should be renewed. Check the brush spring pressure by hooking a spring balance under the spring lip.

The correct tension is 30—40 ozf (0,9—1,1 kgf).

It is essential that replacement brushes are the same grade as those originally fitted. Genuine spares should always be used. To remove the brushes, unscrew the four fixing screws. one to each brush. In re-assembling care must be taken to re-connect the field coil and interconnector leads, held by two of the fixing screws. Before inserting brushes in their holders, it is advisable to blow through the holders with compressed air or clean them with a cloth moistened with petrol.

The commutator should be clean, entirely free from oil or dirt. Any trace of such should be removed by pressing a clean dry **fluffless** cloth against it, while armature is hand rotated.

If the commutator is dirty or discolored, tilt the brushes and wrap a strip of fine glass or carborundum paper (not emery cloth) round the commutator, with the abrasive side inwards. Rotate the armature by hand until the surface is even. Clean with a petrol moistened cloth.

If repair is necessary to the commutator or switch gear etc., the starter must be dismantled. This should be done only in accordance with the method given.

## DISMANTLING THE STARTER

(Figs. Q.9 and Q.10 refer).

Remove the starter from the engine, and proceed as follows:-

1. Unscrew the shaft lock-nut (1) (L.H. thread on clockwise rotation machine), remove pinion stop (2), shim washers (3) and return spring (4).
2. Remove the two cover screws (55) from the drive-end shield and unscrew the exposed field coil terminal screws (54) and (58).
3. Remove the commutator end cover-band (26).
4. Unscrew the brush-lead screws, ease off brush springs and lift brushes from the holders. Note that removing the brush screws also frees the field coil and interconnector leads.
5. Remove the spring-clip (29) and take off the end cap (34).
6. Remove the circlip (31), thrust washer (30), shim-washers (35), steel ball (32) and spring (36).
7. Unscrew and withdraw the two throughbolts (37) from the commutator end-shield (27).
8. Remove the commutator end-shield, and take off the shaft-shims (28).
9. The yoke (22), pole-pieces (23) and field coils (24) can now be removed as one assembly, leaving the armature completely exposed.
10. Unscrew the eight pole-shoe fixing screws (21) and take out the pole-pieces, and fieldcoils, taking care not to damage the leatheroid (25), inserted between the coils and yoke.

## DISMANTLING THE OPERATING MECHANISM

1. Holding the pinion (6) and drive-end shield (8) rigid, release the ball lock and withdraw the shaft from the pinion sleeve (44), by rotating the armature in an anti-clockwise direction (clockwise on L.H. rotation machines).

   **Note—**

   **This may require a little more than the normal force, because of probable burring resulting from the action of the ball lock. Withdrawal of the shaft causes the four steel balls (16) to fall through to the inside of the pinion sleeve, and these should now be recovered.**

2. Using circlip pliers, remove the circlip (20) from the pinion sleeve-end.
3. Remove the trip-collar (19) and ball locking collar spring (18). Slide off the locking collar (17).
4. Withdraw the pinion (6).
5. Remove the two screws (51) from the main terminal connecting link (48). Loosen the main terminal (47) and remove the link.
6. Remove the resistance lead (52) from the moving contact plate.
7. Remove the two screws (57) holding the trip-gear and remove by threading the trigger (40) through the slot in the moving contact plate.
8. Remove the two screws (50) holding the stop plate and remove the plunger assembly (11).

9. Unhook the plunger spring (14) from the sliding plunger (11).

10. Take off the moving contact plate, remove the contact spring (42).

11. Remove both solenoid and main terminals (46) and (47) from the end-shield.

12. Unscrew the three solenoid end-plate fixing screws (49), (53) and (56). Take out the endplate (43) complete with the solenoid housing. If the plate offers resistance, screw in two 2BA screws, (approx. 2 in (50 mm) long) one into the trip gear fixing hole, the other into the stop-plate fixing hole. The end plate may then be easily extracted.
**Under no circumstances should the solenoid windings and resistor assembly be disturbed or any damage done to the mica housing.**

## REPAIR AND TESTING INSTRUCTIONS
## COMMUTATOR

Examine commutator for wear which, if not severely pitted or grooved can be cleaned up with fine glass or carborundum paper (do not use emery cloth), whilst spun in a lathe. If however, the commutator is badly worn it should be skimmed, taking a very light cut, if possible with a diamond tool to provide the desired high quality finish.

The commutator insulating segments must not be undercut.

## ARMATURE COILS

The respective armature coils can be tested for continuity or short circuits by mounting the armature between centres and connecting the commutator to an ordinary battery through the medium of two brass or copper brushes mounted at an angle of 90° to each other. Contact is then made to any two adjacent commutator bars by means of hand spikes which are connected direct to a milli-volt meter.

A variable resistance should be included in the battery circuit capable of carrying the full output of the battery and adjusted to give 2 volts or less on the armature. The armature is then rotated until every commutator bar has been tested, the reading on the milli-volt meter in each case should read approximately the same; any big variation, indicating a fault in the coil connected to one of the commutator bars under test. A reduction in the milli-volt reading will be generally found due to a short circuit while an increased reading will indicate either an open circuit or a faulty connection.

In the event of an armature being found to be faulty, it should be returned direct to a C.A.V. Agent.

## ARMATURE SHAFT

Examine the elliptical recesses in the armature shaft for burrs caused by the steel balls and carefully file these off. Finally inspect the helices for any signs of damage. Thoroughly clean with a suitable cleaning fluid and lightly oil using Cal tex Thuben 90 or SAE 90 oil.

## FIELD COILS

These can be simply tested when in position for short circuits to the yoke and poles by means (of hand spikes connected to a mains supply and in series with a lamp of suitable voltage positioned on the live side of the system. One spike should be applied to the end of the winding and the other to the yoke. If the lamp does not light then insulation is intact. Take care to remove all other connections to the coils and insulate bare ends.

There is no easy way of testing internal shorts in the coils as the resistance is very low ; new coils should be tried if existing ones are suspect.

## BEARINGS

If either the commutator or drive end bearings are worn and need replacing, proceed as follows:

**(a) Commutator End Bearing**

1. Press the old bearing bush out of the end shield.
2. Press the new bearing into the end shield by using a stepped highly polished mandrel. A special fitting pin, with a dimension of 0.6263 in 0.0002 in (15,908 0,005 mm), is supplied by the makers. After assembly, the bore should be within the limits 0.6258 in to 0.6268 in (15,895 to 15,921 mm). **No machining should be attempted.**

**Note—**
**Before fitting a new bearing bush it should be completely immersed for 24 hours in clean thin engine oil.**

**(b) DRIVE END BEARING**

1. Press out the old bearing bush from the inside of the end-shield.

2. Press in new bush taking care to keep the lubricating wick away from the bore by using a split dolly. Finally set up the end-shield on a lathe and turn the bore using a spigot diameter as a register, to 1.126-1.137 in (28.6-28,62 mm).

**PINION**

If the pinion teeth are badly worn, obtain a replacement and offer this up to the shaft to ensure freedom of movement. Should it be necessary they can be lightly lapped together.

**SOLENOID AND OPERATING MECHANISMS**

Examine all moving parts for wear. Inspect the electrical leads for chafing and impaired insulation.

Examine the springs for possible fracture and replace as necessary. After any removal, the spring pressures should be checked before re-assembly In accordance with the following:-e

Ball-lock spring (18) (Fig Q.9) - 11 lbf/in (1,97 kgf/cm)
Pinion return spring (4) - 8.6 lbf/in (1.54 kgf/cm)
Main contact (plunger) spring (14) 91/2 - 12 lbf (4,31 - 5,44 kgf) when compressed to 3/16 in (4,76 mm).
Contact return spring (42) 6 - 7 lbf (2,72 - 3,18 kgf) when compressed to 1/4 in (6,35 mm).

**CONTACTS**

Examine the "fixed " and "moving " contacts, and clean them with spirit or very fine carborundum paper.

If the contacts are badly burnt and pitted, they should be replaced. As replacements are not supplied ready machined, it will be necessary to face them when in position.

It is essential, when facing the "fixed" contacts, that they are kept to the angle shown in Fig. Q.12.

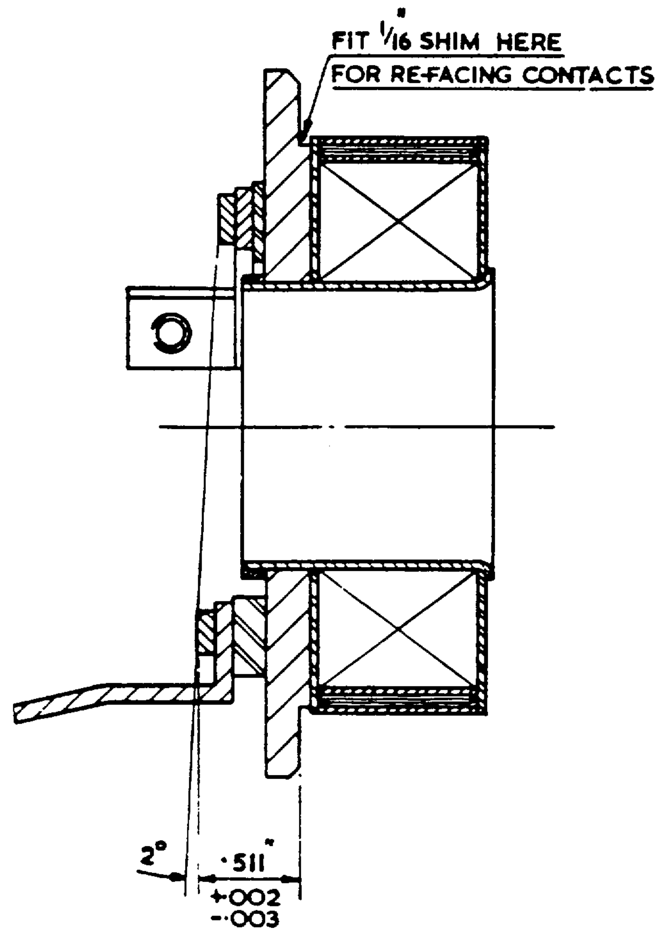



*Fig. Q.12*

This can most easily he done by placing a 1/16 in (1,6 mm) shim behind the end-plate and the faceplate on the lathe. This will provide the required 2° angle.

Make sure that the shim is placed on the correct side.

Alternatively, if a number of refacing operations are likely to be dealt with, a suitable face-plate can be made up for attaching to the lathe. This should have one side machined to the 2° angle, as shown in Fig. Q.13. The end-plate of the solenoid can then be secured to it, and the contacts skimmed.

In facing the "movi ng" contacts, it is essential to keep to a dimension within the limits 0.250 in to 0.247 in (6,35 to 6,27 mm), between the rear side of the back-plate and the contact face.

Finally, when the two contacts are assembled, the distance between them on the first step, should be accurately maintained at 0.071 in to 0.056 in (1,80 to 1,42 mm). To compensate, shims may be added under the "fixed" contacts, prior to machining.

## ASSEMBLING THE STARTER

1. Assemble the pole-shoes and field-coils and fix into yoke with the aid of a pole-shoe expander and a wheel operated screw-driver. Care should be taken not to trap the leatheroil (25) Fig. Q.9 beneath the pole-pieces. See that the screw holes in the field coils are in their correct position for connecting to the brush boxes and solenoid switch.

## ASSEMBLING SWITCH

1. Screw the solenoid into the drive end-shield. Check that the solenoid end-plate is flush against the drive end-shield shoulder, and paint insulating varnish at live points near to' earth to prevent tracking.
2. See that the solenoid earth lead is attached to the "fixed" contact screw (59). (Note that in "insulated return" machines, this lead is taken to a different point, viz, one side of connecting link bracket).
3. Assemble solenoid terminal (46) in drive end-shield and connect the solenoid lead to it. Assemble the positive main terminal (47) In position, but do not tighten.
4. Assemble the moving contact onto the plunger and see that the contact spring is correctly and firmly located. Ensure that the second turn of the spring cannot jump over the first coil, by pushing the plunger through the moving contact assembly, until it is fully compressed.
5. Place the plunger return spring (14) in position. Oil the plunger by lightly smearing with Caltex Thuben 90 oil. Insert the assembled contact and plunger into the solenoid. As the plunger is inserted, its locating shoulders must pick up with the return spring.

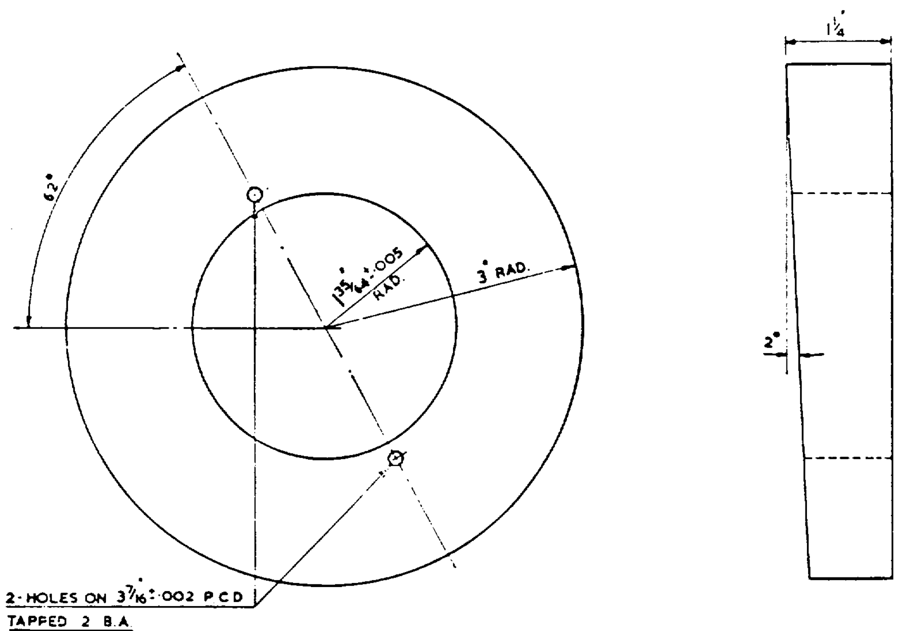



*Fig. Q.13. Face Plate.*

## ALTERNATIVE METHOD OF ASSEMBLY IN PLACE OF PARAGRAPH 3

Assemble commutator shield, yoke, drive end and armature together temporarily without shims at the commutator end and measure distance between pinion face and flange with the shaft pushed towards the drive end. Dismantle starter and add shims inside commutator end shield on the shaft to give 1 in ± 0.002 in (47,63 ± 0.05 mm) between flywheel and starter flange face. Then assemble commutator end-shield and add shims on the shaft between commutator end shield and the shaft circlip so that the armature end float is 0.062 —0.072 in (1,57—1,83 mm). This gives the desired 1/16 in (1.6 mm) float on the armature assembly. A simple tool for this purpose is shown in Fig. Q.14. The measurement from the square base to the cross member is 1.877 in (47,68 mm) on one side and 1.900 in (48,26 mm) en the other, so that with feelers, the correct size shims can be ascertained.

## TEST PROCEDURE

### TESTS ON COMPLETE STARTER

1. **Ensure there is NO connection to the main terminal.**
2. Pull the pinion forward by hand, approximately 1/16 in (1,6 mm) and let go. The pinion should return to its original position.
3. Energize the solenoid, by means of a battery connected between the solenoid terminal (46) Fig. F.10 and the earth terminal on the commutator end-shield. The pinion must move forward 1 in (6,35 mm) minimum.
4. With the solenoid still energized, pull the pinion slowly forward by hand. The trip collar must act upon the trigger at least k in (3,18 mm) before the pinion reaches its stop. It is possible to feel this action taking place.
5. With the pinion at the end of its outward travel, the ball-lock device should now have come into operation, locking the pinion. There must be approximately 0.005 0.010 in (0,127 — 0,254 mm) play between the pinion and shaft stop.
6. Apply a spring load pressure of 30 lbf (13,6 kgf) to the pinion face, by means of a compression spring balance. The pinion must remain in the forward position.
7. Remove the solenoid connection. The pinion must now return to its normal position in one sharp movement.

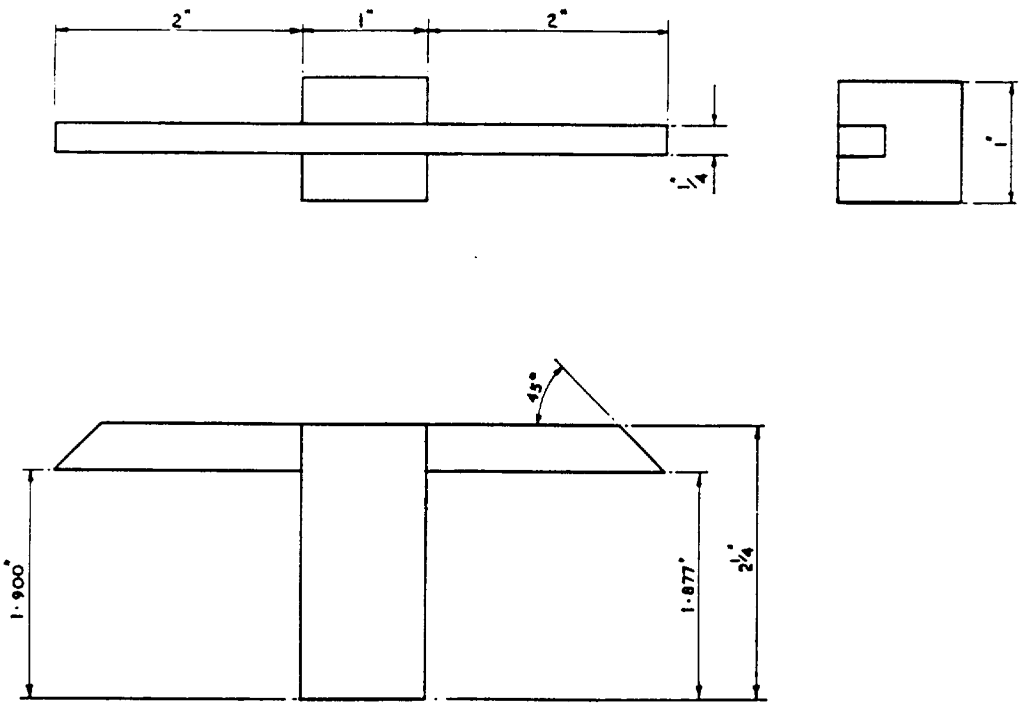



*FIG. Q.14*

6. Thread the trigger (40) of the trip assembly, through the moving contact slot. Place the two fixing screws (57) into the trip support, press the plunger assembly downwards maintaining the pressure, whilst tightening the fixing screws.

7. Fix the contact stop-plate into position by means of the two screws (50). Secure the flexible resistance lead to the moving contact (52). Ensure that the square-ended tag does not touch the back-plate, and that the solenoid leads are outside this lead to prevent chafing.

8. Check that the plunger can he compressed at least 0.3125 in (7,94 mm) without the trip being released, and that the first contact makes between 0.057 in —0.081 in (1,45—2,06 mm) movement.

9. Insert the connecting link (48) between the positive terminal (47) and the fixed contact. Screw in the two screws (51) before tightening the positive terminal post (47).

## ASSEMBLING PINION

1. Unscrew and remove the oil-plug (7) and wick-spring. Push the wick temporarily out of the way to ensure free entry of the pinion sleeve.

2. Insert the pinion into the drive end-shield.

3. Fit the ball-lock collar (17) in place, with its spring, trip collar (19) and circlip. Ensure that the lock collar slides freely.

4. Using a medium grade grease, assemble the four steel balls (16) into the pinion-sleeve holes by inserting them through the sleeve bore. Press the balls firmly into the holes to allow free entry of the armature shaft.

## ASSEMBLING ARMATURE

1. When assembling the armature to the pinion, it should be noted that the helices are formed by a three start thread, and the correct thread must be selected so that the steel balls forming the lock will locate in the shaft recesses (39). To assist correct selection, both pinion and shaft ends have corresponding "pop" marks.
   Release the ball-lock by pulling the lock collar towards the commutator end and holding in this position push the pinion up to the shaft shoulder.

2. Assemble armature and drive end shield to yoke assembly, ensuring that dowel is correctly located.

3. Stand the above assembly vertical, with the flange resting on a support, and the pinion face resting on another support, 1 7/8 in ± 0.002 in lower (47,6 ± 0,051 mm). Place a straight-edge across the yoke face and build up with shims on shaft until a dimension of 0.285 in ± 0.020 in (7,24 ± 0,508 mm) between the commutator sleeve and the yoke face is obtained. This will give 1/16 in (1,6 mm) end movement of the shaft, when the commutator endshield is assembled.

4. Check that the commutator end-shield turns freely on the shaft and screw up the two through bolts (37).

5. If necessary, add shims between the commutator end-shield and the shaft circlip (31), to maintain a dimension of 1.872—1.877 in (47.55—47.68 mm), between the pinion nose (6A) and flange face (8B).

6. Place the shaft spring (36) in position, and insert the pad and ball. Replace the cover and clip into position. The end-shield should be stoned to remove any scoring etc., sustained in dismantling the end cover clip. Failure to do so, may result in damage to the sintered bronze bearing.

7. Complete the assembly by fitting brushes, field screws, pinion return-spring, stop, and shaft lock-nut.
   Screw the two cover-screws (55) into position, in the drive end-shield, and replace the commutator end cover-band accurately to exclude all dirt

8. Remove the shaft lock-nut, pinion stop, shim and spring. Pull the pinion forward about 1/4 in (6,35 mm).

9. Apply a spring load to the drive end of the shaft. The spring at the commutator end must start to compress between 13—19 lbf (5,9 to 8,6 kgf), reading to 19—25 lbf (8,611,34 kgf), after T in (1,6 mm) movement.

10. Replace shaft nuts, shim and spring.

**PERFORMANCE TESTS**

1. Brushes to be bedded over at least 75% of their area.

2. Fit the starter to a special flywheel rig and connect the power supply.

3. With a supply of 10 volts only, check that the starter fully engages with the flywheel.

4. With a 12 volts supply circuit, complete five operations under each of the following conditions, on a locked flywheel.
   (a) Distance between flywheel and pinion set at 0.068 in (1,73 mm).
   (b) Distance between flywheel and pinion set at 0.196 in (4.98 mm).

**PERFORMANCE FIGURES**

The figures obtained must be within the following limits.

1. Typical Lock Torque: 36.5 lbf ft (5 kgf m) with 950-1050 A at 6.0 V.

2. Typical Torque at 1250 -1300 rev/min: 12 lbf ft (1.7 kgf m) with 420 480 A at 9.5 V.

3. Typical Light Running Current: 100-120 A at 7,000 rev/min.

**INSULATION TEST**

1. Using a 500v megger, the following tests should show an insulation resistance of not less than I megohm.

2. Lift earth brushes and check the main terminal to earth.

3. With earth brushes still raised, check the positive brush to earth.

**Insulated Return Electrical System**

With this system, the thermostart starting aid is insulated from the induction manifold by an insulated "BLOCK" bush. When a thermostart unit or insulating bush is replaced, care must be taken not to exceed the torque figure quoted on Page B.1. Overtightening of these parts can crack the insulating bush and could cause hard starting and an electrical short.

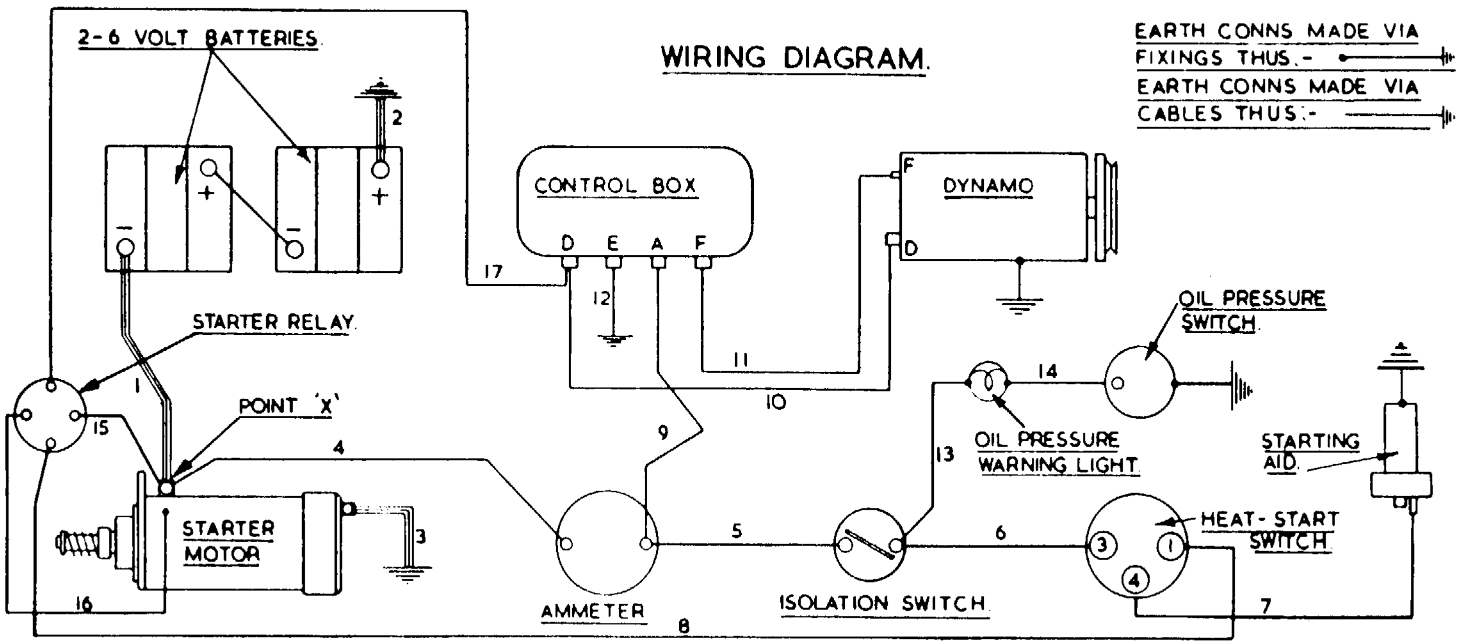



*Fig. Q.15. Typical Wiring Diagram.*
*(incorporating dynamo)*

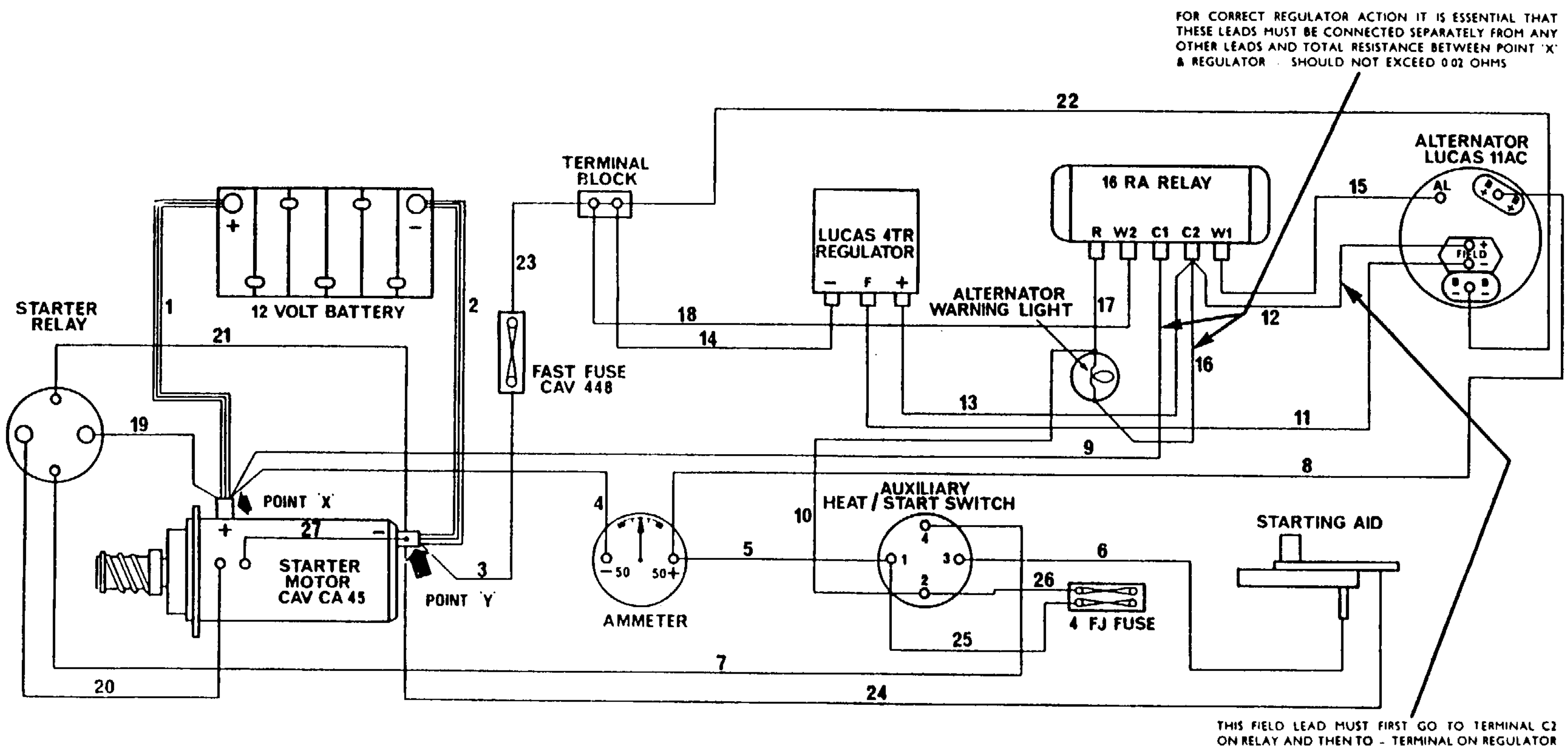



*Fig. Q.16.*
*Typical Wiring Diagram.*
*(incorporating alternator).*

## LUBRICATING OILS

Lubricating oils should meet the requirements of the U.S. Ordnance Specifications MIL-L-46152 or MIL-L-2104C. The lubricating oils for use in Perkins Diesel engines should have a **minimum** Viscosity Index of 80.

**Note:**

**Operators are advised not to use a lubricating oil to the MIL-L-T104C specification in 4.236 marine engines for the first 25/50 hours of operation.**

Some of these oils are listed below and on next page but any other oils which meet these specifications are also suitable.

### MIL-L-46152 Oils

| Company | Brand | S.A.E. Designation | | |
|---|---|---|---|---|
| | | 0°F (-18°C) to 30°F (-1°C) | 30°F (-1°C) to 80°F (27°C) | Over 80° F (27°C) |
| **B.P. Ltd.** | Vanellus M | 10W | 20W | 30 |
| | Vanellus M | | 20W/50 | 20W/50 |
| **Castrol Ltd.** | Castrol/Deusol CRX | 10W | 20 | 30 |
| | Castrol/Deusol CRX | 10W/30 | 10W/30 | 10W/30 |
| | Castrol/Deusol CRX | | 20W/50 | 20W/50 |
| | Deusol RX Super | | 20W/40 | 20W/40 |
| **A. Duckham & Co. Ltd.** | Fleetol HDX | 10 | 20 | 30 |
| | Fleetol Multi V | | 20W/50 | 20W/50 |
| | Fleetol Multilite | 10W/30 | 10W/30 | 10W/30 |
| | Farmadcol HDX | | 20 | 30 |
| | Hypergrade | | 15W/50 | 15W/50 |
| | Fleetmaster | | 15W/40 | 15W/40 |
| **Esso Petroleum Co. Ltd.** | Essolube XD-3 | 10W | 20W | 30 |
| | Essolube XD-3 | | 15W/40 | 15W/40 |
| **Mobil Oil Co. Ltd.** | Delvac 1200 Series | 1210 | 1220 | 1230 |
| | Delvac Special | 10W/30 | 10W/30 | 10W/30 |
| **Shell** | Rimula X | 10W | 20W/20 | 30 |
| | Rimula X | 10W/30 | 10W/30 | 10W/30 |
| | Rimula X | | 15W/40 | 15W/40 |
| | Rimula X | | 20W/40 | 20W/40 |
| | Rotella TX | 10W | 20W/2G | 30 |
| | Rotella TX | | 20W/40 | 20W/40 |
| **Total Oil Co. Ltd.** | Total Super HD | | 20W/20 | 30 |
| | Total HD2-M | 10W/30 | 20W/40 | 20W/50 |
| | Total HD3-C (Rubia S) | 10W | 20W/20 | 30 |
| | Total HD3-C (Rubia TM) | | 15W/40 | 15W/40 |
| | Total Universal Tractor Oil (Multagri) | | 20W/30 | 20W/30 |
| | Total Super Universal Tractor Oil (Multagri TM) | | 20W/30 | 20W/30 |

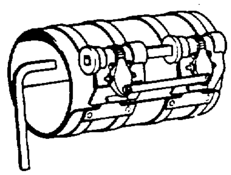
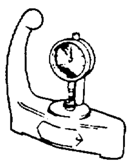
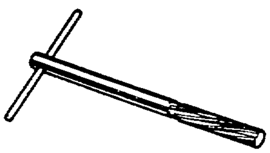
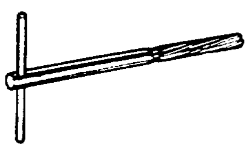
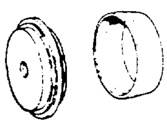
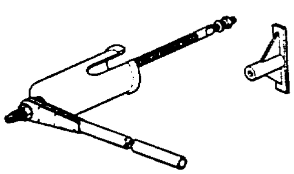
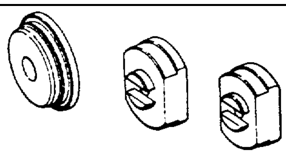
## MIL-L-2104C Oils

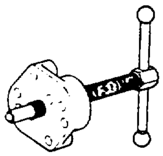
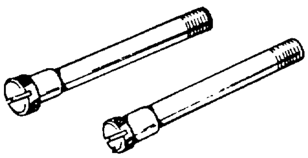
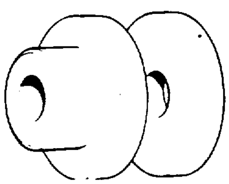
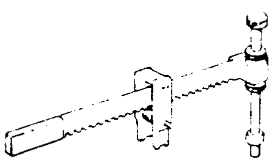
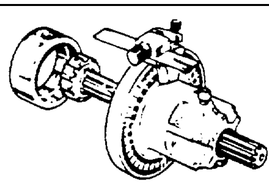
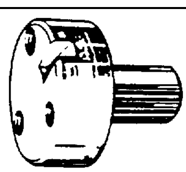
| Company | Brand | S.A.E. Designation | | |
|---|---|---|---|---|
| | | 0°F (-18°C) to 30°F (-1°C) | 30°F (-1°C) to 80°F (27°C) | Over 80° F (27°C) |
| **B.P. Ltd.** | Vanellus C3 | 10W | 20W/20 | 30 |
| **Castrol Ltd.** | Castrol/Deusol CRD | 10W | 20 | 30 |
| | Deusol RX Super | | 20W/40 | 20W/40 |
| | Agricastrol HDD | 10W | 20 | 30 |
| | Agricastrol MP | | 20W/30 | 20W/30 |
| | Agricastrol MP | | 20W/40 | 20W/40 |
| **A. Duckham & Co. Ltd.** | Fleetol 3 | 3/10 | 3/20 | 3/30 |
| | Farmadcol 3 | 3/10 | 3/20 | 3/30 |
| | Hypergrade | | 15W/50 | 15W/50 |
| | Fleetmaster | | 15W/40 | 15W/40 |
| **Esso Petroleum Co. Ltd.** | Essolube D-3HP | 10W | 20W | 30 |
| | Essolube XD-3 | 10W | 20W | 30 |
| | Essolube XD-3 | | 15W/40 | 15W/40 |
| **Mobil Oil Co. Ltd.** | Delvac 1300 Series | 1310 | 1320 | 1330 |
| **Shell** | Rimula CT | 10W | 20W/20 | 30 |
| | Rimula X | 10W | 20W/20 | 30 |
| | Rimula X | 10W/30 | 10W/30 | 10W/30 |
| | Rimula X | | 15W/40 | 15W/40 |
| | Rimula X | | 20W/40 | 20W/40 |
| | Rotella TX | 10W | 20W/20 | 30 |
| | Rotella TX | | 20W/40 | 20W/40 |
| **Total Oil Co. Ltd.** | Total HD3-C (Rubia S) | 10W | 20W/20 | 30 |
| | Total HD3-C (Rubia TM) | | 15W/40 | 15W/40 |
| | Total Super Universal Tractor Oil (Multagri TM) | | 20W/30 | 20W/30 |

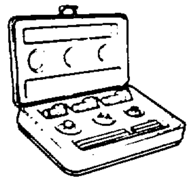
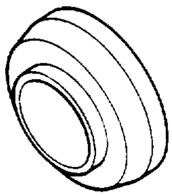
**The above specifications are subject to alteration without notice.**

**APPROVED SERVICE TOOLS**

Available from V. L. Churchill & Co. Ltd., Daventry, Northamptonshire, NN11 4NF, England.

| | Tool No. | Description |
|---|---|---|
|  | No. 8 | PISTON RING SQUEEZER |
|  | PD.418 | PISTON HEIGHT AND VALVE HEIGHT GAUGE<br>A simple method of quickly checking piston height and valve depth. |
|  | PD.137 | VALVE GUIDE REAMER<br>.015" o/size. |
|  | PD.138 | VALVE GUIDE REAMER<br>.030" o/size. |
|  | PD.145 | CRANKSHAFT REAR OIL SEAL REPLACER ADAPTOR<br>(LIP TYPE SEAL) |
|  | PD.150A | CYLINDER LINER REMOVER/ REPLACER (MAIN TOOL)<br>For Field Service replacement of single liners. Not advised for complete overhaul. For this work use adaptors with a hydraulic ram unit. |
|  | PD.150-1B | ADAPTORS FOR PD.150<br>Suitable for cylinders of 3.6" dia. and 3.87" dia. Removal and replacement. |

| | Tool No. | Description |
|---|---|---|
|  | 155B | BASIC PULLER<br>The cruciform head with multiple holes at different centres is used with adaptors listed below. |
|  | PD 155-1 | ADAPTORS FOR PD.155B<br>Used to remove water pump pulleys<br>Also suitable to remove Camshaft Gears. |
|  | 335 | CON ROD JIG & 336 MASTER ARBOR |
|  | 336-102 | ARBOR ADAPTOR<br>Used with 335. |
|  | 6118B | VALVE SPRING COMPRESSOR |
|  | PD.6118-4 | ADAPTOR FOR 6118B |
|  | MS.67B | TOOL FOR CHECKING FUEL INJECTION PUMP TIMING |
|  | PD.67B-1 | ADAPTOR FOR USE WITH MS.67B |

| | Tool No. | Description |
|---|---|---|
|  | MS.73 | VALVE SEAT CUTTERS<br>(For 45° Seats) |
|  | PD.162 | TIMING CASE COVER CENTRALIZING<br>TOOL |

## EXAMPLES OF SERVICE FACILITIES

### Service Publications

The following Service Literature may be purchased through your local Perkins Distributor.

Workshop Manuals

Operators Handbooks

Crankshaft Regrinding

Fault Finding Guide

Engine Brake Testing Data

Installation and Maintenance Guide for Static Standby Engines

Etcetera

### Service Instruction

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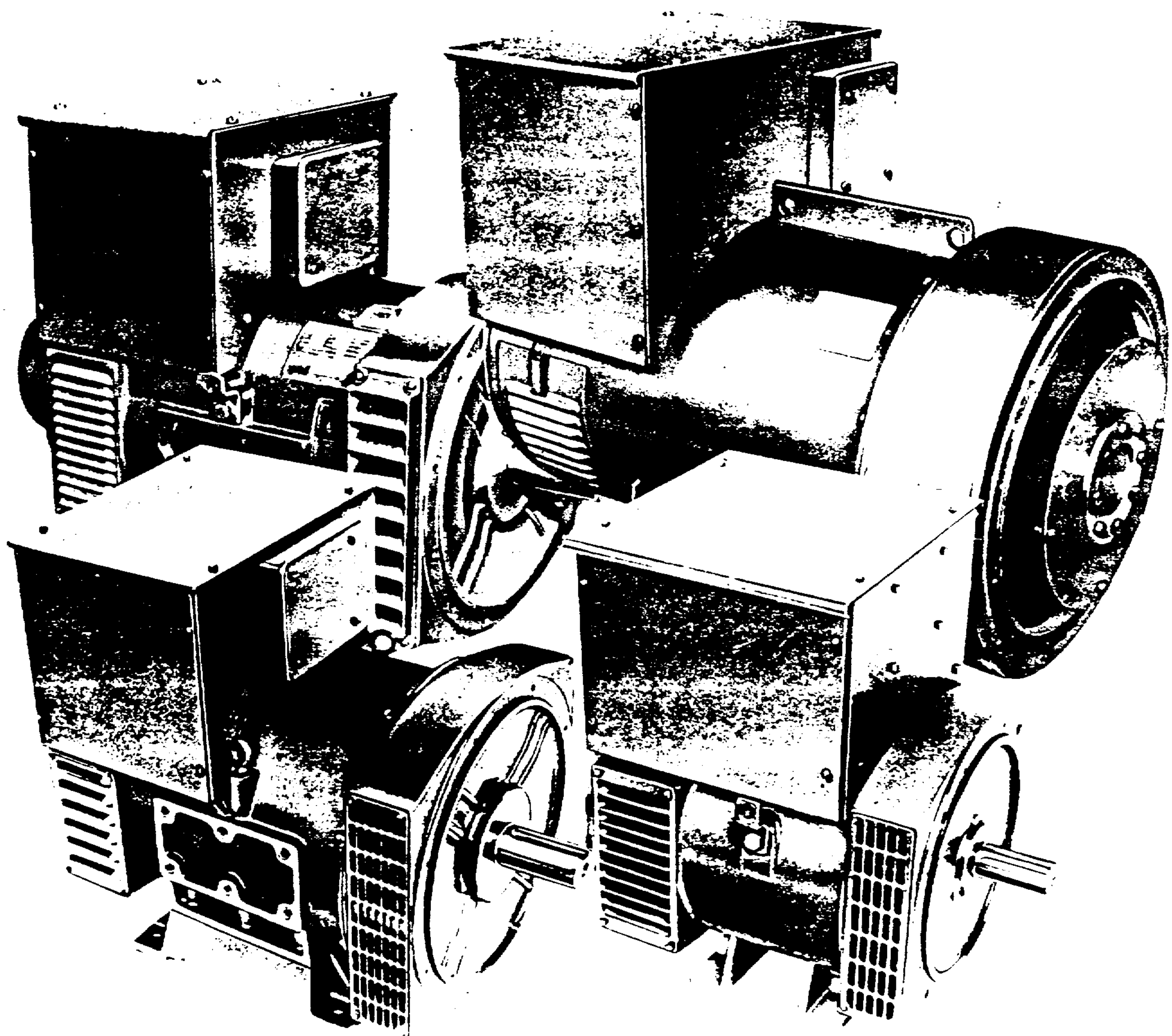
## INDEX

'C' Range

NEWAGE STAMFORD

**FRAMES 1,2 &3**
**Series 4 A.V.R. Controlled**
**Operation & Maintenance Manual**
**Machine Designations-**
**PC164**
**SC and MSC 144, 244,344**



**Publication No. 1H - 059 1st Edition**

## CONTENTS

## SECTION ONE

## GENERAL DESCRIPTION

The Stamford 'C' range a.c. generator is a brushless, revolving field high performance machine. The frame sizes covered in this book are fitted with Series 4 excitation system on SC1 - 3 frame sizes and Series 6 excitation system on PC1 frame size. The machines are. 4 pole, A.V.R. controlled with a broad operating voltage range and with a 12 wire reconnectable facility. The standard windings listed below cover most world voltages.

| WDG. No. | FREQ | SERIES STAR | PARALLEL STAR | SERIES DELTA | SERIES ZIG-ZAG STAR | PARALLEL ZIG-ZAG | REMARKS |
|---|---|---|---|---|---|---|---|
| | | 3 ph. 4W. | 3 ph. 4W. | 3 ph. 4W.<br>1 ph. 2W. | 3 ph. | 1 ph 3W | |
| 211 | 50 | *380-415 | 190-208 | 220-240 | --- | 220-240 | 12W- Reconnectable |
| | 60 | *440- 480 | *220 -240 | 254 -277 | 380-415 | 240** | |
| 17 | 50 | 440-500 | 220-250 | --- | 380-415 | --- | 12W Reconnectable |
| | 60 | 550 - 600 | --- | --- | 460 - 480 | --- | |
| 19 | 50 | 415 460 | 210 - 230 | 240 - 266 | 360 -400 | 240 - 266 | 12W Reconnectable |
| | 60 | --- | --- | --- | 430480 | --- | |

**NOTES:**

1. *** To operate at 346 Volts 50 Hz, 416 Volts 60 Hz in Series Star or 208 Volts 60 Hz in Parallel Star de-rate machine output to 0.93.**
   ****· To operate at 240 Volts 60 Hz in Parallel Zig-Zag de-rate machine output to 0.9.**

2. **For windings 211 and 17 when connected Series Zig-Zag Star the machine output must be de-rated to 0.87.**

### MACHINE DESIGNATION

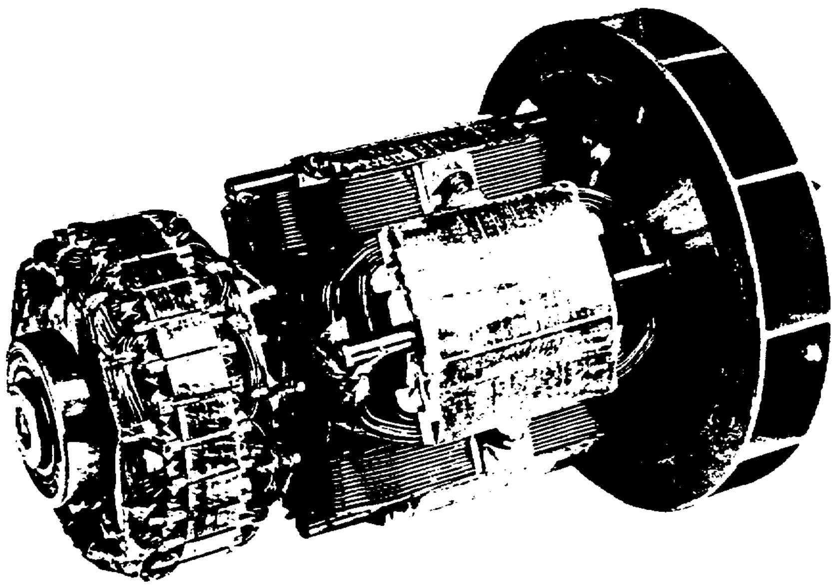
To facilitate identification, a simple coded system is used comprising letters and numbers. For example an industrial machine with a designation SC1440 would be identified as follows: The first letter ('S') indicates the series of machines and the second letter ('C') the range. The first number (1) indicates the frame, the second number (4) the excitation system and the third number (4) the number of poles. The letter ('D') after the numbers indicates the core length. For marine machines, the designation is prefixed by the letter 'M' (e.g. MSC144D).

### CONSTRUCTION

The machines are ventilated, screen protected and drip proof to BS4999 Part 20 and can be in either single or two bearing form. All machines are based around a cast or fabricated frame and cast iron endbrackets with a large sheet metal terminal box mounted at the non-drive end.

The stator/rotor core is produced from low loss electrical grade sheet steel laminations, which are jig built and welded under a fixed pressure to give an extremely rigid core to withstand vibration and load impulses The completed wound components are all insulated and impregnated to Class H limits.

A high grade precision machined shaft carries the rotor assembly which comprises the generator rotating field system, incorporating a fully interconnected damper winding, the exciter rotor/rotating rectifier system and cooling fan. The rotor is mechanically wedged and supported on the end winding to allow an overspeed of up to 2250 rev/min. On completion the whole rotor assembly, is dynamically balanced to within precision limits to ensure vibration-free running. The photograph below shows the complete assembly.



**Typical 4 Pole Rotor**

The rotor is supported by liberally rated, sealed for life ball bearings.,

Depending on output and frame size the exciter can be mounted internally or externally to the N.D.E. bearing.

The A.V.R. is mounted from the front panel (D.E.) of the terminal box.

Removable access covers are provided at the D.E. and N.D.E. of the machine. Both side panels and top panel are removable on the terminal box to provide easy access to the output terminals and other ancillary equipment.

# SECTION TWO

# INSTALLATION

## HEALTH AND SAFETY NOTE

**Important**

**British Government Health and Safety at Work Act, 1974**

In view of the above Act it is necessary to draw your attention to the following.

On adaptors/flanges fitted between the a.c. generator and engine the openings must be guarded. Where integral guards are not provided an external protection cover must be fitted.

All a.c. generators are designed with screen protected and drip proof enclosures and as such are not suitable for mounting outdoors unless adequately protected by the use of canopies.

## VENTILATION

When installed in a room without special ventilation arrangements it must be ensured that the ambient temperature of the normal operating conditions does not exceed the maximum value for which the machines are designed. (Normally a maximum of 40°C). Heat dissipation and cooling air requirements are available on request.

## INITIAL CHECKS

If it is necessary to store the machine for long periods, the storage accommodation should be clean, dry and well ventilated. We would recommend the use of anti-condensation heaters to ensure that winding insulation is kept in a good condition where machines are stationary for long periods, i.e. standby plant. Before installation of an a.c. generator which has been kept in storage the insulation resistance of the windings should be checked using a megger or similar instrument. It is essential that the automatic voltage regulator (A.V.R.) is completely isolated before testing, otherwise damage to the electronic components may be sustained. If radio interference suppression capacitors have been fitted in the terminal box these should also be disconnected. If the tests show that the insulation resistance is below 0.5 of a megohm, the machine should be dried out and the test made again. With a completely dry machine the resistance value should be at least 2 megohms. The machine windings can be dried out by applying warm air from a fan heater or similar apparatus into the machine openings. Alternatively, the main stator windings may be short circuited, and the generating set run with the exciter stator supplied from a d.c. source. A 12 volt 0.5 amo d.c. supply should be connected to the exciter stator leads, marked X and XX.

Normally no longer than half an hour will be required for drying out windings in this manner. After this period of time the insulation level should be checked and the drying out Procedure repeated if necessary.

## VOLTAGE ADJUSTMENT

As the machines are offered for a broad operating voltage range it may be necessary to adjust the factory set voltage to meet individual requirements and this should be carried out as follows:-

1. Remove A.V.R. box lid (SC type) or terminal box lid (PC type).
2. Adjust VOLTAGE RANGE control to required voltage.
3. Adjust STABILITY CONTROL (only if necessary) until stable operation is obtained 'ON and 'OFF' load. (Turning control clockwise increases A.V.R. 'gain').

If a hand trimmer has been supplied for remote voltage control, fine adjustment to the nominal voltage level set by the RANGE control can be made. (See page 31 for details).

## UNDER FREQUENCY PROTECTION ADJUSTMENT

This is set for 50 Hz or 60 Hz operation by means of a "JUMPER" lead on the A.V.R.

## EARTHING ARRANGEMENT

On all star connected machines a substantial neutral terminal is provided for connection to the distribution network. This is not connected to the frame of the machine. The a.c. generator frame should, however, be solidly earthed to the generating set bedplate and connected to the common system earth. On generating sets used for mains failure standby special earthing arrangements may be necessary and the local area Electricity Authority or Company should be consulted.

## DIRECTION OF ROTATION

All machines are fitted with a radial bladed fan and are suitable for running in either direction of rotation. The standard machine is supplied to give a phase sequence U.V.W. with the machine running clockwise looking at the drive end unless otherwise specified at the time of ordering. If machine rotation is reversed after the machine has been dispatched apply to factory for appropriate instructions and wiring diagrams.

## MAIN TERMINAL ARRANGEMENT

The main output terminals have been designed to accept cables rated in accordance with normal standard specifications for single or multicore cables, and are based on the use of crimped-type cable terminations.

**Frame PC1** - The terminal arrangement consists of 4, M6 dia. stud terminals
**SC1** - The terminal arrangement consists of 4, M6 dia. stud terminals
**SC2** - The terminal arrangement consists of 4, M10 dia. stud terminals
**SC3** - The terminal arrangement consists of 4, M12 dia. stud terminals

In all cases the 4 output terminals are marked U.V.W. and N.

## A.C. GENERATOR TO ENGINE ASSEMBLY

### Torsional Vibration

Torsional vibrations occur in all engine driven shaft systems and may be of a magnitude to cause damage at certain critical speeds. It is therefore necessary to consider the torsional vibration effect on the a.c. generator shaft and couplings. It is the responsibility of the generator set manufacturer to ensure comparability, and for this purpose drawings showing the shaft dimensions, coupling details and rotor inertias are available for customers to forward to the engine supplier.

### Two Bearing Machines

It is beyond the scope of this publication to give guidance on ways and means of a.c. generator installation in great depth due to the many different designs of generating sets and engine configurations. However, it is recommended that the engine/a.c. generator is mounted on a substantial steel bedplate with machined cads to ensure accurate engine/a.c. generator alignment. Where machine faces cannot be accurately achieved, it is necessary to fit shims under the engine/a.c. generator feet to ensure alignment and avoid vibration.

If flexible mountings are used under the bedplate and their position is far removed from the corresponding engine/ a.c. generator feet, a rigid bedplate becomes essential otherwise distortion during running will disturb the alignment or possibly create vibration.

### Couplings

A good quality flexible coupling should be fitted and alignment carefully checked, preferably in accordance with the coupling manufacturers' recommendation, to avoid excessive shaft and bearing stresses. In addition a flexible coupling will ensure that in the majority of cases torsional vibration problems will not arise.

Normally machines of this size are flexibly coupled. However, if belt drives are required full details of the drive, belt size and pulley dimensions should be forwarded to ensure bearing loadings and shaft stresses are not excessive.

### Single Bearing Machines

Alignment of single bearing a.c. generators is critical. If necessary, shims should be fitted under the feet to counteract any irregularities in the mounting surfaces.

If there is any doubt about the alignment, the covers at the none-drive end should be removed and the air gap checked with long feeler gauges to ensure uniformity around the periphery of the rotor.

### Assembly to Engines

The sequence of assembly to the engines should generally be as follows:-

1. Check on engine distance from the flywheel/coupling mating face to engine flywheel housing face. This should be within ±0.5 mm of nominal dimension. This is necessary to ensure that the a.c. generator bearing does not thrust against the bearing caps.

2. Check that the bolts securing the flexible plates to the shaft hub are tight and locked into position. Torque tightening is as follows:-

   PC1 Bolt size M10. Torque tighten to 5.7 kgf-m (56N•m) (41 lbf-ft)
   SC1 Bolt size M12. Torque tighten to 10 kgf-m (98N•m) (72 Ibf-ft)
   SC2/3 Bolt size M16. Torque tighten to 25 kgf-m (244N•m) (180 Ibf-ft)

3. Remove drive end a.c. generator covers for access to coupling and adaptor bolts.

4. Check that coupling discs are central with adaptor spigot. This can be adjusted by the tapered wooden wedges supplied between the fan and adaptor for transit reasons; Alternatively the rotor can be suspended by means of a rope sling through the adaptor opening.

5. Offer the a.c. generator to engine and engage both flexible plates and housing spigots at the same time, finally pulling home by using the housing and coupling bolts.

6. Tighten coupling to flywheel bolts.

7. Remove wooden wedges and replace covers.

8. Run the machine up to speed and check for excessive vibration.

**CAUTION NOTE: When dismantling a.c. generator from the engine, care should be taken to ensure that the rotor is positioned with a pole at the bottom center line. This is to avoid any damage to the bearing or exciter by limiting the rotor movement to that of the air-gap.**

## SECTION THREE

## OPERATION OF THE MACHINE

### OPERATION

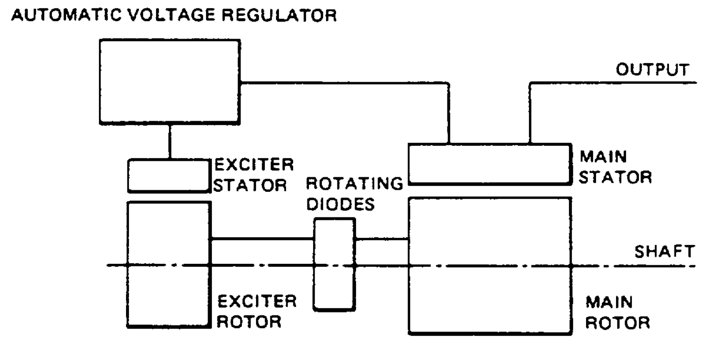



*Fig. 1. Block Diagram of Excitation System*

The block diagram above indicates the main electrical components and basic interconnections.

The control system is based on the main stator winding providing excitation power via the automatic voltage regulator (A.V.R.) to the main exciter. Residual magnetism of the machine is utilized via a circuit within the A.V.R. to provide a positive voltage build up. A reference signal is fed into the A.V.R. from the main stator through a high source impedance which is rectified and smoothed to maintain the voltage regulation to within fine limits. The main exciter output is fed into the main rotor windings via a rotating 3 phase bridge rectifier unit incorporating a surge suppressor to protect the diodes against voltage transients during heavy load surges, i.e. short circuits or out of phase paralleling.

A frequency sensitive circuit is incorporated into the A.V.R. which functions only when the shaft speed falls below approximately 90% of the rated speed. The voltage then reduces proportionally to any further reduction in speed, thus assisting the prime mover to recover after the application of high starting torque motor loads or high kilowatt load changes. This also provides low speed protection to the main rotor by ensuring the excitation does not exceed the safe operating level at all speeds.

### PERFORMANCE

#### Voltage regulation

Voltage regulation is maintained within the limits of **±2%** from no load to full load including cold to hot variations at any power factor between 0.8 lagging and unity and inclusive of a speed variation of $4\frac{1}{2}$%. If Current Sensing Kit supplied (for improved regulation of **±1%**) see Section Six accessories.

#### Waveform Distortion, TH F and TI F Factors

The total distortion of the voltage waveform with open circuit between phases or between phases and neutral is in the order of **2%**. On a 3 phase balanced harmonic-free load the total distortion is in the order of **3.5%**. Machines are designed to have a THF better than **2%** and a TIF better than **50**.
A 2/3 pitch factor is standard on all stator windings to eliminate 3rd, 9th, 15th................ harmonic voltages on the line-neutral waveform.

#### Response

Rapid response to transient load changes is a significant feature, upon application of full load at a power factor of 0.8 lagging, the output voltage recovers to within 3% of the steady state value in **0.25** seconds. The machines comply with the transient conditions laid down by BS 4999 Part 40 voltage grades VR2 11 to VR2.23 as standard. Check with factory for compliance with grades VR2.31 to VR2.23.

## Motor Starting

An overload capacity equivalent to **250%** full load impedance at zero p.f. can be sustained for **10** seconds.

### Short Circuit

A current forcing unit must be fitted at the time of manufacture to provide a sustained short circuit current for discrimination of protective devices. Following the initial short circuit current envelope determined by the machine reactances/time constants, the standard machine does not support a sustained short circuit current.

### Voltage Build Up

The exciter design is such that voltage build-up is achieved from residual levels only.

### Standby Ratings

These are in accordance with NEMA MG 1 - 22.84.

### Parallel Operation (SC Machines Only)

The standard machine is fitted with a fully interconnected damper winding and the standard phases sequence is U-V-W when rotating clockwise viewed from the drive end. When paralleling Stamford a.c. generators the neutrals can be connected. When paralleling dissimilar machines it is recommended that the neutrals are not connected as differences in waveform may result in harmonic currents. For types of parallel operation refer to Section - Six Accessories.

### AUTOMATIC VOLTAGE REGULATOR TYPES

**PC (Series 6)** The A.V.R. on this frame designation is two phase sensed and controls the voltage within close limits under all load conditions providing high performance and the flexibility needed for most generator applications. The external wiring has been kept simple and comprises 3 push-on-type connections. By keeping the wiring simple no optional electrical accessories are available.

**SC (Series 4)** Two types of A.V.R. can be fitted on this frame designation depending upon the application and performance required:-

Type 1. The standard A.V.R. is two phase sensed and controls the voltage within close limits under all load conditions, providing high performance and flexibility needed for most generator applications. The design is such that a wide range of electrical accessories can be added to enhance the Specification.

Type 2. This comprises a special A.V.R. and three phase sensing unit for special applications and derives its sensing voltage from all 3 phases of the machine. All generators when an unbalanced load is applied, will result in differences between phase to phase and phase to neutral voltages depending upon the degree of unbalanced load. It is normally accepted that if unbalanced loading can be limited to within 30% the impact on the machine regulation will be marginal on both two phase and three phase sensed A.V.R.'s. If, for any reason, unbalanced loading occurs above this level the overall regulation will exceed the normal specified limits. On a two phase sensed A.V.R., the phase directly linked with the A.V.R. sensing, will be maintained to close regulating limits but the other phase will float outside the normal regulation limits. By incorporating a three phase sensed A.V.R. overall regulation will not improve but the overall balance around a set point will improve. For example, if the overall voltage regulation is 5% on a two phase sensed A.V.R. the regulation could be all one way either +5% or -5% on one of the phases and close to 0% on the other phases. On the three phase sensed A.V.R. although the overall regulation would still be 5% this would tend to float around the nominal setting to give a regulation of +2% between all phases.

A second advantage of three phase sensing is that it provides a more stable reference when operating on thyristor or rectifier loads which, due to the high harmonic content in the current waveform distort the generator waveform. The recommendation is that where high thyrsitor or rectifier loads are used, the best results will be obtained with a three phase sensed A.V.R.

**NOTE: A range of electrical accessories is available for both two phase and three phase sensed A.V.R.'s see Section 6 for details.**

### MARINE MACHINES (SC TYPE ONLY)

In order to meet the requirements of marine classifying societies certain modifications to the standard machine are required. From the electrical performance point of view the standard machine is suitable for marine use providing a current forcing unit is fitted to give short circuit maintenance for discrimination of protective devices. From the mechanical point of view it is necessary to incorporate a shaft manufactured from approved material and to add drip-proofing features to cater for the inclination of the machine in the form of louvered covers on the air outlets The requirements of most main classifying societies can be met in this way.

## SECTION FOUR

## SERVICE AND MAINTENANCE

### MAINTENANCE

Routine servicing of the a.c. generator is confined to an insulation resistance check on the windings if the machine has not been run for a considerable length of time.

#### Insulation Test

Prior to testing the insulation to earth of the various windings, it is advisable that the A.V.R. is isolated from the windings by disconnecting the push-on terminals. The machine can then be "Meggered" without risk of damaging the control circuits.

### FAULT FINDING PROCEDURE

Fault finding can be simplified considerably, by dividing the machine into two test sections:

A. THE WINDINGS AND THE MAIN RECTIFIER ASSEMBLY

B. THE ELECTRONIC CONTROL SYSTEM AND ITS WIRING

### SECTION A THE WINDINGS AND THE MAIN RECTIFIER ASSEMBLY

#### Separately Exciting the Machine

The a.c. generator is separately excited to give an indication of the condition of the windings and main rectifier assembly. For the frame sizes covered in this manual a 12 volt d.c. battery supply is sufficient to obtain the full output voltage within + or - 10%, at no load, with the speed correct at nominal.

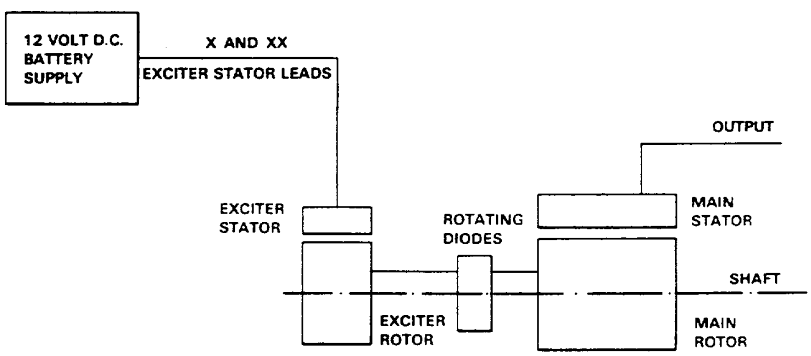



*Fig. 2. Method of Separately Exciting the Machine*

The d.c. supply is connected to the exciter stator leads marked X and XX , which should be removed from the A.V.R. terminals X and XX respectively. It is also advisable to remove the rest of the push-on terminals from the A.V.R. prior to this test.

With the battery connected to the stator leads, the machine is now run up to full speed (it Is essential that the speed is correct for this test), and with a multimeter or voltmeter the following tests are made on the output from the main stator terminals.

#### Voltage is Balanced and within 10% of the Nominal

This indicates that the exciter windings, main windings and main rectifier diodes are in good working order, and it is therefore not necessary to carry out the following tests up to and including "Main Excitation Windings". Fault; finding should continue with test "A.V.R. Sensing Supply from the Main Stator".

**Voltage Balance between Phases**

The voltages between the three phases, and each phase to neutral, should be balanced, and if an unbalance is shown on any phase of more than 1%, this indicates that a fault exists in the main stator windings. This test should be carried out with all of the customer's external connections removed to eliminate the possibility of external shorts between the machine and the main isolator. Further tests can be made on the resistance values of the stator windings (see Winding Resistance Chart, at the end of this section).

**Voltage Balanced but Reading Low when Separately Excited**

This indicates that a fault exists in either the main rotating rectifier assembly, or one of the excitation windings i.e. the main rotor and/or the exciter stator and rotor. **First check that the d.c. separate excitation supply is not lower than 12 volts, and that the speed is correct**

**Rectifier Diodes**

The diodes on the main rectifier assembly can be checked with a multimeter. The flexible leads connected to each diode should be disconnected at the terminal end, and the forward and reverse resistance checked. A healthy diode will indicate a very high resistance (infinity) in the reverse direction, and a low resistance in the forward direction. A faulty diode will give a full deflection reading in both directions with the test meter on the 10,000 ohms scale, or an infinity reading in both directions.

**Replacement of Faulty Diodes (See Fig. 11).**

The rectifier assembly is split into two plates, the positive and negative, and the main rotor is connected across these plates. Each plate carries 3 diodes, the negative plate carrying negative based diodes, and the positive plate carries positive based diodes. Care must be taken to ensure that the correct polarity diodes are fitted to each respective plate. When fitting the diodes to the plates they must be tight enough to ensure a good mechanical and electrical contact, but should not be overtightened. The recommended torque tightening is 2.03 - 4.74 N•m.

**Surge Suppressor**

This is a protection device which prevents high transient voltages from damaging the main rectifier diodes. All machines are fitted with a single surge suppressor connected across the +ve & -ve rectifier plates. The resistance of this device varies considerably, depending upon the meter used to check it. As a general guide, the forward resistance should be in excess of 500 ohms. The reverse resistance should be considerably higher i.e. above 10 k ohms. A faulty surge suppressor will be either open circuit or short circuit in both directions.

**Main Excitation Windings**

If after establishing and correcting any fault on the rectifier assembly the output is still low when separately excited, then the main rotor, exciter stator and exciter rotor winding resistances should be checked (see Resistance Charts), as the fault must be in one of these windings. The exciter stator resistance is measured across leads X and XX. The exciter rotor and main rotor resistances, can be obtained from the connections to the main rectifier assembly The exciter rotor is connected to six studs which also carry the diode lead terminals. The main rotor winding is connected across the two rectifier plates. The respective leads must be disconnected before taking the readings.

**A.V.R. Supply Leads from Main Stator**

The final test which can be made in the separately excited condition is to ensure that the supply from the main stator to the A.V.R. is correct. The voltages at the A.V.R. leads are derived from the main stator winding and the levels can be determined by checking the connections and referring to the wiring diagram.

## SECTION B THE ELECTRONIC CONTROL SYSTEM

**A.V.R.**

Should the previous tests prove successful, any faults can now be assumed to be within the voltage control system and its respective wiring. This system can be affected by bad connections, therefore, the wiring between the auxiliary terminals and the A.V.R. push-on terminals should be carefully examined for broken, loose or corroded connections. The sensing circuit leads have been covered in a previous section.

**Accessories**

Forming an integral part of the electronic circuitry there may be fitted one or more electrical accessory. These items must also be checked for loose, broken or corroded connections, and their resistance values checked. See Section 6 - Accessories.

## DISMANTLING THE MACHINE

Metric Threads are used throughout.

**NOTE: On SINGLE BEARING MACHINES before removal from the prime mover, if possible, position the rotor such that a full pole face is at the bottom of the main stator core.**

### Removal of the A.V.R. (SC1 - 3)

1. Remove the 4 screws retaining A.V.R. lid.
2. Disconnect all cables to A.V.R.
3. Remove 4 pillars retaining A.V.R.

### Removal of A.V.R. (PC1)

1. Remove terminal box lid.
2. Disconnect all cables to A.V.R.
3. Remove 4 screws retaining A.V.R.

### Removal of Main Rotor Assembly

1. Remove all access covers and terminal box lid.
2. Disconnect exciter leads X + & XX - at the inline spade connectors inside the terminal box.
3. Two Bearing Machines only:- remove screws securing the D.E. endbracket.

3a. Two Bearing Machines only:- position rotor with a full pole face at the bottom and tap endbracket out of its spigot.

3b. Lower rotor on to stator core.

3c. Withdraw D.E. endbracket from bearing.

4. Single Bearing Machines only:- remove screws securing adaptor and tap adaptor out of its spigot.
5. Internal Exciter Machines:- remove N.D.E. bearing cap securing screws and bearing cover.

5a. Remove N.D.E. endbracket securing screws, using 2 of these screws, push endbracket out of its spigot by using the 2 threaded holes in the endbracket flange.

5b. Withdraw N.D.E. endbracket complete with exciter stator.

6. External Exciter Machines:- with external cover removed disconnect main rotor leads from rectifier

6a. Remove socket head capscrew securing exciter rotor stub shaft.

6b. Withdraw exciter rotor/rectifier/stub shaft assembly

6c. Remove N.D.E. bearing cap securing screws.

6d. Remove N.D.E. endbracket securing screws, using 2 of these screws, push endbracket out of its spigot through the 2 threaded holes in the endbracket.

6e. Withdraw N.D.E. endbracket complete with exciter stator.

7. Slide rotor out of stator bore towards the D.E. and withdraw rotor.

**NOTE: For removal of rotor of the SC2/3 alternator it maybe necessary to use rope slings as follows.**

1. To withdraw the rotor from the stator, it must be lifted by means of rope slings at both ends, and inched out towards the drive end, until half of the main rotor core is protruding out of the stator. At this point it is safe to release the weight from the rope slings.
2. Tightly bind a rope sling around this portion of the rotor core, and take the weight on this sling.
3. With both ends of the rotor held, manually slide the rotor out of the stator bore. Care should be taken during this operation to prevent damage to the windings and rectifier assembly by manually guiding the non-drive end of the rotor assembly as it is withdrawn.

**WARNING: The rope sling may not be at the centre of gravity of the rotor, and guidance at the ends of the rotor is essential.**
**As the rotor is fully withdrawn from the stator core, THE FULL WEIGHT OF THE ROTOR MUST BE SUPPORTED BY THE CRANE. If the core is allowed to drop more than 6 mm at this point, it will make contact with the stator windings, and may damage them.**

### Re-Assembly

Reverse process of the above.

### WINDING RESISTANCE CHART

| Frame Size | Exciter Stator | Exciter Rotor /Ph-Ph | Stator Winding 211 /Ph | Stator Winding 17 /Ph | Stator Winding -19 /Ph | Rotor |
|---|---|---|---|---|---|---|
| 1A | | | 1.62 | 2.16 | 2.01 | 0.81 |
| 1B | 27 | 0.242 | 1.13 | 1.67 | 1.40 | 0.88 |
| 1C | | | 0.79 | 1.06 | 0.95 | 0.96 |
| 1D | | | 0.66 | 0.87 | 0.69 | 1.03 |
| 1E | 28 | 0.252 | 0.41 | 0.58 | 0.44 | 1.18 |
| 1F | | | 0.27 | 0.42 | 0.33 | 1.36 |
| 1G | 31 | 0.274 | 0.21 | 0.31 | 0.25 | 1.53 |
| 2A | | | 0.21 | 0.30 | 0.24 | 0.58 |
| 2B | 27 | 0.064 | 0.15 | 0.21 | 0.19 | 0.65 |
| 2C | | | 0.125 | 0.19 | 0.15 | 0.69 |
| 2D | 31 | 0.070 | 0.08 | 0.12 | 0.10 | 0.82 |
| 2E | | | 0.06 | 0.083 | 0.077 | 0.93 |
| 3A | | | | | | |
| 3B | 37 | 0.082 | 0.041 | 0.059 | 0.045 | 1.34 |
| 3C | | | 0.028 | 0.043 | 0.033 | 1.55 |
| 3D | | | 0.022 | 0.031 | 0.029 | 1.71 |
| | | | 0.019 | 0.027 | 0.023 | 1.88 |

**NOTES:**
1. **All figures are approximate.**
2. **Resistance figures are at 200C.**
3. **The figures given are for Series Star Connections on main stator.**
4. **For details of voltage ranges available from above Windings - see page 1.**

## SECTION FIVE

## RECOMMENDED SPARES/SECTIONAL ARRANGEMENTS/PARTS LISTS

### RECOMMENDED SPARES

The following list comprises of replaceable items which can be held by the machine owner for Service and Maintenance requirements.

| Description | Quantity per Machine |
|---|---|
| Bearing Drive End (2 Bearing Machines Only) | 1 |
| Bearing Non Drive End | 1 |
| Diode (Forward) | 3 |
| Diode (Reverse) | 3 |
| Automatic Voltage Regulator (A.V.R.) | 1 (See Note) |
| Surge Suppressor | 1 |

**NOTE** **Machines fitted with 3 phase sensing equipment require a special A.V.R.**

When ordering spare parts, the following information must be quoted.

1. Machine serial Number and type (the serial number can be obtained from the machine nameplate or the drive end of the main shaft).
2. Description of part and plate reference number.
3. Quantity required.

Orders and inquiries for spare parts should be addressed to:

Newage Engineers Limited
Spares Department
P.O. Box 17, Barnack Road
Stamford
Lincolnshire, PE9 2NB, England

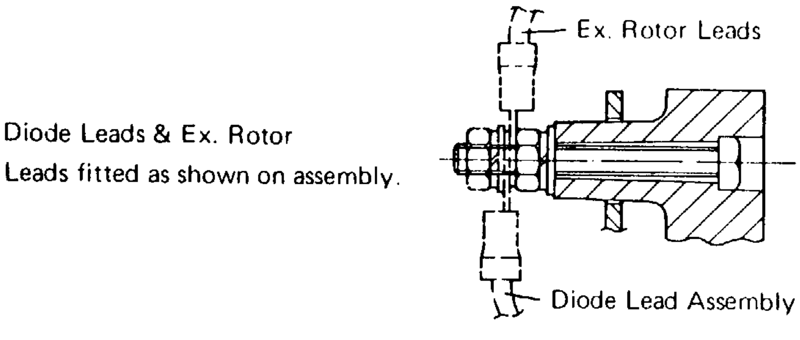
Telephone: 0780-62552 Telex 32268 Cables Newage Stamford
or any of our subsidiary companies listed on the back page

A full technical advice and on-site service facility is available from our service department at the above address.

## PARTS LIST

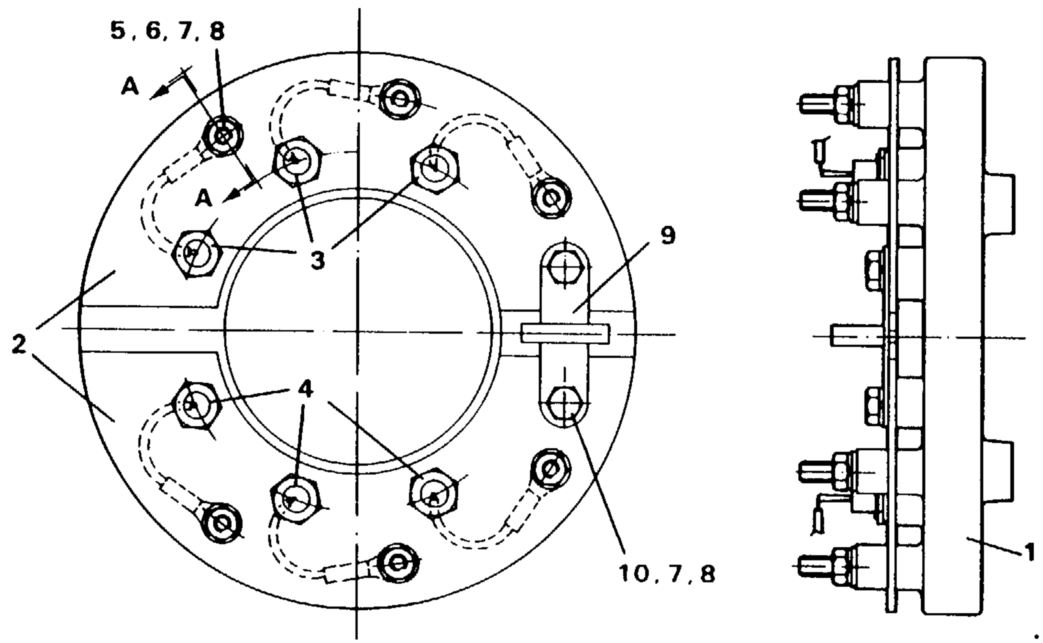
## SC3 TWO BEARING MACHINE (OUTBOARD - EXCITER)

| Plate Ref | Description | Plate Ref | Description |
|---|---|---|---|
| 1 | N.D.E. Endbracket | 26 | N.D.E. Cover |
| 2 | N.D.E. Louvred cover | 27 | D.E. louvres (when fitted) |
| 3 | D.E. Endbracket | 28 | Feet |
| 4 | Main rotor key | 29 | A.V.R. box |
| 5 | Lifting plate | 30 | A.V.R. box lid |
| 6 | Main frame | | |
| 7 | Wound main stator assembly | | |
| 8 | Wound main rotor assembly | | |
| 9 | Fan | | |
| 10 | Shaft | | |
| 11 | Wound exciter stator assembly | | |
| 12 | Wound exciter rotor assembly | | |
| 13 | Main rectifier assembly | | |
| 14 | N.D.E. sealed bearing | | |
| 15 | N.D.E. Outer bearing cap | | |
| 16 | N.D.E. Inner bearing cap | | |
| 17 | Terminal box | | |
| 18 | Terminal box lid | | |
| 19 | Automatic voltage regulator | | |
| 20 | Main terminal panel | | |
| 21 | Auxiliary terminal panel | | |
| 22 | Main terminal panel stud and nut | | |
| 23 | Waved washer D.E. | | |
| 24 | D.E. sealed bearing | | |
| 25 | Screen D.E. | | |




Scrap Section A - A

| Plate Ref. | Description | Qty |
|---|---|---|
| 1 | Hub | 1 |
| 2 | Fin | 2 |
| 3 | Diode (fwd) | 3 |
| 4 | Diode (rev) | 3 |
| 5 | Hx. Screw | 6 |
| 6 | Hx. Nut | 6 |
| 7 | Pl. Washer | 8 |
| 8 | SC. L/Washer | 8 |
| 9 | Varistor | 1 |
| 10 | Hx. Screw | 2 |




**NOTES:**

**Fitting of Diodes.**

1. **Underside of diodes to be smeared with Midland Silicone 'heat sink' compound type MS2623. This compound must not be applied to the diode threads.**
2. **Diodes to be tightened to a torque load of 2.03 - 2.37 N· m.**
3. **A rectifier assembly must comprise diodes from one manufacturer only.**

*Fig. 13 Rotating Rectifier Assembly*

## SECTION SIX

### ACCESSORIES (all in terminal box except hand trimmer)

### HAND TRIMMERS FOR REMOTE CONTROL (SC MACHINES ONLY)

A remote hand trimmer can be provided to give fine adjustment to the output voltage of approx. 6%. The hand trimmer works in conjunction with the range control fitted to the A.V.R. to give the voltage range specified in Section One. **Resistance value** - 4.7 k ohms.

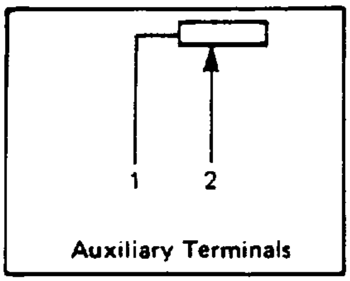



*Fig. 14. Wiring details*

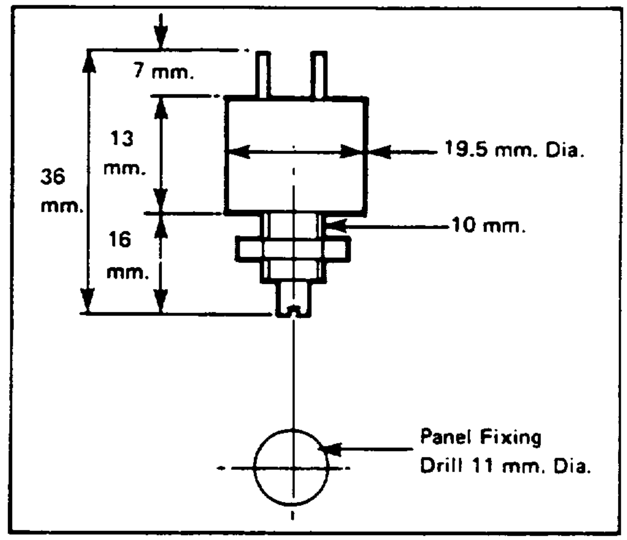



*Fig. 15. Fitting details*

### PARALLEL OPERATION (SC MACHINES ONLY)

There are two important rules to bear in mind when paralleling two or more generators.

1. It is the engine that controls the kW load sharing.

2. It is the generator A.V.R. that controls the kVAr load sharing.

If the engine governors are not electrically interconnected and generator excitation systems are not electrically interconnected, then the larger the engine speed droop when kW load is applied and the larger the generator voltage droop with circulating current, the more flexible and stable the system becomes to obtain load sharing when the generators are in parallel. If closer control of both engine speed and generator voltage is required, then some form of cross connection is required between the governor systems and generator excitation systems.

The standard machine is fitted with a fully interconnected damper winding and the standard phase sequence is UVW when rotating clockwise viewed from the drive end. When paralleling Stamford a.c. generators, the neutrals can be connected but when paralleling dissimilar machines it is recommended that the neutrals are not connected as differences in waveform may result in harmonic currents.

Two paralleling systems can be supplied for the Stamford 'C' range a.c. generators.

Quadrature Droop - For both similar and dissimilar control systems provided, a droop circuit is fitted to all machines.

**Quadrature Droop Kit**
This is the most widely used and simple of paralleling systems and comprises a current transformer (C.T.) and burden resistor (see Fig. 16), or a current transformer (C.T.) and burden choke (see Fig. 17).

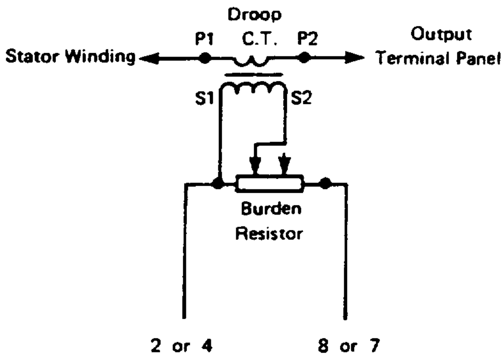



*Fig. 16. Auxiliary Terminals (See Note 2)*

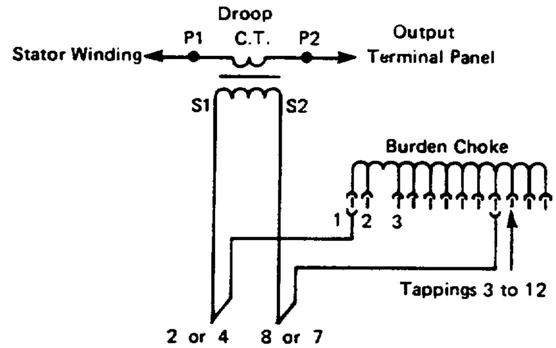



*Fig. 17. Auxiliary Terminals (See Note 2)*

**NOTES:**

1. **Depending on machine type, one or more main stator cables are connected to each output terminal, insert droop C.T. in one cable only. See Fig. 17 for C.T. position and wiring diagram.**
2. **Connect to auxiliary terminals 2 - 8 (after removing link) on two phase sensed machines and 4 - 7 (after removing link) on three phase sensed machines.**

**Operation**

As stated earlier paralleling systems fitted to the generator can only ensure that the excitation system maintains the output voltage to the correct level to give satisfactory kVAr load sharing and minimize circulating currents to acceptable levels. As far as kW load sharing is concerned, this is entirely due to the engine throttle/governor setting.

For both two phase and three phase sensed machines the operation is the same in that any circulating current between machines produces a voltage across the burden-resistor or choke which directly adds or subtracts from the sensing voltage fed into the A.V.R. This makes the excitation system sensitive to circulating currents and ensures correct sharing of the kVAr load. The larger the droop voltage is set, the more flexible becomes the excitation system to reduce circulating currents and ensure kVAr load sharing. In most cases a 5% droop on the output voltage at full load, zero p.f. lag. is satisfactory, this setting impacts to worsen the voltage regulation by approx. 1% at full load, unity p.f. and approx. 3% at full load, 0.8 p.f. When a unity power factor load (kW) is applied the voltage produced across the burden resistor/choke adds vectorally at right angles to the sensing voltage and has a minimal effect. When the machines are run individually, the droop circuit can be switched out by short circuiting auxiliary terminals 2 to 8 on the two phase sensed A.V.R. and 4 to 7 on the three phase sensed A.V.R. to obtain the close regulating characteristics of the machine.

Setting up the droop circuit can be difficult as in most cases only unity p.f. load is available. A simple way of setting up the droop circuit under these conditions is to measure the voltage across the resistor/choke when load is applied, this should be in line with the graph Fig. 18 to obtain approx. 5% droop at full load zero p.f. lag.

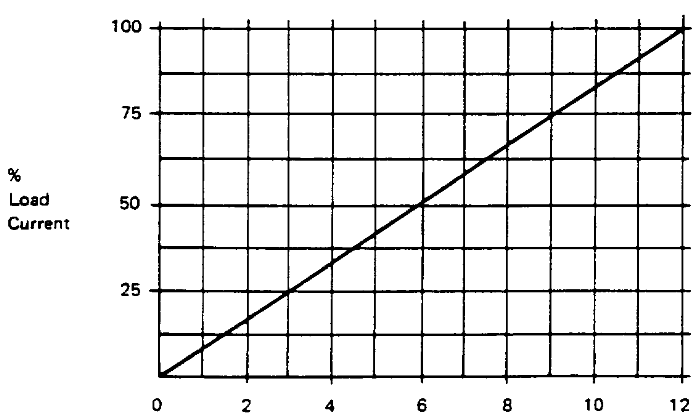



*Fig. 18. Burden Resistor/Choke Voltage*

The other important factor is to ensure that the voltage produced across the burden resistor/choke adds with the A.V.R. sensing voltage in the correct direction. If for any reason this is reversed, a rising characteristic will result which will give an unstable condition for parallel operation and will produce high circulating currents. This can be checked quite simply by applying a unity p.f. load on each machine separately and measuring the voltage across auxiliary terminals 6 to 2 and 6 to 8 on the two phase sensed A.V.R. and across auxiliary terminals 6 to 7 and 6 to 4 on the three phase sensed A.V.R. If the circuit is functioning correctly, the voltage across 6 to 2 should be less than the voltage across 6 to 8 and the voltage across 6 to 7 should be less than the voltage across 6 to 4.

| **A.V.R. Type** | **Stator Connection (Standard phase rotation)** | | **Paralleling** | | | |
|---|---|---|---|---|---|---|
| | | | **Quadrature Droop** | | **Astatic** | |
| | | | **Fig.** | **C.T. Position** | **Fig.** | **C.T. Position** |
| Two Phase Sensed | 4 Wire & 6 Wire Star | | 16 | W2 | | Not available |
| | 12 Wire | Series Star | 16 | W2 | | |
| | | Series Delta | 16 | W2 | | |
| | | Parallel Star | 16 | W2 | | |
| | | Series Zig-Zag Star | 17 | W2 | | |
| Three Phase Sensed | 4 Wire & 6 Wire Star | | 17 | V2 | | Not available |
| | 12 Wire | Series Star | 17 | V2 | | |
| | | Series Delta | 16* | W2 | | |
| | | Parallel Star | 17 | V2 | | |
| | | Series Zig-Zag Star | 16* | V2 | | |

*Fig. 19. Droop C.T. Positions*

**NOTES:**

1. ***For these stator connections the C.T. secondary leads S1 and S2 must be reversed for correct machine operation.**

2. **Standard phase rotation is U.V.W. when a.c. generator is rotating clockwise viewed at the drive end. For phase rotation U.V.W. when rotating anti-clockwise refer to factory for details.**

**General Notes on Paralleling**

**Main Metering Requirements**

For successful synchronization and load sharing between two or more a.c. generators, the following meters and equipment are essential:

**Voltmeter**

This can be one voltmeter per machine, or one which is switchable to either. The latter is more accurate for initial voltage setting to ensure identical voltages. Another voltmeter may be fitted to the main bus-bars for monitoring the machine on load.

**Ammeter**

At least one ammeter per machine is required, preferably with phase to phase switching.

**Wattmeter**

At least one wattmeter per machine is essential to observe the load sharing of the prime movers, i.e. engines.

**Frequency Meter**

As with the voltmeter, this can be one per machine or preferably one which is switchable to either, and another registering the bus-bar frequency.

**Synchronizing Equipment**

This can be in the form of a synchronizing meter or a system of lamps connected across the a.c. generators to be paralleled. The synchronizing meter gives a direct indication when the machines are in synchronism. The lamps are connected across like phases, i.e. U-U, V-V, W-W, such that the machines are in phase when the lights are dimmed. It is important to rate the lamps to at least twice the machine voltage and in most instances it would be necessary to connect two or three in series.

**Protection Devices**

In addition to essential protection devices, i.e. overload circuit breaker, fuses, etc. it is recommended that the breakers have a shunt release coil working in conjunction with a reverse power relay trip. This ensures that, should one of the sets malfunction for any reason, i.e. engine shutdown, voltage drop, etc. the power transferred from the other set, which is now trying to 'motor' the failed plant, will then de-energize the contact breaker and disconnect the sets.

**Setting Up Procedure for Parallel Operation**

The droop equipment should be tested and set correctly and the machines can be set for synchronization as follows:

1. The speed of each set must be adjusted to the nominal frequency of the system, i.e. 50 Hz or 60 Hz.

2. The voltage of each machine can now be set identically on the hand voltage trimmers or A.V.R. range control.

3. The machine should only be paralleled when the difference in frequency between the two sets is small enough to enable the breaker to be closed when the in-phase condition is observed. This is achieved by adjusting the speed of the incoming set to match the set on the bus-bars and the easiest method of speed adjustment is with a governor motor control and a Raise/Lower speed control button.

   **Care must be taken to ensure that the machines are exactly in phase before paralleling is attempted, as the forces set up by out of phase paralleling can create severe mechanical and electrical stresses in the sets.**

4. As load is applied any discrepancy between the kW meters can be eliminated by slight adjustment of the speed on one of the machines.

5. With the kW meters sharing load correctly, any discrepancy between the ammeters can be eliminated with slight adjustment of the voltage on one of the machines.

   **NOTE: Current discrepancies are due to circulating currents which flow between the sets when there is a difference in excitation levels between the a.c. generators. High circulating currents may be due to a reversal in one of the droop transformers or incorrect adjustment of the droop setting on the burden resistor or choke. In general, when paralleling identical machines, the amount of droop should be approximately equal on all sets.**

## CURRENT SENSING - IMPROVED VOLTAGE REGULATION KIT (SC MACHINES ONLY)

The standard machine is voltage sensed and if required current sensing can be added to make the machine more flexible to improve the voltage regulation where semi-conductor or thyristor loads are used which distort the voltage waveform of the machine. This unit can also be used to impact on the sensing circuit of the A.V.R. to overcome voltage drops where long cables between the generator and load are used. The unit consists of a current transformer C.T. and burden resistor. See Fig. 20.

The components are identical to those used for the quadrature droop kit for Parallel Operation, the only difference is that the circuit is arranged to be more sensitive between unity to 0.8 p.f. (lag) loads.

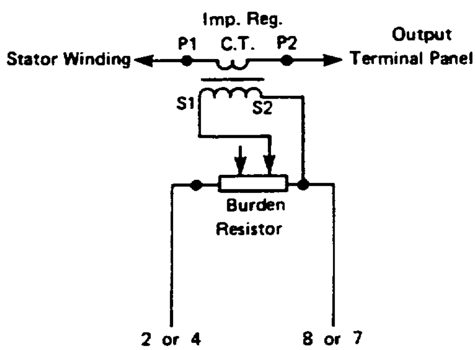



*Fig. 20. Auxiliary Terminals (See Note 2)*

**NOTES:**

1. **Depending on machine type, one or more main stator cables are connected to each output terminal, insert improved regulation C.T. on one cable only. See Fig. 21 for C.T. position and wiring diagrams.**

2. **Connect to auxiliary terminals 2 - 8 (after removing link) on two phase sensed machines and 4 - 7 (after removing link) on three phase sensed machines.**

| A.V.R. Type | Stator Connection (Standard phase rotation) | | Improved Voltage Regulation Fig. | Improved Voltage Regulation C.T. Position |
|---|---|---|---|---|
| Two Phase Sensed | 4 Wire & 6 Wire Star | | 20 | V2 |
| | 12 Wire | Series Star | 20 | V2 |
| | | Series Delta | 20 | V2 |
| | | Parallel Star | 20 | V2 |
| | | Series Zig-Zag Star | 20* | W2 |
| Three Phase Sensed | 4 Wire & 6 Wire Star | | 20* | V2 |
| | 12 Wire | Series Star | 20* | V2 |
| | | Series Delta | 20* | V2 |
| | | Parallel Star | 20* | V2 |
| | | Series Zig-Zag Star | 20* | U2 |

*Fig. 21. Improved Regulation C.T. Positions*

**NOTES:**

1. ***For these stator connections the C.T. secondary leads S1 and S2 must be reversed for correct machine operation.**

2. **Standard phase rotation is U.V.W. when a.c. generator is rotating clockwise viewed at the drive end. For phase rotation U.V.W. when rotating anti-clockwise refer to factory for details.**

### Resistance Values

Burden Resistor - 1000 ohms     C.T. Secondary - 16 ohms

**R.F.I./E.M.I. - SUPPRESSOR KIT**

In case where R.F.I./E.M.I. levels to BS800 are required an additional suppressor kit is recommended. The connections are shown below:-

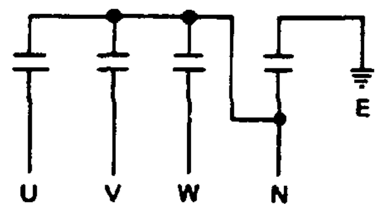



*Fig. 22. Main Terminals*

**ANTI-CONDENSATION HEATERS**

It is recommended that anti-condensation heaters are fitted on standby applications, marine applications or where the machine is standing idle for long periods of time. The most effective anti-condensation heaters are taped directly to the overhang windings of the stator and as such must be fitted during the winding stage. See Fig. 23. On this basis heaters **must** be specified at time of ordering.

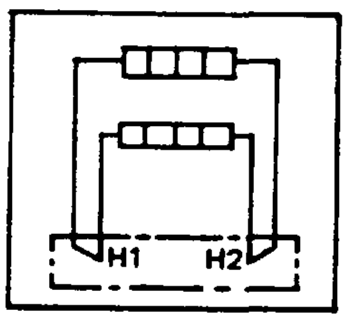



*Fig. 23*

**NOTE: For reasons of safety, all heater leads are terminated in a separate box located on the outside of the main terminal box.**

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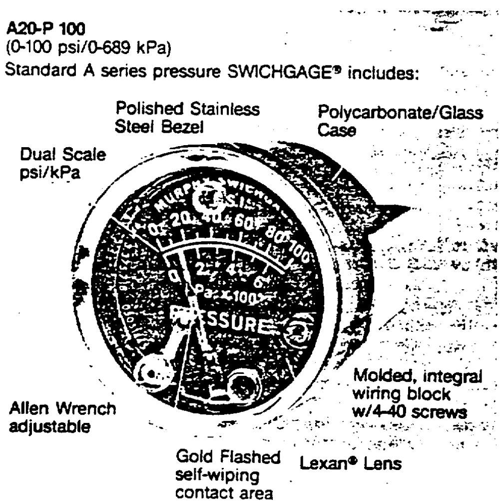
**A20 SERIES PRESSURE**
**MURPHYGAGES)® AND SWICHGAGES'**

**Bulletin A20P-7973**
**Revised 12-30-81**
**Catalog Section 05**
**Class (R)**

Modeled after the time-and-work-tested, steel case **SWICHGAGEâ** , the A20 series offers the same accuracy and durable dependability as the original instruments, also options for ungrounded systems and corrosive environments. These **SWICHGAGES â ,** have the front face, adjustable and visible limit contacts that act as switches upon contact with the gauge pointer: wiring is easily completed on the integral, molded terminal block; Environmentally Sealed models do not require oil seal; micro-switches can be added for alarms or to provide a snap-action SPDT **SWICHGAGEsâ**

Applications: For situations that require accurate gauging of critical pressures that cannot be constantly watched by personnel, the A20 pressure series monitors and can alarm and/or shut-down equipment: on Energy, Agriculture, Industrial, Construction, or Marine installations.




| **A20 Pressure SWICHGAGES â** |
|---|
| • Accurate, Visible Gauging & Integral, Adjustable Limit Contacts in one instrument. |
| • Polycarbonate/Glass case for corrosive atmospheres and ungrounded electrical systems |
| **· Case can be Environmentally Sealed** |
| **Also available as a MURPHYGAGEâ or with a micro-switch for Alarm Before Shut-down** |

**STANDARD SPECIFICATIONS**:
(See also OPTIONS LIST)
**Dial:** 2" (50.8 mm), white on black, psi & kPa
**Case:** 2-3/64" (50.99 mm). black, Lexan®' 500/glass filled.
Mounting Hole: 2-1/16" (52.4 mm)
Mounting Panel Thickness: 1/8" (3.2 mm) max.
Mounting Bracket: included
**Bezel**: Polished SS: non-glare black optional
**Gauge Connection**: 1/8-27 NPTM
**Sensing Element**: Diaphragm of beryllium copper
**Gauge Accuracy**: 2%, In the Operating Range (mid 1/3 of scale)
**Over Pressure**: Dial scales 0-15 psi (0-103 kPa) thru 0-200 psi (0-1.38 MPa) withstand up to twice scale; 0-300 psi (0-2.07 MPa) scale. to 500 psi (3.45 MPa) max.
**SWICHGAGE' Contacts**: SPST: pointer and limit contact: N.C. when the low limit is met N.O. when pointer operates above limit Contact Area: pointer is nickel silver: limit contact is silver: current carrying areas are gold flashed. Contacts have patented self-cleaning motion to ensure electrical continuity.
**Contact Rating**: 2 A @ 30 VAC/DC
**Limit Contact Adjustment**: 40% of scale by Allen wrench
**Wiring Connections**: molded terminal block. 4-40 screws
**Shipping Weight**: 8 ozs. (23 kg)

**MODELS in the A20 Series of Pressure Instruments:**

| **MODEL** | **DESCRIPTION** |
|---|---|
| **STANDARD** | |
| **A20-PG** | **MURPHYGAGEÒ** |
| **A20-P** | **std. SWICHGAGEÒ** |
| **A20-PV HL** | **pressure/vacuum. Hi & Lo** |
| **with OPTIONS** | |
| **A20-PG ES** | **MURPHYGAGEÒ. Environmental Seal** |
| **A20-P ES** | **SWICHGAGEÒ, Environmental Seal** |
| **A20-P HL** | **High & Low contacts** |
| **A20-PK** | **Knob adj. (1 A @ 125 VAC)** |
| **A20-PK ES** | **K model, Environmental Seal** |
| **A20-PK HL** | **K model, High & Low contacts** |
| **A20-P ABS** | **Alarm Before Shut-down** |
| **A20- EO** | **SPDT Snap-Action SWICHGAGE'** |

**OPTIONS LIST:**
**Gauge Only**: Order a MURPHYGAGE®
**Environmentally Sealed**: An internal silicone lung compensates for ambient temperature changes, silicone O-rings seal the case. For corrosive atmospheres order models with the "ES" designator. (More Info. on Bul. PA25-7972)
**High & Low Contacts**: For applications where both high and low pressures are critical, order models with the "HL" designator. Acts as SPDT switch see wiring diagram.
**K Models**: Nylon knob adjustment on front contact models allows **SWICHGAGEâ** contact rating. 2 A @ 30 VAC/DC or 1 A @ 125 VAC.

**Alarm Before Shut-down**: std. SWICHGAGE® includes a micro switch, preset at the factory to switch for alarm before the front low contact Is made: see Contact Setting Chart, wiring diagram, and description on this bulletin.

**Snap-Action SWICHGAGE**®: A20-EO has an internal SPDT micro switch only. for three wire control: can be wired to make or break a circuit. See description., switch set point and wiring diagram on this bulletin

**HOW TO ORDER**:

- Select the A20 pressure model that suits your needs by determining:

(1)**MURPHYGAGEâ** or **SWICHGAGEâ**

(2) Low (std.) or Low & High (HL) contacts
(3) or a 3 wire snap-action switch (EO)
(4) std. or Environmentally Sealed (ES)
(5) type of adjustment: std. (Allen wrench) or Knob (K)
(6) Alarm Before Shut-down
(7) Operating Range (will fit in mid 1/3 of dial scale)

- Basic Models

| | | | |
|---|---|---|---|
| A20-PG | A20-PG ES | A20-PK | A20-P ABS |
| A20-P | A20-P ES | A20-PK ES | A20-EO |
| A20-PVHL | A20-P HL | A20-PK HL | |

- Add to the basic model number the psi high point of the dial scale you need: if operating range is 50 psi (345 kPa) to 110 psi (758 kPa), Dial Scale is 0-150 psi (0-1.03 MPa).

**EXAMPLE**: You want a std. **SWICHGAGEâ** with Knob adj., environmentally sealed. and a dial scale of 0-150 psi: order model A20-PK 150 ES. If you need a snap-action **SWICHGAGEâ** dial range 0-100 psi, but do not want factory switch Set Point of 15 psi: you want it set at 27 psi: order model A20-EO 100 w/27 psi Set Point.

**A20-EO: Snap-Action Pressure SWICHGAGEâ** The A20-EO models include a standard A series MURPHYGAGE' and an internal, SPDT, snap-action micro switch. The micro switch is adjustable, but field adjustment is not recommended; standard factory settings are listed on the Contact & Micro Switch Set Point Chart, other set points must be specified when ordering. The switch is Set (Wiring Diagram) by falling pressure; the Reset point will be approximately 100/o of scale above that Set point. (10% differential is inherent in the physical movement of the SPDT micro switch.) By knowing the low side setting. this 3 wire **SWICHGAGEâ** can be used to make or break a circuit. For example: you have a 100 psi A20-EO, factory set at 15 psi: the switch will snap open at + 10% of scale, about 25 psi: this A20-EO 100 could be used to light a lamp (Set/NC) during engine start-up, then put out the lamp as operating pressure rises above 25 psi. The micro switch is rated 4 A @ 125 VAC and 3 A @ 30 VDC Inductive. When specifying Set Point, keep it in the lower 50% of scale.

**The Pressure Ranges*** listed below are available for A20 series
MURPHYGAGES® and SWICHGAGES® see Contact & Micro Switch Set Point Chart for standard factory settings.

| DUAL PRESSURE SCALES psi | kPa/MPa | Add to model # dial scale key |
|---|---|---|
| 0-15psi | 0-103 kPa | 15 |
| 0-30 psi | 0-207 kPa | 30 |
| 0-50 psi | 0-345 kPa | 50 |
| 0-75 psi | 0-517 kPa | 75 |
| 0-100 psi | 0-689 kPa | 100** |
| 0-150 psi | 0-1.03 MPa | 150 |
| 0-200 psi | 0-1.38 MPa | 200 |
| 0-300 psi | 0-2.07 MPa | 300 |

*A20-PVHL has ONE RANGE ONLY: 5 psi to 20" Hg vacuum.
**Standard Dial Scale

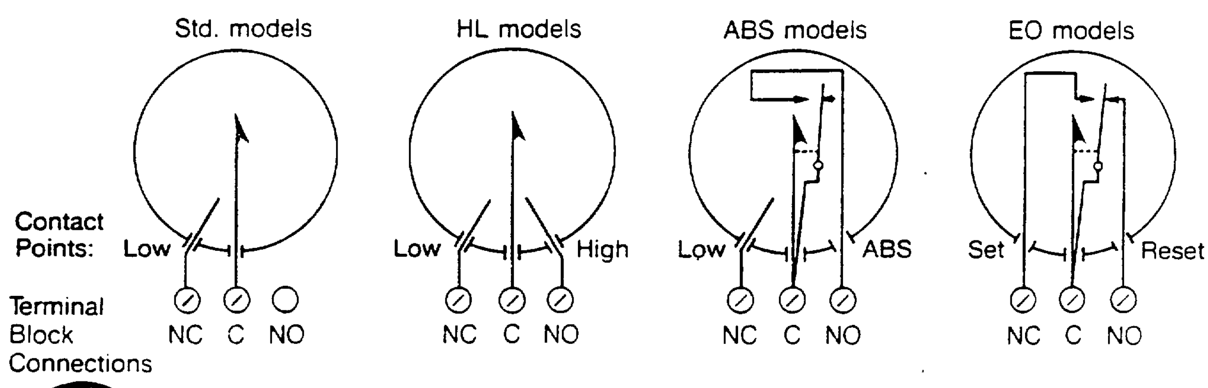
**CONTACT & MICRO SWITCH SET POINT CHART:**[a]

| Pressure Range | Std. models contract | HL models contacts low | high | ABS models[b] Cont./Switch Low | High | EO models[b] SPDT switch Low |
|---|---|---|---|---|---|---|
| 0-15 | 3 | 3 | 12 | 3 | 6 | 3 |
| 0-30 | 7 | 7 | 24 | 5 | 8 | 5 |
| 0-50 | 10 | 10 | 40 | 8 | 11 | 8 |
| 0-75 | 15 | 15 | 60 | 10 | 13 | 10 |
| 0-100 | 20 | 20 | 80 | 15 | 18 | 15 |
| 0-150 | 30 | 30 | 120 | 20 | 23 | 20 |
| 0-200 | 50 | 50 | 150 | 50 | 53 | 50 |
| 0-300 | 75 | 75 | 225 | 75 | 78 | 75 |

[a] Chart is in psi, and settings are manufacturer recommended. Standard **SWICHGAGEâ** can be adjusted in the field.
[b] ABS and EO micro switch settings are not easily adjusted in the field: switches are set at Std. unless Specified when ordering.

**A20-P ABS: SWICHGAGE' with Alarm Before Shut-down**
The A20-P ABS has a standard front adjustable low contact for equipment shut-down, and an internal micro switch for alarm before shut-down (see wiring diagram). The front contact is wired to the NC terminal of the **SWICHGAGEâ** and is set at the std. low pressure shut-down point. The internal switch has one side of a SPDT switch set to contact just before shut-down pressure. The NO terminal connects the micro switch to alarms. Both the adjustable, front contact and the micro switch are preset at the factory: if settings other than standard are necessary, specify your Set Points when ordering. STANDARD WIRING DIAGRAMS: A20 Pressure Series. The circuits are shown with pressure in the operating range.

**STANDARD WIRING DIAGRAMS:** A20 pressure series. The circuits are shown with pressure in the operating range.





FRANK W. murphy MFR., INC.
HOME OFFICE
3131 South Sheridan Box 45248 Tulsa U SA 74145
Phone 918-627-3550 Telex 49-2332

ENGINEERED SYSTEMS & SERVICE from:

FRANK W MURPHY MANUFACTURER INC
PO Box 45248 Tulsa Oklahoma 74145 — 918/627-3550 TLX 492332

MURPHY SOUTHERN DIVISION
PO Box 36989 Houston Texas 77036 — 713-666-4393 TLX 762529

FRANK W MURPHY LIMITED
178 High St Teddington, Middlesex TW11 8HU England — 01 977 0193 TLX 928063

MURPHEK PTY LTD
215 Parramatta Road, Auburn, (NSW) Australia — 02/647-1977 TLX 22574

MURPHY SAFETY SWITCH OF CALIFORNIA
PO Box 788 Palmdale, California 93550 — 805/947-7108

**A20T Series**
**TEMPERATURE**
**SWICHGAGES®**

Bulletin A20T-7974
Effective 5-15-79
Catalog Section 10
Class R

A20T Series **SWICHGAGESÔ** have the same heavy duty mechanical movement as the steel case Series 20-T which have proven their reliability in millions of installations around the world. New A20T housing was developed to provide 'above ground' circuits for marine and other installations where 'grounded' circuits are not practical.

Designed for use on applications where a two or three wire circuit for alarm, shutdown or process control is required, ALONG WITH ACCURATE VISUAL MONITORING OF TEMPERATURES. These instruments are ideal for:

- Engine Coolant
- Crankcase Oil
- Transmission Oil
- Air/Oil in Compressors
- Refrigeration Systems
- Outboard Bearings
- ANY PLACE AN ACCURATE GAUGE AND A RELIABLE SWITCH IS NEEDED.

**HOW TO ORDER**

**Model A20T:**

Standard model with recessed hex socket contact adjustment. May be sealed "Tamperproof". Wiping contacts rated 2 amps @ 30 VAC/DC.

**Model A20T-K:**

Front nylon knob contact adjustment. Rated 1 amp @ 125 V AC. 2 amps @ 30 V AC/DC Model A20T-ES: Environmentally sealed. Internal 'breathing lung' of silicone inhales & exhales ambient gases & salt air. Standard with hex socket contact adjustment. Contacts rated 2 amps @ 30 V AC/DC.

**Model A20T-KES:**

Same as above with front knob contact adjustment. Rated 1 amp @ 125 V AC. 2 amps @ 30 V.

**SPECIFICATIONS**

**Dial:**

2" dia. dual scale, °F and °C.

**Case:**

2-1/32" dia. to fit S.A.E. 2-1/16" S.A.E. hole In instrument panel.

**Bezel:**

Polished stainless steel. Black, non-glare available.

**Range:**

100°-250°F. is standard. Optional: -20°-120°, 90°-160°, 100°- 220°, 100°-325°. 200° to 450°.

**Capillary Tube:**

**Drawn copper, heavy P.V.C. armor coat. High temperature soldered to SWICHGAGESÔ and thermal bulb ends. Sealed with neoprene vibration dampeners. Std. length 48". Available to 65 feet.**

**Thermal Bulb:**

Copper, for rapid heat transier.

**Engine or Process Connector:**

1/2" plated steel is standard. See catalog engineering print. 10-02-163 for specs. on fittings from 1/4" N.P.T. with most metric & B.S.P. up to 3/4" N.P.T.

**Separable Thermowells:**

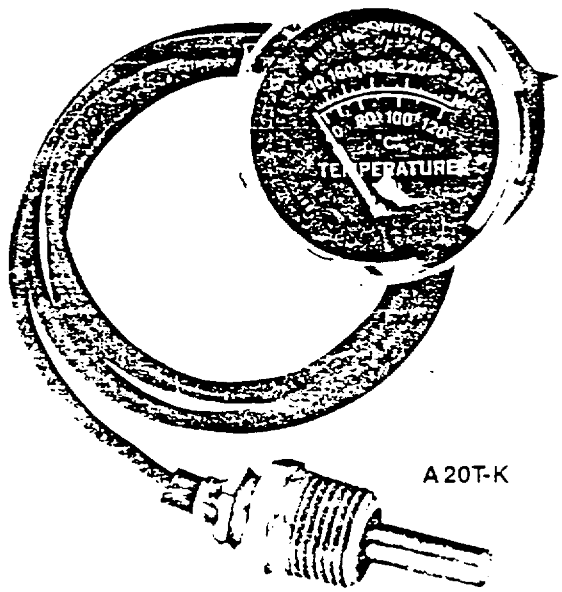
See catalog.

**Model A20T:**

**EXCLUSIVE FEATURES**

- **ACCURATE GAUGE: 2% in operating range**
  **+PLUS+**
  **VISIBLE, WIPING CONTACTS IN ONE UNITI!**
- **POLYCARBONATE/GLASS CASE. CORROSION & SHOCK PROOF.**
- **UNBREAKABLE LEXANS LENS**
- **"UNGROUNDED" CASE HAS INTEGRALLY MOLDED TERMINAL BLOCK AND SCREW TERMINALS.**

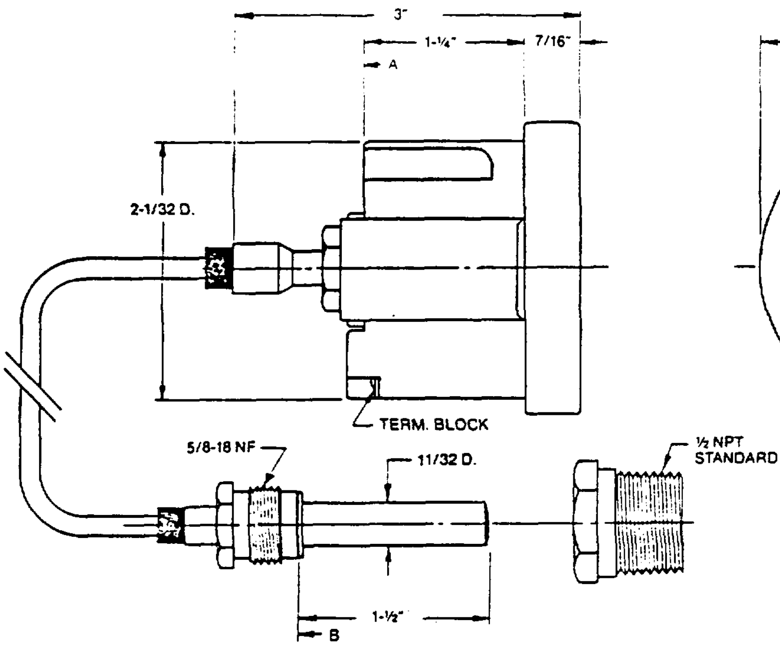
**(Replaces "C" contact steel case SWICHGAGES®)**

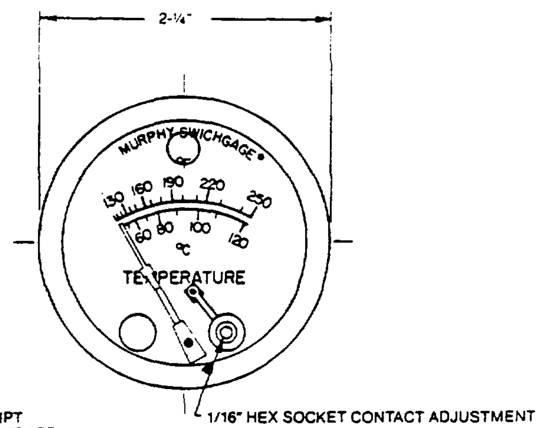



A 20T-K

- Mechanics. electricians, maintenance supervisors and OWNERS like **SWICHGAGESÔ** simplicity and reliability. They can SEE Temperature being measured: can SEE and test contact settings.
- Built to take vibration and shock on constant duty Diesel engines, gives them stamina to 'take It' on any IOD In any climate.
- THEY COST LESS!!! Compare parts and LABOR to install. wire up and give maintenance checks on **SWICHGAGES®** with costs of Less accurate electric gauges, gauge senders and blind' switch sensors.
- **SWICHGAGESÔ** are adaptable to alarm, shutdown or automate any engine or electric motor powered machine

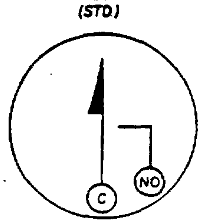
**CAUTION: Temperature sensing bulb must be emersed in water or some other medium to send temperature changes to the SWICHGAGESÔ. Loss c! water will leave the bulb dry which prevents the SWICHGAGESÔ from responding Quickly to increasing temperatures. making it useless An L'52 level SWICHGAGESÔ can De mounted at a minimum sate water level to shut-down equipment on rapid water loss.**



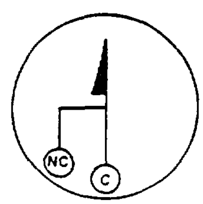




Murphy MECHANICAL temperature SWICHGAGES® have the same rugged movement as pressure units — with a heat sensitive chemical fill-in a closed system. For internal construction details see "The Inside Story" on Bulletin PA257972, Catalog Section 05.

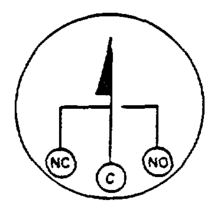
A20T (STD)



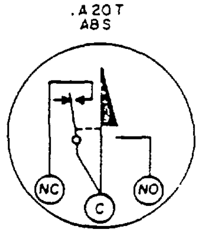

A20T LOW CONTACT



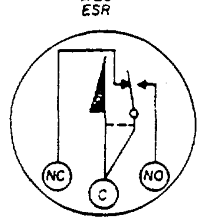

A20T H.L




A20T ABS




A20 ESR




MOLDED TERMINAL MARKING (on back of SWICHGAGES®) simplify wiring circuits for alarm, shutdown or automation.

FRANK W. murphy MFR., INC.
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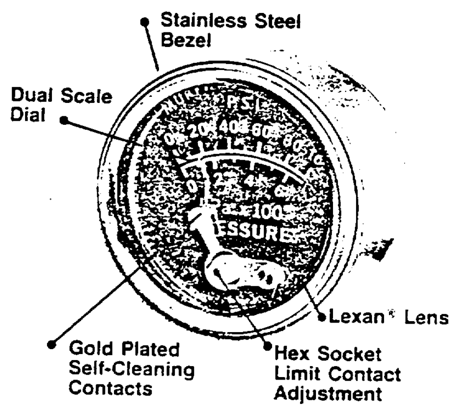
215 Parramatta Road, Auburn, (NSW) Australia — 02/647-1977 TLX 22574
MURPHY SAFETY SWITCH OF CALIFORNIA
P.O. Box 788, Palmdale, California 93550 — 805/947-7108

Instruction Booklet: 2025P-INS
Effective: 10-15-83
123456789 Revision: 9-28-84

**INSTRUCTIONS FOR INSTALLATION & MAINTENANCE**
**OF PRESSURE & VACUUM SWICHGAGES®**
**SERIES: 20-P, 25-P, A20-P, A25-P**
**INCLUDING V, VWC, ABS, EO, DP MODELS**

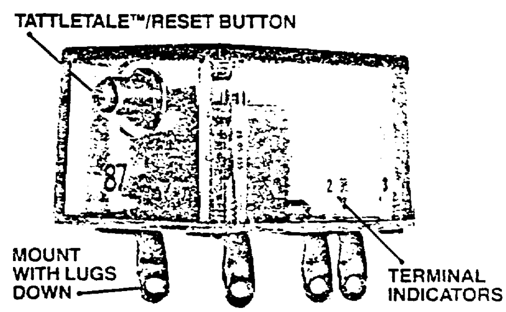
## TYPICAL PRESSURE SWICHGAGE®



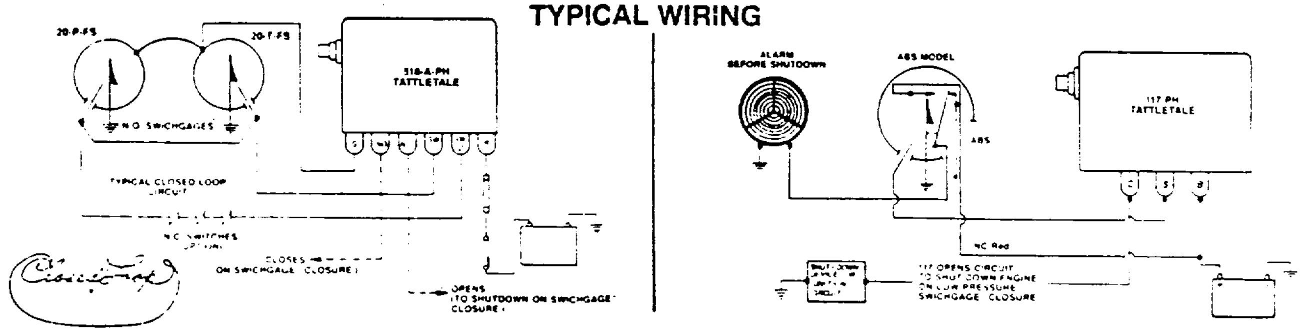

A **SWICHGAGEâ** is an indicating gauge, having adjustable limit contacts that act as switches when closed with the gauge's pointer/contact. **SWICHGAGES â** are available in various sizes and shapes to adapt to most applications, for temperature, pressure, liquid level, vibration, or speed. These are dry contact type switches for light duty electrical switching and should be used with a Murphy Magnetic Switch or Transformer Relay. Both electrical and mechanical experience is necessary for proper installation and maintenance.

## TYPICAL TATTLETALE MAGNETIC SWITCH"

TATTLETALE® Magnetic Switches
Murphy manufactures several, patented magnetic switches for protection of the light duty **SWICHGAGE®** contacts and to ensure positive shut-down of equipment. There are magnetic switches for Capacitor Discharge ignition, Magneto, or battery systems, and models for electric motor driven equipment. TATTLETALES® are pop-out indicators that show the cause of shut-down. If several TATTLETALES® are used in conjunction on with several different **SWICHGAGE®,** the first one out will lockout all other magnetic switches. Be sure the type of Magnetic Switch matches the power source used to trip it.




- **Note: At equipment start-up, the magnetic switch reset button must be held In until no-mal operation occurs, unless closed SWICHGAGES Ô are locked out by time delay or lockout button. (Not applicable for Mag. or C.D. power)**




**SEE BULLETIN M-6797 FOR MURPHY TATTLETALES & MAGNETIC SWITCHES**

## BASIC DESCRIPTION

**20 & 25 SERIES PRESSURE/VACUUM SWICHGAGEÔ.**

20 Series (2-1/16", 52mm mounting hole) and 25 series (2-11/16" 68mm mounting hole) have steel cases and are diaphragm actuated. The pointer/contact grounds through the case to complete the switch circuit. The limit contact(s) is wired to power, through a Murphy Magnetic Switch. See diagrams for **SWICHGAGEâ** wire color code. Contacts are rated 2A @ 30V resistive(pilot duty); gauge connection is 1/8-27 NPT. See installation and typical wiring diagrams for wire up of **SWICHGAGEâ** and Murphy magnetic switch.

**A20 & A25 SERIES PRESSURE/VACUUM SWICHGAGE®.**

A20 series 12-1/16", 52mm mounting hole) and A25 series (2-11/16 68mm mounting hole) have polycarbonate cases and are diaphragm actuated. These cases have molded, isolated terminals for switch contact: the pointer-contact is wired to common or ground: the limit contact(s) is wired to power, through a Murphy magnetic switch. See **SWICHGAGEÔ** diagrams for terminal codes. Contacts 2A @ 30V resistive (pilot duty); gauge connection 1/8-27 NPT. See installation and typical wiring diagrams on this sheet, for wire up of **SWICHGAGE®** and Murphy magnetic switch.

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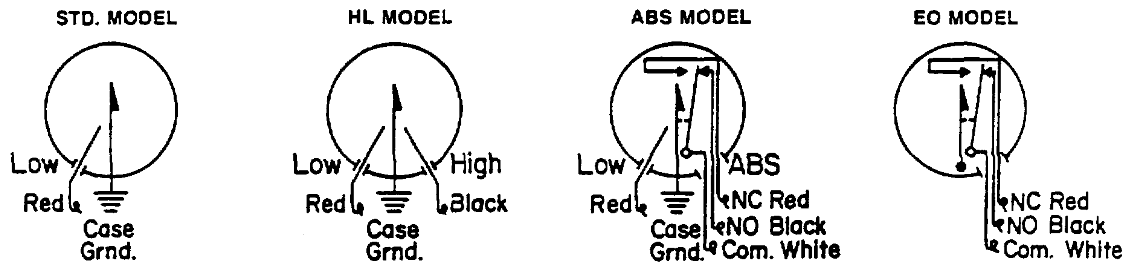
**STANDARD ELECTRICAL DIAGRAMS: 20 & 25 - PRESSURE/VACUUM SERIES**

THESE DIAGRAMS ARE SHOWN WITH POINTER IN THE NORMAL OPERATING RANGE.

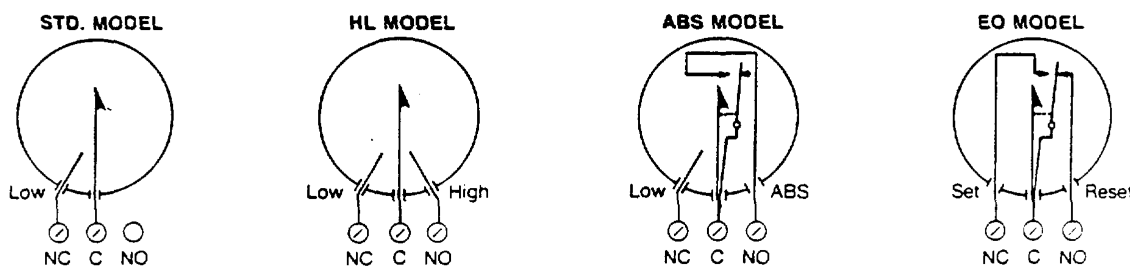



| | | | |
|---|---|---|---|
| **Std. Switch Rating:** | Pilot Duty 2A @ 30 VAC/DC resistive | **Micro-Switch Rating:** | 3A @ 30 VDC inductive<br>4A @ 125 VAC inductive |

---

**STANDARD ELECTRICAL DIAGRAMS: A20 - PRESSURE/VACUUM SERIES**

THESE DIAGRAMS ARE SHOWN WITH THE GAUGE POINTER IN THE NORMAL OPERATING RANGE.

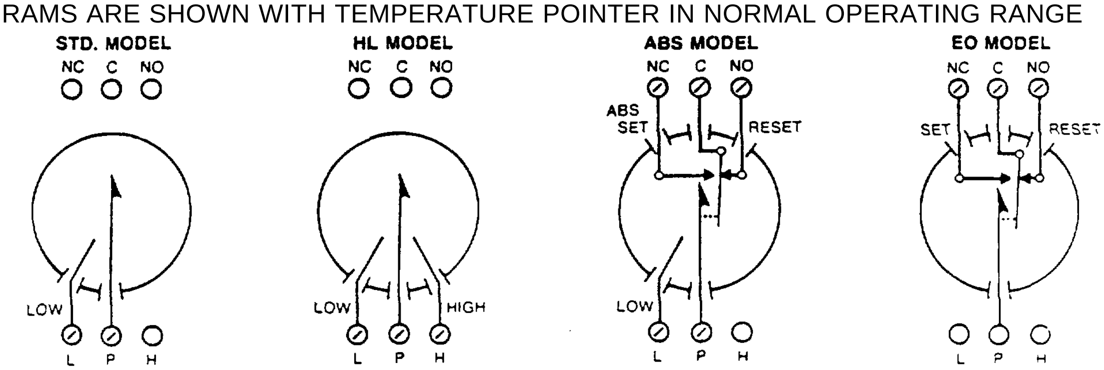



| | | | |
|---|---|---|---|
| **Std. Switch Rating:** | Pilot Duty 2A @ 30 VAC/DC resistive | **Micro-Switch Rating:** | 3A @ 30 VDC inductive<br>4A @ 125 VAC inductive |

---

**STANDARD ELECTRICAL DIAGRAMS: A-25 - PRESSURE/VACUUM SERIES**

THESE DIAGRAMS ARE SHOWN WITH TEMPERATURE POINTER IN NORMAL OPERATING RANGE




| | | | |
|---|---|---|---|
| **Std. Switch Rating:** | Pilot Duty 2A @ 30 VAC/DC resistive | **Micro-Switch Rating:** | 3A @ 30 VDC inductive<br>4A @ 125 VAC inductive |

## SPECIAL APPLICATION SWICHGAGES": ABS, EO, DP, VWC, ST

### ALARM BEFORE SHUT-DOWN
### TWO SWITCH OPTION

ABS: **SWICHGAGEâ** with Alarm Before Shut-down

The ABS has a standard, front limit-contact for low pressure equipment shut-down and an internal, SPDT micro switch for Alarm Before Shut-Down (see Wiring Diagram). When the low side of the micro switch SETS (preset point, on falling pressure), the NC side of the switch completes a circuit to activate an alarm. From this point the pressure must increase approximately 10% of scale before the micro switch will RESET and open the circuit; if pressure falls, the shut-down circuit will be completed.

**NOTE: The front contact shut-down limit setting (adjustable) and micro switch low point are preset at the factory; if settings other than standard are necessary, then specify when ordering.**

### FILTER DIFFERENTIAL PRESSURE

**DP: Differential Pressure SWICHGAGE**

Installation: 1) connect the input side of the filter to the center port: 2) connect the filter output pressure to the upper port -

**CAUTION: use a 7/16" wrench on the upper port's wrench flats to prevent damage to the gauge. DO NOT over tighten port connections; 3) set the limit contact to the manufacturer's filter specifications: 4) connect wiring to alarm and/or shutdown devices.**

### DRY AIR CLEANER RESTRICTION

**VWC: Water Column Calibrated, Vacuum SWICHGAGE**

Installation: 1) mount the VWC away from engine vibration; 2) run the vacuum line from the gauge to a point between the air cleaner and (a) carburetor on carbureted engine, (b) turbocharger on turbocharged diesels, (c) the engine on naturally aspirated diesels. NOTE: a flexible section is essential at some point in the vacuum line to eliminate vibration. Be sure the **SWICHGAGE**® is grounded in a 12 or 24 volt system, and that the alarm used Is of the same voltage as the battery.

### MICRO-SWITCH! LIMIT CONTROL

**EO: SNAP-ACTION Pressure SWICHGAGE**

An EO is the combination of a **MURPHYGAGEâ** and a SPDT micro switch. The switch will SET (see wiring Diagram) at its preset low pressure point on falling pressure. As the pressure rises, the switch will RESET, approximately 10% of scale above the low pressure SET point. (The 10% difference is inherent in the physical movement of the micro switch.) By knowing the low pressure SET point, this 3 wire SWICHGAGE can be used to make or break a circuit.

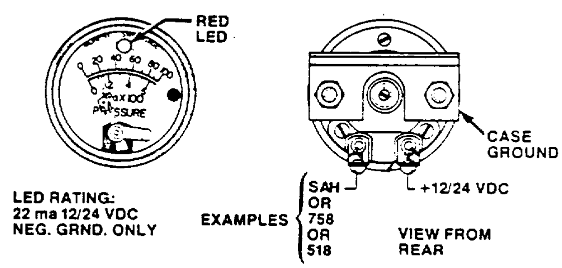
For Example, you have a 0-100 psi EO with a SET point of 15 psi: the switch will RESET at +10% of scale or 25 psi. This EO could be wired to light a lamp on low pressure start-up, and then put out the lamp as pressure rises past 25 psi.

The SPDT micro switch is rated 3 A @ 30 VDC inductive and 4 A @ 125 VAC inductive.

### FLASHING LED ALARM

**ST: LED Flashes On SWICHGAGE"**

Closure The ST has a standard, front limit-contact for low pressure alarm. For shut-down or auxiliary alarm, wire to compatible rating, see examples of Murphy audible alarm and magnetic switches given below.




TROUBLE SHOOTING TIPS (Where problem appears to involve Murphy products)

| PROBLEM | PROBABLE CAUSE & POSSIBLE CORRECTION |
|---|---|
| Engine will not start | • Blown fuse in magnetic switch circuit: replace with 14 A fuse.<br>• False ground in control circuit: repair.<br>• Open circuit (Fault Sensitive): repair.<br>• Control circuit overloaded by accessories: reroute accessories. |
| False Shut-down | • Intermittent shorting in wiring due to wear or insulation breakdown check all wiring, replace as necessary.<br>• Fault Sensitive circuit has intermittent open or short: check all wiring, replace as needed.<br>• Vibration causes the magnetic switch to trip: repair, replace or relocate switch as needed. |
| SWICHGAGE closes but does not trip the magnetic switch or kill the engine. | • Incomplete circuit: locate open circuit and repair.<br>• Magneto not providing power to primary terminal post: repair magneto.<br>• C.D. type magnetic switch being used with magneto or battery: replace with correct switch. |
| SWICHGAGE closes and kills engine. but does not trip the magnetic switch | • Defective magnetic switch binds outside, prevents trip: adjust or replace the switch.<br>• Conventional magnetic switch is used with C.D. ignition: replace with a C.D. designated switch. |
| TATTLETALE tripped but engine still running (mag. or C.D.). | • Lost ground to kill engine: repair. |
| Pointer will not operate properly. inaccurate readings. | • Clogged lines or pulsation dampener: remove and clean or replace.<br>• Kinked/crimped/broken pressure or vacuum line: replace line. |
| Pointer or contact burned in two | • Without exception this Is caused by incorrect wiring or a short circuit: refer to wiring diagrams and recheck wiring: replace SWICHGAGE'. |

If you need additional assistance, contact YOUR LOCAL MURPHY DEALER, or a Murphy representative at one of the offices listed on this form.

## TYPICAL INSTALLATION

**SWICHGAGE® INSTALLATION** (Refer to drawing)

1. Secure the SWICHGAGE' in the panel, using the clamp and nuts provided.

   **NOTE: Be sure the SWICHGAGE® and panel are grounded.**

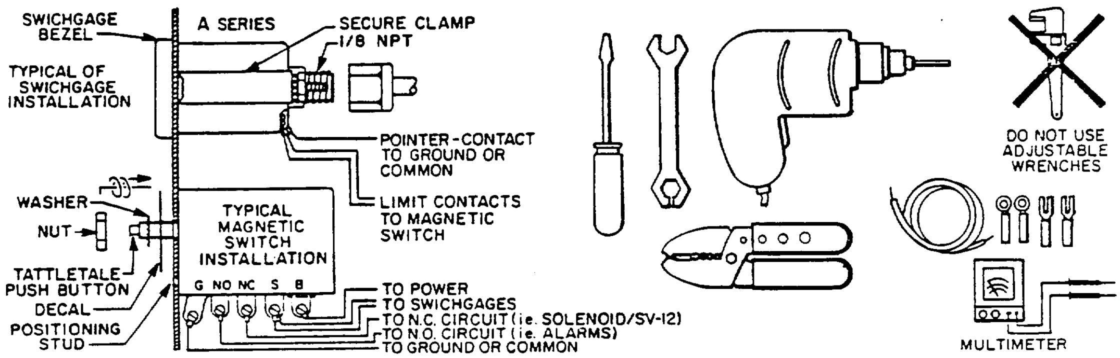
2. Connect the pressure or vacuum line, using a 1/8 NPT adaptor at the **SWICHGAGE®** end.

   **NOTE: Be sure that pressure line is clean and that pipe dope or teflon used on fittings does not block the line.**

3. If not in a prewired panel, wire the limit switchless) to a Murphy magnetic switch or relay.

   **NOTE: Pilot duty (2 A @ 30 V resistive) contacts must be protected from high current: disconnect power during wire-up.**

**TEST**: Start equipment: wait for pointer to lift off low contact: check readings, close limit switch(es) to alarm/shutdown; adjust limit contact to correct limit point.




**USE THE PROPER TOOLS - DO NOT OVERTIGHTEN**

Murphy recommends mounting **SWICHGAGE®**, and magnetic switches away from excessive vibrations and the use of panel shock mounts wherever vibration may occur. Handle all instruments with care: although durable, these products should not be subjected to rough handling, dropping, or severe vibrations.

**Magnetic Switches**: Mount with electrical lugs down. If necessary, drill the TATTLETALE® and pilot-stud holes (template provided); clean away burrs and filings. Position the magnetic switch in the panel, making sure the pilot stud is in place. Add TATTLETALE® decal, then washer, then nut and tighten.

**BASIC WIRING OF SWICHGAGE® AND MAGNETIC SWITCH**

- Disconnect battery or other power during installation.
- Murphy components are easily wired-up and maintained.

Use good quality wire and terminals. Be sure all connections are Clean, Complete and Correct. The wiring and the type of magnetic switch differ for various applications, but a knowledge of basic electrical functions and of the circuits necessary for the specific job (what you want to happen), and common sense will make the system work the way you want It to work

See examples of typical wiring and instructions packed with each magnetic switch.

---

**IMPORTANT, PLEASE READ COMPLETELY**

**SWICHGAGE®**, Murphy magnetic switches and valves, properly installed and maintained, are effective, work-ready tools in any preventive maintenance program. For optimum performance, check these tools periodically: look for frozen pointers, kinked or worn tubing, broken wiring or loose connections: close the contacts, then watch for expected results. Replace any damaged or worn parts: clean and repair as necessary. Murphy will repair or replace parts covered by the Murphy two year limited warranty.

- Check the wiring; it must be Correct and Complete: tight connections, unbroken insulation, no accidental grounds, do not run shut-down wires with ignition wiring.
- Check all tubing and connections for leaks.
- Mount magnetic switches and Murphy valves in an upright position, to prevent moisture collection and shorting.

**Cleaning Lexan Lenses**: since many strong solvents and cleaners can haze and permanently damage the clear poly-carbonate lens on **SWICHGAGE®**, please use one of the solutions listed here: **mild soap and water;** mineral spirits; white kerosene; VM&P naphtha; heptane; hexane; varsol No. 2; menthyl/isopropyl/isobutyl alcohols: 1 & 3 denatured alcohols; freons TF & TE; petroleum ether (65°C boiling pt.).

**CAUTION: Many of these cleaners are flammable. DO NOT USE when the equipment is running or very hot. Keep away from sparks and flame.**

Installation Sheet: 2520T-INS
Effective: 07-15-84
123456789 Revision: 2-1-85

# INSTRUCTIONS FOR INSTALLATION & MAINTENANCE OF TEMPERATURE SWICHGAGES®

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MURPHY SOUTHERN DIVISION 713/342-0297
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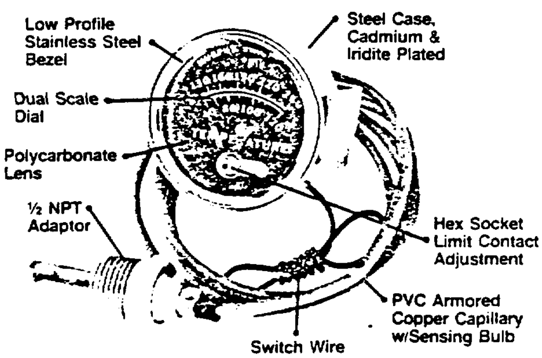
FRANK W. MURPHY LIMITED (0202) 827223
22 Blackmoor Rd., Verwood, Dorset BH21 6AY, England TLX 418388
MURPHEK PTY. LTD. 02/647-1977
215 Parramatta Road, Auburn, (NSW) Australia TLX 22574
MURPHY SAFETY SWITCH OF CALIFORNIA
P.O. Box 788, Palmdale, California 93550 805/272-4700

**SERIES**
**20-1**
**20-St**
**25-1**
**A20-1**
**A25-1**
**ESR**

## TYPICAL TEMPERATURE SWICHGAGE®




A SWICHGAGE® is an indicating mechanical gauge, having adjustable limit contacts that act as switches when closed with the gauge's pointer/contact. SWICHGAGES® are available various sizes and shapes to adapt to most applications, for temperature, pressure, liquid level, vibration, or speed. The are dry contact type switches for light duty electrical switch and should be used with a Murphy Magnetic Switch or Transformer Relay. Both electrical and mechanical experience necessary for proper installation and care.

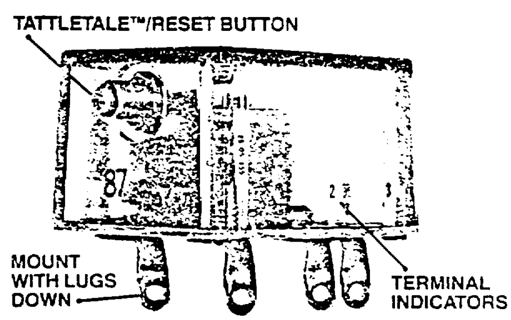
Temperature SWICHGAGE® operate on the same mechanic principal as pressure SWICHGAGES®. Expansion of sending fluid in the bulb, as temperature increases, translates into pressure on the diaphragm, forcing the pointer to read calibrated; closure with the limit contact initiates alarm and/or shut-down.

## TYPICAL TATTLETALE MAGNETIC SWITCH""

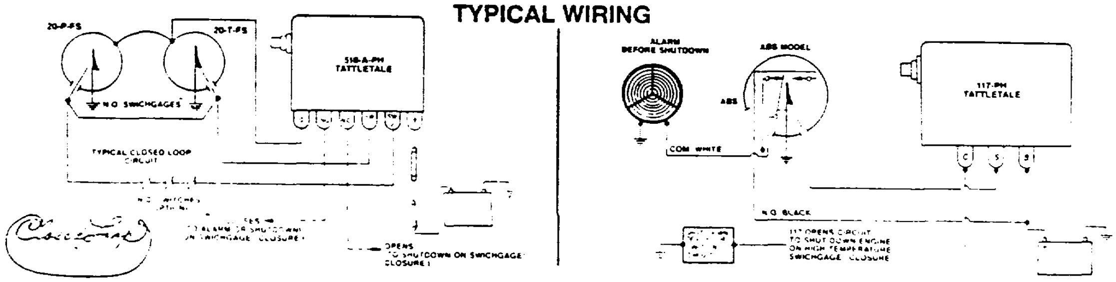
TATTLETALE® Magnetic Switches

Murphy manufactures several, patented magnetic switches for protection of the light duty SWICHGAGE® contacts and to ensure positive shut-down of equipment. There are magnetic switches for Capacitor Discharge Ignition. Magneto, or battery systems, and models for electric motor driven equipment. TATTLETALES® are pop-out indicators that show the cause of shut-down. If several TATTLETALES® are used in conjunction with several different SWICHGAGE®, the first one out will lockout all other magnetic switches. Be sure the type of Magnetic Switch matches the power source used to trip it.

**· Note: At equipment start-up, the magnetic switch reset button must be held in until normal operation occurs, unless closed SWICHGAGES® are locked out by time delay or lockout button. (Not applicable for Mag. or C.D. power)**




## TYPICAL WIRING



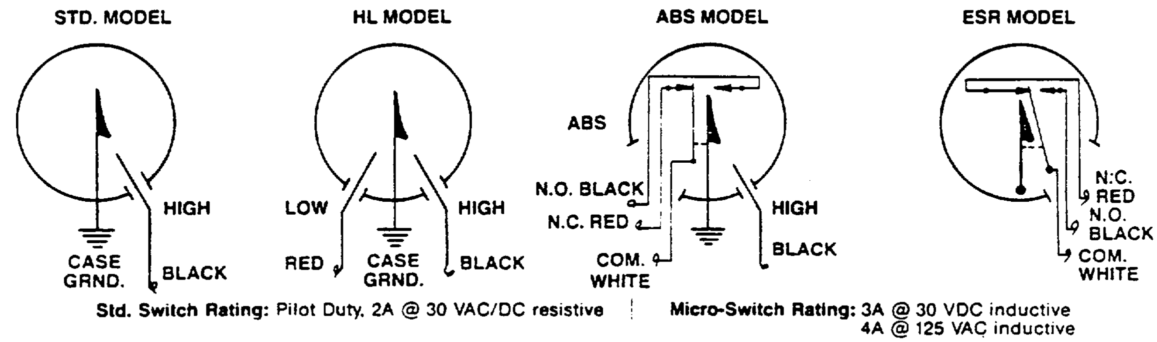

**SEE BULLETIN M-6797 FOR MURPHY TATTLETALES & MAGNETIC SWITCHES**

## BASIC DESCRIPTION

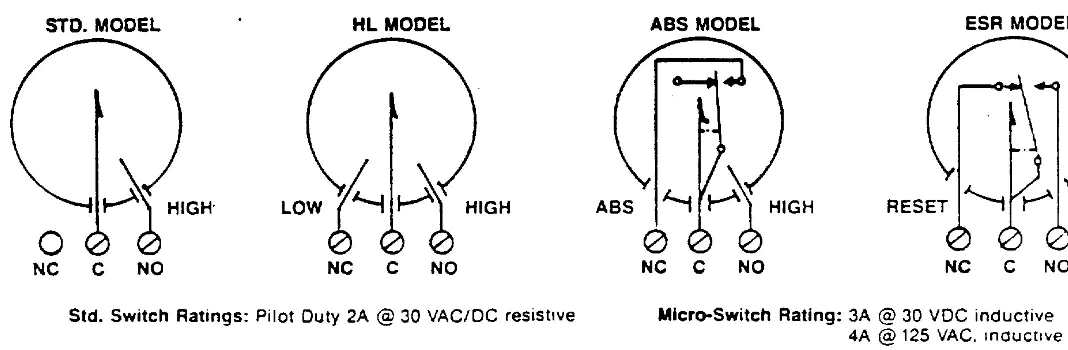
**20 & 25 SERIES TEMPERATURE SWICHGAGE®.**
20 series (2-1/16", 52mm mounting hole) and 25 series (2-11/16", 68mm mounting hole) have steel cases and are diaphragm actuated. The pointer/contact grounds through the case to complete the switch circuit. The limit contact(s) is wired to power, through a Murphy Magnetic Switch. See diagrams for SWICHGAGEâ wire color code. Contacts are rated 2A @ 30V resistive (pilot duty); bulb adapter is 1/2 NPT. See installation and typical wiring diagrams for wire up of SWICHGAGEâ and Murphy magnetic switch.

**A20 & A25 SERIES TEMPERATURE SWICHGAGEÒ**
A20 series (2-1/16", 52mm mounting hole) and A25 series (2-11/16", 68mm mounting hole) have Lexan cases and are diaphragm actuated. These cases have molded, isolated terminals for switch contact: the pointer-contact is wired to common or ground; the limit-contact(s) is wired to power through a Murphy magnetic switch. See SWICHGAGE® diagrams for terminal codes. Contacts 2A @ 30V resistive (pilot duty); bulb adapter is $^{1}/_{2}$ NPT. See installation and typical wiring diagrams on this sheet, for wire up of SWICHGAGE® and Murphy magnetic switch.

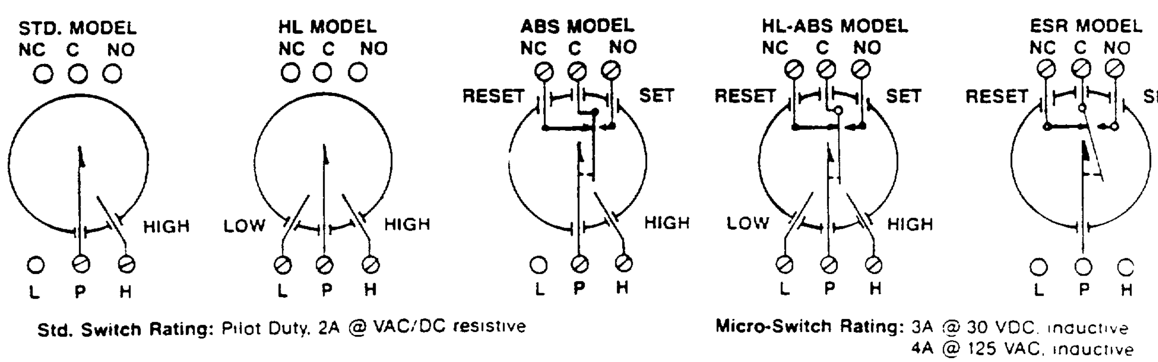
**STANDARD ELECTRICAL DIAGRAMS: 20 & 25-TEMPERATURE SERIES**
THESE DIAGRAMS ARE SHOWN WITH TEMPERATURE POINTER IN NORMAL OPERATING RANGE.



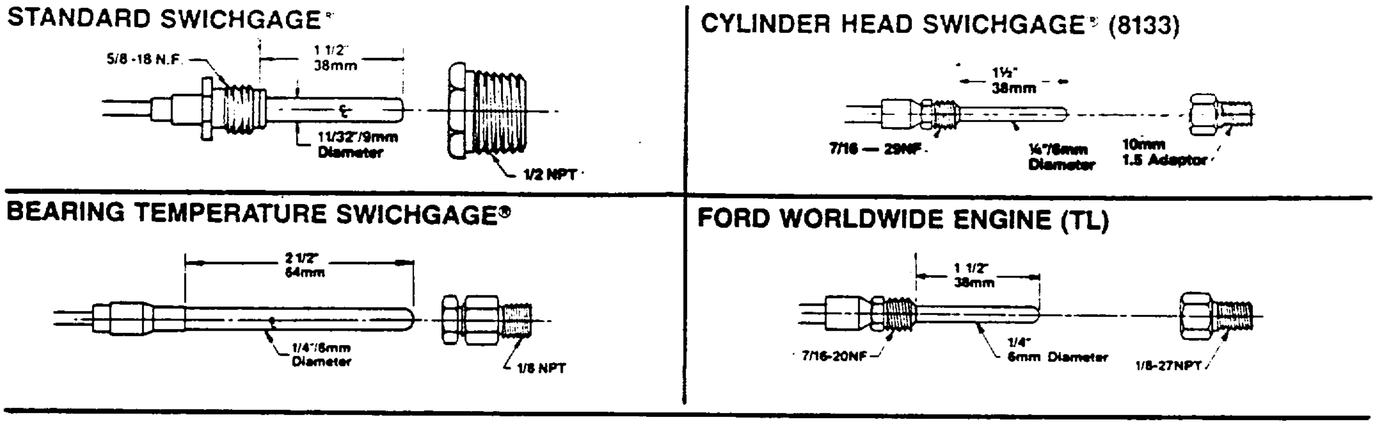

**STANDARD ELECTRICAL DIAGRAMS: A20 - TEMPERATURE SERIES**
THESE DIAGRAMS ARE SHOWN WITH THE GAUGE POINTER IN THE NORMAL OPERATING RANGE.




**STANDARD ELECTRICAL DIAGRAMS: A-25 - TEMPERATURE SERIES**
THESE DIAGRAMS ARE SHOWN WITH TEMPERATURE POINTER IN NORMAL OPERATING RANGE



## STANDARD BULBS & ADAPTERS




## SPECIAL APPLICATION SWICHGAGE®. ABS, ESR

### ALARM BEFORE SHUT-DOWN TWO SWITCH OPTION

**ABS: SWICHGAGE® with Alarm Before Shut-down**

The ABS has a standard, front limit contact for high temperature equipment shut-down and an internal SPDT micro switch for Alarm Before Shut-Down (see Wiring Diagram). When the high side (preset high temperature point) of the micro switch SETS, the NO terminal completes a circuit to activate an alarm. A decrease in temperature of approximately 10% of scale is necessary before the switch will RESET and open the circuit; a continued increase will complete the shut-down circuit.

**NOTE: The front contact shut-down limit setting (adjustable) and micro switch high point are preset at the factory; if settings other than standard are necessary, then specify when ordering.**

### MICRO-SWITCH" LIMIT CONTROL

**ESR: SWICHGAGE® WITH High Limit Micro-Switch**

The ESR is an accurate temperature gauge with a 3-wire, SPOT Micro-Switch, for high limit alarm and/or shut-down of equipment.

The Switch will SET (see wiring diagram, NO closes) on rising temperature; it will RESET as temperature falls to approximately 10% of scale below the SET point. By knowing the high SET point, the ESR can be used to make or break a circuit.

**EXAMPLE**: When temp. rises on the 250°F model to the SET limit, a fan could be turned-on; when the temp. falls, approximately 25°F, to the RESET point the fan would turn-off.

**NOTE: Specify high limit when ordering.**

**TROUBLE SHOOTING TIPS (Where problem appears to involve Murphy products)**

| PROBLEM | PROBABLE CAUSE & POSSIBLE CORRECTION |
|---|---|
| Engine will not start | • Blown fuse in magnetic switch circuit: replace with 14 A fuse.<br>• False ground in control circuit: repair.<br>• Open circuit (Fault Sensitive): repair.<br>• Control circuit overloaded by accessories: reroute accessories. |
| False Shut-down | • Intermittent shorting in wiring due to wear or insulation breakdown check all wiring, replace as necessary.<br>• Fault Sensitive circuit has intermittent open or short: check all wiring, replace as needed<br>• Vibration causes the magnetic switch to trip: repair, replace or relocate switch as needed |
| SWICHGAGE closes but does not trip the magnetic switch or kill the engine. | • Incomplete circuit: locate open circuit and repair.<br>• Magneto not providing power to primary terminal post: repair magneto.<br>• C.D. type magnetic switch being used with magneto or battery: replace with correct switch. |
| SWICHGAGE closes and kills engine. but does not trip the magnetic switch | • Defective magnetic switch binds outside, prevents trip: adjust or replace the switch.<br>• Conventional magnetic switch is used with C.D. ignition: replace with a C.D. designated switch. |
| TATTLETALE tripped but engine still running (mag. or C.D.). | • Lost ground to kill engine: repair. |
| Pointer will not operate properly, inaccurate readings. | • Bulb not inserted to full length or low coolant level.<br>• Kinked/crimped/broken capillary. |
| Pointer or contact burned in two | • Without exception this is caused by incorrect wiring or a short circuit: refer to wiring diagrams and recheck wiring: replace SWICHGAGE®. |

If you need additional assistance, contact YOUR LOCAL MURPHY DEALER, or a Murphy representative at one of the offices listed on this form.

## TYPICAL INSTALLATION

**SWICHGAGE® INSTALLATION** (Refer to drawing)

1. Secure the **SWICHGAGE®** in the panel, using the clamp and nuts provided.

**NOTE G**: **Be sure the SWICHGAGE and panel are grounded**.

2. If necessary, drain coolant or lubricant to a level below the sensor entry point. Prepare the MURPHY adaptor nut (others may damage bulb) with teflon tape or pipe dope and screw securely into place.

3. Slide the sending bulb through the adaptor and secure with the union nut. If necessary, refill the system to operational level.

**NOTE B: Use only the union nut to remove the bulb. When refilling the system, loosen the union nut until fluid flow then tighten; this prevents air pockets in the adaptor.**

4. Wire the limit switch(es) to a Murphy magnetic switch or relay.

**NOTE F: Light duty (2 A @ 30 V resistive) front contacts must be protected from high current: disconnect power during wire-up.**

**CAUTIONS: (Refer to drawing)**

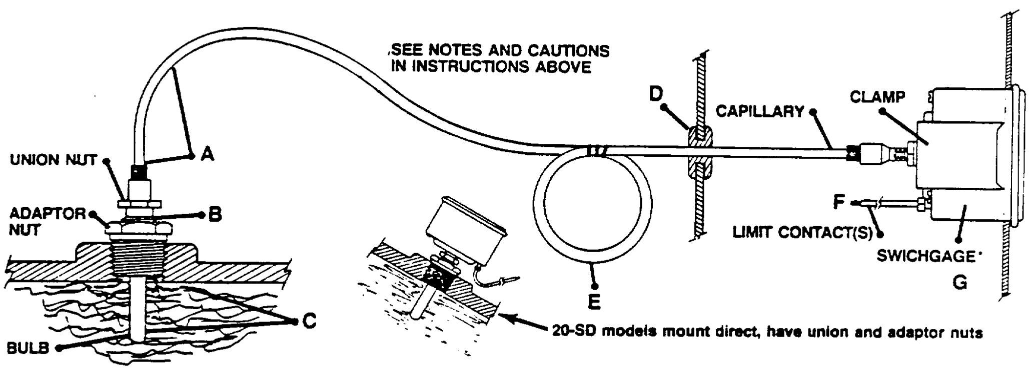
**A. Avoid sharp bends, especially at gauge and at adapter: minimum diameter 2"/50 mm.**

**C. Bulb must be immersed in coolant or lubricant to operate N. properly. Be sure obstructions do not damage bulb when in-serted. Insert bulb to full depth.**

**D. If going through a firewall, use a grommet or other protective surrounding.**

**E. Coil and secure excess capillary tube. Keep tube away from other high temperature components.**

**TEST:** Start equipment and check readings; close limit switch or cause engine to heat to alarm/shut-down point.




**USE THE PROPER TOOLS - DO NOT OVERTIGHTEN**

Murphy recommends mounting SWICHGAGES® and magnetic switches away from excessive vibrations and the use of panel shock mounts wherever vibration may occur. Handle all instruments with care: although durable, these products should not be subjected to rough handling, dropping, or severe vibrations.

**Magnetic Switches**: Mount with electrical lugs down. If necessary, drill the TATTLETALEâ and pilot-stud holes (template provided); clean away burrs and filings. Position the magnetic switch in the panel, making sure the pilot stud is in place. Add TATTLETALEâ decal, then washer, then nut and tighten.

**BASIC WIRING OF SWICHGAGEâ AND MAGNETIC SWITCH**

- Disconnect battery or other power during installation
- Murphy components are easily wired-up and maintained

Use good quality wire and terminals. Be sure all connections are Clean, Complete, and Correct. The wiring and the type of magnetic switch differ for various applications, but a knowledge of basic electrical functions and of the circuits necessary for the specific job (what you want to happen), and commonsense will make the system work-the way you want it to work.

See examples of typical wiring and instructions packed with each magnetic switch.

---

**IMPORTANT, PLEASE READ COMPLETELY**

**SWICHGAGE®** Murphy magnetic switches and valves, properly installed and maintained, are effective, work-ready tools in any preventive maintenance program. For optimum performance, check these tools periodically: look for frozen pointers, Kinked or worn tubing, broken wiring or loose connections: close the contacts, then watch for expected results. Replace any damaged or worn parts: clean and repair as necessary Murphy will repair or replace parts covered by the Murphy two year limited warranty

- Check the wiring: it must be Correct and Complete: tight connections, unbroken insulation, no accidental grounds, do not run shut-down wires with ignition wiring.
- Check all tubing and connections for leaks.
- Mount magnetic switches and Murphy valves in an upright position, to prevent moisture collection and shorting.

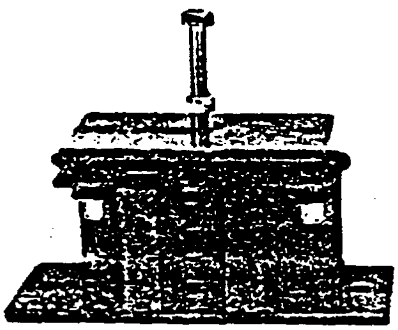
**CLEANING**: If steam cleaning will be used, epoxy seal all magnetic switches. Cleaning Lexan Lenses: since many strong solvents and cleaners can haze and permanently damage the clear polycarbonate lens on SWICHGAGESâ, please use one of the solutions listed here: **mild soap and water;** mineral spirits; white kerosene; VM&P naphtha, heptane, hexane, varsol No. 2; methyl/isopropyl/isobutyl alcohols; 1 & 3 denatured alcohols: freons TF & TE; petroleum ether (65°C boiling pt.)

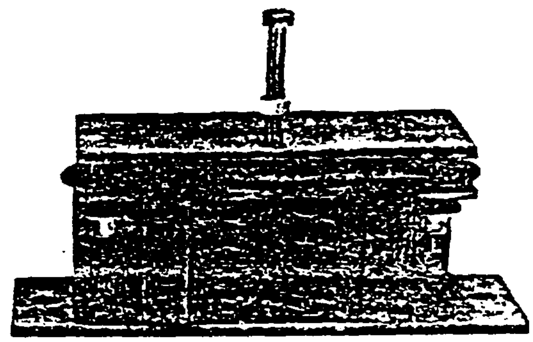
**CAUTION: Many of these cleaners are flammable. DO NOT USE when the equipment is running or very not .Keep away from sparks and flame.**

**#064334CMA**

**SERIES 630**
**SPRING ISOLATORS**
**FOR**
**· SEISMIC · MARINE · MOBILE**
**APPLICATIONS**

**Catalog No. 83A-170**





**Extra Strength Housing Design:** All welded steel housing with unique structure design provides the extra safety for the seismic, marine and mobile applications.

**Superior Isolation Efficiency:** Series "630" spring isolator provides static deflection from 1" to 1.5". As a result it effectively reduces the vibration and improves the over all equipment performance.

**Effective Noise Reduction:** The resilient washers interrupt the structure-borne noise transmission paths to prevent noise amplifications caused by sounding-board effect.

**Laterally Stable:** Elastomer cushioned housing provides damping and controls excessive horizontal movement.

**Vertically Secured:** Vertical restraints with resilient grommets prevent the upper housing from being pulled out from the anchored base.

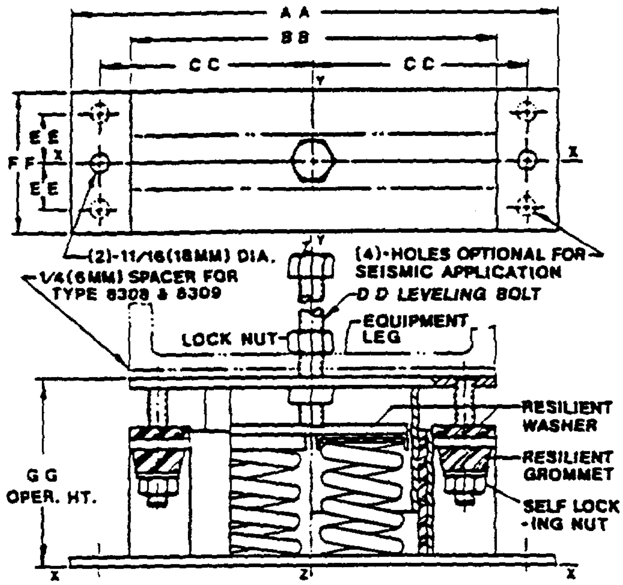
**Easy to Install:** Built-in leveling bolt eliminates shimming in all applications, and saves Installation cost.

**Variations Available:** Internal level adjustment, high strength leveling bolt and special modifications are available.

**ACE MOUNTINGS CO., INC**

**11 CROSS AVENUE**
**SOUTHAMY NJ 79**
**(201) 721-6200**

## DIMENSIONS - LOAD RATING




| SIZE | COLOR | TYPE & MAX. LOAD LBS. 631 6308 | TYPE & MAX. LOAD LBS. 632 6309 | DEFLECTION INS. |
|---|---|---|---|---|
| A | GRAY | 150 | 300 | 1.5 |
| B | TAN | 260 | 520 | 1.3 |
| C | YEL. | 435 | 870 | 1.3 |
| D | GREEN | 550 | 1100 | 1.1 |
| E | RED | 780 | 1560 | 1.0 |
| F | SILVER | 1070 | 2140 | 1.0 |
| G | BROWN | 1400 | 2800 | 1.0 |
| H | BLACK | 1800 | 3600 | 0.9 |
| K | BL'K & YEL. | 2500 | 5000 | 0.9 |

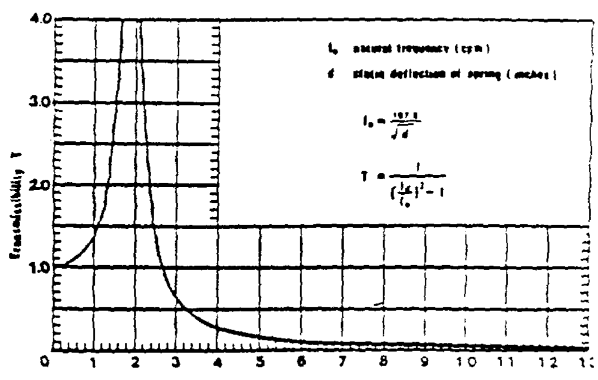
Note: Type 6308 & 6309 contain a 1-1/4"X1/4" thick spacer on the top plate for the off-set loading application.

| TYPE & SIZE | DIMENSION - INS.(MM) | | | | | | |
|---|---|---|---|---|---|---|---|
| | AA | BB | CC | DD | EE | FF | GG |
| 631 6308 A-K | 12 (305) | 8 (203) | 5 (127) | 5/8-11 | 1-1/4 (32) | 4-1/2 (114) | 6 (152)<br>6-1/4 (159) |
| 632 6309 A-H | 16 (406) | 12 (305) | 7 (178) | 5/8-11 | 1-1/4 (32) | 4-1/2 (114) | 6-1/4 (159)<br>6-1/2 (165) |
| 632 6309 K | 16 (406) | 12 (305) | 7 (178) | 3/4-10 | 1-1/4 (32) | 4-1/2 (114) | 6-3/8 (162)<br>6-5/8 (168) |

| TYPE & SIZE | LOAD RATING FOR SEISMIC RESTRAINT | | | | | | |
|---|---|---|---|---|---|---|---|
| | HOUSING | | | LEVELING BOLT | | | |
| | | | | STANDARD | | OPTIONAL | |
| | X-X | Y-Y | Z-Z | X-X & Y-Y | Z-Z | X-X & Y-Y | Z-Z |
| 631 6308 A-K | 12700 | 7850 | 8200 | 4800 | 8200 | 6900 | 11000 |
| 632 6309 A-H | 33400 | 10000 | 8200 | 4800 | 6200 | 6900 | 11600 |
| 632 6309 K | 33400 | 10000 | 8200 | 9630 | 14200 | 9640 | 18200 |

Note:

1. Series "630" spring isolator are suitable for seismic zone #1, #2, #3 and #4 applications in most conditions.
2. Seismic protection calculation available.



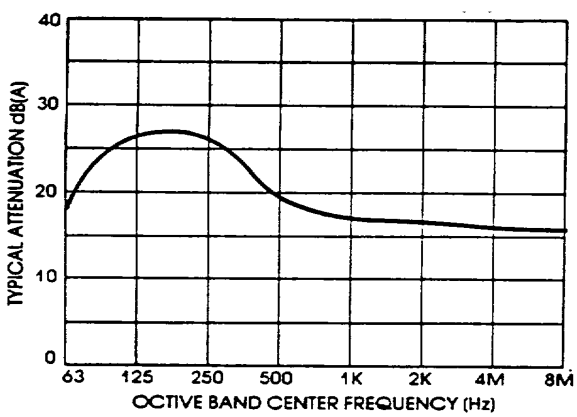

TRANSMISSIBILITY vs FREQUENCY

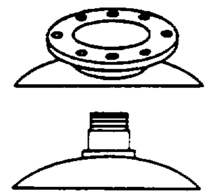

ACE MOUNTINGS CO., INC.

11 CROSS AVENUE
SOUTH AMBOY, N.J. 08879
(201) 721-6200

**Industrial "400"**
**Level Exhaust Silencers**

## TYPICAL Attenuation CURVE dB(A)



**"F" Mounting Range**
Standard in sizes 4" to 14". Drilling matches 125/150# ASA standard.

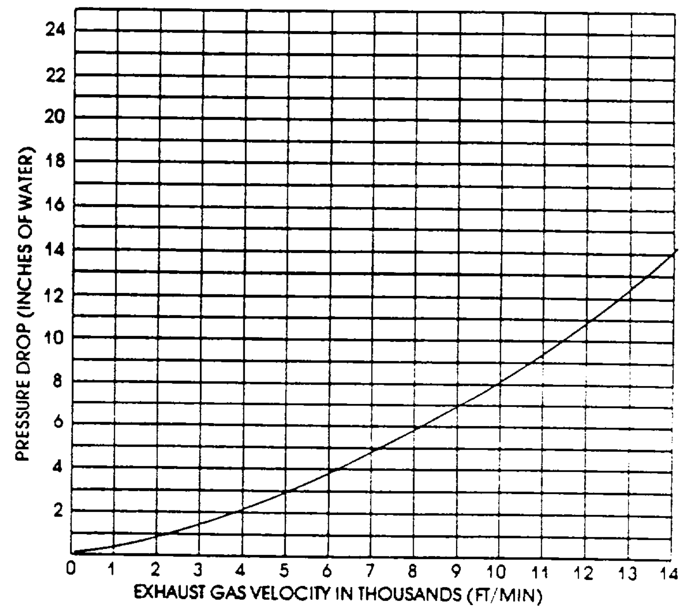
**"P" Pipe Ends**
NPT ends offered in sizes 3/4" through 4".

Companion flanges available for 4" to 14".

**Application:**
Nelson Industrial Level Silencers are designed to reduce total engine exhaust noise 12-18dB(A). These silencers are recommended where minimum silencing is required and ambient noise levels are medium to high.

**Construction**:
**Mild Steel:** Nelson Silencers over 26.1 O.D. are fabricated of mild steel as standard material. Maximum operating temperature is 1100°F.
**Aluminized Steel**: Nelson Silencers through 26.1 O.D. are fabricated of aluminized steel as standard materials. This material has a maximum operating temperature is 1250°F
**Silicon Aluminum Paint**: Nelson Silencers through 26.1 O.D. are given a coat of high heat resisting silicon aluminum paint.
**Gray Primer**: Nelson Silencers over 26.1 O.D. are given a coat of high heat resisting gray primer as standard paint.

**PRESSURE DROP:**

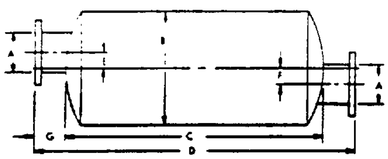



**Sample Specification:**
The silencer is to be a Nelson Industrial "100" Level Silencer constructed of aluminized steel (26.1 inch body diameter and smaller) or mild steel (larger than 26.1 inch body diameter) with all welded construction and suitable for mounting in any position. The silencer shall be complete with the following Nelson accessories:______________________________

____________________________________________________________

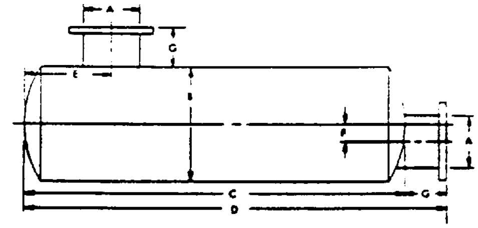
____________________________________________________________

## TYPE 1



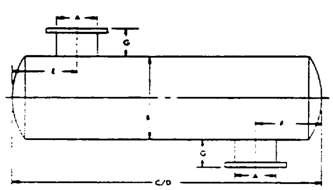
| MODEL Number | A Nominal Inlet Dia | B Body Dia O.D. | C Body Length | D Over All Length | E Offset To C/L | F Offset To C/L | G Inlet Length |
|---|---|---|---|---|---|---|---|
| 41107 | $^{3}/_{4}$" | 4.0 | 10.7 | 13.5 | 0 | 0 | 1.4 |
| 41110 | 1" | 4.6 | 12.0 | 16.0 | 0 | 0 | 2.0 |
| 41113 | $1^{1}/_{4}$ | 5.6 | 13.8 | 17.8 | 0 | 0 | 2.0 |
| 41115 | $1^{1}/_{2}$ | 6.1 | 22.2 | 26.0 | 0 | 0 | 1.9 |
| 41120 | 2" | 7.6 | 22.6 | 26.6 | 0 | 0 | 2.0 |
| 41125 | $2^{1}/_{2}$ | 8.1 | 27.6 | 32.6 | 0 | 0 | 2.5 |
| 41130 | 3" | 8.5 | 30.6 | 36.6 | 0 | 0 | 3.0 |
| 41135 | $3^{1}/_{2}$ | 9.0 | 31.8 | 38.0 | 0 | 0 | 3.1 |
| 41140 | 4" | 10.1 | 32.0 | 38.0 | 2.3 | 2.3 | 3.0 |
| 41150 | 5" | 12.1 | 32.0 | 38.0 | 2.8 | 2.8 | 3.0 |
| 41160 | 6" | 14.1 | 32.8 | 38.4 | 3.4 | 3.4 | 2.8 |
| 41180 | 8" | 18.1 | 48.4 | 58.0 | 0 | 0 | 4.8 |
| 41182 | 10" | 22.1 | 50.0 | 58.0 | 0 | 0 | 4.0 |
| 41184 | 12" | 22.1 | 65.0 | 73.0 | 0 | 0 | 4.0 |
| 41186 | 14" | 36.1 | 70.0 | 77.0 | 0 | 0 | 3.5 |
| 41188 | 16" | 42.1 | 83.0 | 91.0 | 0 | 0 | 4.0 |
| 41199 | 18" | 42.1 | 95.0 | 103.0 | 0 | 0 | 4.0 |
| 41121 | 20" | 48.3 | 97.0 | 104.0 | 0 | 0 | 3.5 |
| 41122 | 22" | 54.3 | 99.0 | 107.0 | 0 | 0 | 4.0 |

## TYPE 3



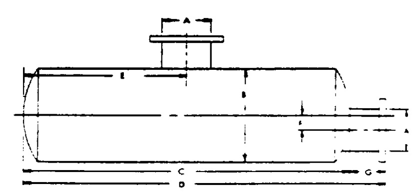
| MODEL Number | A Nominal Inlet Dia | B Body Dia O.D. | C Body Length | D Over All Length | E Offset To C/L | F Offset To C/L | G Inlet Length |
|---|---|---|---|---|---|---|---|
| 43107 | $^{3}/_{4}$" | 4.0 | 10.6 | 12.1 | 1.7 | 0 | 1.5 |
| 43110 | 1" | 4.6 | 11.9 | 13.9 | 2.0 | 0 | 2.0 |
| 43113 | $1^{1}/_{4}$ | 5.6 | 13.7 | 15.7 | 2.2 | 0 | 2.0 |
| 43115 | $1^{1}/_{2}$" | 6.1 | 22.1 | 24.1 | 2.4 | 0 | 2.0 |
| 43120 | 2" | 7.6 | 22.6 | 24.6 | 3.3 | 0 | 2.0 |
| 43125 | $2^{1}/_{2}$ | 8.1 | 27.6 | 30.1 | 3.8 | 0 | 2.5 |
| 43130 | 3" | 8.5 | 30.6 | 33.6 | 3.8 | 0 | 3.0 |
| 43135 | $3^{1}/_{2}$ | 9.0 | 31.8 | 34.8 | 4.4 | 0 | 3.0 |
| 43140 | 4" | 9.0 | 31.8 | 34.8 | 4.9 | 0 | 3.0 |
| 43150 | 5" | 12.1 | 29.9 | 33.9 | 5.4 | 0 | 4.0 |
| 43160 | 6" | 14. 1 | 30.4 | 34.4 | 6.7 | 0 | 4.0 |
| 43180 | 8" | 18.1 | 48.4 | 53.2 | 9.2 | 0 | 4.8 |
| 43182 | 10" | 22.1 | 50.0 | 54.0 | 12.0 | 0 | 4.0 |
| 43184 | 12" | 22.1 | 65.0 | 69.0 | 14.0 | 0 | 4.0 |
| 43186 | 14" | 36.1 | 70.0 | 82.0 | 15.0 | 0 | 4.0 |
| 43188 | 16" | 42.1 | 83.0 | 87.0 | 16.0 | 0 | 4.0 |
| 43199 | 18" | 42.1 | 95.0 | 99.0 | 19.0 | 0 | 4.0 |
| 43121 | 20" | 48.3 | 97.0 | 101.0 | 0.0 | 0 | 4.0 |
| 43122 | 22" | 54.3 | 99.0 | 103.0 | 1.0 | 0 | 4.0 |

## TYPE 2



| MODEL Number | A Nominal Inlet Dia | B Body Dia O.D. | C Body Length | D Over All Length | E Offset To C/L | F Offset To C/L | G Inlet Length |
|---|---|---|---|---|---|---|---|
| 42107 | $^{3}/_{4}$" | 4.0 | 10.6 | 10.6 | 1.7 | 1.7 | 1.5 |
| 42110 | 1" | 4.6 | 11.9 | 11.9 | 2.0 | 2.0 | 2.0 |
| 42113 | $^{1}/_{4}$" | 5.6 | 13.7 | 13.7 | 2.2 | 2.2 | 2.0 |
| 42115 | $1^{1}/_{2}$" | 6.1 | 22.1 | 22.1 | 2.4 | 2.4 | 2.0/ |
| 42120 | 2" | 7.6 | 22.6 | 22.6 | 3.3 | 3.3 | 2.0 |
| 42125 | $2^{1}/_{2}$" | 8.1 | 27.6 | 27.6 | 3.8 | 3.8 | 2.5 |
| 42130 | 3" | 8.5 | 30.6 | 30.6 | 3.8 | 3.8 | 3.0 |
| 42135 | $3^{1}/_{2}$" | 9.0 | 31.8 | 31.8 | 4.4 | 4.4 | 3.0 |
| 42140 | 4" | 9.0 | 31.8 | 31.8 | 4.9 | 4.9 | 3.0 |
| 42150 | 5" | 12.1 | 29 9 | 29.9 | 5.4 | 5.4 | 4.0 |
| 42160 | 6" | 14.1 | 30.4 | 30.4 | 6.7 | 6.7 | 4.0 |

## TYPE 4



| MODEL Number | A Nominal Inlet Dia | B Body Dia O.D. | C Body Length | D Over All Length | E Offset To C/L | F Offset To C/L | G Inlet Length |
|---|---|---|---|---|---|---|---|
| 44540 | 4" | 9.0 | 32.4 | 35.2 | 16.2 | 0 | 3.0 |
| 44550 | 5" | 12.1 | 30.2 | 34.1 | 15.1 | 0 | 4.0 |
| 44560 | 6" | 14.1 | 30.8 | 34.6 | 15.4 | 0 | 4.0 |
| 44580 | 8" | 18.1 | 50.9 | 54.2 | 25.4 | 0 | 4.0 |
| 44582 | 10" | 22.1 | 49.9 | 54.0 | 25.0 | 0 | 4.0 |
| 44584 | 12" | 26.1 | 49.0 | 53.0 | 25.0 | 0 | 4.0 |
| 44586 | 14" | 36.1 | 70.0 | 82.0 | 35.C | 0 | 4.0 |

**Nelson**
P O Box 428 - HWY 51 West
Stoughton, WI 53589
Area (608) 873-4200
Telex 265-433

electric power controls

**OPERATION MANUAL**

**ROWPU BARGE**
**NO, 55-1930**

**MAIN SERVICE GENERATION AND DISTRIBUTION SWITCHBOARD**

P.O. Box 5146 · Springfield, Illinois · 62705 · Phone [217] 629-8506

**SECTION 1: COMPONENT FUNCTION**

A. A. C. Metering and Generator Control

1. A. C. Ammeter (AM)

   a. Reads the generator load on each phase of the generator. Generator full load rating is 243 amps.

2. A. C. Voltmeter (VM)

   a. Reads the generator voltage between any two phases. Voltage should read 460 volts at all times when generator is running. Voltage can be adjusted the volt adjust rheostat located under the voltmeter switch. Voltmeter can be calibrated for scale by checking the actual voltage at the breaker with a calibrated voltmeter and adjusting the voltmeter pointer by the screw adjustment on the meter front.

   b. The Bus voltmeter reads the voltage between phase A & B at all times and is there to compare the main bus voltage to the generator voltage when paralleling.

3. Frequency Meter (FM)

   a. Reads the generator frequency. Frequency should always be 60 Hertz at all times when the generator is running.

   b. The bus frequency meter reads the bus frequency at all times and is there to compare the main bus frequency to the generator frequency when paralleling.

4. Ammeter Switch (AS)

   a. Selects which phase of generator load current the Ammeter is reading. The Ammeter is scaled to read the full generator current at a ratio of 80:1 and a full scale deflection of 5 amps. So at full load of 243 amps the Ammeter will receive 3.04 amps.

   b. The switch shorts out the current transformers that are not connected to the Ammeter which not only prevents high voltage build up at the open current transformer terminals but also maintains current sensing for the reverse power relay.

5. Voltmeter Switch (VS)

   a. Selects two phases of generator to read the voltage on. The voltmeter is scaled to read the generator voltage at a ratio of 4: 1 and a full scale deflection of 150 volts. So at proper voltage of 460 volts the voltmeter will receive 115 volts.

   b. Also selects phase A & B of the bus for proper voltage level comparison before synchronizing.

6. Voltage Adjust Rheostat

   a. Adjust the generator voltage to maintain 460 volts at all times.

b. Adjusts the generator voltage during synchronization to match the bus voltage.

7. Governor Speed Switch (GS)

   a. Adjusts the generator frequency to maintain 60 hertz at all times.
   b. Adjust the generator frequency during synchronization to bring the generator in synchronization with the bus.

8. Idle/Run Switch (IRS)

   a. In the Idle position the engine will run at a low speed for warm up or maintenance checking. The generator breaker cannot be closed in this position.
   b. In the Run position the engine will run at full speed for accepting the load. The switch should always be left in the run position.

9. Synchroscope (SS)

   a. The synchroscope is used for checking synchronization between any generator and the main bus. When the rotating needle is pointing straight up the generator is synchronized to the bus. When the rotating needle is pointing straight down the generator is completely (180 electrical degrees) out of phase with the bus. When the generator is rotating faster than the bus frequency the needle will rotate counter clock wise. When the generator is rotating slower than the bus frequency the needle will rotate clock wise.

10. Generator Selector Switch (GSS)

   a. This switch selects which generator is being synchronized to the main bus.
   b. The off position will turn off the synchroscope but not the voltmeter and frequency meter.
   c. The switch should always be placed in the off position while not being used for synchronization. If the switch is placed in the position of a generator that is not running the bus voltage will back feed through the synchroscope to the generator and present hazardous voltages at the generator during maintenance.

11. Ground Detector Lights and Test Switch

   a. The lights will be full bright during normal operation when the main bus is energized.
   b. When the test push button is pressed all lamps will maintain the same brightness unless a phase is grounded or has a resistance to ground. If the phase is grounded the light will go out when the button is pressed. If the phase has a resistance to ground the lamp will glow dimly in proportion to the amount of resistance. The grounded wire must be corrected to prevent ground current flowing in the ships Hull.

12. Potential Transformers (P.T.)

   a. All are rated 50 VA capacity.

b. All primary fuses are, high capacity, inrush time delay, 1 amp fuses.
c. All secondary fuses are low capacity, one time, 2 amps fuses.
d. PT 1,2 & 4,5 are connected open delta,. The primary line to line is 460 volts and secondary line to line is 115 volt. Phase B is grounded on all secondaries for proper fuse protection and common A. C. reference voltage between circuits.
e. PT 3 is the bus potential transformer connected on lines A & B.
f. PT 6,7,8 are connected wye to wye. The primary line to ground is 265 volts and the secondary is 110 volts.

13. Current Transformers (CT)

a. The current transformers are mounted so that the generator phase wires must run through them, therefore, all load currents are sensed and converted to a smaller current that can be easily handled by switches and meters.
b. Current transformers are constant current devices which means the current remains constant with various loads. When the load on a current transformer changes the voltage reduces and the current remains the same. It is easy to see that when a current transformer secondary terminals are open (no current) the voltage will rise high. For this reason, the secondary terminals on the current transformers are either connected to the Ammeter and reverse power relay or shorted out by means of the Ammeter switch. This is done to prevent arcing at the switch contacts and high voltage at the current transformer terminals.

B. BREAKER CONTROL

1. Generator Run Lights

a. 120 Volt lamp operates from PT1 which is connected to the respective generator's phases A & B.

2. Breaker Position Lights

a. 120 volt breaker closed light operates through the breaker auxiliary contact 'a' which closes when the breaker is closed.
b. 120 volt breaker open light operates through the breaker auxiliary contact 'b' which closes when the breaker is open.
c. The breaker auxiliary contacts are mounted inside the breaker case and wired out to terminal strips TB B located directly behind the breaker pan.

3. Under Voltage Relay (UVR)

a. Each breaker has a separate under voltage relay that shunt trips the breaker upon loss of generator voltage.
b. Each generator under voltage relay operates at 120 volt from PT1 which is connected to the respective generator's phases A & B.
c. The 120 volt input to each generator undervoltage relay has a normally closed contact of the reverse power relay in. series. When a reverse power occurs the breaker is shunt

tripped off by removal of voltage to the respective under voltage relay.

d. The 120 volt input to each generator undervoltage relay has a normally closed contact of the shore power auxiliary relay (BR-SP) in series, When the shore power breaker is closed the BR-SP relay contact opens which prevents generator voltage from operating the respective under voltage relay. The generator breaker cannot be closed when its shunt trips circuit is energized. This interlocking between breakers is provided to prevent paralleling any generator with shore power.

4. Reverse Power Relay (RPR)

a. Each generator has a reverse power relay which senses current in phase A and voltage across phase A & B.

b. Reverse power can occur when two or more generators are running in parallel. If one generator does not accept load, usually because its unloaded running speed is less than the other generators (called speed droop), the other generators will motorize the drooping generator which is called reverse power. Reverse power not only creates extra loads on the other generators but can hurt the engine being powered.

c. The reverse power relay is screw driver adjustable from 4% to 20% of normal forward power with a separate screwdriver adjustment from 0.5 to 20 seconds. Adjustment should be made to over ride normal reverse power surges when breakers are first closed or when loads change. Motor start up currents can cause reverse power surges during the time required for a motor to go from start to full speed.

d. A normally closed contact of the reverse power relay will shunt trip the breaker by removing voltage from the under voltage relay.

e. A normally open contact of the reverse power relay will signal the auto start to shut the engine down on reverse power.

5. Shunt Trip Relay (STR)

a. The shunt trip relay operates from the Power Monitor relay. When the Power Monitor operates from loss of phase or reverse phase, the shunt trip relay will operate to shunt trip the shore power breaker.

6. Breaker Relay (BR-SP)

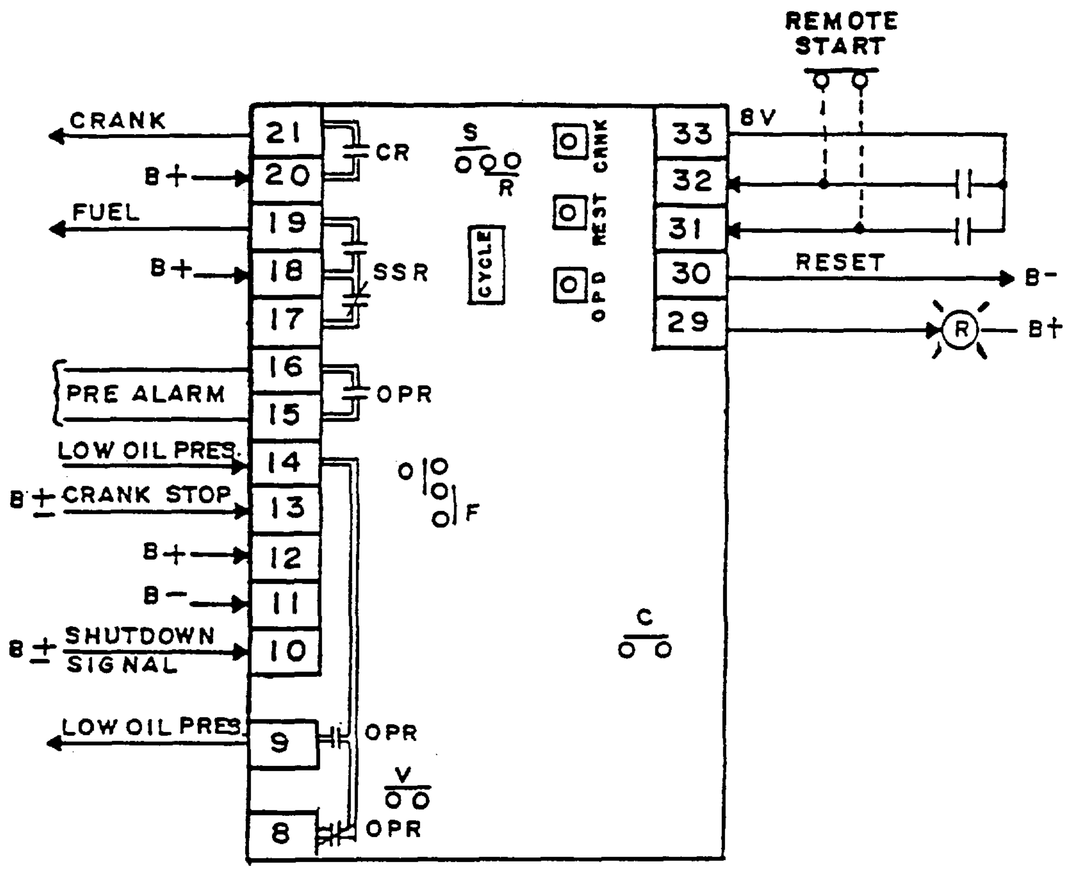
a. The breaker relay operates from an auxiliary 'a' contact in the shore power breaker. When the shore power breaker is closed the breaker relay operates to shunt trip all three generator breakers.

b. The electrical interlock between the shore power breaker and the generator breakers prevent the shore power and generators from operating in parallel at anytime.

C. ENGINE CONTROL

1. Autostart Module (ASM)

a. Basic module connections and jumper selections



b. Connections:

1) Connect B+ to terminals 12, 18, 20.

2) Connect B- to terminal 11.

3) Connect engine crank solenoid to terminal 20 and B-.

4) Connect engine run solenoid (or governor control B+ terminal) to terminal 19 and B-.

5) Connect low oil pressure shut-down signal to terminal 14. The OPR relay contact from terminal 14 to 9 closes 15 to 45 seconds after engine runs.

6) Connect low oil pressure warning signal (when used) to terminal 16. The OPR relay contact from terminal 16 to 15 closes 15 to 45 seconds after engine run.

7) Connect crank cut-out to terminal 13 either positive or negative, 8) Connect all engine failure signals to terminal 10. All signals must be of the same polarity either positive or negative. When used in conjunction with an LM-4 Light Module, the common failure output on the LM-4 provides this signal to the Autostart.

9) For single light Autostart operation, connect the common failure light to terminal 29 and B+. Common failure juniper "F" must be in place for dingle light operation, (see jumper selection below).

10) Terminal 30 goes to ground in reset (off) position of engine control switch. This signal is used to reset the Light Module.

11) Connect the engine control switch as shown:

    Terminal 33 is a regulated 8 volt supply.

    Terminal 32 arms the engine failure lockout and the remote start contact.

    Terminal 31 will start cranking the engine to run by the manual switch or the remote start contact.

c. Jumper Selection:

1) Voltage Jumper:

    This jumper is located directly behind terminal 8 and is marked "V". When this jumper is in place the system is ready to operate at 12 to 24 VDC. When clipped out the system is ready to operate at 32 VDC.

2) Re-Crank Jumper:

    This jumper is red insulated and located next to the large 2200 MFD capacitor and marked "C". When in place the system can be manually re-cranked immediately after an engine shut down signal. When clipped out the system will re-crank only after a 20 second time delay after an engine shut down signal. Re-crank delay is always in effect, independent of jumper, when the engine control switch is in the automatic position.

3) Over Crank-Common Failure Jumper:

This jumper is yellow insulated and located by the side of OPR relay and marked "O" & "F", There are two positions with three solder holes, the center hole being common. This jumper is used for converting from a 4 light Autostart to a single light Autostart. In the "O" position terminal 29 will signal over-crank and all common failure inputs. Never install both jumpers at the same time. The Autostart will operate as either an over-crank output or a common failure output.

4) Run-Stop Jumper:

This jumper is green insulated and located just above the CRANK & REST potentiometers and marked "R" & "S". There are two positions with three solder holes, the center one being common. This jumper programs SSR relay to energize to run or to energize to shut down. The jumper will be in the "R" position for energize to run type fuel systems, When energized to shut down, relay SSR will operate for 20 seconds. The re-crank delay jumper "C" must be clipped for timed shut down.

5) Crank Cycle Jumper:

Place this jumper in any position on the DIP socket from 1 to 8 for cycle selection (count from left to right). When this jumper is out, the Autostart will never overcrank but continually crank until the engine runs.

6) Timing Adjustments:

All timing potentiometers adjust maximum time in the clockwise direction and minimum timing in the counter-clock-wise direction.

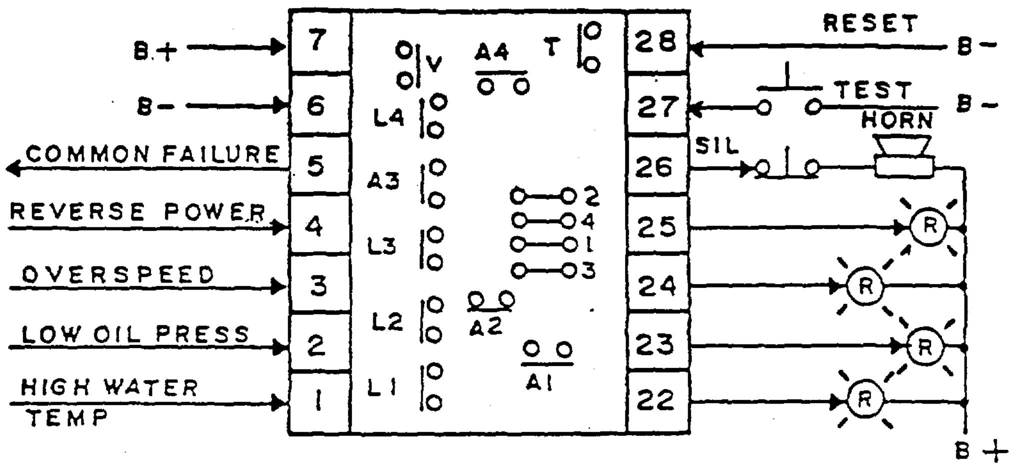
Location of the timing potentiometers are from left to right; oil pressure delay (OPD), rest time delay (REST), crank time delay (CRNK).

Each timing adjustment should be calibrated with a stop watch. The potentiometers are linear, therefore, adjust to a point that seems correct and then check with a stop watch. Continue this procedure until calibrated.

Repeatability of timing is within 1% of full adjustment.

2. The Light Module (LM-4)

a. Basic module connections and jumper selections.




b. Connections:

1) Connect high water temperature device to terminal 1 either B+ or B-.

2) Connect low oil pressure engine device to terminal 2 through OPR time delay contact in the Autostart. (See-Autostart Module: Item A.)

3) Connect overspeed engine device to terminal 3 either B+ or B-.

4) Connect overcrank from terminal 29 of the Autostart to terminal 4.

5) Connect common failure output terminal 5 to common failure input on the Autostart terminal 10.

6) Connect 5+ to terminal 7.

7) Connect B- to terminal 6.

8) Connect the respective lights to terminals 22, 23, & 25 as shown on the diagram. Connect the other side of the lights to B+ or terminal 27. (When terminal 27 is not being used for lamp test-see LAMP TEST JUMPER.)

9) Connect the alarm horn to terminal 26 through a normally closed push-button as shown on the diagram.

c. Jumper Selection:

Each jumper is marked 1, 2, 3, 4 to correspond to input signals at terminals 1, 2, 3, 4 respectively.

L 1, 2, 3, 4 GREEN INSULATED JUMPER. When in place the Light Module will lock-in on that corresponding signal input and require system reset before the light will go out. When clipped cut the corresponding light will go on and off with the input signal.

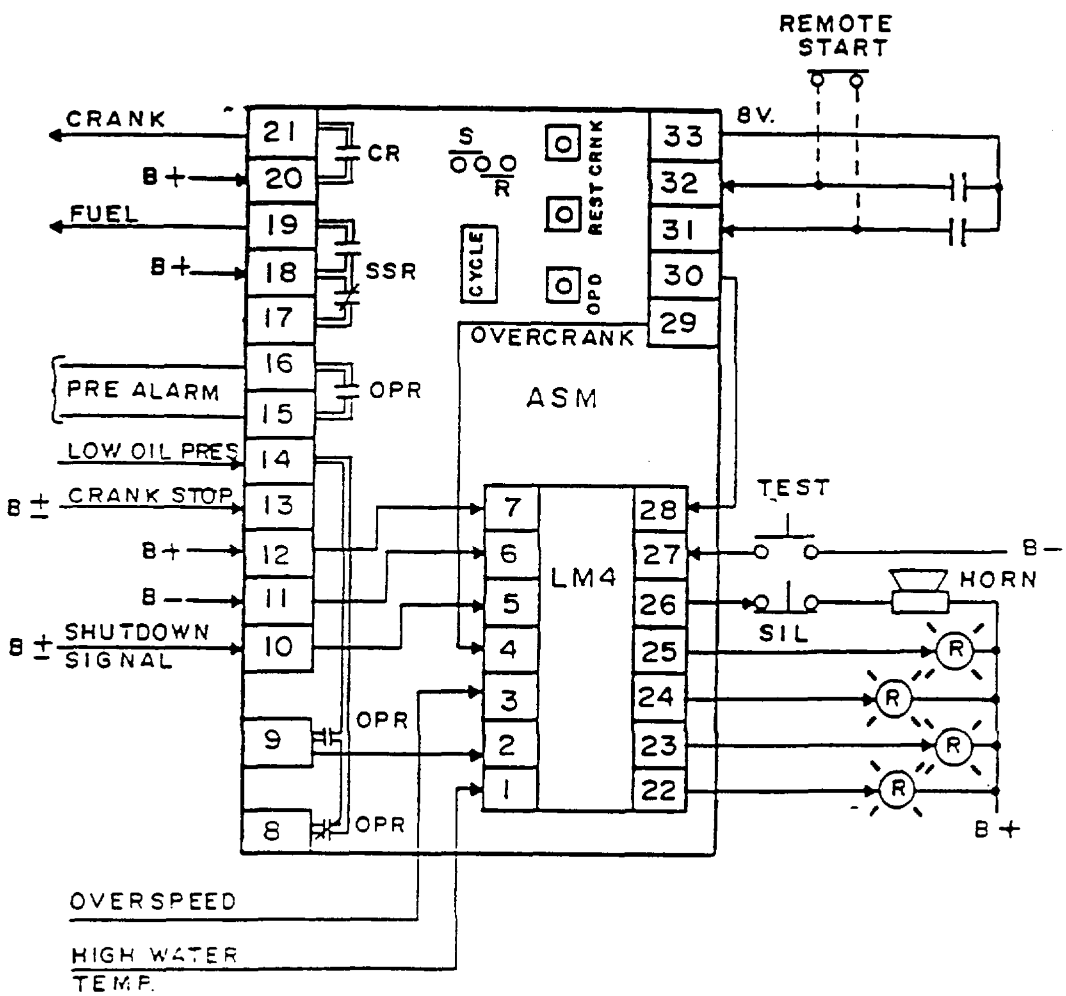
CF 1, 2, 3, 4 RED INSULATED JUMPER. When in place the Light Module will signal common fault at terminal 5. When clipped out the corresponding input signal will not signal the common fault at terminal 5.

A 1, 2, 3, 4 YELLOW INSULATED JUMPER. When in place the horn will sound on that corresponding signal input. When clipped out the horn will not sound when the corresponding signal appears.

LAMP TEST JUMPER MARKED "T". When in place, terminal 27 is a B+ voltage for the lights and horn. When clipped out a lamp test switch can be connected from terminal 27 to B- for simultaneous test of all lamps connected to the module.

VOLTAGE JUMPER MARKED "V". When in place the Light Module will operate at 12 to 24 VDC. When clipped out the Light Module will operate at 32 VDC.

d. The Complete Engine Control System (Autostart And Light Module): All connections shown in the diagram below are described in Articles A & B of this section.



D. Terminal Strips

1. TBB Breaker Terminal Strips

   a. Breaker terminal strips are located on the rear side of the breaker mounting pan, directly behind each respective breaker.

   b. The breaker auxiliary contacts and shunt trip are connected to TBB.

   c. The number with TBB identifies which breaker the strip is for, 1e, TBB-1 is for generator breaker #1, etc.

2. TBC A. C. Voltage Terminal Strip

   a. TBC terminal strips are located behind the rear doors with the potential transformers and fuses.

   b. TBC terminals are used as interlock all A. C. metering and control.

   c. The number with TBC identifies which generator rear cubicle the terminal strip is located, ie, TBC-1 is for generator section #1, etc.

3. TBD Door Terminal Strip

   a. TBD terminal strips are located behind front doors and screw on panels.

   b. TBD-1,2,3 are located behind respective upper generator doors.

   c. TBD-4 is located behind the synchronizing section door.

   d. TBD-5 is located behind the distribution section panel.

   e. TBD-6 is located behind the generator breaker panel.

   f. TBD-7 is located behind the shore power breaker panel.

4. TBE Engine Inter Connect Terminal Strip

   a. TBE terminal strips are located at the engine automatic cranking controls behind each respective generator door.

   b. TBE terminals inter connect the diesel engine for start and stop control.

   c. The number with TBE identifies which engine the strip is for, Ie, TBE-1 is for engine number 1, etc.

5. TBO Engine-Generator Operating Control Terminal Strip

   a. TBO terminal strips are located behind each respective generator door.

   b. TBO terminal inter connect to the following controls:
      1) Idle run switch
      2) Voltage adjust rheostat
      3) Governor speed switch

   c. The number with TBO identifies which engine/generator the strip is for, ie, TBO-1 is for engine/generator number 1, etc.

SECTION 2: SYSTEM OPERATION

A. EACH ENGINE CAN BE OPERATED AT THE SWITCH BOARD OR AT THE ENGINE.

1. TO START AT THE SWITCH BOARD, PLACE THE ENGINE CONTROL SWITCH (ECS) IN THE START POSITION. THE ENGINE WILL AUTOMATICALLY CRANK TO RUN.

2. TO START AT THE ENGINE, PLACE THE ENGINE CONTROL SWITCH (ECS) IN THE 'REMOTE' POSITION. THEN OPERATE THE START SWITCH ON THE ENGINE AND IT WILL AUTOMATICALLY CRANK TO RUN.

3. IN BOTH MODES OF OPERATION THE ENGINE WILL SHUT DOWN AND A FAILURE LIGHT ON THE SWITCH BOARD WILL LIGHT FOR ANY OF THE FOUR FAILURES (REVERSE POWER, OVER SPEED, LOW OIL PRESSURE, HIGH WATER TEMPERATURE.)

4. THE ENGINE CAN BE STOPPED AT THE SWITCH BOARD BY PLACING THE ENGINE CONTROL SWITCH IN THE OFF (RESET) POSITION, NO MATTER WHERE IT WAS STARTED FROM.

5. WHEN THE EMERGENCY STOP PUSH BUTTON ON THE ENGINE IS USED TO STOP THE ENGINE, BE AWARE THAT RESETTING THE BUTTON WILL CAUSE THE ENGINE TO IMMEDIATELY START CRANKING TO RUN AGAIN UNLESS THE ENGINE CONTROL SWITCH IS RETURNED TO THE OFF POSITION.

6. THE VOLTAGE REGULATOR 'IDLE-RUN' SWITCH MUST BE USED WHEN OPERATING THE ENGINE AT IDLE SPEEDS FOR WARM-UP OR MAINTENANCE TESTS.

7. VOLTAGE ADJUSTMENT CAN BE MADE BY ADJUSTING THE VOLTAGE RHEOSTAT WHILE OBSERVING THE VOLTMETER. THE VOLTAGE LEVEL SHOULD BE THE SAME ON ALL PHASES.

8. FREQUENCY ADJUSTMENTS CAN BE MADE BY ADJUSTING THE GOVERNOR SPEED SWITCH WHILE OBSERVING THE FREQUENCY METER.

9. THE GOVERNOR SPEED SWITCH CAN ALSC BE USED TO BALANCE LOADS BETWEEN ENGINES WHEN OPERATION IN PARALLEL. THIS IS ACCOMPLISHED BY THE AMMETERS AND ADJUSTING THEIR RESPECTIVE GOVERNOR SPEED SWITCHES ('RAISE' WILL INCREASE THE LOAD AND 'LOWER' WILL DECREASE THE LOAD.)

10. THE VOLTMETER SWITCH ON GENERATOR NUMBERS ONE AND TWO WILL ALSO READ ONE FHASE OF THE LOAD BUS. THE VOLTMETER SWITCH ON GENERATOR NUMBER THREE WILL ALSO READ ONE PHASE OF SHORE POWER.

B. EACH GENERATOR IS SET UP TO OPERATE IN PARALLEL BY ANY SCHEME OF MANUAL SYNCHRONIZATION. (ALL DISTRIBUTIONS LOAD BREAKERS SHOULD BE CLOSED.)

1. START THE FIRST GENERATOR AND CLOSE ITS BREAKER TO THE BUS.

2. ADJUST THE VOLTAGE AND FREQUENCY FOR THE DESIRED LOAD.

3. START THE SECOND GENERATOR AND ADJUST ITS VOLTAGE AND FREQUENCY TO MATCH THE BUS BY OBSERVING THE BUS VOLTMETER AND BUS FREQUENCY METER.

5. PLACE THE GENERATOR SELECTOR SWITCH (GSS) TO THE POSITION OF THE INCOMING GENERATOR. THE SYNCHROSCOPE WILL INDICATE IF THE INCOMING GENERATOR IS RUNNING FASTER OR SLOWER THEN THE GENERATOR ON THE BUS BY THE DIRECTION OF ROTATION AND SPEED OF THE NEEDLE. BOTH GENERATORS ARE IN SYNCHRONIZATION WHEN THE NEEDLE ON THE SYNCHROSCOPE IS POINTING STRAIGHT UP. BEFORE CLOSING THE INCOMING GENERATOR'S BREAKER BE SURE THE SYNCHCOSCOPE NEEDLE IS PASSING VERY SLOWLY THROUGH SYNCHRONIZATION OR EVEN STOPPED, THEN CLOSE THE BREAKER. ADJUST THE GENERATOR TO PICK UP LOAD BY INCREASING THE GOVERNOR SPEED SWITCH SLOWLY.

6. WHEN CHANGING FROM ONE GENERATOR TO ANOTHER WITHOUT INTERRUPTING THE LOAD, SYNCHRONIZE THE GENERATOR'S THE SAME AS IN PARAGRAPH FIVE EXCEPT; ADJUST THE INCOMING GENERATOR TO ACCEPT LOAD AND THE OUTGOING GENERATOR GO TO DROP LOAD WHILE IN PARALLEL. THIS IS ACCOMPLISHED BY INCREASING THE GOVERNOR SPEED ON THE INCOMING GENERATOR AND DECREASING THE GOVERNOR SPEED ON THE OUTGOING GENERATOR. WHEN THE LOAD IS NEAR ZERO ON THE OUTGOING GENERATOR OPEN IT'S BREAKER.

C. THE SHORE POWER WILL BE USED ONLY WHEN THE GENERATOR BREAKERS ARE OFF.

1. WHEN THE SHORE POWER BREAKER IS CLOSED IT IS NOT POSSIBLE TO CLOSE A GENERATOR BREAKER.

2. THE SHORE POWER BREAKER WILL NOT CLOSE IF THE PHASE IS NOT IN PROPER SEQUENCE OR THE VOLTAGE IS BELOW NORMAL. THE PHASE SEQUENCE LIGHTS INDICATE THE SHORE POWER PHASE ROTATION.

3. THE SHORE POWER BREAKER WILL NOT CLOSE IF ANY GENERATOR BREAKER IS CLOSED FIRST.

D. GROUND DETECTION LIGHTS.

1. THE GOUND DETECTION LIGHTS BURN BRIGHT WHEN THE BUS IS LIVE. WHEN THE TEST PUSH BUTTON IS DEPRESSED THE LIGHTS SHOULD REMAIN UNCHANGED. IF THERE IS A GROUND OR PARTIAL GROUND ON ANY PHASE ITS RESPECTIVE LIGHT SHOULD GO OUT OR BURN DIM WHEN THE TEST PUSH BUTTON IS PRESSED.

SECTION 3: Trouble Shooting Guide

A. When any problem occurs the first thing to do is check all fuses that are involved in the trouble area. A blown fuse can cause unusual operations and metering indications that are difficult to define.

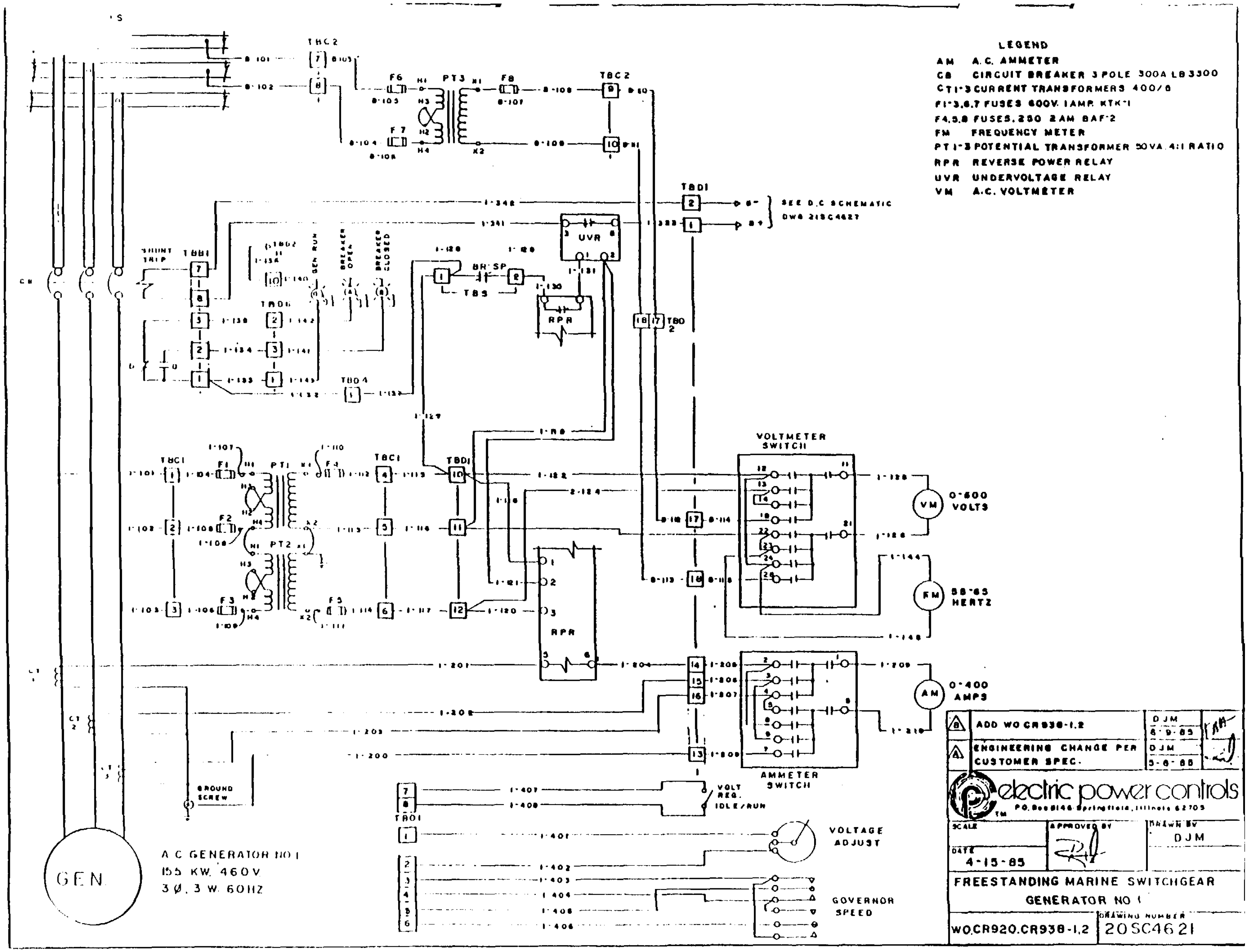
B. The next thing to do is measure voltages at component terminals and thereby determine if the component is functioning. For instance, there should be 120 volt at terminals 1 & 2 on the undervoltage relays when the generator is running to keep the breaker from shunt tripping. If the voltage is present and yet the breaker shunt trips, the undervoltage relay is probably faulty.

C. The following trouble shooting guide will be helpful:

| SYMPTON | CHECK | CAUSE & REMEDY |
|---|---|---|
| Generator breaker shunt trip off and voltmeter does not read on V1-2 while generator is running, frequency meter not working properly. | Fuse F1, 2, 4 | Fuse blown, replace |
| Generator breaker shunt trip while engine is running (no reverse power) | 120 VAC at UVR | Replace UVR if 120 volts is on terminals 1 & 2 |
| | Relay BR not operating properly | Jumper terminals TBS-3,4 for Generator 1. TBS-3,4 for Generator 2. TBS-5, 6 for Generator 3. If jumper corrects problem replace relax. BR Trip shore power breaker off if it is On. |
| Shore power breaker will not close | Check that all Generator breakers are off | Jumper TED4-7 to TBS-9. If breaker closes a "b" contact in one of the Generator breakers is open. Check each "b" contact on TBB 1,2,&3 terminals 4 & 6 |
| | Check phase rotation | Change leads on shore power for proper rotation. |

| SYMPTOM | CHECK | CAUSE & REMEDY |
|---|---|---|
| No response to engine start signal. Engine control switch in Start or Remote | Check battery voltage at terminal 11(B-) and 12(B+) on ASM. | Check wiring back to battery connections for open circuit. Repair as needed. |
| | Check for 8 Volts positive at terminal 33 on ASM. | Check indicating fuse on ASM Module. Replace if blown (Plunger extended) |
| | Check 8 Volts positive at Terminal 31 on ASM when control switch is in start or Remote (In Remote position, the remote start switch must be closed | Check engine control switch and remote start switch for 8 Volt through the switch and contact replace switch or remote start contact or wiring as required. |
| | Remove the failure input wire on Terminal 10 on the ASM and attempt restart. If engine starts manually shut down and check as follows. | Check failure indicating lamps for bad bulbs - engine could be in failure mode (lamp test push button.) Repair engine failure. Check for additional relays or lights or other circuits added to engine failure inputs. These may require diode clipping or blocking to repair - Contact factory. Check for ground signal at Terminal 5 on LM4 with no lights lit - Contact factory. |
| SSR (start/stop relay) energizes (picks up) but CR (crank relay) does not, on engine start | Disconnect wire(s) from ASM terminal 13 and attempt restart with the crank solenoid discon-nected. If auto start cranks, check voltage measurement on engine wires coming crank disconnect speed switch. | Check crank cut out switch on engine - should be normally open or read Zero volts when wires(s) on Terminal 13 of the ASM are disconnected. If switch is okay, contact factory If switch is a solid state speed switch, Contact factory. Any voltage measured on the crank disconnect circuit when disconnected from auto start should be eliminated as a cause of locking the auto start in run mode. |

| SYMPTON | CHECK | CAUSE & REMEDY |
| --- | --- | --- |
| Engine cranks until run speed and then shuts down for 20 seconds and recranks | Check crank, disconnect signal from engine. | Intermittent or loss of crank cut out signal - must be corrected, |
| | Check suppression diode on crank circuit at terminal TBE. | If diode reads open or high in forward bias, replace with IN4004 or equal diode. |



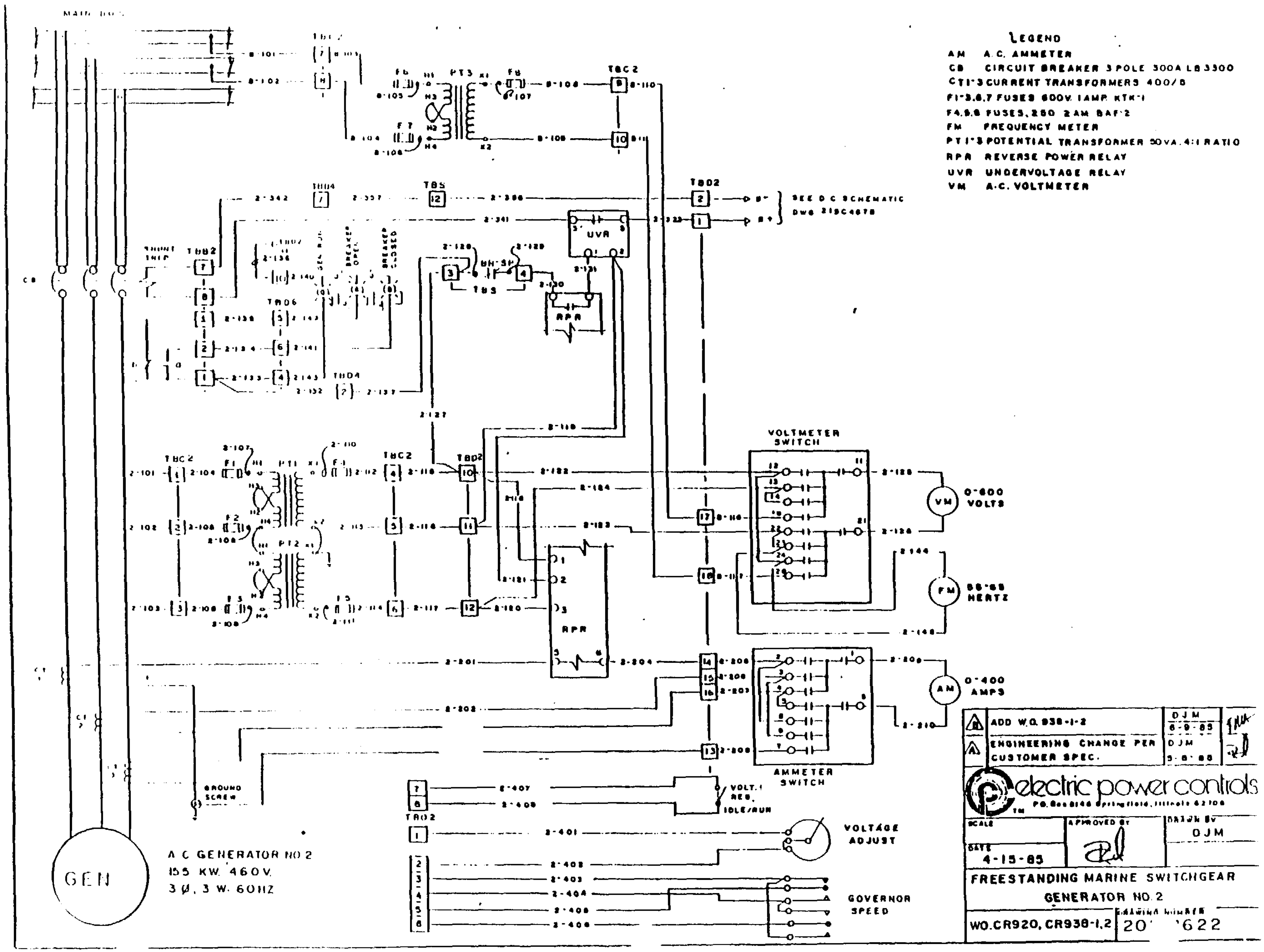

| | | | |
|---|---|---|---|
| B | ADD WO CR938-1,2 | DJM 8-9-85 | |
| A | ENGINEERING CHANGE PER CUSTOMER SPEC. | DJM 5-6-85 | |

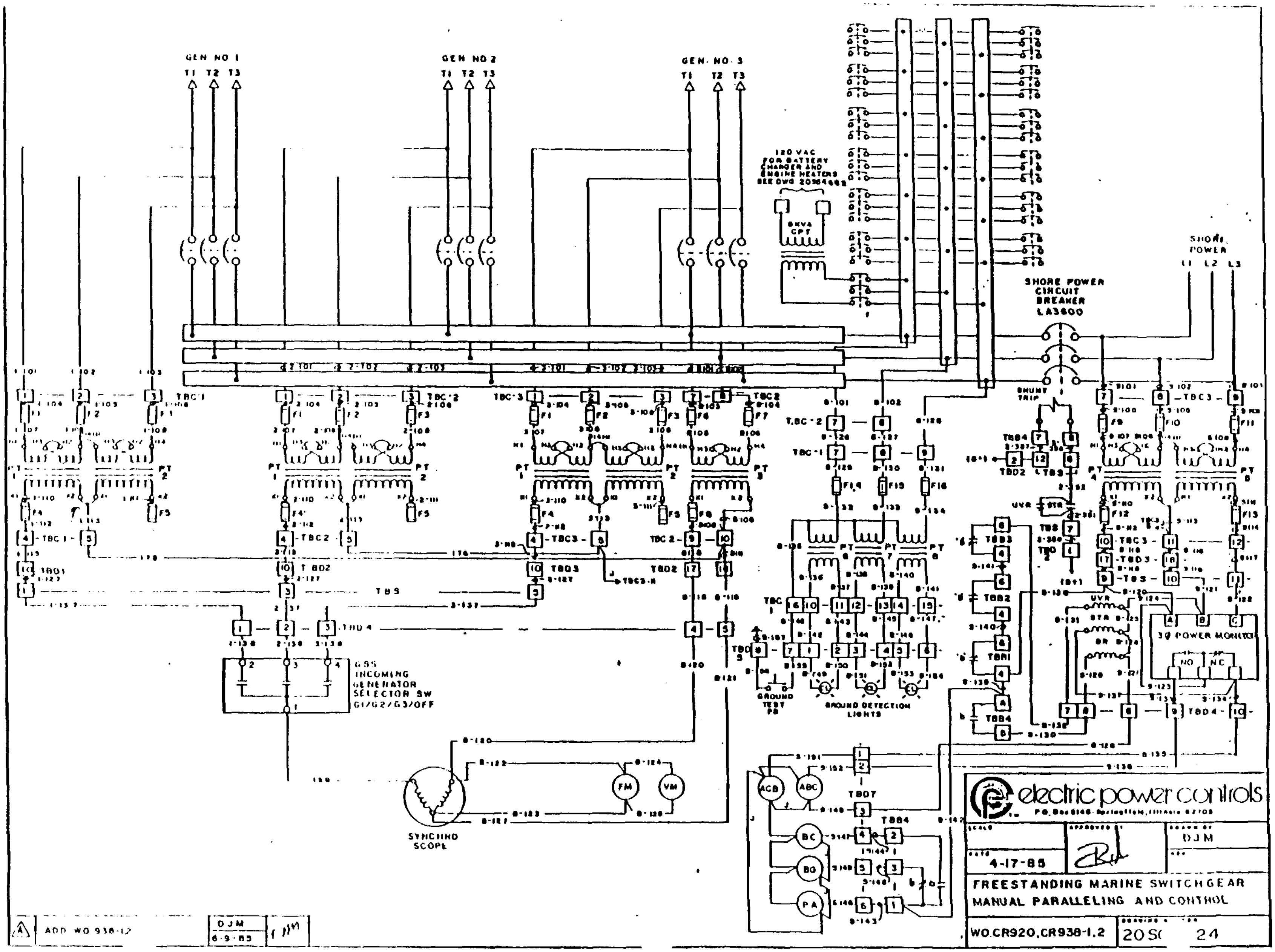
electric power controls
P.O. Box 8146 Springfield, Illinois 62705

| | | |
|---|---|---|
| SCALE | APPROVED BY | DRAWN BY DJM |
| DATE 4-15-85 | | |

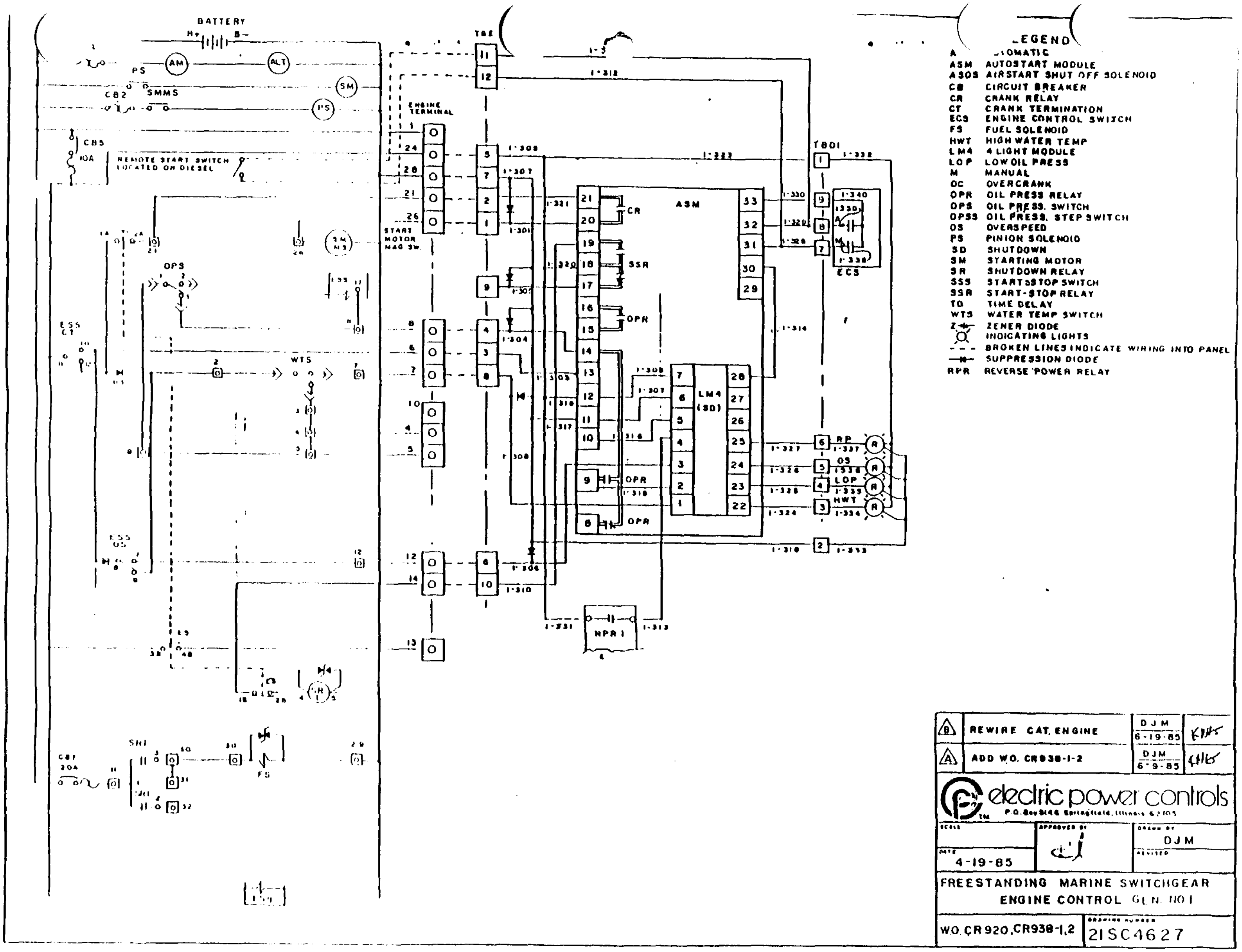
FREESTANDING MARINE SWITCHGEAR GENERATOR NO 1

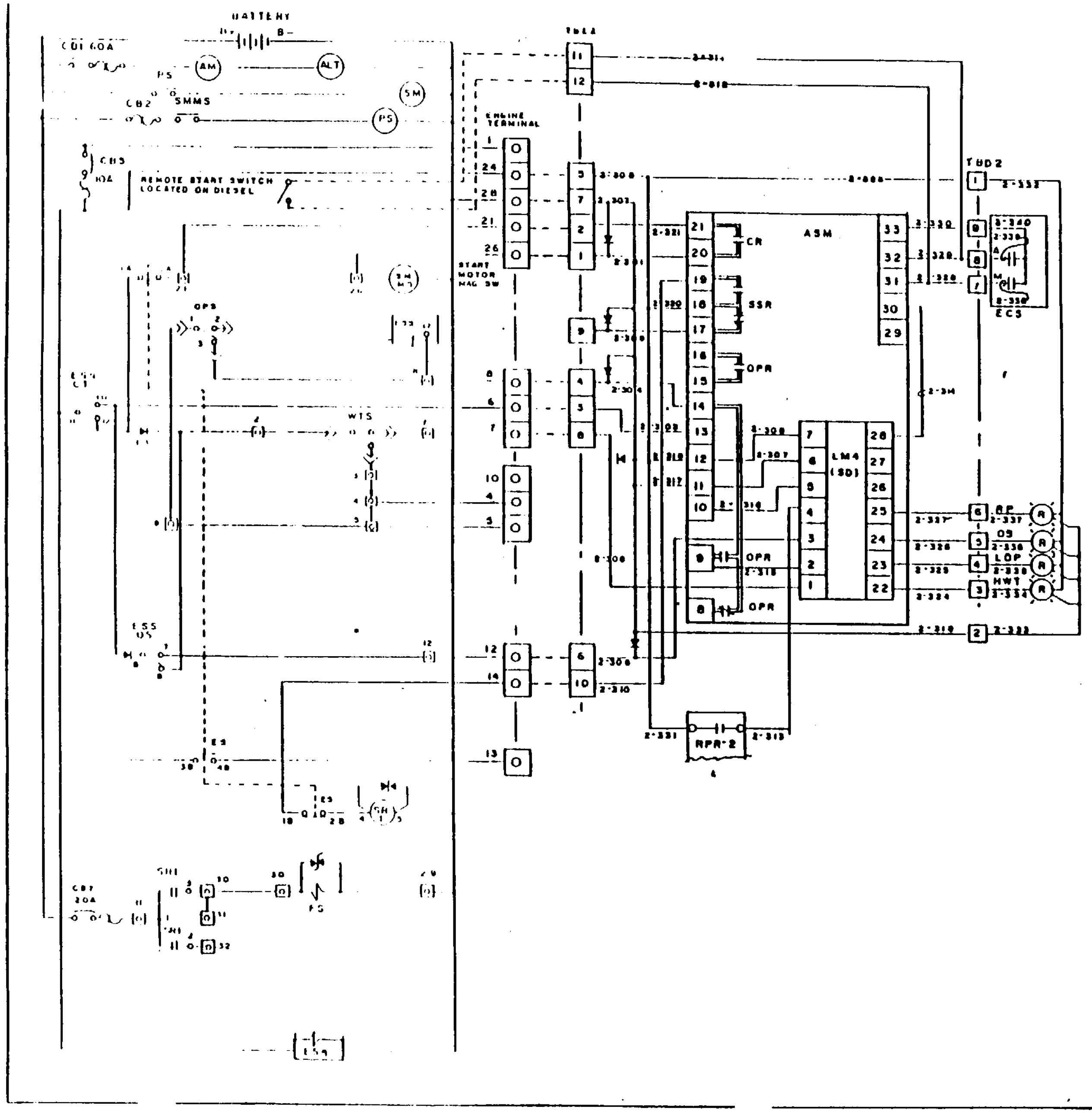
WO.CR920.CR938-1,2 — DRAWING NUMBER 20SC4621


LEGEND
AM A.C. AMMETER
CB CIRCUIT BREAKER 3 POLE 300A LB 3300
CT1-3 CURRENT TRANSFORMERS 400/5
F1-3,6,7 FUSES 600V. 1AMP. KTK-1
F4,5,8 FUSES, 250 2AM BAF-2
FM FREQUENCY METER
PT1-3 POTENTIAL TRANSFORMER 50VA. 4:1 RATIO
RPR REVERSE POWER RELAY
UVR UNDERVOLTAGE RELAY
VM A.C. VOLTMETER
SEE D.C. SCHEMATIC DWG. 21SC4678
VOLTMETER SWITCH
0-600 VOLTS
55-65 HERTZ
0-400 AMPS
AMMETER SWITCH
GROUND SCREW
VOLT. REG. IDLE/RUN
VOLTAGE ADJUST
GOVERNOR SPEED
A.C. GENERATOR NO 2
155 KW. 460V.
3 Ø, 3 W. 60HZ
GEN
ADD W.O. 938-1-2
ENGINEERING CHANGE PER CUSTOMER SPEC.
DJM 6-9-85
DJM 5-8-85
electric power controls
DRAWN BY DJM
DATE 4-15-85
FREESTANDING MARINE SWITCHGEAR
GENERATOR NO. 2
WO.CR920, CR938-1,2
20 622



GEN NO 1
GEN NO 2
GEN NO 3
120 VAC FOR BATTERY CHARGER AND ENGINE HEATERS
SHORE POWER
SHORE POWER CIRCUIT BREAKER
SHUNT TRIP
GROUND TEST PB
GROUND DETECTION LIGHTS
3Ø POWER MONITOR
GSS INCOMING GENERATOR SELECTOR SW G1/G2/G3/OFF
SYNCHRO SCOPE
electric power controls
4-17-85
DJM
FREESTANDING MARINE SWITCHGEAR
MANUAL PARALLELING AND CONTROL
WO.CR920,CR938-1,2
24
ADD WO 938-12
DJM
6-9-85


BATTERY
AM
ALT
SM
PS
CB2
SMMS
CB5
10A
REMOTE START SWITCH LOCATED ON DIESEL
OPS
ESS CT
ESS OS
WTS
ENGINE TERMINAL
START MOTOR MAG SW.
TBE
TBD1
ASM
CR
SSR
OPR
LM4 (SD)
ECS
RP
OS
LOP
HWT
RPR 1
SH1
CB7
30A
FS
LEGEND
A ..IOMATIC
ASM AUTOSTART MODULE
ASOS AIRSTART SHUT OFF SOLENOID
CB CIRCUIT BREAKER
CR CRANK RELAY
CT CRANK TERMINATION
ECS ENGINE CONTROL SWITCH
FS FUEL SOLENOID
HWT HIGH WATER TEMP
LM4 4 LIGHT MODULE
LOP LOW OIL PRESS
M MANUAL
OC OVERCRANK
OPR OIL PRESS RELAY
OPS OIL PRESS. SWITCH
OPSS OIL PRESS. STEP SWITCH
OS OVERSPEED
PS PINION SOLENOID
SD SHUTDOWN
SM STARTING MOTOR
SR SHUTDOWN RELAY
SSS START-STOP SWITCH
SSR START-STOP RELAY
TD TIME DELAY
WTS WATER TEMP SWITCH
ZENER DIODE
INDICATING LIGHTS
BROKEN LINES INDICATE WIRING INTO PANEL
SUPPRESSION DIODE
RPR REVERSE POWER RELAY
B REWIRE CAT. ENGINE DJM 6-19-85
A ADD W.O. CR938-1-2 DJM 6-9-85
electric power controls
DRAWN BY DJM
DATE 4-19-85
FREESTANDING MARINE SWITCHGEAR
ENGINE CONTROL GEN. NO1
W.O. CR920, CR938-1,2
DRAWING NUMBER 21SC4627




## LEGEND

- A — AUTOMATIC
- ASM — AUTOSTART MODULE
- ASOS — AIRSTART SHUT OFF SOLENOID
- CB — CIRCUIT BREAKER
- CR — CRANK RELAY
- CT — CRANK TERMINATION
- ECS — ENGINE CONTROL SWITCH
- FS — FUEL SOLENOID
- HWT — HIGH WATER TEMP
- LM4 — 4 LIGHT MODULE
- LOP — LOW OIL PRESS
- M — MANUAL
- OC — OVERCRANK
- OPR — OIL PRESS RELAY
- OPS — OIL PRESS. SWITCH
- OPSS — OIL PRESS. STEP SWITCH
- OS — OVERSPEED
- PS — PINION SOLENOID
- SD — SHUTDOWN
- SM — STARTING MOTOR
- SR — SHUTDOWN RELAY
- SSS — START-STOP SWITCH
- SSR — START-STOP RELAY
- TD — TIME DELAY
- WTS — WATER TEMP SWITCH
- ZENER DIODE
- INDICATING LIGHTS
- BROKEN LINES INDICATE WIRING INTO PANEL
- SUPPRESSION DIODE
- RPR — REVERSE POWER RELAY

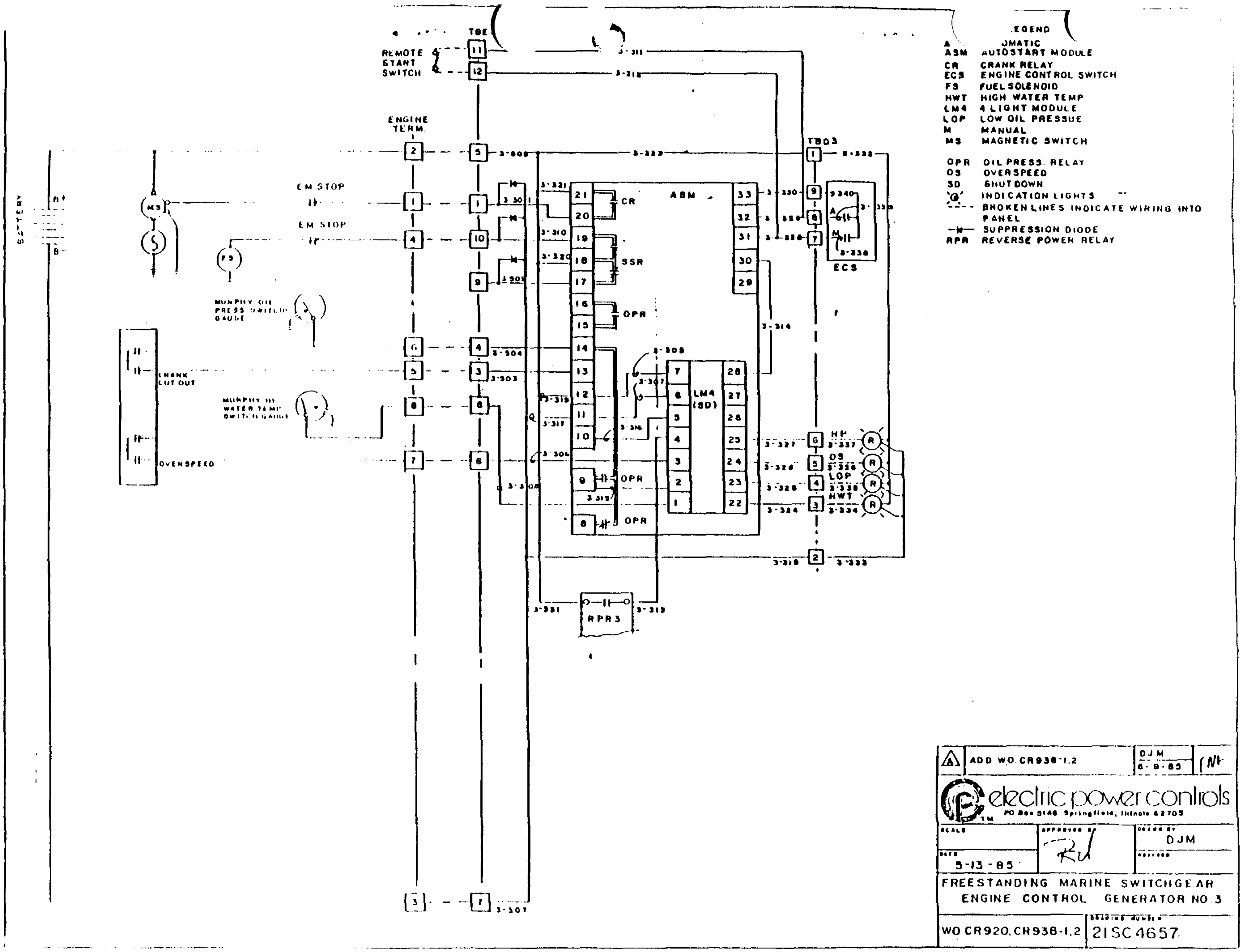
| | | | |
|---|---|---|---|
| B | REWIRE CAT. ENGINE | DJM 6-19-85 | KNK |
| A | ADD W.O.938-1,2 | DJM 6-9-85 | KNK |

electric power controls
P.O. Box ... Springfield, Illinois

DATE 4-19-85 — DRAWN BY DJM

FREESTANDING MARINE SWITCHGEAR
ENGINE CONTROL GEN NO2

W.O. CR920,CR938-1,2 — 21S[illegible]575




ADD W.O. CR938-1,2 DJM 6-9-85

electric power controls
PO Box 5146 Springfield, Illinois 62705

APPROVED BY: RL
DRAWN BY: DJM
DATE: 5-13-85

FREESTANDING MARINE SWITCHGEAR
ENGINE CONTROL GENERATOR NO 3

WO CR920, CR938-1,2
DRAWING NUMBER: 21SC4657

Perkins engines

# OPERATORS MANUAL
# FOR
# MARINE DIESEL ENGINES

| | | |
|---|---|---|
| 4.108 | 6.354 | T6.354MGT |
| 4.154 | T6.354 | V8.510 |
| 4.236 | HT6.354 | TV8.510 |

PRINTED U.S.A.

This handbook is an adaptation of the original Marine Engine Operators Manual produced by the Service Publications Department of Perkins Engines Ltd., Peterborough, England. Every endeavor has been made to ensure that the information contained within this handbook is correct at the date of publication but, because of continuous developments, Perkins Engines reserves the right to alter the contents without notice.

**HANDBOOK FOR**
**MARINE**
**DIESEL ENGINES**

Perkins engines

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Phone: 416/675-3540

Published: 1978
Publication Number: 201 SER 1068A


This marine handbook is general in content and encompasses the whole range of current Perkins marine engines that are marketed in North America. Workshop manuals involving the overhaul of Perkins engines and relevant gearboxes are available, if required, from any Perkins Marine Distributor.

This handbook is distributed to provide guidance for correctly operating and maintaining Perkins marine diesel engines. If correctly installed, correctly operated and correctly maintained, a Perkins diesel engine will provide its owner with years of dependable service.
This handbook also includes information relating to Marine propulsion, trouble-shooting and performing minor engine repairs while afloat.

# PERKINS PARTS
# FOR
# PERKINS PRODUCTS

To ensure you obtain the best results from your engine and to safeguard your warranty, install only genuine Perkins parts. These are readily obtainable throughout the world.

## Table of Contents

**Perkins engines**

## LIMITED MARINE ENGINE WARRANTY

1. DURATION OF WARRANTY
Perkins Engines, Inc. (hereinafter called Perkins) warrants each new engine sold under the trademark "Perkins," and operated in the United States of America or Canada to power marine applications to the first retail purchaser thereof for a period of 12 months or 1,800 hours, whichever event shall first occur, to be free from defects in workmanship and material from the date of delivery to such purchaser.

2. REPLACEMENT OF PARTS UNDER WARRANTY
The responsibility of Perkins is limited to repairing or replacing, at its option, any part or parts of such engines that are returned to Perkins or any authorized Perkins distributor or dealer, with transportation charges prepaid, and which upon examination by Perkins shall disclose to Perkins' satisfaction to have been thus defective.

3. PAYMENT OF REPAIR LABOR COST UNDER WARRANTY
During the first 12 months or 1,800 hours of engine operation, whichever event shall occur first, from the date of delivery to the first purchaser, Perkins or any authorized Perkins distributor or dealer will cover the cost of reasonable labor required to repair any engine or replace any parts found by Perkins to be defective.

4. Perkins' obligation under this Warranty shall not apply to: (a) Starters, Alternators, Transmissions, Clutches. Radiators, or any other proprietary fittings not manufactured by Perkins. These are warranted by their respective manufacturers and not by Perkins. (b) Any engine which shall have been subject to negligence, misuse, accident, misapplication or overspeeding. (c) Any engine that has been repaired or altered by anyone in a manner which in Perkins' sole judgement adversely affects its performance or reliability. (d) Any engine which has been fitted with or repaired with parts or components not manufactured or approved by Perkins which in Perkins' sole judgement adversely affect its performance or reliability. (e) Engine tune-ups, normal maintenance services including but not limited to valve adjustment, normal replacement of service items, fuel and lubricating oil filters, lubricating oil, fan belts, antifreeze, etc. (f) Damages caused by prolonged or improper storage of the engine after shipment from a Perkins factory. (g) Loss of operating time to the user while the engine or engine driven equipment is out of operation, and damage to equipment powered by this engine.

5. This warranty and the obligation of Perkins Engines, Inc. here-under is in lieu of all other express warranties including, without limitations, all other representations to the purchaser. Any implied warranties, including any warranty of merchantability or fitness for a particular purpose, are expressly limited to the duration of this written warranty. In no event shall the purchaser be entitled to recover for incidental or consequential damages. Some states do not allow limitations on how long an implied warranty lasts, so the above limitation may not apply to you. Some states do not allow the exclusion or limitation of incidental or consequential damages, so the above limitation or exclusion may not apply to you. This warranty gives you specific legal rights, and you may also have other rights which vary from state to state.

SPECIAL NOTE

Perkins engines are marketed throughout the world to many manufacturers of original equipment. In order to meet the special requirements of these, engines may on occasion be covered by specific warranties applicable to the requirements of the driven equipment. In these instances the warranty extended by Perkins to said manufacturer supersedes the above warranty.

ENGINE IDENTIFICATION

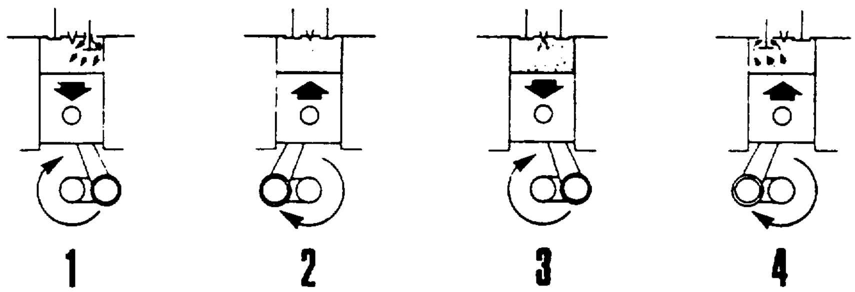
Each Perkins engine is identified by means of an identification code (see page 7). To ensure prompt, efficient results when ordering parts, requesting repairs or information, record the identification code in the space provided below so that it will be available when needed.

Engine Identification Code: ______________________________

**INTRODUCTION**

Dependable performance can be expected from a Perkins marine diesel engine when the operation and maintenance procedures are based upon a clear understanding of diesel engine operating principles. Each moving part of the engine affects the operation of every other moving part and the engine as a whole.

Perkins diesel engines are four stroke cycle engines with either a direct or indirect combustion system. Diesel engines differ from other internal combustion engines in several ways. Compression ratios are higher than in gasoline engines. The intake stroke provides air only to the cylinder. Fuel is delivered to the cylinder in an atomized form by an injector. This fuel, in accurately metered quantities and with exact timing, is delivered to the injectors via extremely high pressure from the fuel injection pump. Ignition of the fuel is effected by the heat developed from compressing the air into the combustion chamber.




**PERKINS DIESEL FOUR STROKE CYCLE**

1. INTAKE STROKE - The piston travels down the cylinder, the intake valve is open and the exhaust valve is closed. The partial vacuum created by the downward stroke of the piston pulls air from outside through the open intake valve into the cylinder.

2. COMPRESSION STROKE - At the end of the intake stroke, the intake valve closes while the piston travels upward on the compression stroke. The exhaust valve remains closed. At the end of the compression stroke, the air in the combustion chamber has been forced by the piston into a space that is one-sixteenth (or less) the original volume available at the beginning of the stroke. Thus, the compression ratio is 16:1 (or, for some engines, greater).

   Compressing the air into a small space causes the temperature to rise to approximately 1000 degrees F. Just before T.D.C., a small atomized, metered charge of fuel is injected into the combustion chamber, the fuel is ignited by the hot air and starts to burn.

3. POWER STROKE - During the power stroke, the piston travels down the cylinder and both intake and exhaust valves are closed. As the air and fuel mixture burns, the gases become hotter and hotter, rapidly expand and add force to crankshaft rotation.

4. EXHAUST STROKE - During the exhaust stroke, the intake valve remains closed, the exhaust valve is open, and the piston on the upward stroke forces the burned gases out of the combustion chamber through the open exhaust valve port.

Turbocharged engines utilize the exhaust to power the turbine and "boost" the density of the intake air, which results in an increase in engine power.

The standard direction of rotation for Perkins marine diesel engines is counterclockwise when viewing the engine from the gearbox end (rear) of the engine. Contrarotating engines (rotation is clockwise when viewing the engine from the rear) are the exception.

Perkins marine engines are manufactured to meet all general marine requirements and to be compatible with specific applications. The engines depicted on pages 12 through 27 do not necessarily typify all the various marine engines in use worldwide.

**Safety Precautions:**

Disregarding fundamental safety rules and precautions may result in injuries to persons coming into contact with or located near an engine. Care should be exercised at all times, particularly in the following respects:

1. The coolant in an operating or recently stopped engine is very hot and under pressure. If the filler pressure cap is suddenly removed the liquid may spurt and cause injury by scalding. Always stop an engine and allow it to cool before removing the cap. Once cool, loosen the cap slowly to relieve the pressure.

2. External assemblies and accessories driven by an engine, such as the pulleys, belts, and alternator/generator, are hazardous to anyone attempting to repair or service it while it is operating. If possible, always stop an engine before servicing it. When necessary to repair or adjust an operating engine, use extreme caution and do not wear loose clothing.

3. The direction of engine rotation and the rotation of any attached or auxiliary drive device are not always the same. The rotation direction of the output shaft should be determined before attaching any auxiliary mechanism that is to be driven by the engine. Failure to consider the respective rotations could result in an unexpected rotation of the mechanism and cause injury.

4. Use extraordinary care when hoisting an engine. Ensure that the hoist is correctly arranged and correctly attached to the engine. Failure to do so may result in fracture of the lifting brackets or other mishap.

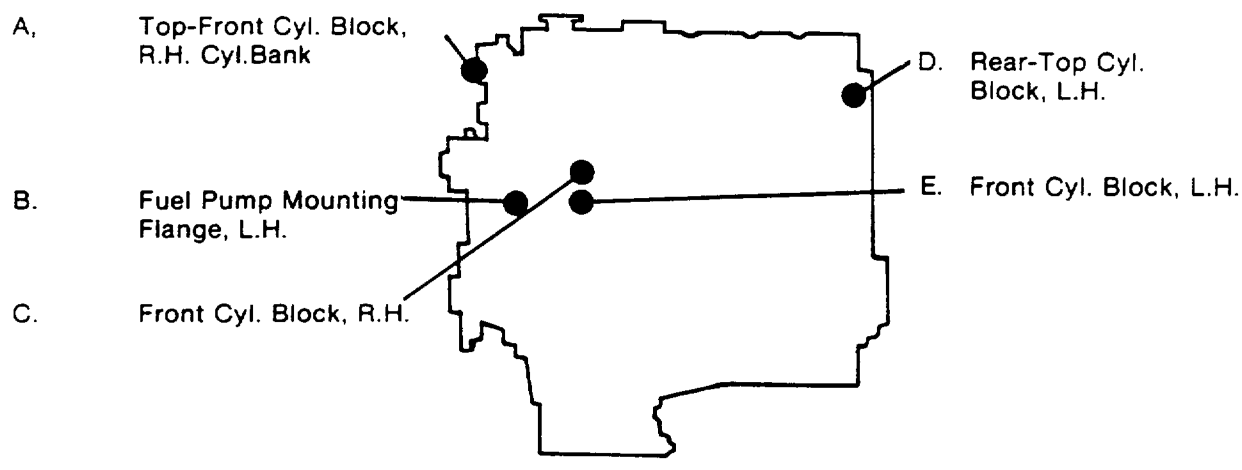
5. Stop the engine before refueling it.

Look for this symbol - it means:
ATTENTION! BECOME ALERT!
YOUR SAFETY IS INVOLVED!
HEED THE INSTRUCTIONS!

Because of the variety of engine applications and their respective uses, it is not possible to anticipate and provide safety precautions for all the potentially hazardous situations that may be encountered during the servicing and operation of a marine engine. In respect to this, each person involved with service and operation should be alert and safety conscious at all times.

**ENGINE IDENTIFICATION LOCATION**

A. V8.510, TV8.510
B. 4.108, 6.354, T6.354
HT6.354, T6.354 MGT
C. 4.236
D. 4.154
E. 4.154 (Newer Engines)
4.236 (Newer Engines)




"R.H."= Right Hand or Alternator Side
"L.H."= Left Hand, Fuel Injection, Pump Side

**Note:**
Left and right hand locations are given assuming that the engine is viewed from the rear.

**ENGINE IDENTIFICATION**

This handbook is applicable to the following marine engine type designations:

| | |
|---|---|
| 4.108 | (M) |
| 4.154 | (M) |
| 4.236 | (M) |
| 6.354 | (M) |
| T6.354 | (M) |
| T6.354 | (MGT) |
| HT6.354 | (M) |
| V8.510 | (M) |
| TV8.510 | (M) |

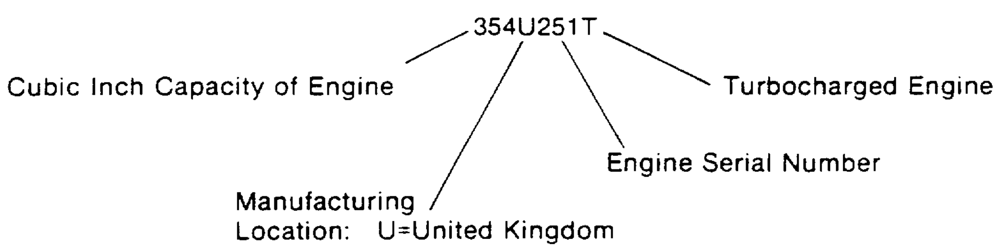
The first numeral (e.g., 4) in the engine designation denotes the number of cylinders, while the second group of numerals (e.g., 108) denotes the cubic inch displacement (C.I.D.) of the engine. The prefix letters (e.g.,T) denote the following:

T - Turbocharged Engine
H - Horizontally Inclined Engine
V - Two banks of cylinders in "V" formation.

*Special version of the T6.354 Marine engine.

The letter "M" in parenthesis indicates the applicable engine was manufactured specifically for marine applications.

Apart from physical differences, each engine can be identified by the engine identification code stamped into the cylinder block. The code is comprised of a combination of numerals and letters (Alphanumeric). At the present time, two identification formats are in existence. The earlier format (e.g., 354U251T) represents the following data:




In addition to the above, contra-rotating (clockwise) engines are further identified by the letter "X" stamped immediately after the manufacturing location code letter (e.g., 354UX252T).

Additional suffix letters may also be included in the code for certain engines. For example:

H - Horizontally Inclined Engine
L - Lip Type Rear Main Bearing Seal

The location of the identification code, as applicable to each engine, is-depicted in the following series of illustrations (Fig. 2a through Fig. 2e). When information, replacement parts or assistance is required, the complete engine identification code should always be quoted.

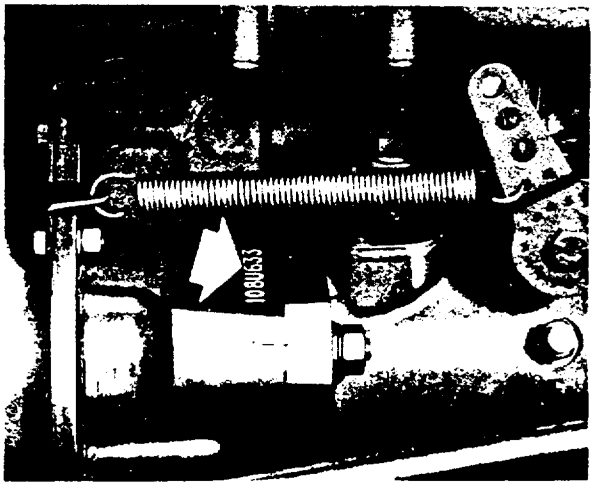



*Fig. 2 (a)*
Engine Identification Location
4.108

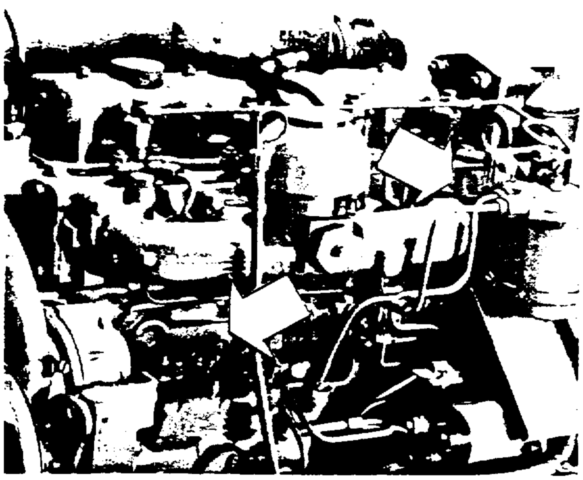


*Fig. 2 (b)*

4.154 Engine Identification Location. Rear-Top of Cylinder Block, Left-Hand Side of Engine. Newer Engines: Left-Hand Side of Engine, above fuel injection pump.

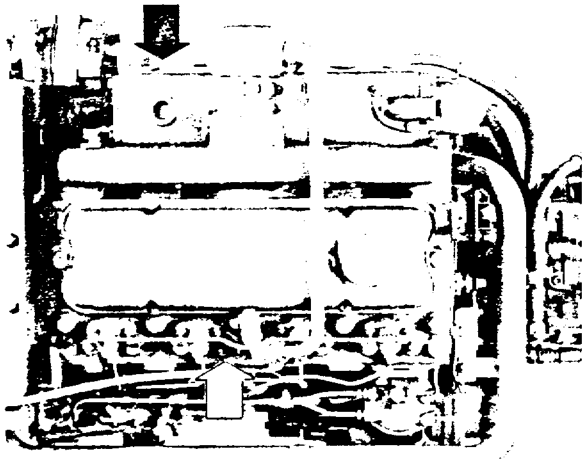


*Fig. 2 (c)*

4.236 Engine Identification Location. Machined Pad Immediately Above and Aft of Alternator, Right-Hand Side of Engine. Newer Engines: Left-Hand Side of Engine, above Fuel Injection Pump.

*Fig. 2 (d)*
6.354, T6.354, HT6.354, and T6.354MGT Engine Identification Location. Fuel Injection Pump Mounting Flange. Left-Hand Side of Engine.

*Fig. 2 (e)*
V8.510 and TV8.510 Engine Identification Location. Top-Front of Cylinder Block, Right-Hand Cylinder Bank.

**NEW FORMAT**

The new format for engine identification will be incorporated by all Perkins manufacturing operations in the near future. At the present time, engines produced in England, Germany, Mexico, and the United States are being identified according to the new format. As with its predecessor, the identification of each engine is accomplished via an alphanumeric code, which can be comprised of up to 15 characters (if a secondary parts list reference is required, six additional characters will be used). The standardized location for each engine's identification is a machined pad situated near the fuel injection pump (left side of engine when viewing from rear). Exceptions to this location may arise for certain engines. The following data is represented in sequence by the alphanumeric identification code characters.

| DATA | CHARACTERS |
|---|---|
| 1. Engine Family | One Alphabetic Letter |
| 2. Engine Type/Phase | One Alphabetic Letter |
| 3. Parts List (Or Standard Option Scheme Order) Reference' | Five Numerals (Or Letter "A" and Four Numerals) |
| 4. Country of Origin | One Alphabetic Letter |
| 5. Production (Or Rebuild) Serial Number | Maximum of Six Numerals (Or Letter "R" and Maximum of Five Numerals) |
| 6. Year of Manufacture | One Alphabetic Letter |

**EXAMPLE:**
TE22282N1256C

*Certain engines may also have a secondary parts list reference stamped immediately below the primary parts list reference.

**EXAMPLE:**
TE20696U501376C
NAP12N

Engine Family and Type/Phase Code Interpretations:
The first two characters of the identification code will always be letters. The first letter represents the engine family and the second represents the engine type/phase. The following interpretation are applicable to engine identification codes.

| FAMILY | TYPE | CODE | FAMILY | TYPE | CODE | FAMILY | TYPE | CODE |
|---|---|---|---|---|---|---|---|---|
| 4.108 | | E | 6.354 | | T | V8.510 | | X |
| | 4.99 | EA | | 6.354 | TC | | V8.510 | XA |
| | 4.107 | EB | | H6.354 | TD | | TV8.510 | XB |
| | T4.107 | EC | | T6.354 | TE | | | |
| | 4.108 | ED | | HT6.354 | TF | | | |
| 4.154 | | G | | 6.3541 | TG | | | |
| | 4.154 | GA | | T6.3541 | TH | | | |
| | | | | 6.3542 | TJ | | | |
| 4.236 | | L | | 6.3543 | TN | | | |
| | 4.236 | LD | | HT6.3543 | TQ | | | |
| | | | | T6.3544 | TU | | | |
| | | | | 6.3544 | TW | | | |

Parts List References:

Following the first two characters (engine family and type/phase code letters) will be either a group of five numerals or the letter "A" followed by a group of four numerals. If five numerals are used, they will be the reference for the engine build parts list. When an engine Is built to a Standard Option Scheme (S.O.S.) order, the reference for the order is comprised of the letter "A" and the last four digits of the order number. The following are examples of both references:

| | |
|---|---|
| PARTS LIST REFERENCE: | 21376 |
| ENGINE IDENTIFICATION CODE: | TR21376U500120C |
| STANDARD OPTION SCHEME NUMBER: | A018752 |
| STANDARD OPTION SCHEME ORDER REFERENCE: | A8752 |
| ENGINE IDENTIFICATION CODE: | LDA8752U501234C |

Country of Origin Code Interpretations:

The next character will be a one-letter code that represents the country where the basic engine was produced. The following interpretations are applicable to engine identification codes.

COUNTRY OF ORIGIN

| | | |
|---|---|---|
| A ................Argentine | G ...................Greece | S ..............India |
| B ................Brazil | J ....................Japan | T...............Turkey |
| C ................Australia | L.....................Italy | U .............United Kingdom |
| D ................Germany | M....................Mexico | X...............Peru |
| E ................Spain | N ....................U.S.A. | Y ..............Yugoslavia |
| F .................France | P ....................Poland | |

*Motores Perkins S.A., Mexico, started using the new identification format in its infancy and uses the letters "MX" vice "M" as the code for Mexico.

Engine Serial Numbers:

Each engine family (if produced at the specific manufacturing location) will have a separate production serial number series initiated at each manufacturing location. To distinguish the new engine serial numbering from that used previously, Peterborough, United Kingdom will start numbering the first produced engine of each family with 500001. All other manufacturing operations will start with 251. Upon attaining serial number 999999, each series will revert to 251. Serial numbers 1 through 250 will always be reserved for prototype engines by each manufacturing operation.

Each manufacturing operation will group rebuilt engines as one type and serialize them progressively regardless of their respective engine family. The serial numbering will start with 251 and progress through 1000 (if necessary) at each location. The letter "R" will be used as a prefix to denote "Rebuilt Engine". For example:

R417

Year of Manufacture Code Interpretations:

The last character in the engine identification code will be a code letter that represents the calendar year during which the engine was either produced or rebuilt. The following interpretations are applicable to engine identification codes:

| LETTER | YEAR |
|---|---|
| B | 1975 |
| C | 1976 |
| D | 1977 |
| E | 1978 |
| F | 1979 |

NOTE: The letters I.O,Q,R, and Z will not be used to represent the year of manufacture.

## ENGINE PHOTOGRAPHS

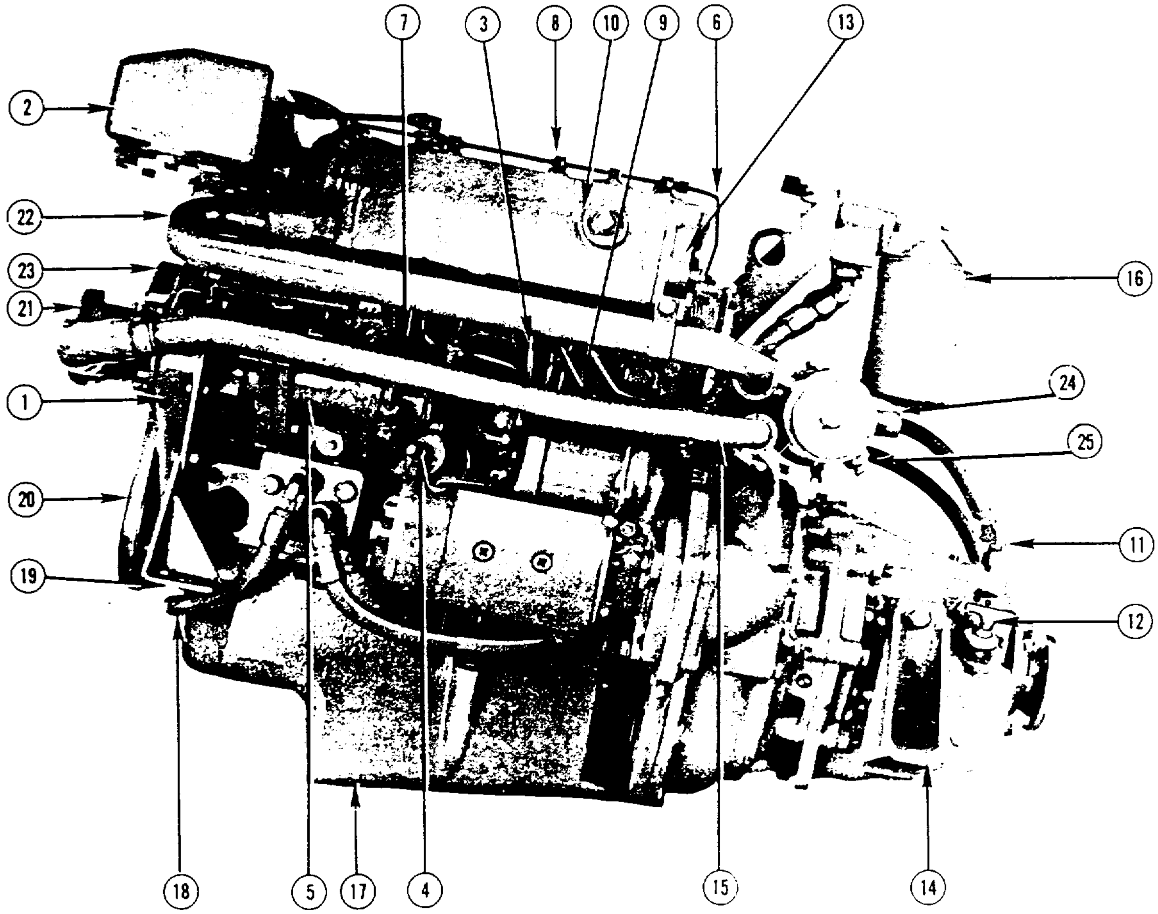



*Fig. 3(a)*
KEY TO 4.108 (M) ENGINE PHOTOGRAPHS

1. Timing Case Cover
2. Header Tank
3. Lub Oil Dipstick
4. Lub Oil Pressure Sender
5. Field Injection Pump
6. Injector Leak-Off Pipe
7. Pressure Pipes, Injection Pump to injectors
8. Injector
9. Fuel Pipes, Filter to Injection Pump
10. Exhaust Manifold
11. Gearbox Forward and Reverse Lever
12. Gearbox Fluid Filler Hole/Dipstick
13. Exhaust Flange
14. Rear Engine Support
15. Sea Water Pipe, to Sea Water Pump Heat Exchanger
16. Lub Oil Filter
17. Oil Pan
18. Hose from Oil Cooler
19. Front Engine Support
20. Crankshaft Pulley
21. Sea Water Pump
22. Fresh Water Pipe, Exhaust Manifold to Heat Exchanger
23. Fresh Water Pump
24. Sea Water Outlet
25. Zinc Anode

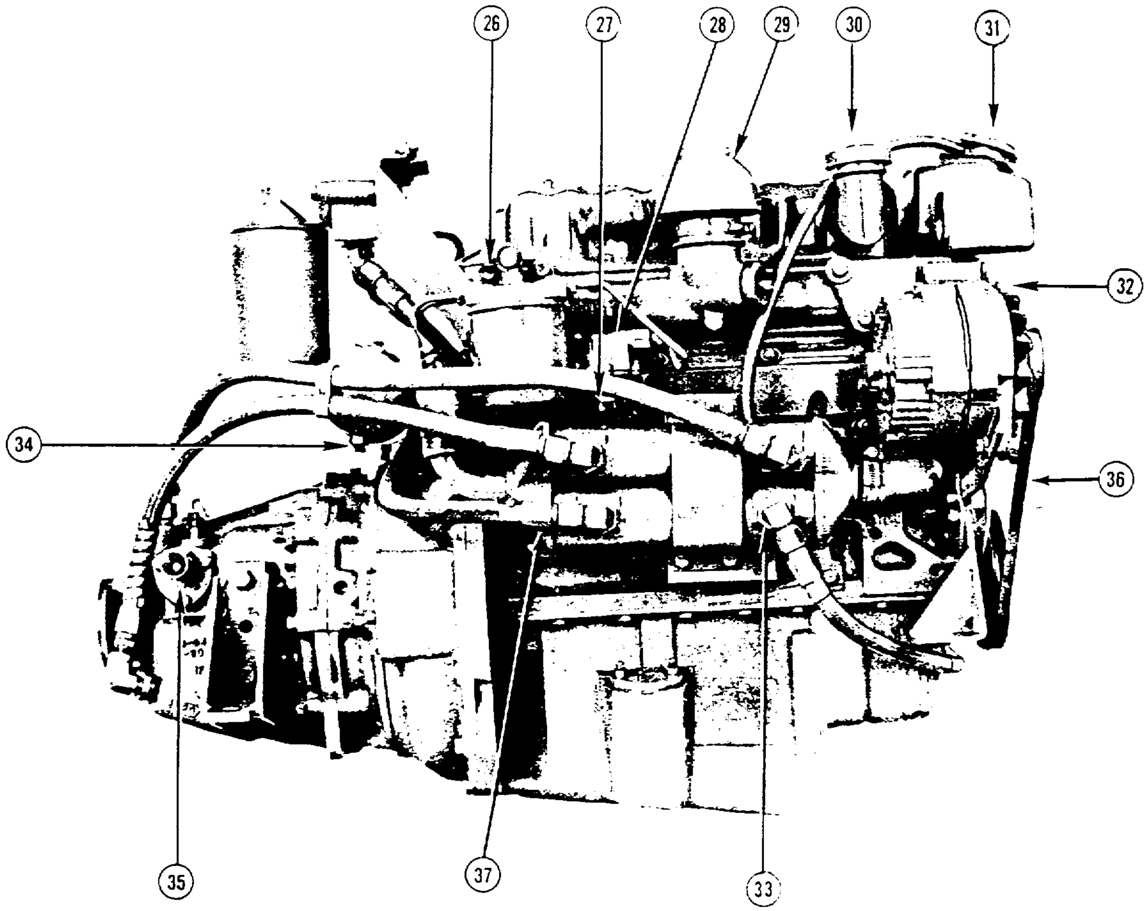



*Fig. 3 (b)*

26. Fuel Filter
27. Fuel Transfer Pump Priming Lever
28. Fuel Transfer Pump
29. Air Filter
30. Lub Oil Filler Cap
31. Fresh Water Filler Cap
32. Alternator
33. Oil Coolers (Engine and Transmission)
34. Heat Exchanger
35. Gearbox Neutral Switch
36. Alternator/Fresh Water Pump Drive Belt
37. Oil Cooler Water Drain

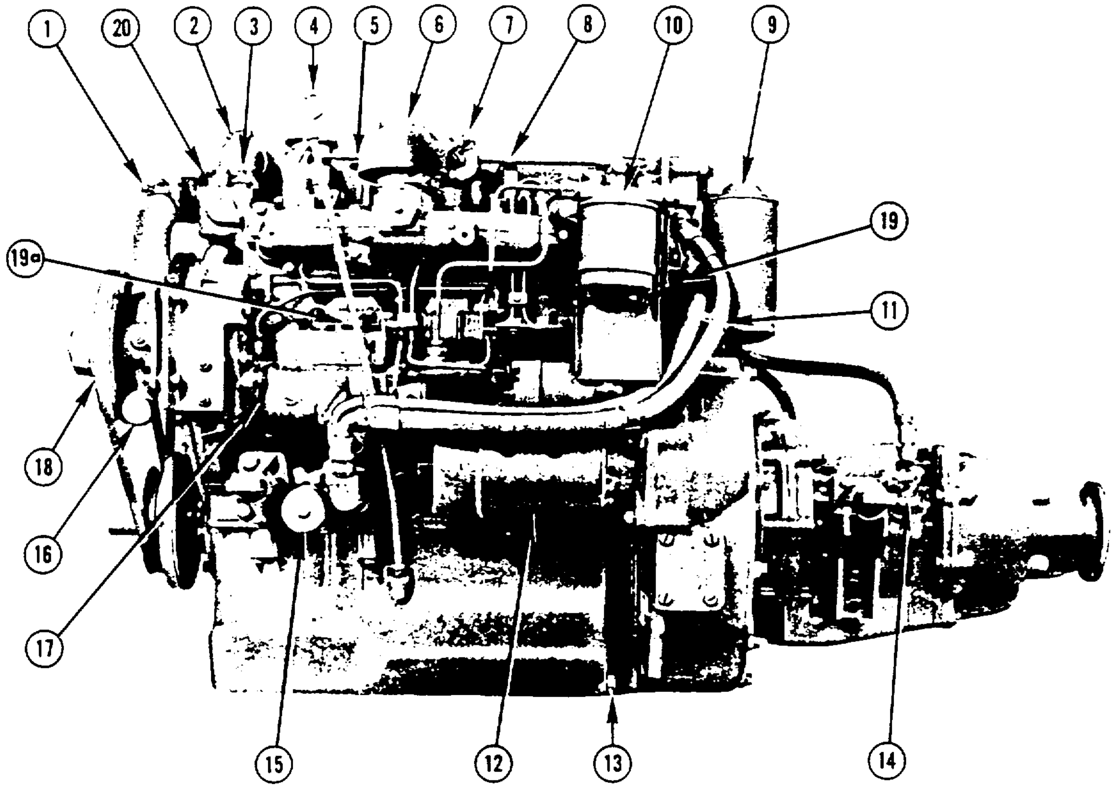



*Fig. 3(c)*
KEY TO 4.154 (M) ENGINE PHOTOGRAPHS

1. Sea Water Pipe from Pump to Heat Exchanger
2. Fresh Water Pipe from Engine to Heat Exchanger
3. Water Temperature Sender
4. Lubricating Oil Dipstick
5. Lubricating Oil Filler Cap
6. Induction Air Filter
7. Closed Circuit Breather Pipe
8. Injector
9. Lubricating Oil Filter
10. Fuel Filter
11. Flexible Lubricating Oil Hoses
12. Starter Motor
13. Lubricating Oil Pan Drain Plug
14. Gear Box Filler and Dipstick
15. Engine Lubricating Oil Pressure Sender
16. Sea Water Pump Inlet
17. Fuel Injection Pump
18. Sea Water Pump
19. Engine Serial Number (Older Engines)

19a. Engine Serial Number (Newer Engines)

20. Thermostat Housing and Water Temperature Sender

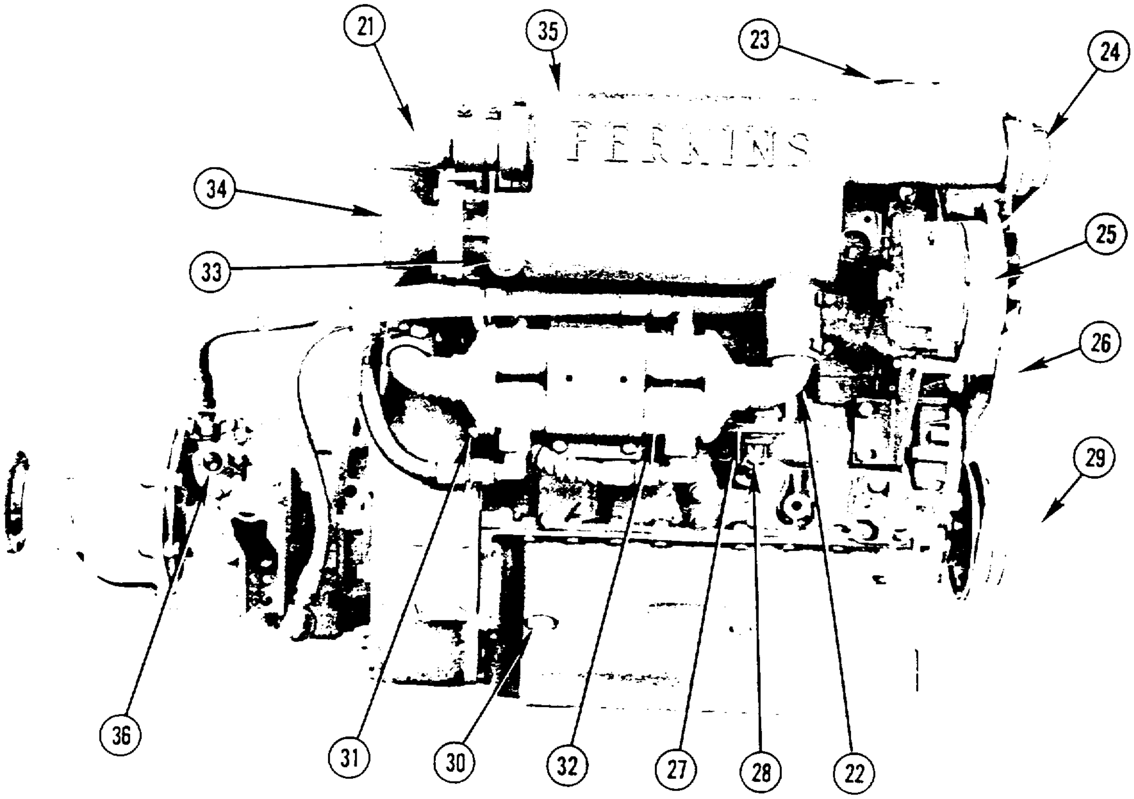



*Fig. 3(d)*

21. Sea Water Outlet From Heat Exchanger
22. Fresh Water Pipe to Lubricating Oil Cooler
23. Fresh Water Filler Cap
24. Sea Water Inlet to Heat Exchanger
25. Alternator
26. Alternator/Fresh Water Pump Drive Belt
27. Fuel Transfer Pump
28. Fuel Transfer Pump Priming Lever
29. Power Take-Off Shaft
30. Lubricating Oil Pan Drain Pump (Position)
31. Lubricating Oil Cooler Water Drain Plug (or Tap)
32. Lubricating Oil Cooler
33. Heat Exchanger/Exhaust Manifold Fresh Water Drain Plug
34. Exhaust Manifold Flange
35. Header Tank/Heat Exchanger, Exhaust Manifold
36. Gear Box Neutral Switch

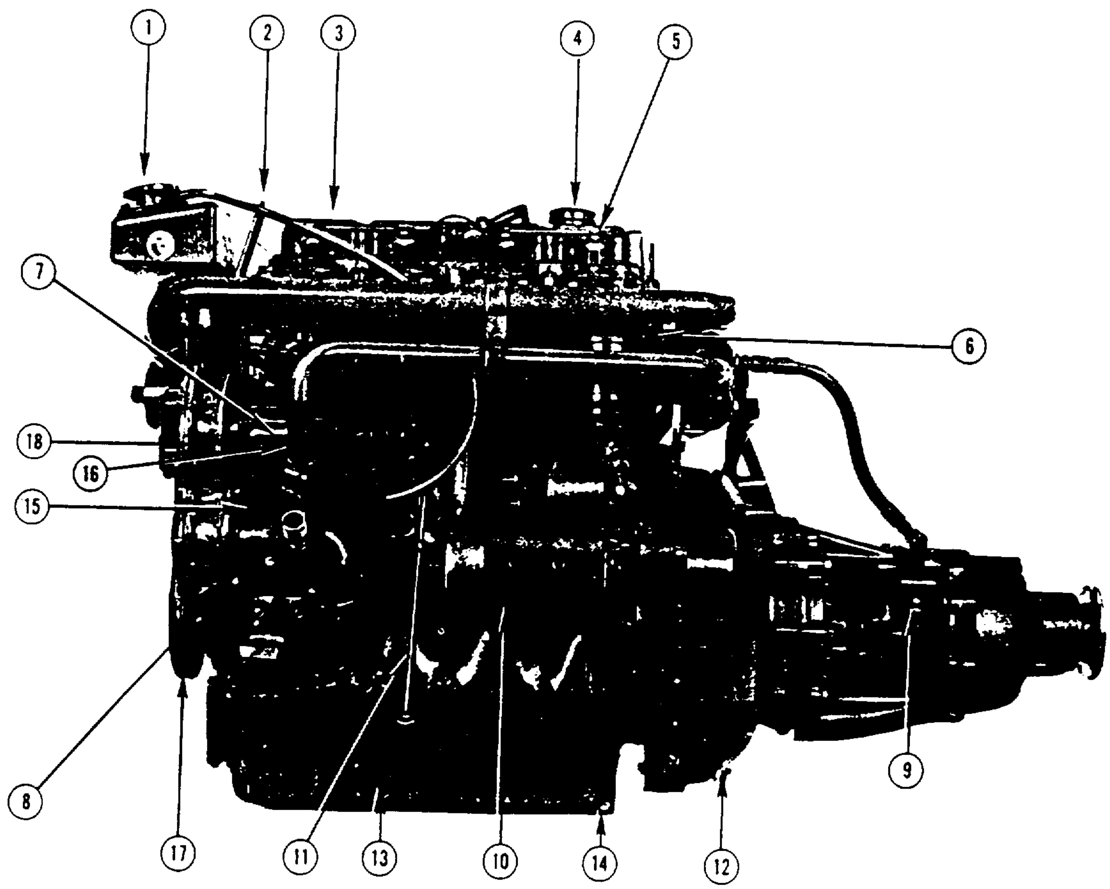



*Fig. 3(e)*
KEY TO 4.236 (M) ENGINE PHOTOGRAPHS

1. Coolant Filler Cap
2. Front Lifting Eye
3. Rocker Cover
4. Lubricating Oil Filler Cap
5. Injector
6. Fuel Oil Filter
7. Fuel Injection Pump
8. Sea Water Inlet to Sea Water Pump
9. Gearbox Filler Plug and Dip-Stick
10. Starter Motor
11. Engine Oil Dipstick
12. Flywheel Housing
13. Lubricating Oil Pan
14. Lubricating Oil Pan Drain Plug
15. Sea Water Pump
16. Water Pipe from Sea Water Pump to Cooler
17. Crankshaft Pulley
18. Timing Case Cover
19. Alternator Pulley
20. Heat Exchanger

20a. Zinc Anode

21. Engine Oil Cooler

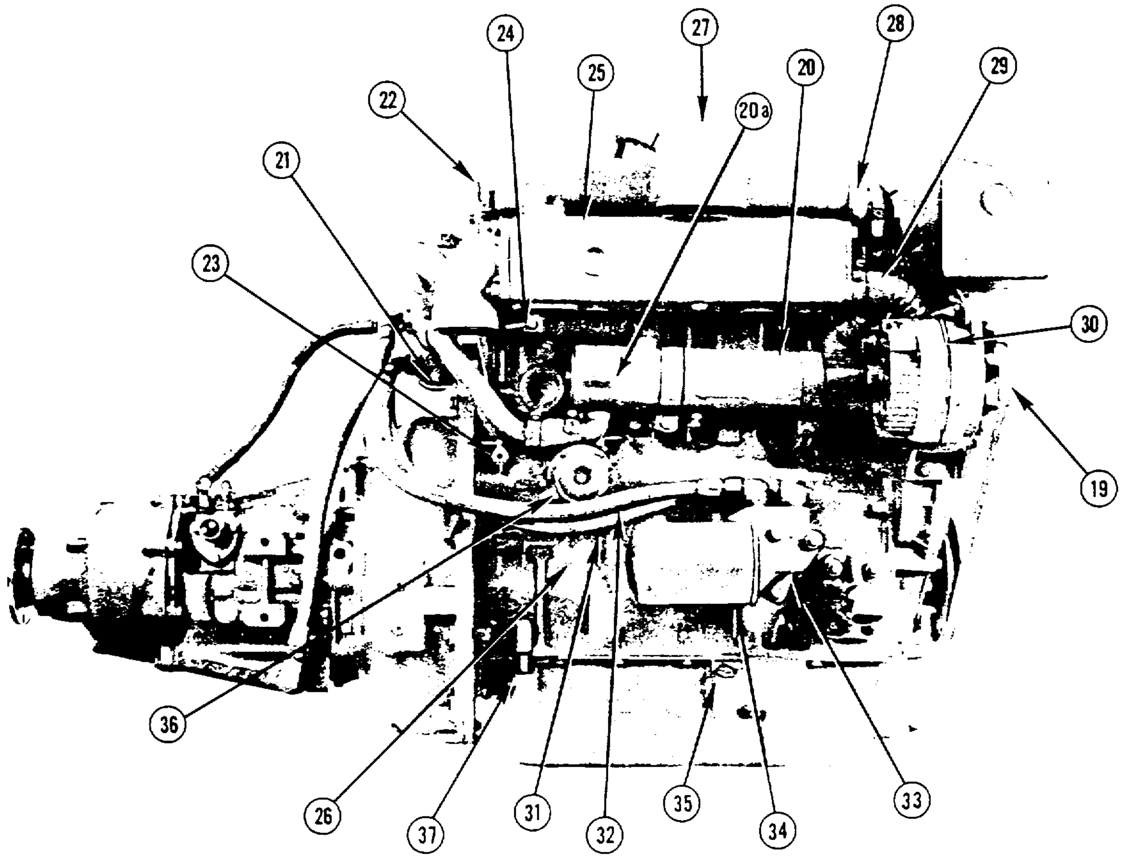



*Fig. 3(f)*

22. Rear Lifting Eye
23. Cylinder Block Drain Tap
24. Exhaust Manifold Drain Tap
25. Exhaust Manifold
26. Cylinder Block
27. Air Filter
28. Induction Manifold
29. Water Pipe from Heat Exchanger to Exhaust Manifold
30. Alternator
31. Oil Pipe to Cooler
32. Oil Pipe from Cooler
33. Oil Filter Adaptor
34. Lubricating Oil Filter
35. Optional Dipstick Position
36. Fuel Transfer Pump
37. Oil Pan Draining Connection

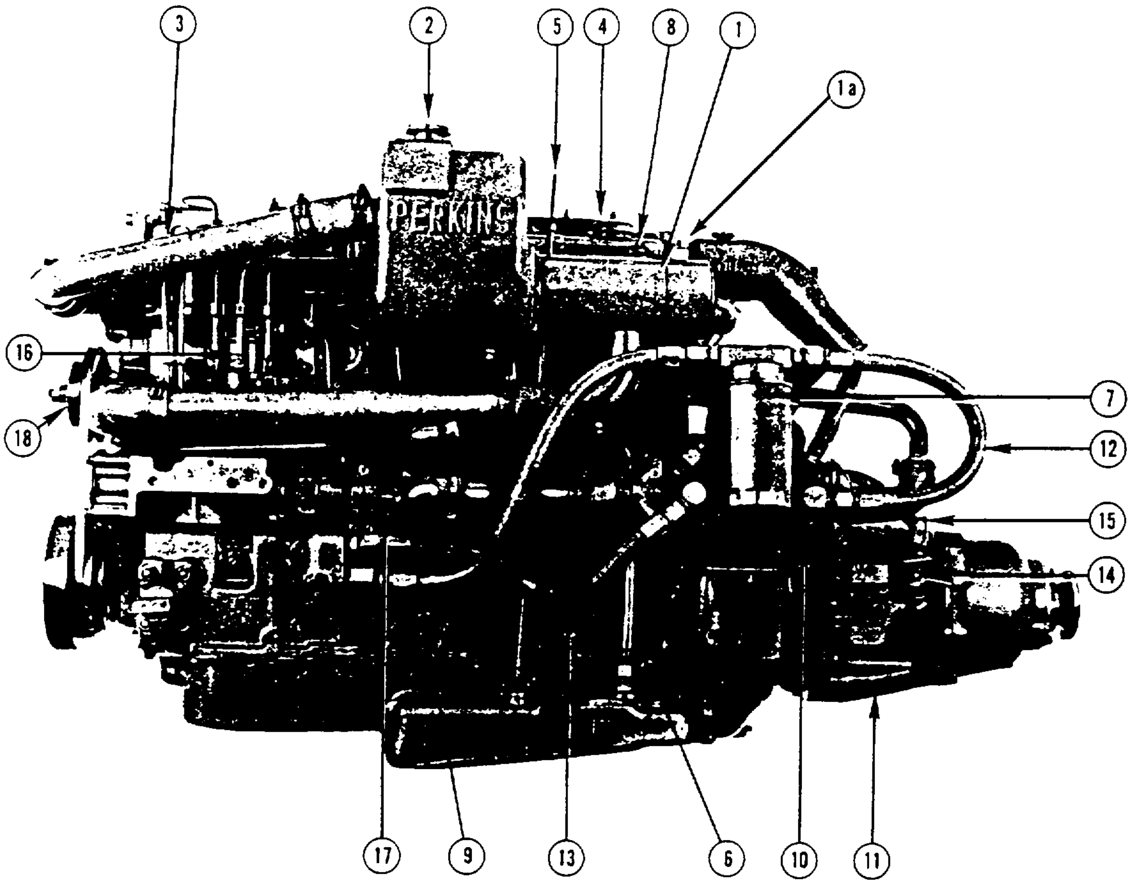



*Fig. 3(g)*

KEY TO 6.354 (M) ENGINE PHOTOGRAPHS

1. Heat Exchanger
1a. Zinc Anode
2. Fresh Water Filler Cap
3. Fuel Filter
4. Lubricating Oil Filler Cap
5. Lub Oil Dipstick
6. Engine Breather Pipe
7. Lubricating Oil Filter
8. Injector
9. Lubricating Oil Hose, Filter to Adaptor
10. Engine Oil Cooler
11. Gearbox
12. Lubricating Oil Hose, Filter to Cooler
13. Lubricating Oil Hose, Cooler to Adaptor
14. Gearbox Filler/Dipstick
15. Forward/Reverse Lever
16. Injection Pump
17. Sea Water Pump
18. Fresh Water Pump

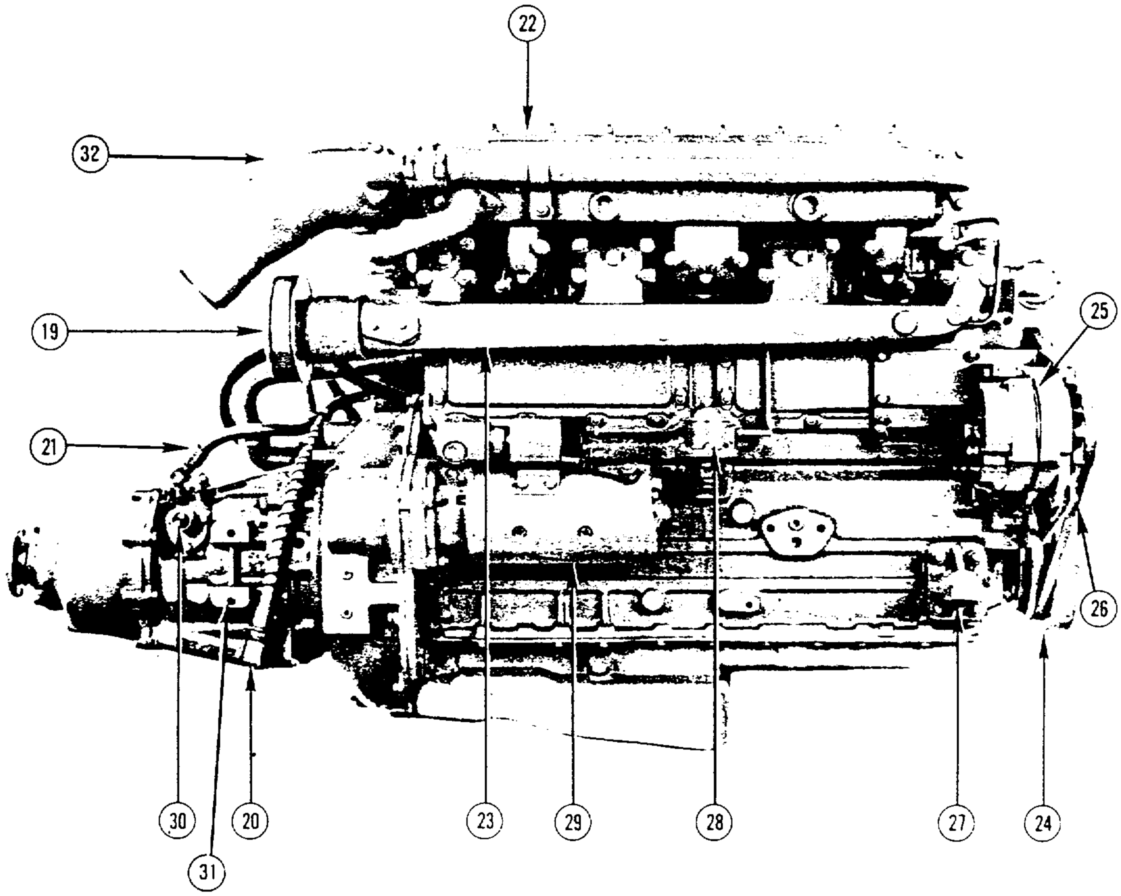



*Fig. 3(h)*

19. Air Filter
20. Gearbox Fluid Hose from Cooler
21. Gearbox Fluid Hose to Cooler
22. Water Cooled Exhaust Manifold
23. Intake Manifold
24. Crankshaft Pulley
25. Alternator
26. Alternator and Fresh Water Pump Drive Belt
27. Engine Front Support Bracket
28. Fuel Oil Transfer Pump (with Priming Lever)
29. Starter Motor
30. Gearbox Neutral Switch
31. Rear Mounting Position
32. Wet Elbow Exhaust

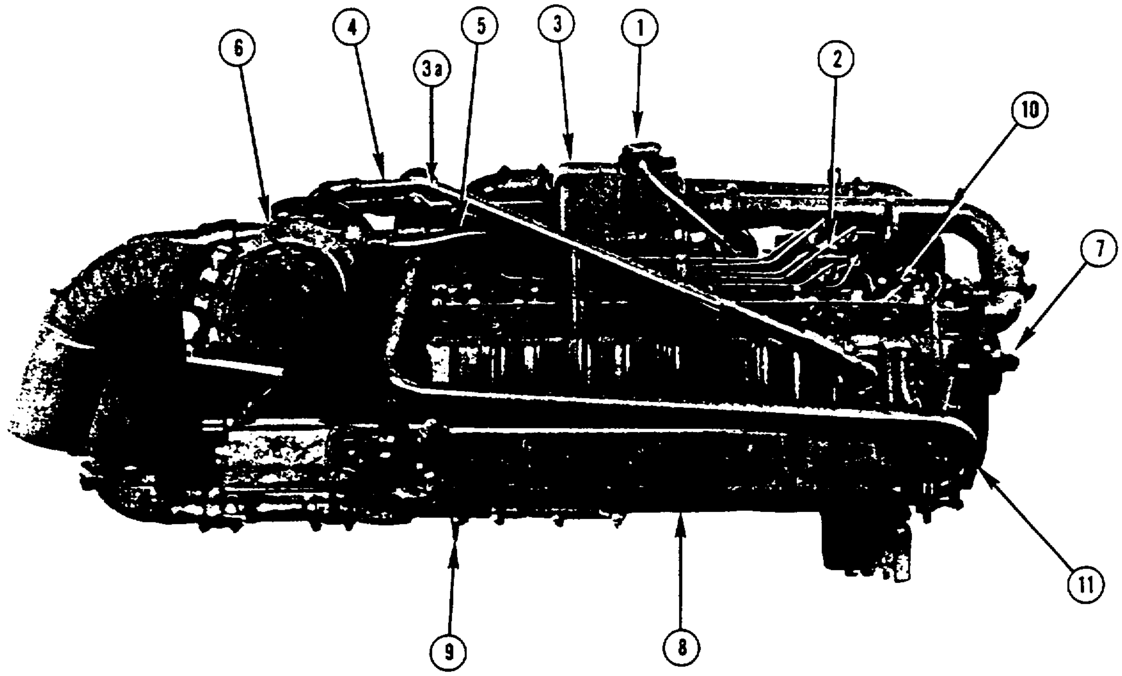



*Fig. 3(i)*

KEY TO HT6.354 (M) ENGINE PHOTOGRAPHS

1. Fresh Water Filler Cap
2. Fuel Injection Pump
3. Header Tank

3a. Zinc Anode

4. Engine Breather Pipe
5. Lubricating Oil Pressure Feed Hose to Turbocharger
6. Turbocharger
7. Fresh Water Pump
8. Exhaust Manifold
9. Water Drain Tap
10. Injector
11. Heat Exchanger to Exhaust Manifold Pipe

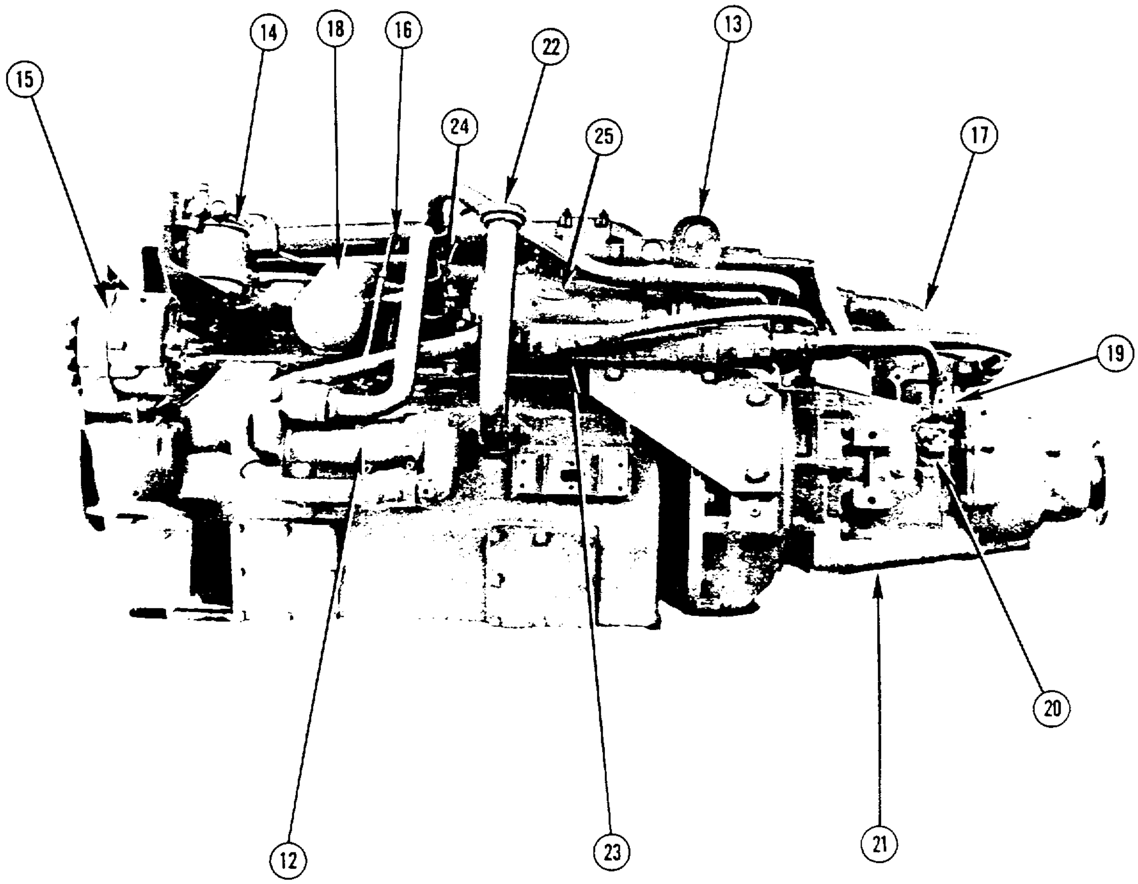



*Fig. 3(j)*

12. Oil Cooler
13. Lifting Bracket
14. Fuel Filter
15. Alternator
16. Dipstick
17. Air Charge Cooler
18. Lub Oil Filter
19. Gearbox Forward/Reverse Lever
20. Gearbox Filler/Dipstick
21. Gearbox
22. Lub Oil Filler Cap
23. Lub Oil/Gearbox Fluid Cooler
24. Sea Water Pump
25. Starter Motor

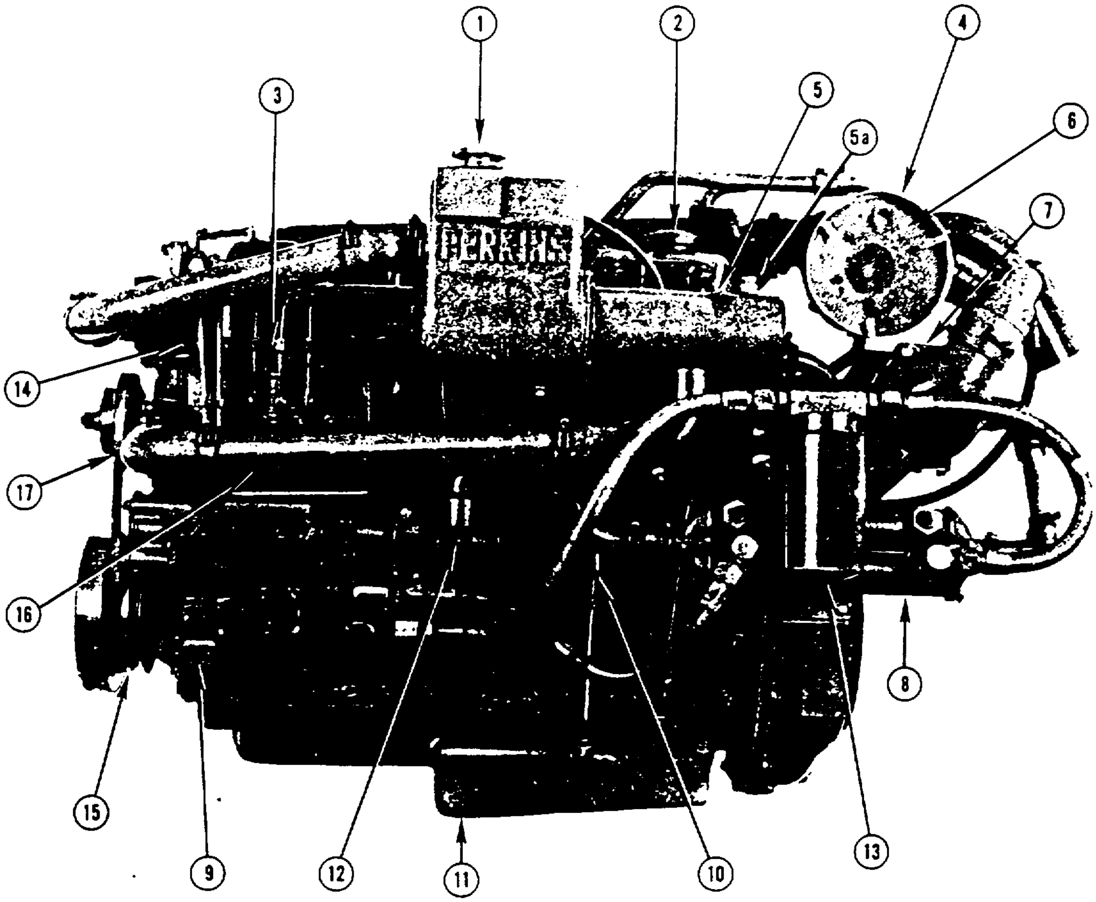



*Fig. 3(k)*

KEY TO T6.354 (M) ENGINE PHOTOGRAPH

1. Fresh Water Filler Cap
2. Lubricating Oil Filler Cap
3. Fuel Injection Pump
4. Turbocharger Air Intake
5. Heat Exchanger
5a. Zinc Anode
6. Air Cleaner
7. Air Charge Cooler
8. Oil Coolers
9. Front Engine Support Bracket
10. Lubricating Oil Pan Dipstick
11. Lubricating Oil Pan
12. Sea Water Pump (L.H. Rotating Engine)
13. Lubricating Oil Filter
14. Fuel Filter
15. Crankshaft Pulley
16. Fresh Water Pipe (Heat Exchanger to Pump)
17. Fresh Water Pump Pulley

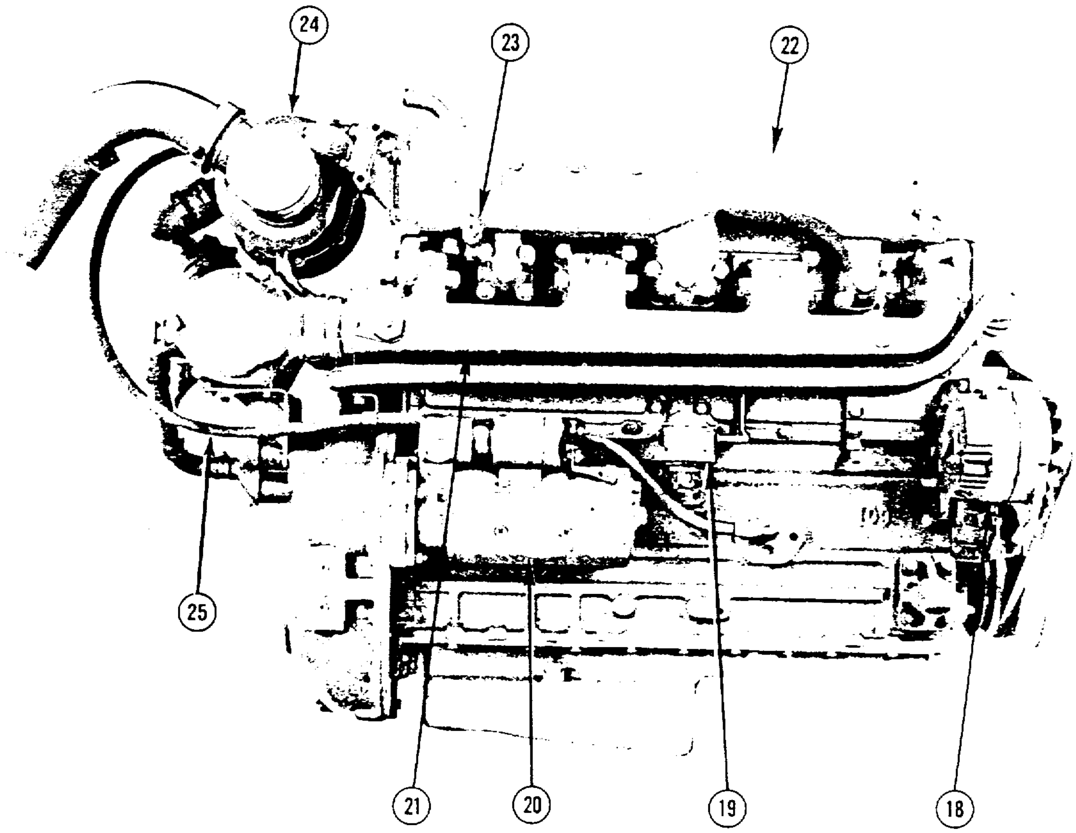



*Fig. 3(l)*

18. Alternator
19. Fuel Transfer Pump (with Priming Lever)
20. Starter Motor
21. Intake Manifold
22. Exhaust Manifold
23. Water Drain Tap
24. Turbocharger
25. Oil Line To Turbocharger

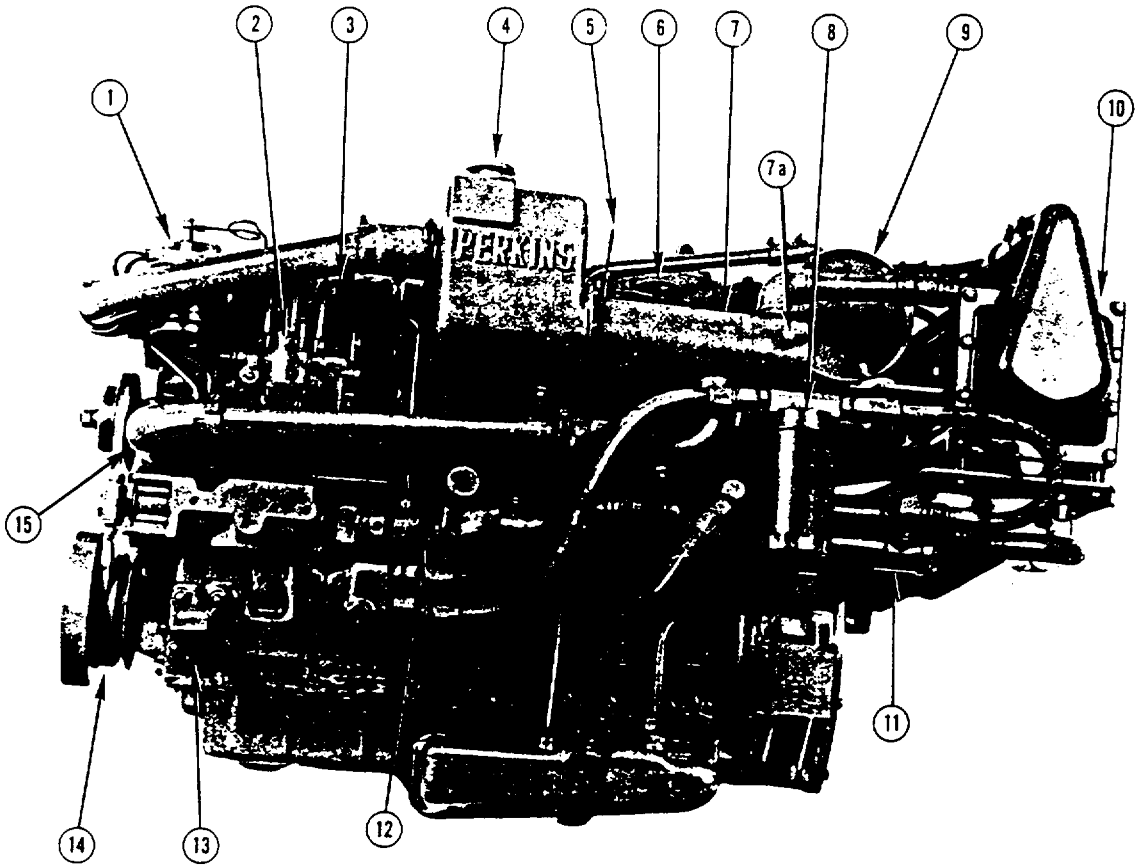



*Fig. 3 (m)*

KEY TO T6.354 MGT ENGINE PHOTOGRAPHS

1. Fuel Filter
2. Injection Pump
3. Injector
4. Fresh Water Filler Cap
5. Lub Oil Dipstick
6 Lub Oil Filler Cap
7. Heat Exchanger
7a. Zinc Anode
8. Lub Oil Filter
9. Air Filter
10. Intercooler
11. Oil Coolers
12. Sea Water Pump
13. Front Engine Mount
14. Crankshaft Pulley
15. Fresh Water Pump

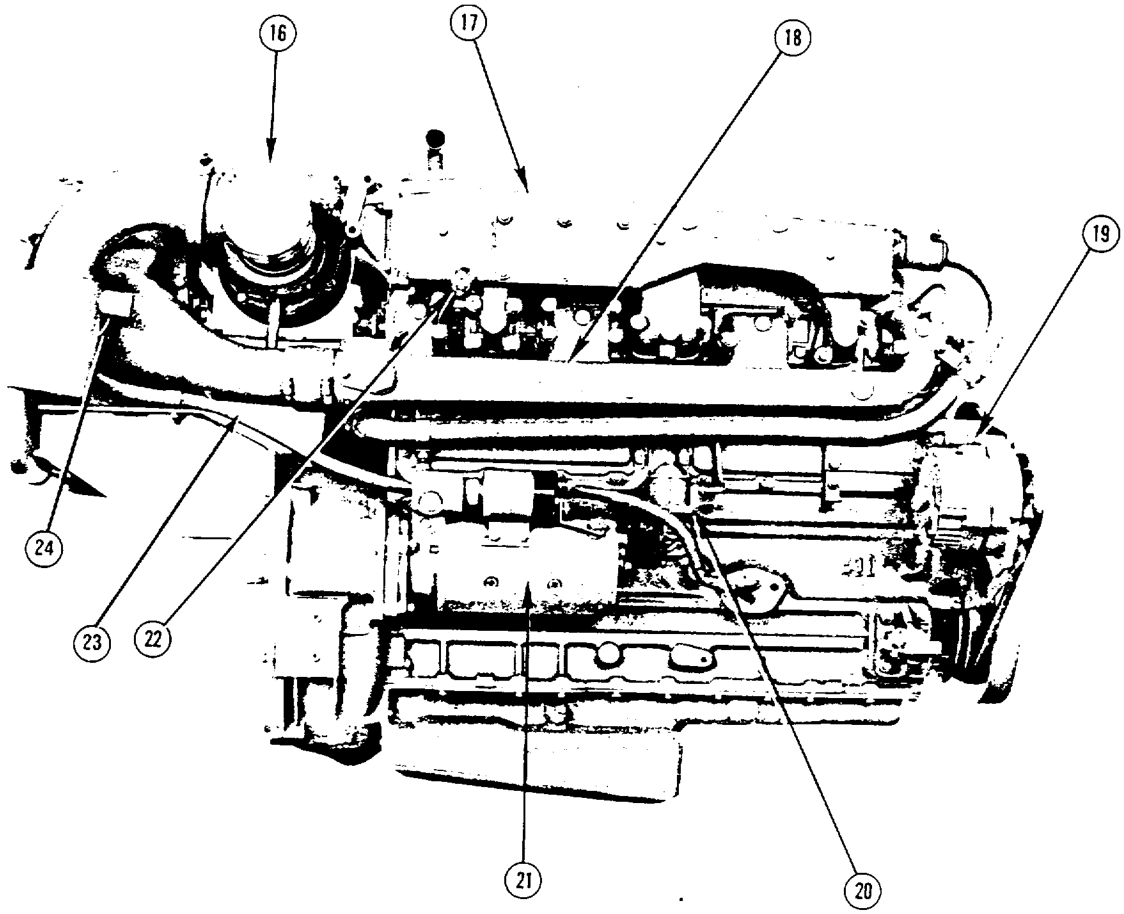



*Fig. 3(n)*

16. Turbocharger
17. Exhaust Manifold
18. Intake Manifold
19. Alternator
20. Fuel Lift Pump (with Priming Lever)
21. Starter Motor
22. Drain Tap
23. Oil Line to Turbocharger
24. Sea Water Inlet from Exhaust Manifold

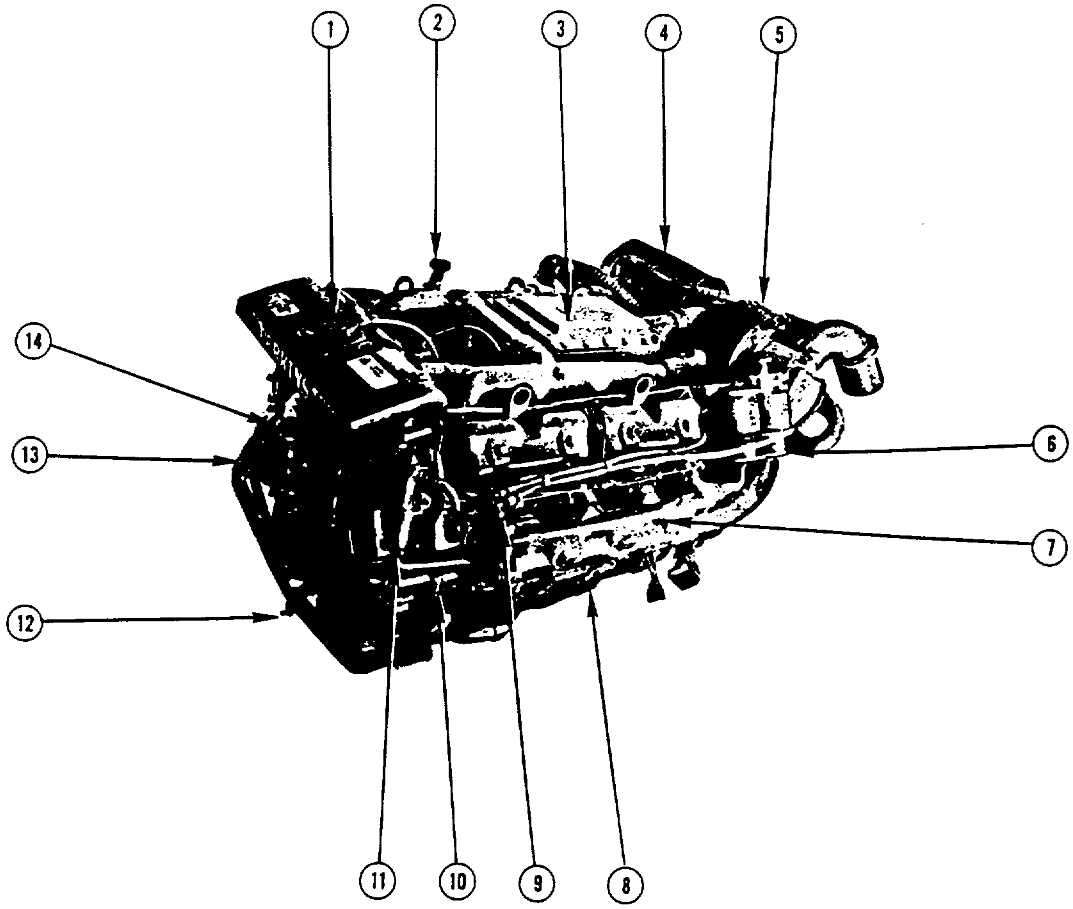



*Fig. 3(o)*

KEY TO TV8.510 (M) ENGINE PHOTOGRAPH

1. Fresh Water Filler Cap
2. Lub Oil Filler Cap
3. Intercooler
4. Air Filter
5. Turbocharger
6. Twin Element Fuel Filter
7. Exhaust Manifold
8. Starter Motor
9. Injector
10. Sea Water Pump
11. Oil Pan Drain Pump
12. Drain Tap
13. Alternator
14. Fresh Water Pump

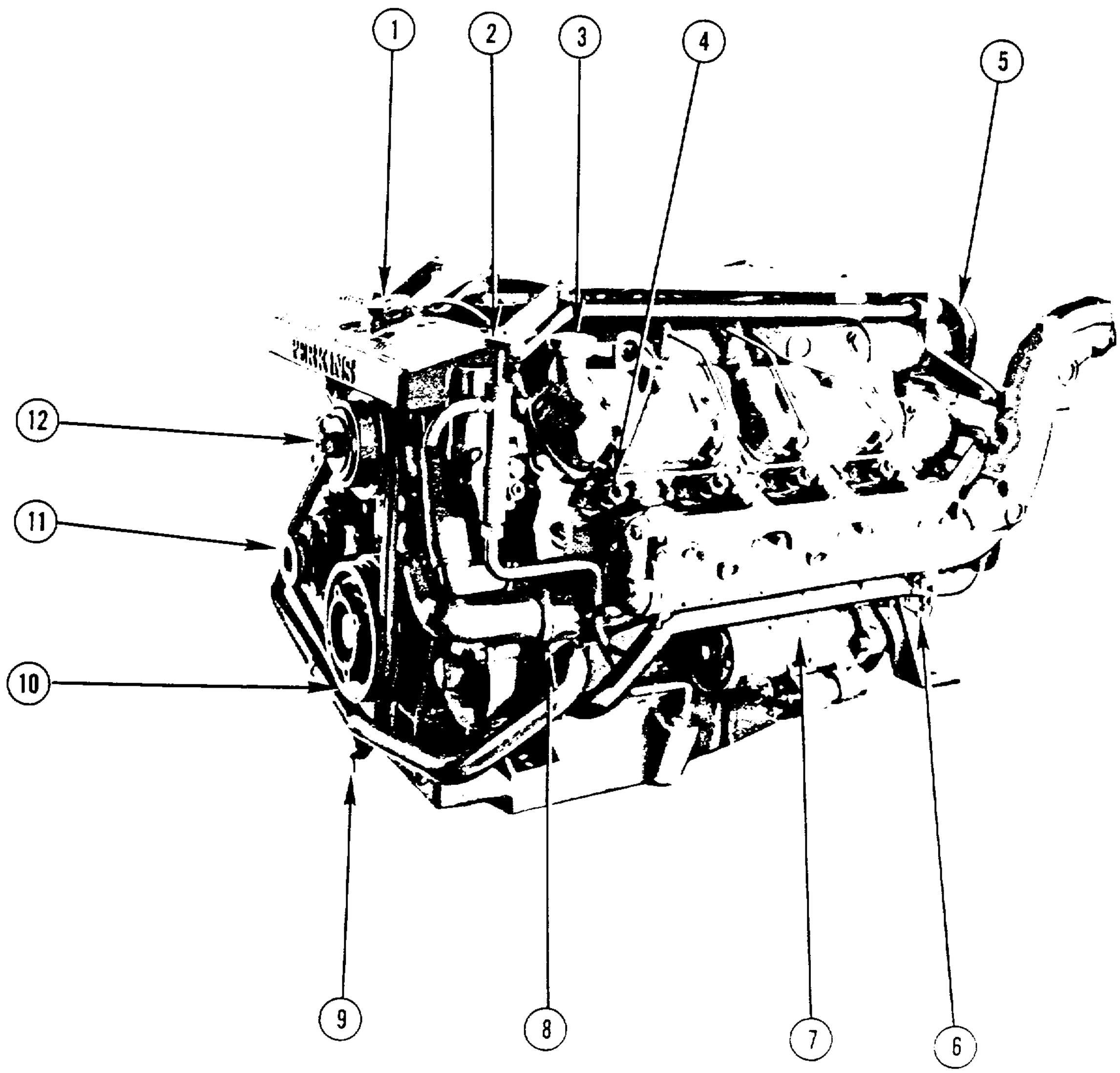



*Fig. 3(p)*

KEY TO V8.510 (M) ENGINE PHOTOGRAPH

1. Fresh Water Filler Cap
2. Oil Pan Drain Pump
3. Lub Oil Filler Cap
4. Injector
5. Air Intake Filter
6. Water Drain Tap
7. Starter Motor
8. Sea Water Pump
9. Water Drain Tap
10. Crankshaft Pulley
11. Alternator
12. Fresh Water Pump

**ENGINE SPECIFICATIONS**

| | 4.108 (M) |
|---|---|
| Engine Type: | In-Line 4-Cylinder, 4-Cycle, Indirect Injection |
| Maximum Shaft Horsepower: | 47 @ 4000* rpm (35.1 skw), 45 @ 3600 rpm (32.8 skw) |
| Displacement: | 107.4 cu. in. (1.76 Litres) |
| Bore and Stroke: | 3.125 x 3.5 in. (79.4 mm x 88.9 mm) |
| Compression Ratio: | 22:1 |
| Firing Order: | 1, 3, 4, 2 |
| Lub Oil Capacity: | 4.2 U.S. Quarts (3.97 Litres) |
| Coolant Capacity: | 2 U.S. Gallons (7.57 Litres) |
| *Special Rating | |

| | 4.154 (M) |
|---|---|
| Engine Type: | In-Line 4-Cylinder, 4 cycle, Indirect Injection |
| Maximum Shaft Horsepower: | 58 @ 3000 rpm (43.3 skw) |
| Displacement: | 153.9 cu. in. (2.53 Litres) |
| Bore and Stroke: | 3.5 x 4.0 in. (88.9 mm x 101.6 mm) |
| Compression Ratio: | 21.5:1 |
| Firing Order: | 1, 3, 4, 2 |
| Lub Oil Capacity: | 9.9 U.S. Quarts (9.37 Litres) |
| Coolant Capacity: | 3. U.S. Gallons (11.6 Litres) |

| | 4.236 (M) |
|---|---|
| *Engine Type: | In-Line 4-Cylinder, 4-cycle, Direct Injection |
| Maximum Shaft Horsepower: | 72 @ 2500 rpm (53.7 skw) |
| Displacement: | 235.9 cu. in. (3.88 Litres) |
| Bore and Stroke: | 3.875 x 5.0 in. (98.43 mm x 127 mm) |
| Compression Ratio: | 16:1 |
| Firing Order: | 1, 3, 4, 2 |
| Lub Oil Capacity: | 8.4 U.S. Quarts (7.95 Litres) |
| Coolant Capacity: | 3.5 U.S. Gallons (13.25 Litres) |

| | 6.354 (M) |
|---|---|
| Engine Type: | In-Line 6-Cylinder, 4-cycle, Direct Injection |
| Maximum Shaft Horsepower: | 115 @ 2800 rpm (85.8 skw) |
| Displacement: | 354.0 cu. in. (5.8 Litres) |
| Bore and Stroke: | 3.875 x 5.0 in. (98.4 mm x 127 mm) |
| Compression Ratio: | 16.1 |
| Firing Order: (Standard Rotation) | 1, 5, 3, 6, 2, 4 |
| Firing Order: (Contra-Rotation) | 1, 4, 2, 6, 3, 5 |
| Lub Oil Capacity: | 10.8 U.S. Quarts (10.22 Litres) |
| Coolant Capacity: | 5.4 U.S. Gallons (20.44 Litres) |

| | T6.354 (M) & HT6.354 (M) |
|---|---|
| Engine Type: | Turbocharged In-Line 6-Cylinder |
| 4-Cycle, Direct Injection | |
| Maximum Shaft Horsepower: | 145 @ 2400 rpm (108.2 skw) |
| Displacement: | 354.0 cu. in. (5.8 Litres) |
| Bore and Stroke: | 3.875 x 5.0 in. (98.4 mm x 127 mm) |
| Compression Ratio: | 15.5:1 |
| Firing Order (Standard Rotation) | 1, 5, 3, 6, 2, 4 |
| Firing Order: (Contra-Rotation) | 1, 4, 2, 6, 3, 5 |
| Lub Oil Capacity T6.354M | 12.6 U.S. Quarts (11.92 Litres) |
| Lub Oil Capacity HT6.354M | 13.8 U.S. Quarts (13.05 Litres) |
| Coolant Capacity: | 5.4 U.S. Gallons (20.44 Litres) |

| | T6.354 MGT |
|---|---|
| Engine Type: | Turbocharged In-Line 6-Cylinder, 4-Cycle, Direct Injection |
| Maximum Shaft Horsepower: | 175 @ 2400 rpm (130.6 skw) |
| Displacement: | 354.0 cu. in. (5.8 Litres) |
| Bore and Stroke: | 3.875 x 5.0 in. (98.4 mm x 127 mm) |
| Compression Ratio: | 15.5:1 |
| Firing Order: (Standard Rotation) | 1, 5, 3, 6, 2, 4 |
| Firing Order: (Contra-Rotation) | 1: 4, 2, 6, 3, 5 |
| Lub Oil Capacity: | 10.8 U.S. Quarts (10.22 Litres) |
| Coolant Capacity: | 5.4 U.S. Gallons (20.44 Litres) |

| | V8.510 (M) |
|---|---|
| Engine Type: | 90° V8-Cylinder, 4-Cycle, Direct Injection |
| Maximum Shaft Horsepower: | 172 @ 2800 rpm (128.3 skw) |
| Displacement: | 510.7 cu. in. (8.36 Litres) |
| Bore and Stroke: | 4.25 x 4.50 in. (108 mm x 114.3 mm) |
| Compression Ratio: | 16.5:1 |
| Firing Order: | 1, 8, 7, 5, 4, 3, 6, 2 |
| Lub Oil Capacity:. | 18.6 U.S. Quarts (17.6 Litres) |
| Coolant Capacity: | 9.3 U.S. Gallons (35.2 Litres) |

| | TV8.510 (M) |
|---|---|
| Engine Type: | Turbocharged 90° V8-Cylinder, 4-Cycle Direct Injection |
| Maximum Shaft Horsepower: | 235 @ 2600 rpm (175.3 skw) |
| Displacement: | 510.7 cu. in. (8.36 Litres) |
| Bore and Stroke: | 4.25 x 4.50 in. (108 mm x 114.3 mm) |
| Compression Ratio: | 15:1 |
| Firing Order: | 1, 8, 7, 5, 4, 3, 6, 2 |
| Lub Oil Capacity: | 18.6 U.S. Quarts (17.6 Litres) |
| Coolant Capacity: | 9.3 U.S. Gallons (35.2 Litres) |

## INSTRUMENTS

Engine monitoring instruments provide the operator with important information concerning the operating condition of the engine. Generally, the instruments are not as precise as test instruments but they will provide sufficiently accurate indications of the operating condition of the engine.

## ENGINE OIL PRESSURE GAUGE

This is one of the most important instruments and should be checked as soon as the engine starts. Normal oil pressure is 30/60 P.S.I. (2.1/4.2 kgf/cm 2) at maximum engine speed with the engine at normal operating temperature. During the life of the engine, as bearing surfaces wear, there will be a gradual decrease in pressure, There will also be a slight decrease in pressure when the oil is hot or if the wrong grade of oil is used during certain climatic conditions. Refer to page 58 for the correct oil grades.

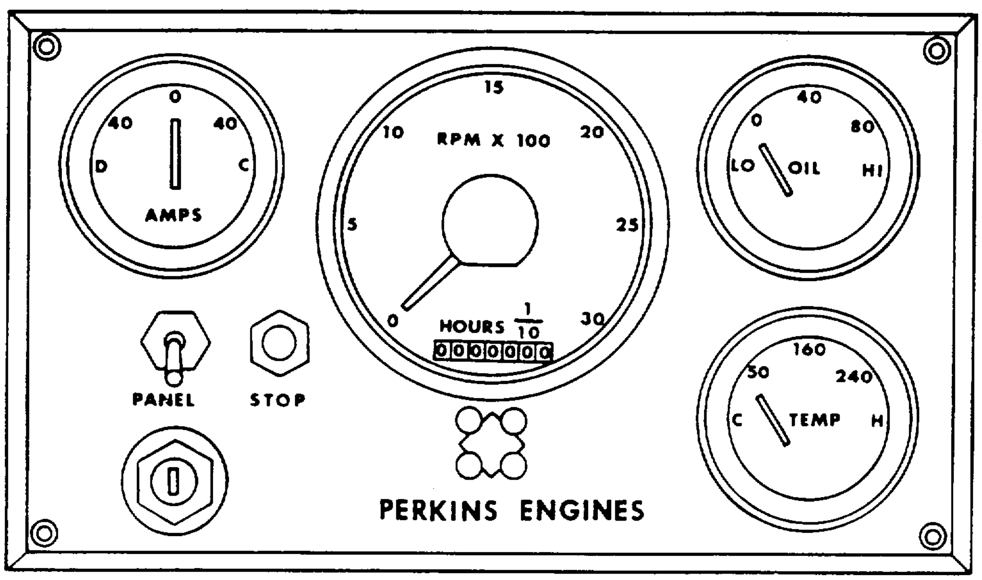



*Fig. 4 Typical Instrument Panel*

## TACHOMETER

This instrument provides the operator with the speed, in revolutions per minute (rpm), of the engine crankshaft. The value indicated on the dial usually has to be multiplied by one hundred (100) to arrive at the engine rpm. (e.g., 20 x 100 = 2,000 rpm).

NOTE: Initial calibration may be required for certain tachometers.

## WATER TEMPERATURE GAUGE

This instrument provides the operator with the temperature of the engine coolant. The coolant temperature (normal) should remain within the ranges listed on page 54. If a higher than normal temperature is experienced, investigate and correct immediately (refer to page 54).

## AMMETER

This instrument provides the operator with an indication of whether or not the battery is being charged by the alternator. An indication that the battery is discharging should be investigated and corrected immediately.

## STARTING AND STOPPING ENGINE

### PREPARATION FOR STARTING

ENSURE FUEL IS TURNED ON!

Open engine coolant seacocks (does not apply to keel cooled engines).

Check coolant level in header tank.

Check engine and gearbox lubricating oil levels (see pages 56 and 59 for oil specifications).

When checking oil level on HT6.354 engines, the procedure outlined on page 56 should be followed. If a V8.510 engine (with in-line pump) has not been running for a period exceeding one month, a pint of engine lub oil should be added to the fuel injection pump through the filler plug. (See 1, Fig. 12 (b), page 50).

Ensure that the fuel tank contains considerably more than the amount of fuel necessary for the intended voyage. The fuel oil should conform to one of the specifications listed on page 45.

External assemblies and accessories driven by an engine, such as pulleys, belts, and alternator/generator, are hazardous to anyone attempting to repair or service it while it is operating. If possible, always stop your engine before servicing it. When necessary to repair or adjust an operating engine, use extreme caution and do not wear loose clothing.

### STARTING THE ENGINE

Engine controls and instruments will vary according to each individual boat builders preference but, in general, the following instructions are applicable to all Perkins marine engines installed in boats manufactured in North America.

1. Place the gearbox in neutral position (Borg-Warner gearboxes have a neutral safety switch that prevents starting in any other position).

   If the engine has not been started for five or more days, it may be necessary to either turn the engine over several times with the starter or operate the priming lever several times to build up the fuel pressure.

2. Place the engine speed control at the maximum *speed position.

3. Press start button or turn the key in clockwise direction release as soon as the engine starts. If the engine fails to run, ensure that the starter pinion and engine have stopped rotating before re-engaging the starter motor. Otherwise, the flywheel ring and starter pinion could be damaged.

4. Place the engine speed control at the position of desired engine rpm.

*For TV8.510 (M) engines, place the engine speed control at one-quarter (1/4) of maximum speed if the engine or weather is warm or at the maximum speed position, if cold.

## COLD WEATHER STARTING

The exact temperature where use of a "Thermostart" is necessary varies from engine to engine and also according to many other variables. In general, if the temperature is below 40°F (30 4°C) and, upon attempting to start an engine, it turns over rapidly, exhausts white smoke but does not start, the use of a "Thermostart" is necessary.

TO USE A THERMOSTART -

1. If the fuel line has a valve, ensure that it is turned to the "on" position.

2. Move the speed control to the maximum position.

3. Push and hold the button labeled "Heater" for 15 to 20 seconds. (Note: Some installations employ key start switches with a "Heater" position).

4. Engage the starter motor. If the engine does not start in 20 seconds, release the button. After 10 seconds re-engage the starter motor. If the engine will not start, check to ensure there is fuel at the inlet and 12Vat the electrical terminal on the "Thermostart". If both are present, remove the air filter housing (or air duct) and visually observe the device to determine if it glows red when the heater switch is engaged. If not, the device is faulty and must be replaced. If there is no fuel at the inlet, ensure that all valves between the fuel supply source and the "Thermostart" are open. If this is not the cause, the next step is to "bleed" the low pressure fuel system. Refer to "bleeding", page 46. If 12V are not available, troubleshoot electrical system.

5. As soon as the engine starts, release starter switch, adjust the throttle for the lowest smooth running engine rpm and allow the engine to warm up.

6. If applicable, close the "Thermostart" fuel supply valve.

## INITIAL OPERATING CHECKS

When the engine starts, check:
1. Oil pressure gauge for sufficient oil pressure.
2. Alternator ammeter for an indication that the battery is being re-charged.
3. Sea water coolant discharge for evidence of proper circulation (not applicable to keel cooled engines).

## OPERATING PRECAUTIONS

A new Perkins engine can be operated at full load when first used, provided sufficient time Is allowed for the engine to attain a temperature of at least 140°F (60°C) before full load is applied. Gradual engine "break-in" is not necessary. In fact, prolonged engine operation with a light load can be harmful because, under these conditions, the piston rings may not seat properly within the cylinder liners.

Engine oil pressure and level should be very closely monitored until it has been established that the engine is functioning normally.

Do not operate the engine at maximum speed for long periods of time. The table on page 33 lists the maximum intermittent and continuous speeds for each respective engine type. An engine should not be operated at maximum speed for a period in excess of one hour. After operating at maximum speed, reduce the speed to maximum continuous rpm* for at least 15 minutes before returning to maximum speed. If an engine is "loaded down" and runs at less than the maximum speed when at full throttle, the same precaution applies.

*The speed of pleasure craft TV8.510 (M) engines must be reduced 200 rpm for a period of two hours before being returned to maximum.

| ENGINE TYPE | MAXIMUM INTERMITTENT SPEED (RPM) | MAXIMUM CONTINUOUS SPEED (RPM) |
|---|---|---|
| 4.108 (M) | 3,600<br>4,000<br>(Special Rating) | 3,000 |
| 4.154 (M) | 3,000 | 3,000 |
| 4.236 (M) | 2,500 | 2,250 |
| 6.354 (M) | 2,800 | 2,400 |
| T6.354 (M)<br>HT6.354 (M) | 2,400 | 2,250 |
| T6.354 MGT | 2,400 | 2,250 |
| V8.510 (M) | 2,800 | 2,500<br>(Medium Duty Rating)<br>2,000<br>(Heavy Duty Rating) |
| TV8.510 (M) | 2,600<br>(Pleasure Craft, planing and light displacement) | 2,400 |
| | 2,400<br>(Light Commercial craft) | 2,200 |

**STOPPING THE ENGINE**

A spring loaded "stop control" push button switch (electric) is located on or near the instrument panel. This switch, in conjunction with a solenoid on the injection pump, functions to stop the flow of fuel to the injection pump.

To stop the engine, press the button until the engine stops running, release, turn the key to the "off" position and place the engine speed control in the minimum speed position.

Some boats may have a mechanical spring loaded pull-to-stop control instead of an electric push button. To stop an engine having this type of control, pull the knob and hold until engine rotation ceases. Upon releasing the knob, ensure it returns to its normal position (i.e., the "run" position) so that the engine may be re-started without difficulty.

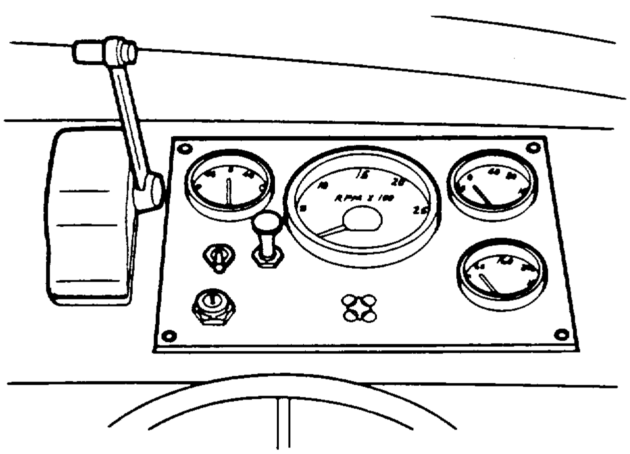


*Fig. 5 Typical Engine Control Console*

## SCHEDULED MAINTENANCE

A Perkins marine engine will have a long and trouble free life provided it is maintained in accordance with the following schedule:

<u>4.108 (M) Engines</u>

DAILY

Check coolant in header tank (see warning on Page 54).
Check engine lub oil level (see page 56).
Check engine oil pressure (if equipped with gauge).
Check gearbox fluid level (see page 59).

FIRST 25/50 HOURS

Change engine lub oil (see page 58).
Renew engine lub oil filter element (s) (see page 57).
Check cylinder head nuts/setscrews for correct torque (see page 41).
Set valve clearances to 0.012 in. (0.30 mm) cold (see page 61).
Check coolant level (header tank) and inspect for coolant leaks.
Check external nuts, setscrews, mounting, etc. for tightness.
Check drive belt tension (see page 56).
Check electrical equipment and connections.
Check for lub and fuel oil leaks.
Check engine idling speed (see page 50).
Check general performance of engine.

EVERY 100 HOURS OR 2 MONTHS (WHICHEVER OCCURS FIRST)

Change engine lub oil (see page 58).
Renew engine lub oil filter element (s) (see page 57).
Clean air intake filter.
* Check drive belt tension (see page 56).
Clean water trap (if equipped).
Check engine for leakage of oil and water.
Change gearbox fluid (Paragon) (see page 61).

EVERY 400 HOURS OR 12 MONTHS (WHICHEVER OCCURS FIRST)

Renew final fuel filter element (see page 49).
Check hoses and clamps.
Drain and clean fuel tank.
Change gearbox fluid (Borg-Warner) (see page 59).

EVERY 800 HOURS

Check sea water pump impeller (see page 54).

EVERY 2,400 HOURS

Arrange for examination and service of accessory equipment, (i.e., starter motor, alternator, etc.).
Service injectors (see page 53).
Check and adjust valve tip clearances (see page 61).

*Drive belt tension should be checked monthly on engines rated above 3000 rpm.

4.154 (M) Engines

DAILY

Check coolant level in header tank(see warning on page 54).
Check engine lub oil level (see page 56).
Check engine oil pressure (if equipped with gauge).
Check gearbox fluid level (see page 59).

FIRST 25/50 HOURS

Change engine lub oil (see page 58).
Renew engine lub oil filter element (s) (see page 57).
Check cylinder head nuts/setscrews for correct torque (see page 41).
Set valve clearances to 0.012 in (0.30mm) cold (see page 61).
Check coolant level (header tank) and inspect for coolant leaks.
Check external nuts, setscrews, mountings, etc. for tightness.
Check drive belt tension (see page 56).
Check electrical equipment and connections.
Check for lub and fuel oil leaks.
Check engine idling speed (see page 50).
Check general performance of engine.

EVERY 100 HOURS OR 2 MONTHS (WHICHEVER OCCURS FIRST)

Clean air intake filter.

EVERY 200 HOURS OR 4 MONTHS (WHICHEVER OCCURS FIRST)

Change engine lub oil (see page 58).
Renew engine lub oil filter element (s) (see page 57).
Check drive belt tension (see page 56).
Check engine for leakage of oil and water.
Clean water trap (if equipped).

EVERY 400 HOURS OR 12 MONTHS (WHICHEVER OCCURS FIRST)

Renew final fuel filter element.
Check hoses and clamps.
Drain and clean fuel tank.
Change gearbox fluid (see page 59).

EVERY 800 HOURS

Check sea water pump impeller (see page 54).

EVERY 2,400 HOURS

Arrange for examination and service of accessory equipment (i.e., starter motor, alternator, etc.).
Check and adjust valve tip clearances (see page 61).
Service injectors (see page 53).

4.236 (M) Engines

DAILY

Check coolant level in header tank (see warning on page 54).
Check engine lub oil level (see page 56).
Check engine oil pressure (if equipped with gauge).
Check gearbox fluid level (see page 59).

FIRST 25/50 HOURS

Change engine lub oil (see page 58).
Renew engine lub oil filter element (s) (see page 57).
Check cylinder head nuts/setscrews for correct torque (see page 41).
Set valve clearances to 0.012 in. (0.30 mm) cold (see page 61).
Check coolant level (header tank) and inspect for coolant leaks.
Check external nuts, setscrews, mounting, etc. for tightness.
Check drive belt tension (see page 56).
Check electrical equipment and connections.
Check for lub and fuel oil leaks.
Check engine idling speed (see page 50).
Check general performance of engine.

EVERY 100 HOURS OR 2 MONTHS (WHICHEVER OCCURS FIRST)

Clean air intake filter.

EVERY 200 HOURS OR 4 MONTHS (WHICHEVER OCCURS FIRST)

Change engine lub oil (see page 58).
Renew engine lub oil filter element (s) (see page 57).
Check drive belt tension (see page 56).
Check engine for leakage of oil and water.
Clean water trap (if equipped).

EVERY 400 HOURS OR 12 MONTHS (WHICHEVER OCCURS FIRST)

Renew final fuel filter element (see page 49).
Check hoses and clamps.
Clean fuel lift pump strainer.
Drain and clean fuel tank.
Change gearbox fluid (see page 59).

EVERY 800 HOURS

Check sea water pump impeller (see page 54).

EVERY 2,400 HOURS

Arrange for examination and service of accessory equipment
(i.e., starter motor, alternator, etc.)
Service injectors (see page 53).
Check and adjust valve tip clearances (see page 61).

6.354 (M), T6.354 (M), T6.354 MGT & HT6.354 (M) Engines

DAILY

Check coolant level (see warning on page 54).
Check engine lub oil level (see page 56).
Check engine oil pressure (if equipped with gauge).
Check gearbox fluid level (see page 59).

FIRST 25/50 HOURS

Change engine lub oil (see page 58).
Renew engine lub oil filter element (s) (see page 57).
Check cylinder head nuts/setscrews for correct torque (see page 40).
Set valve clearances to 0.012 in. (0.30 mm) cold (see page 61).
Check coolant level (header tank) and inspect for coolant leaks.
Check external nuts, setscrews, mountings, etc. for tightness.
Check drive belt tension (see page 56).
Check electrical equipment and connections.
Check for lub and fuel oil leaks.
Check engine idling speed (see page 50).
Check general performance of engine.

EVERY 100 HOURS OR 2 MONTHS WHICHEVER OCCURS FIRST)

Clean air intake filter.
Change engine lub oil - Turbocharged engines with API "CC" oil only.
(see page 58).
Service Injectors (T6.354 MGT only).

EVERY 200 HOURS OR 4 MONTHS (WHICHEVER OCCURS FIRST)

Change engine lub oil (see page 58).
Renew engine lub oil filter element (s) (see page 57).
Check drive belt tension (see page 56).
Clean water trap (if equipped).
Check engine for leakage of oil and water.

EVERY 400 HOURS OR 12 MONTHS (WHICHEVER OCCURS FIRST)

Clean fuel lift pump strainer.
Renew final fuel filter element (see page 49).
Check hoses and clamps.
Drain and clean fuel tank.
Change gearbox fluid (Borg-Warner), (see page 59).

EVERY 800 HOURS

Clean turbocharger impeller, diffuser and oil drain pipe.
Change gearbox lub oil (Twin Disc MG-502 and MG-506), (see page 59).
Check sea water pump impeller (see page 54).
(NOTE: For engines equipped with air charge (intercoolers) coolers refer to page 55).

EVERY 2,400 HOURS

Arrange for examination and service of accessory equipment(i.e., starter motor, alternator, etc.).
Service Injectors (see page 53).
Check and adjust valve tip clearances (see page 61).

V8.510 (M) Engines

DAILY

Check coolant level (see warning on page 54).
Check engine lub oil level (see page 56).
Check oil pressure (if equipped with gauge).
Check gearbox fluid or lub oil level (see pages 59 and 61).

FIRST 25/50 HOURS

Change engine lub oil (see page 58).
Renew engine lub oil filter element (s) (see page 57).
Set valve clearances to 0.012 in. (0.30 mm) cold (see page 61).
Check coolant level (header tank) and inspect for coolant leaks.
Check external nuts, setscrews, mountings, etc. for tightness.
Check drive belt tension (see page 56).
Check electrical equipment and connections.
Check for lub and fuel oil leaks.
Check engine idling speed (see page 50).
Check general performance of engine.

EVERY 100 HOURS OR 2 MONTHS (WHICHEVER OCCURS FIRST)

Clean air intake filter.

EVERY 200 HOURS OR 4 MONTHS (WHICHEVER OCCURS FIRST)

Change engine lub oil (see page 58).
Renew engine lub oil filter elements (see page 57).
Check drive belt tension (see page 56).
Clean water trap (if equipped)
Check engine for leakage of oil and water.

EVERY 400 HOURS OR 12 MONTHS (WHICHEVER OCCURS FIRST)

Renew final fuel filter elements (see page 49).
Service injectors (see page 53).
Check and adjust valve tip clearances (see page 61).
Check hoses and clamps.
Drain and clean fuel tanks.
Change gearbox fluid (Borg-Warner), (see page 59).
Clean fuel lift pump strainer.

EVERY 800 HOURS

Check sea water pump impeller (see page 54).
Change gearbox lub oil (Twin Disc MG-506 and MG-502), (see page 59).

EVERY 2,400 HOURS

Arrange for examination and service of accessory equipment (i.e., starter motor, alternator, etc.).

TV8. 510 (M) Engines

DAILY

Check coolant level (see warning on page 54).
Check engine lub oil level (see page 56).
Check gearbox fluid or lub oil level (see pages 59 and 61).
Check oil pressure (if equipped with gauge).

FIRST 25/50 HOURS

Change engine lub oil (see page 58).
Renew engine lub oil filter elements (see page 57).
Set valve clearances to 0.012 in (0.30 mm) cold (see page 61).
Check coolant level (header tank) and inspect for coolant leaks.
Check external nuts, setscrews, mountings, etc., for tightness.
Check drive belt tension (see page 56).
Check electrical equipment and connections.
Check for lub and fuel oil leaks.
Check engine idling speed (see page 50).
Check general performance of engine.

EVERY 100 HOURS OR 2 MONTHS (WHICHEVER OCCURS FIRST)

Clean air intake filter.
Change engine lub oil if using API "CC" oil (see page 58).

EVERY 200 HOURS OR 4 MONTHS (WHICHEVER OCCURS FIRST)

Change engine lub oil if using API "CD" oil (see page 58).
Renew engine lub oil filter elements (see page 57).
Check drive belt tension (see page 56).
Service injectors (see page 53).
Clean water trap (if equipped).
Check engine for leakage of oil and water.

EVERY 400 HOURS OR 12 MONTHS (WHICHEVER OCCURS FIRST)

Renew final fuel filter elements (see page 49).
Check and adjust valve tip clearances (see page 61).
Check hoses and clamps.
Drain and clean fuel tanks.
Change gearbox fluid (Borg-Warner), (see page 59).
Check gearbox oil/fluid cooler for water flow restrictions (see page 55).
Clean fuel lift pump strainer.

EVERY 800 HOURS

Clean turbocharger impeller, diffuser and oil drain pipe.
Check sea water pump impeller (see page 54).
Change gearbox lub oil (Twin Disc MG-502 and MG-506) (see page 59).

EVERY 2,400 HOURS

Arrange for examination and service of accessory equipment (i.e., starter motor, alternator, etc.). See page 62 for Air Charge Cooler servicing.

ALL ENGINES

The intervals listed are general in their application. The operator should compare the maintenance schedule for his particular engine with the schedule established by the manufacturer of his boat and should always adopt the shorter interval. Also, the maintenance intervals should be reduced to conform with any exceptional operating condition. such as continuous sustained high speeds or temperatures.

An operator usually is familiar with the water he is operating in, therefore, checking the weed trap (at the water intake) at appropriate intervals is left to his discretion.

The zinc pencil (anode) in the heat exchanger will need replacing periodically in accordance with the operating conditions of the boat and engine. Refer to the engine photographs for the respective location (not applicable to 4.154 (M) and V8.510/TV8. 510 (M) engines).

The thermostat, in carrying out its function of controlling temperature can, contrary to general thoughts on the method of its operation, open and close numerous times during each hour of engine operation. In so doing, like any other type of mechanical device, it may not maintain its efficiency indefinitely. Therefore, it is recommended that it be replaced after each two years of operation or more frequently if there are indications that it is not functioning correctly.

CYLINDER HEAD TIGHTENING SEQUENCES

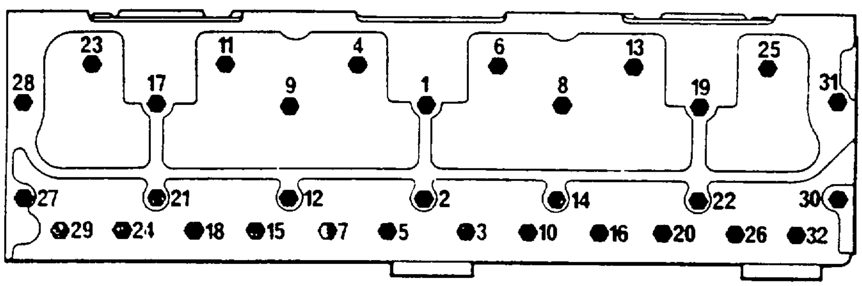



*Fig. 6(a) Tightening Sequences for Cylinder Head Nuts and/or Setscrews 6.354 (M), T6,354 (M), HT6.354 (M), T6.354 MGT*

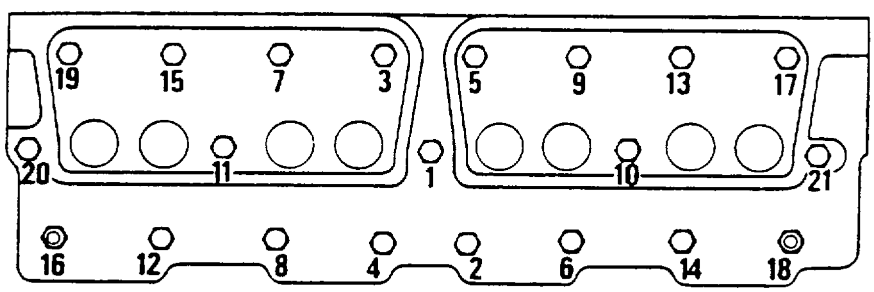



*Fig. 6(b) Tightening Sequence for Cylinder Head Nuts and/or Setscrews V8.510/TV8.510 (M)*
*(Applicable To Both Banks.)*

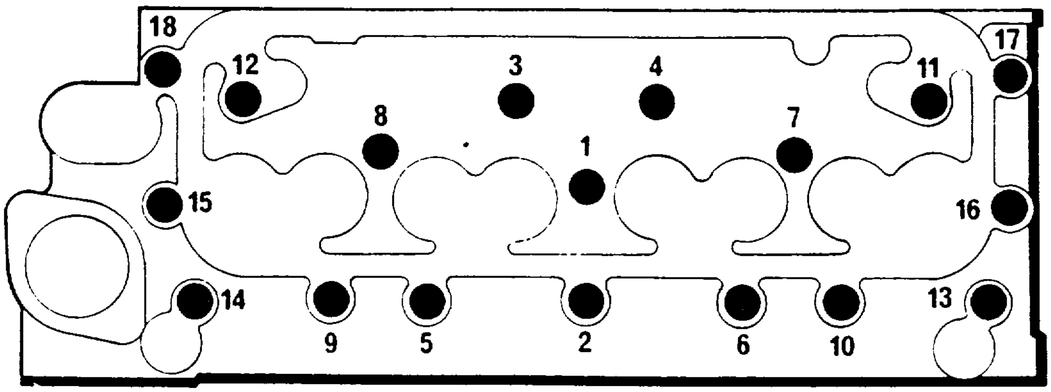



*Fig. 6(c) 4.108 (M)*

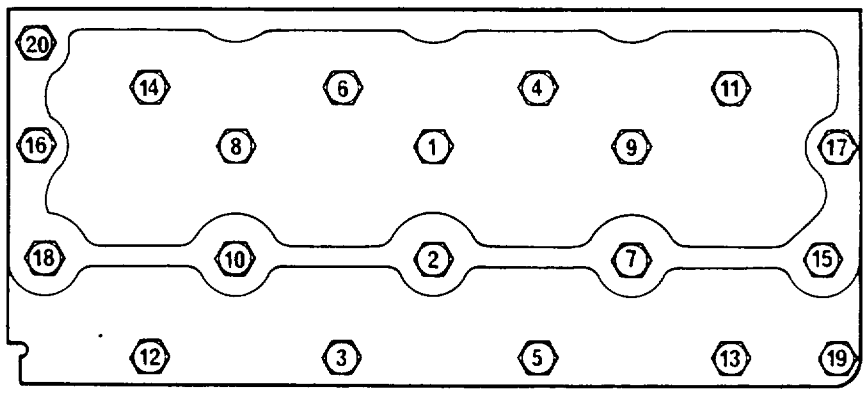



*Fig. 6 (d) 4.154 (M)*

| Cylinder Head Nuts and/or Setscrews | Torque Tension lbf ft. | kgf m |
|---|---|---|
| 4.108 (M) | 60 | 8.3 |
| 4.154 (M) | 85 | 11.75 |
| 4.236 (M) | 100 | 13.8 |
| 6.354 (M) | 100 | 13.8 |
| T6.354 (M), HT6.354 (M), T6.354 MGT | 100 | 13.8 |
| V8.510/TV8.510 (M) | 125 | 17.3 |

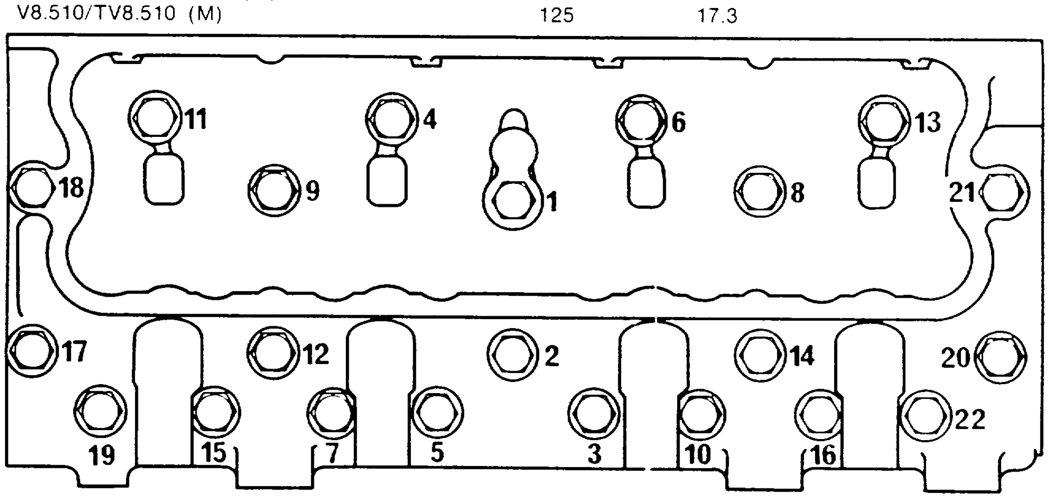



*Fig. 6 (e) 4.236 (M)*

**ENGINE PRESERVATION**

If a boat is to be stored for several months, the engine should be preserved as follows:

1. Clean all external parts.
2. Run engine until warm. Stop and drain the lub oil pan.
3. Discard lub oil filter element (s), clean base (s), fill elements with new oil of an approved grade and install new element (s) (refer to page 57).
4. Clean engine breather pipe (s).
5. Fill lub oil pan to correct level with new oil of an approved grade (refer to page 58).
6. Drain all fuel oil from fuel tanks and filters. Put at least one gallon of inhibiting oil into the fuel tank (refer to "Oil Recommended for Preservation of Fuel System", Page 44). If, because of the construction of the fuel tank, this quantity of oil is inadequate, disconnect the fuel feed line before the first filter and connect a small capacity auxiliary tank. If the tank (s) cannot be drained, they should be filled with fuel and a temporary tank (inserted in the fuel feed line) should be filled with an inhibiting oil.
7. Bleed the fuel system as detailed on page 46.
8. Start engine and run it at half speed for 15 minutes to circulate the oil through the injection pump, pipes and injectors.
9. Seal the tank air vent (or filler cap) with waterproof adhesive tape.

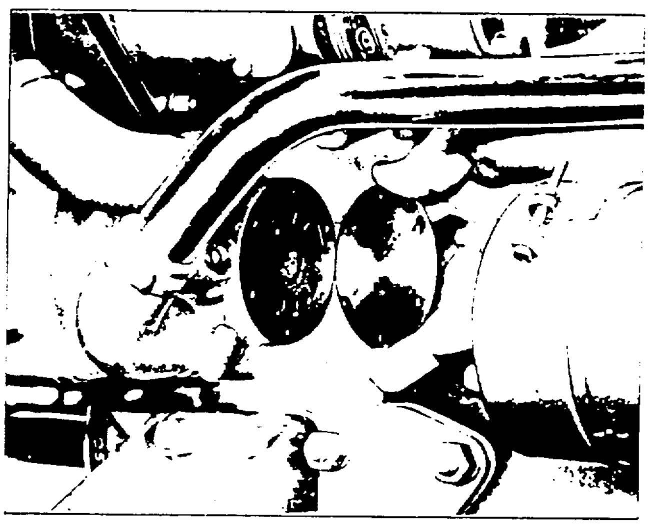


*Fig. 7 (a)*

*Fig. 7 (b)*

10. Drain water from heat exchanger and engine cylinder block. The heat exchanger should be removed and serviced. The cylinder block may be back-flushed through the drain points with the thermostat removed. If it is decided to refill the fresh water system partially with antifreeze, the precaution on page 45 should be noted. For 4.108 engines, "bleeding" may be necessary when filling the cooling system (refer to page 44, item 6)

11. Remove the end plate from the sea water circulating pump and lubricate the interior of the pump body with Glycerine or MARFAK 2HD grease (refer to Fig. 7) or remove impeller for the preservation period.

12. Remove the injectors and spray into the cylinder bores /4 pint (0.014 litre) of lubricating oil divided between all cylinders. Rotate the crankshaft one complete revolution and replace injectors. Direct injection engines require an atomized spray.

13. Remove the air cleaner (s) and any piping. Seal the air intake with waterproof adhesive tape.

14. Remove the exhaust pipe (s) and seal the manifold port.

15. Remove cylinder head cover (s), lubricate the rocker assembly and replace cover (s).

16. Remove water pump drive belt (s).

17. BATTERIES
    a. Remove the battery (s) and fill cells with distilled water.
    b. Recharge (see warning on page 63).
    c. Clean the terminals and lightly smear with petroleum jelly.
    d. Store in a cool, dry, dust free place. Avoid any freezing risk.
    e. Recharge once a month.
18. STARTERS AND ALTERNATORS

    Clean terminals and smear lightly with petroleum jelly. The alternator, starter, and terminals must be protected from precipitation.

## OIL RECOMMENDED FOR PRESERVATION OF FUEL SYSTEM

A fuel oil having the following characteristics should be used for preservation of the fuel system.

| | |
|---|---|
| Viscosity: | Should not be greater than 22 centistokes at the lowest ambient temperature expected upon restarting. |
| Pour Point: | Must be at least 150 (-10°C) lower than the lowest ambient temperature expected upon restarting and should be lower than the lowest temperature likely to be encountered during the storage period. |
| Example: | Shell Fusus "A" or equivalent. In the event an oil of this type is not available, use clean, new #1 diesel fuel to prevent waxing at low temperatures. |

## PREPARING THE ENGINE FOR OPERATION

When the engine is to be returned to operating condition, the following procedure must be followed:

1. Thoroughly clean all external parts and reinstall the sea water pump impeller (if removed).
2. Remove tape from the fuel tank vent (or filler cap).
3. Drain fuel tank to remove any remaining oil and condensed water and refill the tank with fuel oil. If tanks have been filled in lieu of draining, drain the water from the trap (if provided by the boat builder).
4. Install new fuel filter element and vent the filter (see page 46).
5. Vent and prime the fuel injection pump (see page 46).
6. Close all coolant drain taps and fill the system with clean coolant. Check for leaks. If a 4.108 marine engine is installed with the front of the engine lower than the rear of the engine (this is note recommended installation), it is possible for an air lock to develop when the cooling system is refilled. To prevent this, loosen the plugs on top of the manifold and cylinder head so that the air can escape during the refilling operation.
7. Rotate fresh water coolant pump by hand to ensure freedom of the water pump seals. If the pump will not rotate with a reasonable amount of force, it will have to be removed to determine the cause of the restriction.
8. Reinstall water pump drive belt (s).
9. Remove the rocker cover (s), lubricate rocker assembly (s) with engine oil, and replace cover (s).
10. Remove tape from the air intake (s), clean filter (s), reinstall the air cleaner (s), and any removed intake pipe.
11. Remove tape from the exhaust manifold port and reinstall the exhaust pipe (s).
12. STARTER AND ALTERNATOR Wipe the petroleum jelly from the terminals and check that all connections are secure.
13. Connect the battery (s)
14. Check the level and condition of the lub oil in the oil pan. Change the oil if necessary. Attend to the oil level in the in-line fuel injection pump (see page 48).
15. Open raw water seacocks.
16. Start the engine in the normal manner and check for sufficient oil pressure and battery charge. While the engine is reaching its normal operating temperature, check for water and oil leaks.

**NOTE:**
**If the foregoing instructions are observed, the storage and return to operation should be efficient and without any adverse effect on the engine. However, Perkins Engines cannot accept liability for direct or consequential damage that might arise following periods of storage.**

**COLD WEATHER PRECAUTIONS**

Precautions against damage from freezing should be taken If the engine is to be left exposed to cold weather. Either drain the cooling system or, where this is not convenient, a good quality anti-freeze that incorporates a suitable corrosion inhibitor may be used.

If anti-freeze Is used to protect an engine from freeze damage, ascertain whether it is suitable for use in Perkins Engines and also ensure that it will have no harmful effect on the cooling system in general. Most popular brands (e.g., Prestone) are acceptable.

**WARNING: HARMFUL OR FATAL IF SWALLOWED. If anti-freeze is swallowed, induce vomiting immediately. Call a physician. Do not store in open or unlabeled containers. KEEP OUT OF REACH OF CHILDREN.**

To drain the cooling system, the taps on the cylinder block must be opened. There may be other drain taps on the exhaust manifold, oil cooler. etc., all of which must be opened.

When the engine is drained, the fresh water pump will also drain but. In sub-freezing weather. rotation of the pump may be prevented by:

a. locking of the impeller by ice because the pump hole was blocked by sediment and the pump was not completely drained.
b. locking of the seal because of frozen globules of moisture between the seal and the gland.

When operating in sub-freezing weather:

1. Before starting the engine turn the fresh water pump by hand; this will indicate if the pump is frozen. If frozen, this should free any ice formation.
2. If it is impossible to turn the pump by hand, the engine should be filled with warm water
3. To avoid this trouble, it is advisable, after the water has been drained, to run the engine for a few seconds at idling speed. This will disperse any moisture remaining In the pump After an anti-freeze solution has been used, the cooling system should be thoroughly flushed in accordance with the manufacturers instructions before refilling with normal coolant.

If the foregoing action is taken no harmful effects should be experienced but Perkins cannot be held responsible for any freeze damage or corrosion which may be Incurred.

**FUEL SYSTEM**

The importance of cleanliness in all parts of the fuel system cannot be overstressed. Dirt and sludge can destroy an engine.

**FUEL OIL SPECIFICATIONS**

Diesel fuel oil refined according to the following specifications are acceptable for Perkins engines:

ASTM Classification ........................................ D-975-66T
Grades ........................................ No. 1 or No. 2
Federal Specification ........................................ VV-F-800
Grades ........................................ DF-A (Arctic), DF-1 or DF-2
Cetane No. (Ignition Quality) ........................................ 45 (Minimum)

## BLEEDING THE FUEL SYSTEM

If the boat runs out of fuel, or whenever any part of the system between the fuel tank and fuel injection pump has been disconnected, the fuel system will have to be bled.

Engines Equipped with C.A.V. DPA Rotary Type Fuel Injection Pumps

1. Loosen the air vent screw on the side of the governor housing (refer to fig. 8(a) (b) (c) (d) (e) NOTE: Two wrenches may be required for 6.354 engines if the screw is coated with paint.

2. Loosen the vent attached to one of the two hydraulic head locking screws. Refer to figs. 8(f) (g) (h) (i). Unscrew vent plug on top of fuel filter (if equipped).

3. Operate priming lever on fuel transfer pump (if this is not possible, the camshaft driving the pump lever may be on maximum lift; turn engine one revolution) and when fuel, free from air bubbles, issues from each venting point, tighten the screws in the following order:

1. Fuel Filter Cover Vent Screw.

2. Head Locking Screw.

3. Control Gear Vent Screw.

4. Slacken the pipe union nut (See Fig. 8(j) (k) (l) at the pump inlet, operate the priming lever and retighten when fuel free from air bubbles, issues from around the threads.

5. Slacken union nuts at the injector ends of two of the high pressure pipes.


*Fig. 8 (a) 4.108*
For newer engines see 11 (d)


*Fig. 8 (b) 4.154*

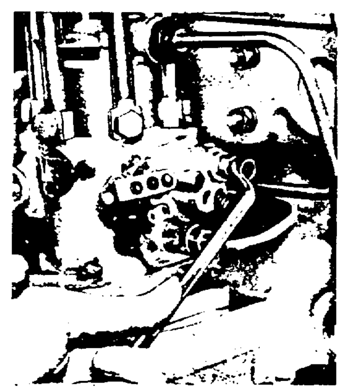


*Fig. 8 (c) 6.354, T6.354*


*Fig. 8 (d) T6.354 MGT*


*Fig. 8 (e) 4.236*

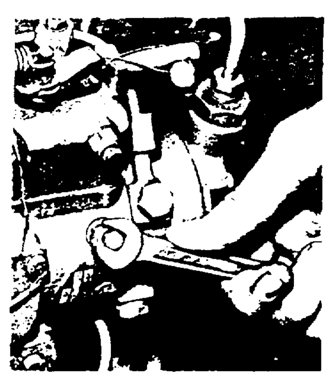


*Fig. 8 (f) 4.236*

6. Set throttle at the fully open position (ensure stop/run lever is in run position).
7. Turn engine with starter until fuel, free from air bubbles, issues from both fuel pipes.
8. Tighten the union nuts on both fuel pipes. The engine is ready for starting.

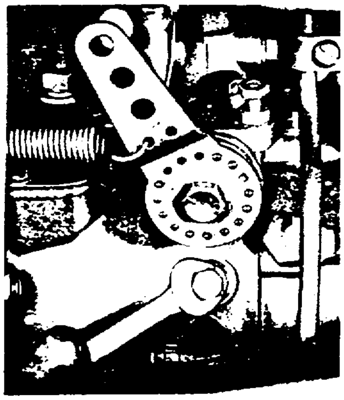


*Fig. 8 (g) 4.108*

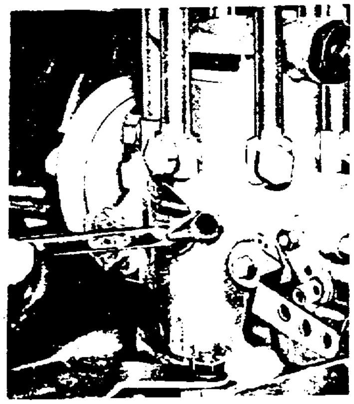


*Fig. 8 (h) 6.354 (all)*

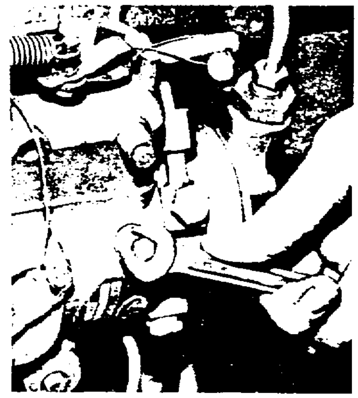


*Fig. 8 (i) 4.154*

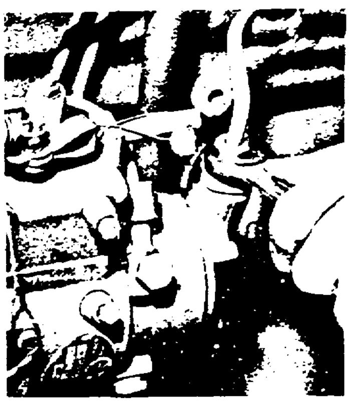


*Fig. 8 (j) 4.236 & 4.154*

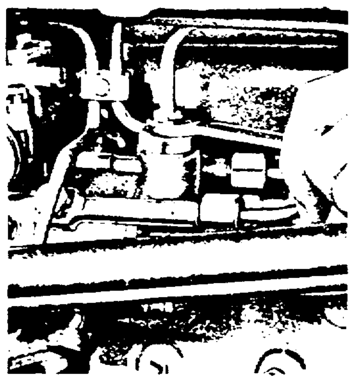


*Fig. 8 (k) 4.108*

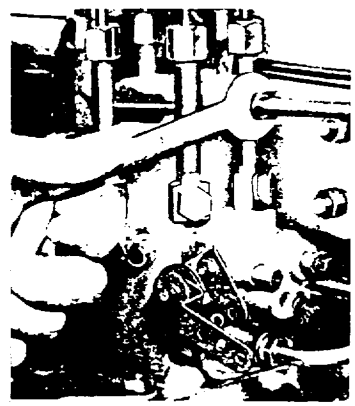


*Fig 8 (l) 6.354 (all)*

V8.510 Engines equipped with in-line fuel injection pumps

1. Unscrew final filter vent plug (see Fig. 9 (a) ).

2. Unscrew the two vent plugs or vent screws on the fuel injection pump by two or three turns. These plugs are located on each side of the fuel inlet connection on the right hand side of the pump (See Fig. 9 )b) ).

3. Operate priming lever on the fuel transfer pump. If the transfer pump driving cam Is on maximum lift, it will not be possible to operate the hand primer. If so, turn the engine through one revolution and proceed.

When fuel free from air bubbles, issues from the venting points, tighten the fuel filter vent plug and then the fuel injection pump vent plugs.

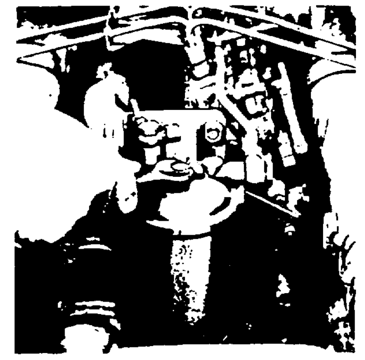


*Fig. 9 (a)*

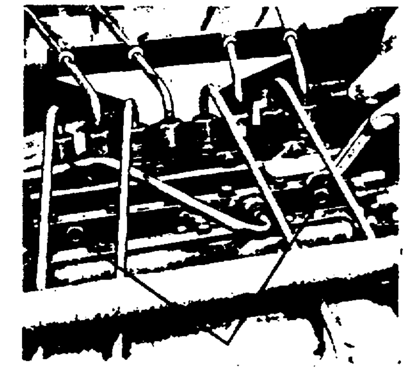


*Fig. 9 (b)*

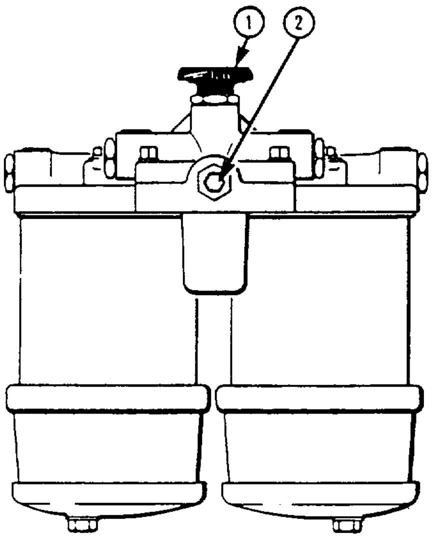



*Fig. 9 (c)*

Key to Fig. 9(c) TV8.510 (M)
1. Priming Pump Handle
2. Fuel Filter Vent Plug

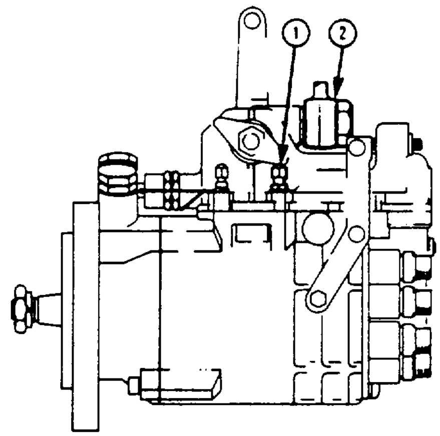



*Fig. 9 (d)*

Key to Fig. 9 (d) TV8. 510 (M)
1. Idling Speed Adjusting Screw
2. Fuel Pump Return Connection

<u>Engines equipped with S.I.G.M.A. rotary type fuel injection pumps</u>

1. Unscrew the vent plug on the front of the fuel filter (see Fig. 9(c) two or three turns.
2. Unscrew the priming pump handle on top of the filter and operate the pump until fuel, free from air bubbles, issues from the connection. Tighten the connection.
4. Screw the priming pump handle securely back into the filter head casting.
5. Slacken the unions at the injector end of two of the high pressure pipes.
6. Place the accelerator in the fully open position and turn the engine with starter until fuel, free from air bubble, issues from both pipes.
7. Tighten the unions of the fuel pipes. The engine is ready to start.

FUEL FILTERS

Two fuel filters are usually installed on Perkins Marine Engines, one in the fuel transfer pump and the other, a self contained unit with renewable element, mounted on the engine. 4.108 engines do not have a filter in the fuel transfer pump. A fine wire mesh filter within the fuel tank filter and a water trap between the tank and transfer pump are highly recommended to pre-filter the fuel.

To renew filter elements

1. Clean exterior of filter assembly.
2. Unscrew setscrew at top of filter head (see Fig. 10 (a) ).
3. Lower base and discard element (see Fig. 10 (b) ).
4. Clean filter head and base in suitable cleaning fluid.
5. Install sealing rings.
6. Install new element in base.
7. Place square against filter head and tighten setscrew.
8. Bleed fuel system as described previously.

*Fig. 10 (a)*

*Fig. 10 (b)*

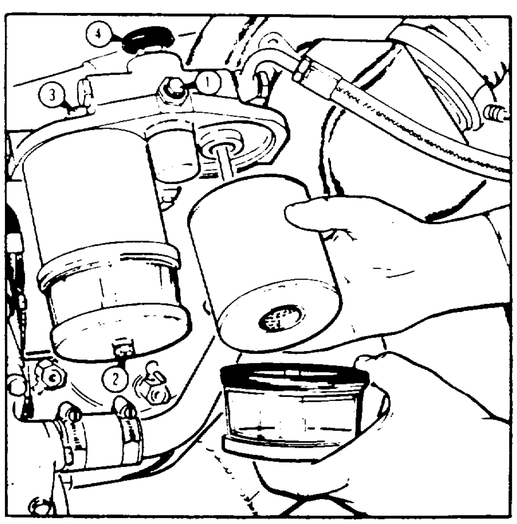



*Fig. 10 (c)*

To Renew Final Fuel Filter Elements TV8.510 (M)

Both elements should be changed at the same time, as follows:

1. Thoroughly clean exterior of filter assembly.
2. Unscrew vent plug (1, Fig 10 (c) ) by two or three turns and drain filter by releasing drain plugs (2, Fig. 10 (c) ).
3. Unscrew filter bowl securing setscrews at top of filter (3, Fig. 10 (c)) remove bottom covers and transparent bowls and discard elements. Ensure, when removing elements, that no fuel is allowed to leak onto the engine.
4. Thoroughly clean filter head, bottom covers and transparent bowls in a suitable cleaning fluid.
5. Inspect sealing rings and renew, if damaged in any way.
6. Place bottom covers, transparent bowl and new elements together, position these assemblies squarely under the filter head and secure with their retaining setscrews.
7. Reinstall drain plugs in bottom covers.
8. Unscrew priming pump handle (4, Fig. 10 (c)) from filter head and operate pump until fuel, free from air bubbles, issues from filter vent point.
9. Tighten vent plug and screw pump handle into filter head.

**IDLING SPEED SETTING**

C.A.V. Rotary Type Pumps

D.P.A. pumps have three types of adjustment. The first type is a spring loaded screw (6.354). The second is on the reversible governor head and consists of a setscrew and locknut. The third is on the governor housing (mechanically governed type pump) and consists of a nut and setscrew.

For the first type, turn the screw clockwise to increase engine speed or anti-clockwise to decrease (see Fig. 11 (a) ).

For the second type, undo the locknut and set the speed (see Fig. 11 (c) and 11 (d) ). This must be done in conjunction with the setting of the anti-stall device (see page 51).

For the third type, undo the locknut and set the required speed.

S.I.G.M.A. Rotary Type Pumps (TV8.510 (M) )

The idle speed adjustment screw is shown in Fig. 9 (d).

In-Line Pumps

The idle adjustment screw is the upper of the two adjustable stop screws situated at the right hand rear of the fuel injection pump (V8.510 (M) engines, Fig. 11 (b)).

The idling speed will vary according to application. For details, inquire at the nearest Perkins. C.A.V. or Simms distributor. (Or Perkins Engines Service Department: Farmington, Michigan or Rexdale, Ontario).

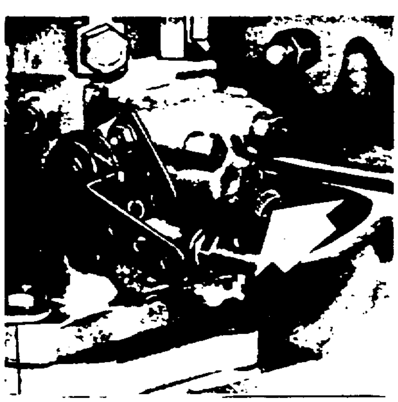


*Fig. 11 (a)*

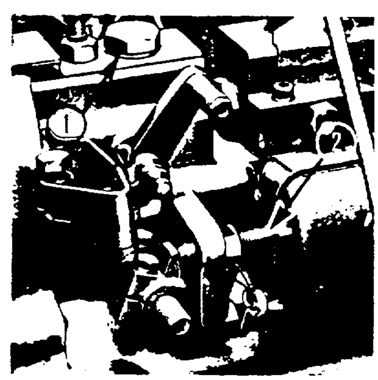



*Fig. 11 (b)*

**ANTI-STALL DEVICE**

S.I.G.M.A. Rotary Type Pump (TV8.510 (M))
There is no anti-stall device incorporated in this type of fuel injection pump.

C.A.V. DPA Rotary Type Pumps
Refer to Fig. 11 (c) (d)

1. Slacken locknut (2 or 7 ) sufficiently to enable the anti-stall adjusting screw (1 or 6) to be unscrewed two complete turns.

2. Adjust idling speed to 625 rpm* with idling adjustment screw (4 or 2).

3. Screw down anti-stall adjusting screw (1 or 6) until there is a very slight increase in engine speed, bring back half a turn and lock with lock nut (2 or 7).

4. Accelerate engine to maximum no load rpm and immediately return to idle (See page 32). Should the period of return from maximum rpm to idle exceed three seconds, the device has been turned too far.

'This idle speed may vary according to application. If in doubt, refer to your nearest Perkins Distributor.

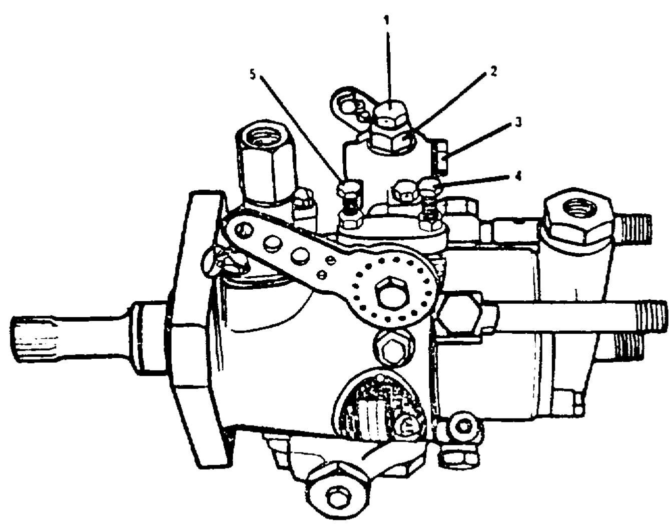
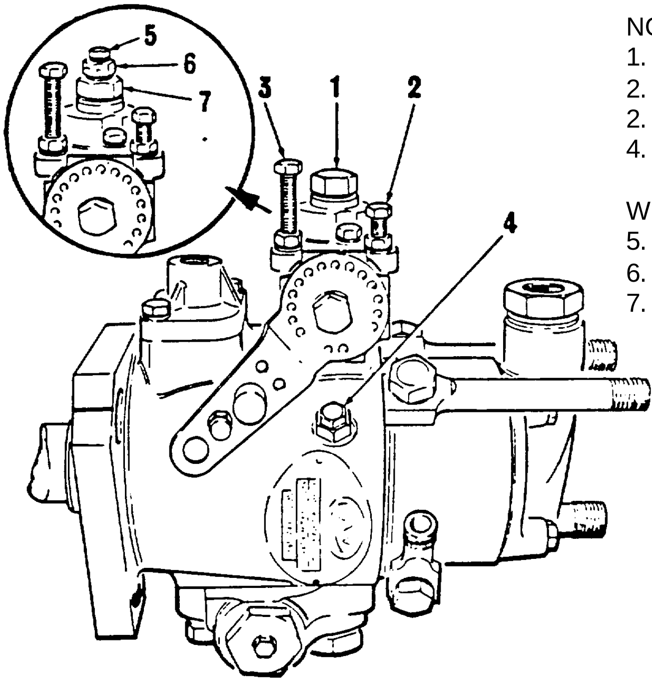



*Fig. 11 (c) Earlier Fuel Pump*

1. Anti-stall adjusting screw
2. Anti-stall locknut
3. Air vent screw
4. Idle adjustment screw
5. Maximum speed screw

If the engine stalls out, the device has not been turned in far enough. The necessary adjustment should be made to overcome either situation.

**Do not attempt to adjust the maximum speed screw (5). This is a factory adjusted setting that requires special test equipment. If the setting is altered, the result may be severe engine damage.**



NO ANTI-STALL DEVICE
1. Governor Housing Bleed Screw
2. Idle Adjustment Screw
2. Maximum Speed Screw
4. Hydraulic Head Bleed Screw

WITH ANTI-STALL DEVICE
5. Governor Housing Bleed Screw
6. Anti-stall Adjusting Screw
7. Locknut

*Fig. 11 (d) Later Fuel Pump*

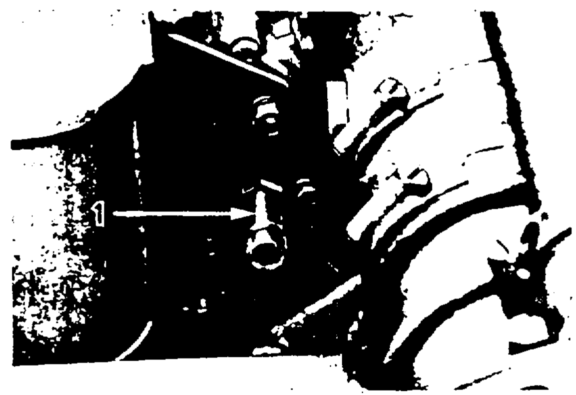


*Fig. 11 (e)*

<u>In-Line Pumps</u>

1. Screw out anti-stall device by two or three turns (refer to Fig. 11 (e) for V8.510 engines).

2. With engine warmed up. adjust idle speed adjustments for 500 rpm.

3. Screw in the anti-stall device until it just affects idle speed. Back out 3/4 turn and lock with locknut.

4. Operate speed control lever and check to ensure that the anti-stall device is not influencing the idle speed setting and that the engine does not stall out when the lever is quickly closed.

<u>C.A.V. Thermostart Device</u>

Two different types of C.A.V. Thermostarts are installed on Perkins engines. The discontinued type, Mark I, s still in use with older engines while the current type, Mark III, is widely used with newer engines.

Bleeding the Thermostart:

The Mark Ill device incorporates a heat sensitive bi-metallic element to open and close the fuel inlet valve. If the device is used "dry" (i.e., without fuel) the bi-metallic element will become distorted because of the excessive heat and thereafter will not function properly to shut off the fuel. The result of unmetered fuel entering the combustion chambers will be difficult starting, black exhaust smoke and additional engine noise. Also, it can cause hydraulic lockup, which can, in turn, cause the connecting rods to be bent.

In consideration of the consequences described above, it is imperative that before attempting to start a new engine or an engine having any part of its low pressure fuel system dismantled, the fuel system and the fuel line to the Thermostart device must be "bled" to ensure fuel availability.

To "bleed" the fuel system-

1. Loosen the air vent screw on the injection pump governor control housing.
2. Loosen the hydraulic head vent screw on the side of the injection pump body.
3. Loosen the vent plug on the top of the primary fuel filter.
4. Operate the fuel transfer pump priming lever until fuel free from air bubbles issues from each venting location. While continuing to operate the lever, tighten the screws in the following order.
   a) Primary fuel filter vent screw.
   b) Hydraulic head vent screw.
   c) Governor vent screw.
5. Loosen the fuel line connection at the inlet to the Thermostart device.
6. Operate the fuel lift pump priming lever until fuel free from air bubbles issues from the loosened connection. While continuing to operate the lever, tighten the connection.

**INJECTOR TESTING AND REPLACEMENT**

Normally, defective injectors can be isolated by loosening the pipe union nut on each injector in turn while the engine is running at approximately 800 rpm. As each nut is loosened, fuel will not be injected into the associated cylinder and, as a result, the engine rpm will decrease if the injector was previously functioning normally. If the engine rpm remains constant, the injector is probably defective.

When installing a replacement injector remember to also include a new copper seating washer. These are special washers and ordinary washers can not be used for this purpose. The recess in the cylinder head, the faces of the washer and the corresponding face of the nozzle holder cap must be perfectly clean to ensure a leak proof seal. The importance of injectors being seated squarely and secured with the correct torque cannot be emphasized too strongly. Even a slight "canting" of the injector can result in fouling and distortion of the nozzle and needle valve. This canting can also result in leakage between injector and cylinder head, with a resultant engine mis-fire.

TORQUE - To ensure squareness and free entry of the nozzle into its bore, the securing nuts must be tightened evenly until a torque of 12 Ibf ft (1.7 kgf m) is attained. Overtightening of these securing nuts can result in a fractured injector flange and/or a fouled nozzle needle valve.

**TIGHTENING HIGH PRESSURE FUEL PIPE NUTS**

Fuel leakage from high pressure pipe unions will result if the nuts are over-tightened. Excessive torque can cause the ferrule (olive) and/or the collar of the nut to be damaged. The correct torque is 12/15 Ibf ft. (1.7 - 2.0 kgf m)

If a high pressure pipe union leaks fuel because the nut has not been tightened sufficiently, the nut should only be tightened enough to stop the leak.

**COOLING SYSTEM**

Two types of cooling systems are employed on Perkins marine engines, i.e., indirect and keel cooling.

Indirect Cooling: This system incorporates a heat exchanger, coolant in a closed circuit and raw (sea) water used as the cooling medium. The raw water discharge can be routed into the exhaust silencing system. A thermostat in the closed circuit system keeps the engine at an operating temperature of 150 - 200°F (65 - 93ºC) for 4.108 engines and 168 - 197°F (75 -91 °C) for the remainder of the marine engine range. Two water pumps are used.

Keel Cooling: This is the same system as above except the dissipation of heat is accomplished by pipes located outside the hull, usually at an angle between the keel and the garboard strake. The length and diameter will be determined by the engine requirements.

Coolant Capacities: Heat Exchanger System

4.108 (M)
2 U.S. Gallons (7.57 Litres)

4.154 (M)
3 U.S. Gallons (11.36 Litres)

6.354 (M) All
5.4 U.S. Gallons (20.44 Litres)

V8.510 (M), TV8.510 (M)
9.3 U.S. Gallons (35.2 Litres)

4.236
3.5 U.S. Gallons (13.25 Litres)

**COOLING SYSTEM MAINTENANCE**

Rubber Impeller Type Water Pump

This type of pump is used for raw water circulation.

The pump should never be run in a dry condition (impeller blades will tear) and, if the engine is not to be operated for any length of time, it will be necessary to pack the water pump with MARFAK 2HD grease. (If this is not available, glycerine may be used). This is effected by removing the pump end plate' to give access to the interior of the pump. Insert the grease, or glycerine, through the top-most pipe connection (after removing the rubber hose). Turn the engine over to spread the lubricant. This treatment is usually effective for about three months and should be repeated if stored for a longer period of time.

'Refer to Page 43.

With 4.154 marine engines, the raw water pump will have to be removed from the engine to gain access to the end plate.

NOTE: ALWAYS KEEP A SPARE IMPELLER ON BOARD

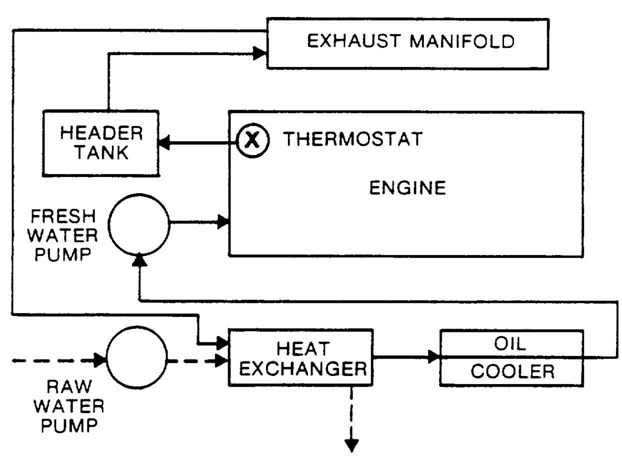



Fig. 12, Typical Heat Exchanger Cooling System Using Separate Heat Exchanger and Engine Oil Cooler.

## Heat Exchangers, Oil Coolers and Air Charge Coolers

A heat exchanger usually consists of a casing with a core (tube stack), which is the actual heat exchanger. The oil cooler usually has a smaller core and is sometimes an integral part of the engine heat exchanger.

The heat exchanger and coolers should be serviced every season. However, it is stressed that, depending on operating conditions, this period may have to be reduced. Although the coolant temperatures of new engines cease to fluctuate after a short period of operation, the stabilized (normal operating) temperatures will vary slightly from engine to engine because of design tolerances, installation and hull variations. once the normal operating temperature has been established for a particular engine, any excessive rise in temperature should be considered abnormal and immediately investigated. If a cooling system problem is suspected (or confirmed) the following guidelines will provide a means for isolating the cause.

1. Check the coolant level in the header tank and ensure the proper pressure cap is being used (7 psi or .492 kgf/cm2). The coolant in an operating or recently stopped engine is very hot and under pressure. If the filler pressure cap is suddenly removed the liquid may spurt and cause injury by scalding. Always stop an engine and allow it to cool before removing the cap. Once cool, loosen the cap slowly to relieve the pressure.

2. Check the sea cock and strainer for obstructions - clean where necessary.

3. Check the sea water pump impeller-renew if damaged. Ensure that no pieces of the impeller (if broken) have passed into the connecting pipes (i.e., inlet and outlet) because, if so, they could restrict water flow.

4. Check all heat exchangers (coolers) for obstructions within the cooling core tubes on the sea water side. Once the end cap and/or plates are removed, any minute scaling within the core tubes can be removed by passing a rod (slightly smaller than the internal bore) through the tubes. Do not use excessive force when pushing the rod through the tubes.

   If the tubes are so clogged that a rod can not be passed through them, the core will have to be removed from its casing and boiled in a caustic soda solution. Commercial cooling system cleaners can be used for this purpose, providing they are recognized as being acceptable by the heat exchanger manufacturer. Reassemble with new gaskets, seals and "O" rings.

   If a reduced power and/or excessive smoke condition exists in addition to an Increase in coolant temperature with a turbo charged engine having an air charge cooler (Inter cooler), check the inter cooler and, if necessary, clean as described for heat exchangers.

5. Check - especially if the engine was operated in muddy or silty water- the exhaust manifold outlet elbows and the exhaust water injection connections for mud or silt restrictions.

6. Oil Coolers - both engine and gear box - can also effect engine coolant temperatures. Oil coolers should be checked and cleaned as described for heat exchangers.

7. It is particulary important for TV8.510 marine engines to check the last cooler in the sea water system - usually the gear box oil cooler - for water flow restrictions. This cooler should be checked any time there is suspicion of a higher than normal temperature and, in addition, it should be checked at least yearly with seasonal weekend cruising and twice yearly with extended cruises.

Water Pump Drive Belts
Check the tensions of the sea (4.154 M) and fresh water pump drive belts. When correctly adjusted, the depression of the belt by the thumb between water pump and crankshaft pulley should be approximately 3/8" (10 mm).

Seacocks and Strainers
Ensure that seacocks are open prior to starting the engine and that, after the engine has started, there is a flow of water from the discharge pipe. The interval between the cleaning of the strainer is left to the discretion of the operator but regular checks should be made to ensure there are no restrictions. Fig. 13 depicts a typical seacock.

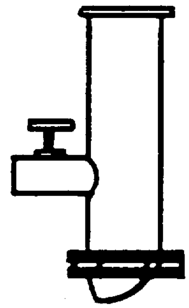


*Fig. 13*

Thermostats
The thermostat, by controlling engine operating temperature within a given range, plays an important part in the operating efficiency and life of an engine. Therefore it is essential that it functions correctly at all times.

**LUBRICATING SYSTEM**

The importance of correct and clean lubrication cannot be stressed too highly. Care should be taken in the selection of oil to ensure that it is correct for the climatic conditions. The oil pan should be filled to the correct level but DO NOT overfill above the full mark.

Because of the variance in delivery of the lubricating oil pump and scavenge pump, the following procedure is recommended for horizontal 6.354 engines when changing the lubricating oil.

1. Fill engine oil pan to full mark on the dipstick.
2. Run the engine until at normal operating temperature, idle engine for two minutes and shut down.
3. Top up oil pan to full mark on dipstick. This replaces residual oil remaining in the crankcase.

For routine oil level checks, horizontal engines should be idled for two minutes before reading the dipstick. The oil level should not be checked with the engine running at speeds in excess of 1000 rpm, or if the engine has been shut down from speeds of over 1000 rpm without the two minutes idling period.

Oil Pressure
Engine oil pressure should be 30/60 psi (2.1/4.2 kgf/cm2) at normal operating speed and temperature. It is normal for the pressure to drop while the engine is idling and when the oil is hot.

Oil Filters
The lubricating oil filter installed on most Perkins marine engines is the screw-on canister type. The canister is secured to the filter head by a threaded adaptor.

Perkins diesel engines require the use of high quality lube oil filters made to Perkins original equipment standards. To protect our customers from filters that do not meet Perkins specifications, we have established minimum performance standards based on SAE oil filter test procedures SAE J806a. The Perkins Farmington Engineering Department maintains a list of filter manufacturers who have supplied test data to SAE J806a and have met Perkins minimum standards. These standards in general preclude the use of low quality, low cost filters.

Renewing Oil Filter
1. Clean exterior of filter.

2. Unscrew and discard the oil canister.

3. Clean the filter head and threaded spigot.

4. Pour (slowly) clean engine lub oil into the center of the replacement canister until full'.

5. Using clean engine lub oil, lightly oil the top seal of the replacement canister.

6. Screw replacement canister onto filter head until the seal just touches head and then tighten by hand a further half turn. If the canister is overtightened, difficulty may be experienced in removal.

7. Run the engine and check for leaks. Do not run the engine at high idle until oil pressure has built up. Recheck oil level and top up as necessary.

*It is recommended that before installing a new screw-on filter canister, it should be primed with oil. Clean lubricating oil should be poured slowly in the center threaded orifice, allowing time for the oil to fill the canister through the filter medium. When attaching a canister to a filter head not in the straight-up position, a small quantity of oil in the stack pipe may be spilled before the canister is screwed home onto its seal.

**RECOMMENDED ENGINE LUBRICANTS**

The recommended engine lubricating oil for naturally aspirated Perkins marine engines is a reputable brand of oil meeting the minimum requirements of U.S. Military Specification MIL-L-46152 when a fuel having a maximum sulfur content of 1.3% by weight is used. This was formerly known as MIL-L-2104B and can be identified by API Service Classification "CC" Lubricating oil for turbocharged engines should meet the requirements of MIL-L-2104C. which can be identified by API Service Classification "CD".

Should questions arise concerning a particular brand of lub oil, consult the supplier. Synthetic Lubricating Oils

As the result of continuing requests for Perkins approval of synthetic lubricating oils, the following policy is announced:

1. General Policy

   Perkins Engines does NOT recommend the use of synthetic lubricating oil for the following reasons:

   a. General experience to date shows the potential for excessive engine wear, particularly with reference to piston rings, cams and gears.

   b. Experience to date shows the potential for premature seal and other elastomer deterioration.

   c. Synthetic oils have been found to be subject to critical quality control requirements. Critical compounding is required and small deviations result in greater than expected performance variations.

   d. No major name brands currently have acceptable compounds. The other than name brand suppliers are difficult to identify and evaluate as dependable suppliers.

2. Exceptions to General Policy

Some products on the market are not true synthetic lubricating oils. Instead, they are man-made hydrocarbons (sometimes referred to as "synthesized hydrocarbon"). This type of man-made fluid is the only available oil with a molecular structure having good high temperature properties and yet not containing the waxy materials that interfere with low temperature flow. Because of the properties of these fluids, Perkins makes the following exceptions to its "no synthetic" rule:

a. The fluid must meet or exceed MIL-L-46167 or MIL-L-46152 quality levels.

b. It must be synthesized hydrocarbon oil versus synthetic oil.

c. The customer must request in writing approval for use in a specific geographical location.

d. If lubrication connected wear and/or failure problems develop, the approval may be rescinded.

LUBE OIL SPECIFICATIONS:
(Minimum Viscosity Index of 80)

| ALL ENGINES | |
|---|---|
| NATURALLY ASPIRATED | TURBOCHARGED |
| MIL-L-46152 (API "CC") with 200 hr. Oil Change Period | MIL-L-2104C (API "CD") with 200 hr. Oil Change Period |
| | MIL-L-46152 (API "CC") with 100 hr. Oil Change Period |

VISCOSITY REQUIREMENTS: All engines except 4.108

| TEMPERATURE RANGES DEGREES F | ENGINE OIL VISCOSITY'* |
|---|---|
| Zero to 30 | SAE 10W |
| 30 to 80 | SAE 20W20 |
| 80 and over | SAE 30 |
| 4.108 ENGINES | |
| Zero to 45 | SAE 10W |
| 45 to 80 | SAE 20W20 |
| 80 and over | SAE 30 |

'Multi-viscosity oils may be used providing the viscosity range is compatible with the specified viscosity (e.g., 10W/30 may be used in lieu of 10W oil).

# GEARBOXES (TRANSMISSIONS)

The following gearboxes are attached to Perkins engines when supplied from production, but other boxes may be attached by certain boat builders.

| | |
|---|---|
| 4.108 | Borg-Warner 71 CR or Paragon |
| 4.154 | Borg-Warner 71 CR |
| 4.236 | Borg-Warner 71 CR or Borg-Warner 72 CR |
| 6.354 | Borg-Warner 72 CR/C or Borg-Warner 71 CR/C |
| T6.354* | Borg-Warner 72 CR/C |
| HT6.354 | Borg-Warner 72 CR/C |
| V8.510 | Borg-Warner 72 CR, 73 CR or Twin Disc MG-502 |
| TV8.510 | Borg-Warner 73 CR or Twin Disc MG-506 |

*Also T6.354 MGT

## BORG-WARNER - Procedure for checking fluid level

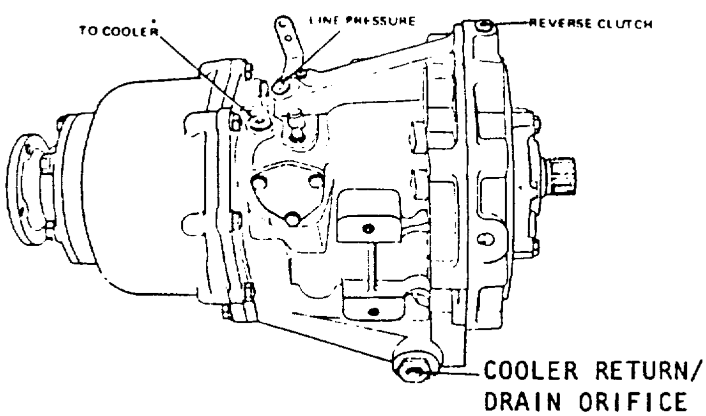
The fluid level should be checked immediately after shut-down and sufficient fluid added to bring the level to the full mark on the dipstick. The dipstick assembly need not be threaded into the case to determine fluid level. Newer gearboxes have plug type dipsticks.

Filling - Transmission fluid (Type "A") should be added until it reaches the full mark on the dipstick. The unit should be rotated at idling speed for a short time to fill all circuits.

The maximum interval between fluid changes for Borg Warner "Velvet Drive" marine transmission is 400 hours operating time or 12 months (each boating season), whichever occurs first.

The condition of the fluid filter (if equipped) screen should be checked and cleaned if necessary prior to refilling the transmission.

**NOTE: Vee Drive, 2.1:1 reduction units and CR-2 Drop Center transmissions do not have filter screens. The filter screen for all other units is located within the cooler return/ transmission fluid drain orifice.**




Fluid Pressures and Temperatures (71CR/C and 72CR/C)
Fluid Pressures should be 110-150 PSI (7.53-10.55 kgf/cm2) at normal operating temperatures of 150-165ºF (65.55-73.8°C). At low temperatures or excessive speeds, pressure may rise to 200-250 PSI (14.06-17.58 kgf/cm2). The maximum recommended fluid temperature is 190ºF (87.6°C).

Fluid Pressures and Temperatures (73CR)
Fluid Pressure should be 115-140 PSI (8.08 - 9.84 kgf/cm2) at 2000 rpm engine speed with a fluid temperature of 140-190ºF (60-88ºC).

Fluid Capacities

| GEARBOX | LEVEL U.S. QUARTS | LEVEL LITRES | INCLINED U.S. QUARTS | INCLINED LITRES |
|---|---|---|---|---|
| 71C & CR 1:1 | 1.8 | 1.71 | 1.3 | 1.2 |
| 1.50:1 | 2.5 | 2.36 | 2.7 | 2.56 |
| 1.91:1 | 2.5 | 2.36 | 2.7 | 2.56 |
| 2.10:1 | 2.5 | 2.36 | 2.7 | 2.56 |
| 2.57:1 | 2.5 | 2.36 | 2.7 | 2.56 |
| 2.91:1 | 2.5 | 2.36 | 2.7 | 2.56 |
| 72C & CR 1:1 | 2.1 | 2.00 | 1.7 | 1.55 |
| 1.50:1, 1.91:1 | | | | |
| 2.10:1 | 2.7 | 2.56 | 2.8 | 2.55 |
| 2.57:1, 2.91:1 | 2.7 | 2.56 | 2.8 | 2.55 |
| 73C 1:1 | 2.6 | 2.38 | 1.5 | 1.42 |
| 1.51:1, 2.1:1 | | | | |
| 2.9:1 | 2.0 | 1.89 | 2.2 | 2.04 |

**BORG-WARNER MODEL DESIGNATIONS**

Recently Borg-Warner changed the means for identifying their various transmissions. The following cross reference is being included for identification convenience.

| RATIO | PREVIOUS MODEL DESIGNATION | PREVIOUS MODEL DESIGNATION | NEW DESIGN MODEL DESIGNATION |
|---|---|---|---|
| 1:1 | AS1-71C | 10-04-000-036 | 10-17-000-001 |
| 1:1 | AS1-71CR | 10-04-000-037 | 10-17-000-002 |
| 1:1 | AS1-71CB | 10-04-000-038 | 10-17-000-003 |
| 1:1 | AS1-71CBR | 10-04-000-039 | 10-17-000-004 |
| 1.52:1 | AS2-71C | 10-04-000-042 | 10-17-000-005 |
| 1.52:1 | AS2-71CR | 10-04-000-043 | 10-17-000-006 |
| 1.91:1 | AS7-71C | 10-04-000-050 | 10-17-000-007 |
| 1.91:1 | AS7-71CR | 10-04-000-051 | 10-17-000-008 |
| 2.10:1 | AS3-71C | 10-04-000-044 | 10-17-000-009 |
| 2.10:1 | AS3-71CR | 10-04-000-045 | 10-17-000-010 |
| 2.57:1 | AS14-71C | 10-04-000-046 | 10-17-000-011 |
| 2.57:1 | AS14-71CR | 10-04-000-047 | 10-17-000-012 |
| 2.91:1 | AS 15-71C | 10-04-000-048 | 10-17-000-013 |
| 2.91:1 | AS15-71CR | 10-04-000-049 | 10-17-000-014 |
| 1:1 | AS11-72C | 10-05-000-034 | 10-18-000-001 |
| 1:1 | AS11-72CR | 10-05-000-035 | 10-18-000-002 |
| 1.52:1 | AS12-72C | 10-05-000-038 | 10-18-000-003 |
| 1.52:1 | AS12-72CR | 10-05-000-039 | 10-18-000-004 |
| 1.91:1 | AS17-72C | 10-05-000-046 | 10-18-000-005 |
| 1.91:1 | AS17-72CR | 10-05-000-047 | 10-18-000-006 |
| 2.10:1 | AS13-72C | 10-05-000-040 | 10-18-000-007 |
| 2.10:1 | AS13-72CR | 10-05-000-041 | 10-18-000-008 |
| 2.57:1 | AS14-72C | 10-05-000-042 | 10-18-000-009 |
| 2.57:1 | AS14-72CR | 10-05-000-043 | 10-18-000-010 |
| 2.91:1 | AS15-72C | 10-05-000-044 | 10-18-000-011 |
| 2.91:1 | AS15-72CR | 10-05-000-045 | 10-18-000-012 |

**TWIN DISC MG-502 & MG-506 GEARBOXES**

Oils used in this gearbox type must conform with API Service Classification "SD". Any oil that conforms with this specification is suitable. The correct S.A.E. designation to be used will depend upon the temperature of the cooling water at the inlet to the gearbox oil cooler.

| S.A.E. DESIGNATION | |
|---|---|
| Cooling Water Temp. Below 85ºF (29°C) | Cooling Water Temp. Above 85ºF (29°C) |
| 20w/20 | 30 |

PROCEDURE FOR CHECKING OIL LEVEL
The gearbox oil level should always be checked with the engine running at idle speed.

FILLING
Stop the engine. Fill gearbox to "full" mark on the dipstick with API "SD" engine lub oil.
OIL CAPACITY: 4.8 U.S. Quarts (4.55 Litres)
4.8 U.S. Quarts (4.55 Litres)

OIL PRESSURE
Normal pressure is 300-320 psi (21.1 - 22.5 kgf/cm2) at 1,800 rpm and 1800F (830C).
Minimum pressure is 270 psi (18.98 kgf/cm2) at cruising speed.

**PARAGON GEARBOXES**
Procedure for Checking Fluid Level - When the engine is first started, allow it to idle for a few moments. Stop the engine and check the transmission fluid level. Add type "A" transmission fluid, if necessary, to bring the level up to the mark on the transmission dipstick.

Oil Pressure - Normal pressure is 60 psi (4.22 kgf/cm2) at normal operating temperature.

**PROPELLER SHAFT TRAILING (FREE WHEELING)**
Borg Warner have determined through practical experience that sail boats having Borg Warner transmissions (auxiliary engine installations) can sail with the propeller trailing (free wheeling) at unlimited speeds without risking damage to the transmission, providing the unit is filled with fluid (to full mark on dipstick).

Twin engine power boats having one engine inoperative (shut down) with its propeller free-wheeling are also no longer restricted to a maximum speed or rpm, providing the fluid level is maintained at the full mark on the dipstick.

**CHECKING VALVE TIP CLEARANCES**

When rotating engines, they should always be turned in their normal direction of rotation, i.e., anti-clockwise when viewing from the gearbox end. The exception is contra-rotating engines, which is clockwise from the gearbox end.

<u>4.108, 4.154 and 4.236 Engines</u>
The clearance is set between the top of the valve stem rocker and arm and should be 0.012 in. (0.30 mm) cold. Refer to Fig. 14 (a).

When setting valve clearances the following procedure should be adopted:

1. With the valves rocking on No. 4 cylinder (i.e., the period between the opening of the intake valve and the closing of the exhaust valve), set the valve clearances on No. 1 cylinder.
2. With the valves rocking on No. 2 cylinder, set the valve clearances on No. 3 cylinder.
3. With the valves rocking on No. 1 cylinder, set the valve clearances on No. 4 cylinder.
4. With the valves rocking on No. 3 cylinder, set the valve clearances on No. 2 cylinder.

<u>6.354, T6.354 MGT, T6.354 and HT6.354 Engines</u>
The clearance is set between the top of the valve stem and rocker arm and should be 0.012 in. (0.30 mm) cold. Refer to Fig. 14 (a)

When setting valve clearances the following procedure should be adopted.

1. With the valves rocking on No. 6 cylinder (i.e., the period between the opening of the intake valve and the closing of the exhaust valve), set the valve clearances on No .1 cylinder.
2. With the valves rocking on No. 2 cylinder, set the valve clearances on No. 5 cylinder
3. With the valves rocking on No. 4 cylinder, set the valve clearances on No. 3 cylinder.
4. With the valves rocking on No. 1 cylinder, set the valve clearances on No. 6 cylinder.
5. With the valves rocking on No. 5 cylinder, set the valve clearances on No. 2 cylinder.
6. With the valves rocking on No. 3 cylinder, set the valve clearances on No. 4 cylinder.

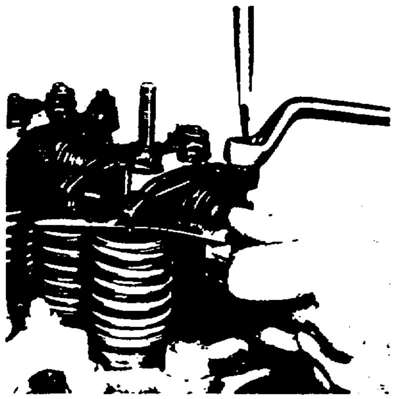


*Fig. 14 (a).*

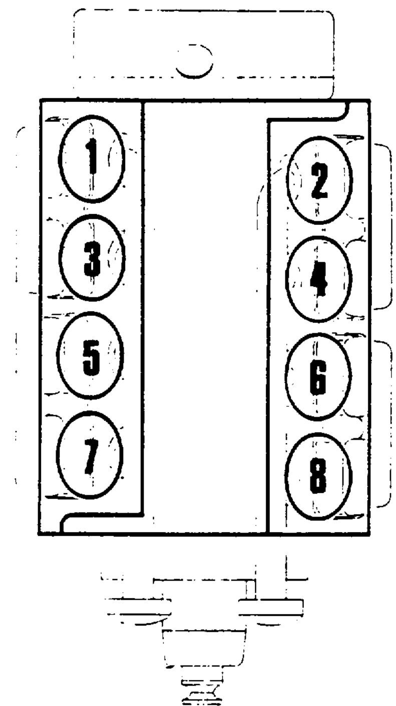



*Fig. 14 (b)*

<u>TV8.510 and V8.510 Engines</u>
The clearance is set between the top of the valve stem and rocker arm and should be 0.012 in. (0.30 mm) cold.

When setting valve clearances the procedure below should be followed. Refer to Fig. 14 (b) for cylinder numbering.

LEFT BANK

1. With the valves rocking on No. 4 cylinder (i.e., the period between the opening of the intake valve and the closing of the exhaust valve), set the valve clearances on No. 1 cylinder.
2. With the valves rocking on No. 6 cylinder, set the valve clearances on No. 7 cylinder.
3. With the valves rocking on No. 2 cylinder, set the valve clearances on No. 5 cylinder.
4. With the valves rocking on No. 8 cylinder, set the valve clearances on No. 3 cylinder.

RIGHT BANK

1. With the valves rocking on No. 3 cylinder, set the valve clearances on No. 8 cylinder.
2. With the valves rocking on No. 1 cylinder, set the valve clearances on No. 4 cylinder.
3. With the valves rocking on No. 7 cylinder, set the valve clearances on No. 6 cylinder.
4. With the valves rocking on No. 5 cylinder, set the valve clearances on No. 2 cylinder.

**ELECTRICAL SYSTEM**

**Alternator**

The alternator has two generating parts, a stator and a rotor. When the rotor rotates inside the stator windings, alternating current (AC) is induced into the stator. This is unsuitable for charging the battery, therefore, a rectification unit comprised of diodes is also built into the alternator. These are connected in such a manner that they provide an output of direct current (DC) for the battery. The alternator output amplitude is controlled by a fully transistorized integral regulator that requires no servicing and is non-repairable. The alternator type and output rating (42 or 61 amp) can be found stamped on the alternator body or identification plate (e.g., 10SI 42A)

**GENERAL PRECAUTIONS FOR ALTERNATORS**

NEVER disconnect the battery or the starter switch while the alternator is running. This will cause a voltage surge in the system and damage the diodes and transistors.

NEVER disconnect any electrical lead without first stopping the engine and turning all switches to the "OFF" position. ALWAYS identify a lead as to its correct terminal before disconnection. A short circuit or reversed polarity will destroy diodes and transistors.

NEVER connect a battery into the system without checking for correct polarity and correct voltage.

NEVER "Flash" connections to check for current flow. No matter how brief the "Flash", the transistors may be destroyed.

NEVER experiment to try to adjust or repair the system unless you have had proper training on alternators, and you have the correct test equipment and technical data.

NEVER ground the field circuit.

NEVER run the alternator if the output circuit is open, (i.e., without an electrical load).

NEVER attempt to polarize an alternator. When using a battery charger disconnect battery cables.

NEVER apply a battery voltage direct to the regulator or alternator field terminals because this will damage the transistors.

ALWAYS disconnect the alternator terminals before carrying out any electrical welding on the boat because the intense magnetic field created by the "make" and "break" of the arc may cause damage to the diodes.

DO NOT check for continuity of the alternator or regulator with insulation testers such as a "Megger", etc.

ALWAYS disconnect the battery before connecting test instruments (except voltmeter) or before replacing any unit or wiring.

**STARTER MOTOR**

The starter motor has a centrifugally operated mechanical overspeed protection device that releases the pinion from the flywheel when it reaches a predetermined excessive speed.
The solenoid and main switch assemblies are mounted on top (external) of the starter motor housing.

Normally, scheduled maintenance is not required.

The starter motor type is stamped on the housing or nomenclature plate.

**BATTERY MAINTENANCE**

**WARNING: Batteries being charged give off explosive gas. Do not smoke or produce any means for spark ignition. Always ensure that batteries are properly and securely located in an area with adequate ventilation and access for maintenance. In addition, the following guidelines should be adopted:**

1. Batteries should be isolated (with isolation switch) when not in use.

2. Maintain correct electrolyte level (just above the top of the separators).

3. Keep batteries clean and dry to avoid possible corrosion and current leakage.

4. Ensure battery connections are clean and tight and, to avoid overheating, that the cable size is adequate for the current load.

5. Ensure that no current conducting components or attachments are located in close proximity to the battery.

## ELECTROLYTIC CORROSION

Corrosion can occur when two dissimilar metals are in contact in the presence of sea water. Care is taken to avoid this in the design of an engine, but different metal types are necessary. Brass or bronze pipe fittings attached to aluminum parts (for example) will result in rapid corrosion. A zinc pencil is inserted into the heat exchanger to assist in the prevention of electrolytic action.

Particular care is necessary when an engine is installed in an aluminum hull. Zinc anodes can be attached to hulls where corrosion cannot be entirely avoided and specialist firms will advise on their use.

Corrosion can also be caused by current leaking from the battery (and other parts of the electrical system) to the hull via the engine or metal attachments.

## RADIO INTERFERENCE SHIELDING

Radio interference in the form of noise can be caused by the alternator, starter motor and other engine-driven equipment. In addition, many boats have electronic equipment aboard (e.g., radar) that could create radio interference. To prevent this interference, adequate shielding must be provided, if possible. Stray electronic radiation shielding is a very complex task and for severe problems it is suggested that a specialist in the field of electronics be consulted.

## EMERGENCY MAINTENANCE AND OPERATING TIPS

If the engine stops the first thing to do is check that the fuel supply is ON. If the fuel valves or taps are all open, check the fuel level in the tank. If the engine has been run until the fuel tank is completely empty there is a very good chance that there is a lot of dirt in the fuel lines. Change the fuel filter and, after refueling, bleed the system and re-start the engine.

If the engine slows down or loses power, the cause could be something wrapped around the propeller. Always check this first. Check the air intake for obstruction and the engine compartment for a good supply of air. Also, the air intake mesh may be clogged with foreign matter sucked from a dirty engine compartment.

If the engine coolant boils, ease down the throttle and try to ascertain the cause. The first check is the sea cock to ensure an adequate cooling water supply. If satisfactory, check raw water pump operation, the impeller may have failed. If so, replace with the spare impeller. A spare should always be carried on board.

If a serious leak occurs on a high pressure fuel pipe, disconnect and direct the flow into a can or other receptacle, and run on the remaining cylinders. DO NOT attempt to flatten and pipe because this will ruin the fuel injection pump. Leaks in low pressure fuel pipes can be temporarily repaired by the use of heavy duty adhesive tape, hose and clamps.

If an auxiliary engine is required to run while the boat is beating to windward, the boat may heel (see chart) without adverse effect on the lubrication system providing the boat is righted occasionally so that the valve gear can be lubricated.

Maximum Continuous Angle of Heel

| Heel | 4.108 | 4.154 | 4.236 | 6.354 | HT6.354 |
|---|---|---|---|---|---|
| To Port | 250 | 300 | 300 | 300 | 360 |
| To Starboard | 250 | 300 | 300 | 300 | 23° |

Coolant leaks can normally be temporarily repaired with heavy duty adhesive tape, hose and clamps.

If a serious oil leak occurs, shut down the engine immediately and try to find the cause. Oil leaks are a lot harder to repair temporarily because of the pressure involved. However, if the main flow can be stopped to a drip or dribble, place a can underneath the leak and replenish the engine with new oil (from a spare oil can) at the same rate as the loss.

Drip trays of metal or glass fiber should be used beneath the engine to stop lubricating oil or fuel oil dripping into the bilges. Care must be taken to avoid galvanic action between the drip tray and engine (e.g., a copper tray should not be used under an aluminum alloy oil pan). Remember to keep the drip tray clean because this provides an early indication of leaks.

**OPERATING PARAMETERS**
Maximum Engine Compartment Temperature (all engines): 140°F (60ºC)

Maximum Battery Compartment Temperature (all engines): 122°F (50º)

Volume of Air Required Per Engine

| VOL. | 4.108 | 4.154M | 4.236M | 6.354M | T6.354M | T6.354MGT | V8.510M | TV8.510M |
|---|---|---|---|---|---|---|---|---|
| ft$^3$/MIN | 105 | 110 | 157 | 250 | 300 | 406 | 365 | 550 |
| M$^3$/MIN | 3 | 3.1 | 4.45 | 7 | 8.5 | 11.5 | 10.5 | 15.5 |

Maximum Exhaust Back Pressure (measured within 12 inches/305mm of engine manifold)

| Press. | 4.108M | 4.154M | 4.236M | 6.354M | T6.354M | T6.354MGT | V8.510 | TV8.510 |
|---|---|---|---|---|---|---|---|---|
| in. Hg | 3 | 3 | 3 | 3 | 1.5 | 1.5 | 3 | 1.5 |
| mm Hg | 76 | 76 | 76 | 76 | 38 | 38 | 76 | 38 |

**ON-BOARD TOOLS AND SPARE PARTS**
An "on board" tool kit for emergency repairs should be supplemented by:

Hose clamps, assorted
Hose, assorted (flex type useful)
Wire (20 AWG or 12-14 AWG Stranded)
Insulating (electrical) tape
Gasket Compound
Magnet (keep away from compass)
Mechanical fingers
Self-gripping (pipe) wrench
Asbestos Lagging
Low pressure fuel pipe olives (ferrules)
Small hacksaw with spare blade
Assorted files
Heavy duty adhesive tape

The two kits listed below on page 66 are applicable to any Perkins marine engine. The part numbers for these parts are listed in the applicable parts book for each engine. These kits are strictly guidelines and may be varied at the discretion of the owner/operator.

MAJOR KIT

| QTY. | DESCRIPTION |
|---|---|
| 1 | Zinc Pencil (Plug) |
| 1 | Injector (6 cyl. engines: 2) |
| 1 pkg. | Injector or Seating Washers |
| 1 | Water outlet Gasket |
| 2 | Fuel Oil Filter Elements |
| 2 | Lub Oil Filter Elements |
| 1 | Water Pump Belt |
| 1 | Alternator Belt |
| 1 | Thermostat |
| 1 pkg. | Leak-Off Washers |
| 1 pkg. | Leak-Off Olives (Ferrules) |
| 1 set | Injection Lines |
| 1 | Transfer Pump and Gasket |
| 1 | Sea Water Pump Kit |
| 1 | Top Gasket Set |
| 1 | Water Pump Kit |
| 4 qts. | Type "A" Transmission Fluid' |
| 8 qts. | Engine Lub Oil |

MINOR KIT

| QTY. | DESCRIPTION |
|---|---|
| 1 | Transfer Pump and Gasket |
| 1 | Injector (6 cyl. engines: 2) |
| 1 pkg. | Injector Seating Washers |
| 1 | Water Outlet Gasket |
| 2 | Fuel Oil Filter Elements |
| 2 | Lub Oil Filter Elements |
| 1 | Water Pump Belt |
| 1 | Thermostat |
| 1 pkg. | Leak-Off Washers |
| 1 pkg. | Leak-Off Olives (Ferrules) |
| 1 | Sea Water Pump Impeller |
| 4 qts. | Type "A" Transmission Fluid' |
| 8 qts. | Engine Lub Oil |

The parts listed above are also offered in kit form by Perkins Engines. Please order from your distributor. Lub oil and transmission fluid must be purchased separately.

*Borg-Warner and Paragon Gearboxes. Twin Disc: Substitute with "SD" engine lub oil.

## TROUBLESHOOTING CHART

| TROUBLE | POSSIBLE CAUSE |
|---|---|
| Low cranking speed | 1, 2, 3, 4 |
| Will not start | 5, 6, 7, 8, 9, 10, 12, 13, 14, 15, 16, 17, 18, 19, 20, 22, 31, 32, 33 |
| Difficult Starting | 5, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 18, 19, 20, 21, 22, 24, 29, 31, 32, 33 |
| Lack of power | 8, 9, 10, 11, 12, 13, 14, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 31, 32, 33 |
| Misfiring | 8, 9, 10, 12, 13, 14, 16, 18, 19, 20, 25, 26, 28, 29, 30, 32 |
| Excessive fuel consumption | 11, 13, 14, 16, 17, 18, 20, 22, 23, 24, 25, 27, 28, 29, 31, 32, 33 |
| Black exhaust | 11, 13, 14, 16, 18, 19, 20, 22, 24, 25, 27, 28, 29, 31, 32, 33 |
| Blue/white exhaust | 4, 16, 18, 19, 20, 25, 27, 31, 33, 34, 35, 45, 56 |
| Low oil pressure | 4, 26, 37, 38, 39, 40, 42, 43, 44, 58 |
| Knocking | 9, 14, 16, 18, 19, 22, 26, 28, 29, 31, 33, 35, 36, 45, 46, 59 |
| Erratic running | 7, 8, 9, 10, 11, 12, 13, 14, 16, 20, 21, 23, 26, 28, 29, 30, 33, 35, 45, 59 |
| Vibration | 13, 14, 20, 23, 25, 26, 29, 30, 33, 45, 48, 49 |
| High oil pressure | 4, 38, 41 |
| Overheating | 11, 13, 14, 16, 18, 19, 24, 25, 45, 47, 50, 51, 52, 53, 54, 57 |
| Excessive crankcase pressure | 25, 31, 33, 34, 45, 55 |
| Poor compression | 11, 19, 25, 28, 29, 31, 32, 33, 34, 46, 59 |
| Starts and stops | 10, 11, 12 |

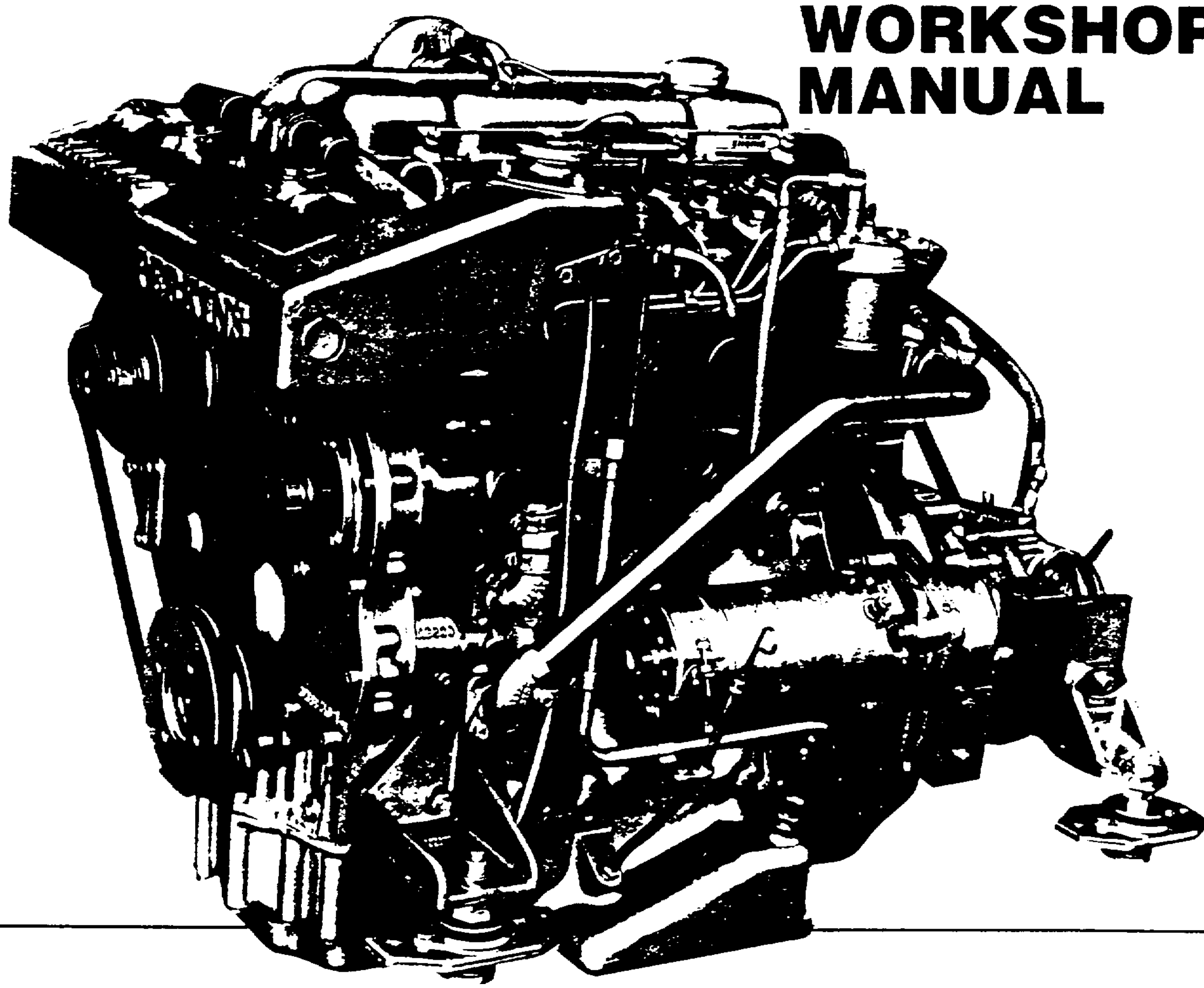
## KEY TO TROUBLESHOOTING CHART

1. Battery capacity low
2. Bad electrical connections
3. Faulty starter motor
4. Incorrect grade of lubricating oil
5. Low cranking speed
6. Fuel tank empty
7. Faulty stop control operation
8. Blocked fuel feed pipe
9. Faulty fuel lift pump
10. Choked fuel filter
11. Restriction in air cleaner
12. Air in fuel system
13. Faulty fuel injection pump
14. Faulty injectors or incorrect type
15. Incorrect use of cold start equipment (if equipped)
16. Faulty cold starting equipment
17. Broken fuel injection pump drive
18. Incorrect fuel pump timing
19. Incorrect valve timing
20. Poor compression
21. Blocked fuel tank vent
22. Incorrect type or grade of fuel
23. Sticking throttle or restricted movement
24. Exhaust pipe restriction
25. Cylinder head gasket leaking
26. Overheating
27. Cold running
28. Incorrect tappet adjustment
29. Sticking valves
30. Incorrect high pressure pipes
31. Worn cylinder bores
32. Pitted valves and seats
33. Broken, worn, or sticking piston ring (s)
34. Worn valve stems and guides
35. Overfull air cleaner or use of incorrect grade of oil (oil bath cleaner)
36. Worn or damaged bearings
37. Insufficient oil in oil pan
38. Inaccurate gauge
39. Oil pump worn
40. Pressure relief valve sticking open
41. Pressure relief valve sticking closed
42. Broken relief valve spring
43. Faulty suction pipe
44. Choked oil filter
45. Piston seizure/pick up
46. Incorrect piston height
47. Open circuit strainer or week strap blocked
48. Faulty engine mounting (housing)
49. Incorrectly aligned flywheel housing or flywheel
50. Faulty thermostat
51. Restriction in water jacket
52. Loose water pump drive belt
53. Gearbox or engine oil cooler choked
54. Faulty water pump
55. Choked breather pipe
56. Damaged valve stem oil deflectors (if equipped)
57. Coolant level too low
58. Blocked oil pan strainer
59. Broken valve spring

INDEX

Engines

# WORKSHOP MANUAL



PRINTED IN U.S.A.

**workshop**
**manual for**
**4.236 marine**
**diesel engines**

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(c)

**Perkins Engines, Inc.**
32500 Van Born Road
P O Box 697 · Wayne. Michigan 48184 · U.S.A.
1982

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This publication is written for world wide use. In territories where legal requirements govern engine smoke emission, noise, safety factors, etc., then all instructions, data and dimensions given must be applied in such a way that, after servicing (preventive maintenance) or repairing the engine, it does not contravene the local regulations when in use.

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## SAFETY PRECAUTIONS

THESE SAFETY PRECAUTIONS ARE IMPORTANT. Reference must also be made to the local regulations in the country of operation.

Do not change the specification of the engine.

Do not smoke when you put fuel in the tank.

Clean away any fuel which has fallen and move material which has fuel contamination to a safe place.

Do not put fuel in the tank during engine operation (unless really necessary).

Never clean, lubricate or adjust the engine during operation (unless you have had the correct training when extreme caution must be used to prevent injury).

Do not make any adjustments you do not understand.

Ensure that the engine is not in a position to cause a concentration of toxic emissions.

Persons in the area must be kept well clear during engine and equipment operation.

Do not permit loose clothing or long hair near parts which move.

Keep away from parts which turn during operation. Note that water pump/alternator drive belts can not be seen clearly while the engine is run.

Do not run the engine with any safety guards removed.

Do not remove the header tank filler cap while the engine is hot and the coolant is under pressure as dangerous hot coolant can be discharged.

Do not use salt water in the closed circuit cooling system or any other coolant which can cause corrosion. Keep sparks or fire away from batteries (especially while during charge) or combustion can occur. The battery fluid can burn and is also dangerous to the skin and especially the eyes.

Disconnect the battery terminals before you make a repair to the electrical system.

Only one person must be in control of the engine/s.

Ensure the engine is only operated from the control panel or operators position.

If your skin comes into contact with high pressure fuel. get medical assistance immediately.

Diesel fuel can cause skin damage to some persons. Use protection on the hands (gloves or special skin protection solutions).

Ensure that the transmission drive control is in "Out of Drive" position before the engine is started.

Extreme care must be taken if emergency repairs have to be made at sea or in adverse conditions.

Fit only correct Perkins Parts.

## POWERPART Consumable Products

To give assistance in the correct operation, service and maintenance of your engine and machine, Perkins Engines. Ltd., have made available the products shown below.

The instructions for the use of each product are given on the outside of each container.

These products are available from your Perkins distributor.

**POWERPART Antifreeze**
Gives corrosion protection and also a more efficient coolant in hot conditions. See Page C.5

**POWERPART Lay-Up 1**
A diesel fuel additive for protection against corrosion. See Page C.4

**POWERPART Lay-Up 2**
Gives inside protection to the engine and other closed systems. See Page C.4

**POWERPART Lay-Up 3**
Gives outside protection to any metal parts. See Page C.4

**POWERPART De-Icer**
To remove frost.

**POWERPART Silent Spray**
Silicone lubrication to lubricate and prevent noise from hinges, slide doors, etc.

**POWERPART Damp Displacer**
To make electrical equipment dry and to give future protection.

**POWERPART Hylomar**
Universal sealing compound to seal joints.

**POWERPART Hylosil**
Silicone rubber sealant to prevent leakage.

**POWERPART Impact Adhesive**
To keep joints in position during installation and other general attachment purposes.

**POWERPART Solvent**
To thoroughly clean metal faces before assembly.

**POWERPART Locking Agent.**
Used to securely install fasteners, sleeves, etc.

## Foreword

This workshop manual has been compiled for use in conjunction with normal workshop practice. Mention of certain accepted practices. therefore. has been purposely omitted in order to avoid repetition.

Reference to renewing joints and cleaning off joint faces, has to a great extent been omitted from the text, it being understood that this will be carried out where applicable.

Similarly, it is understood that in reassembly and inspection, all parts are to be thoroughly cleaned and where present, burrs and scale are to be removed.

It follows that any open ports of high precision components, e.g., fuel injection equipment, exposed by dismantling. will be blanked off until reassembled, to prevent the ingress of foreign matter.

When fitting setscrews into "through" holes into the interior of the engine. a suitable sealant should be used.

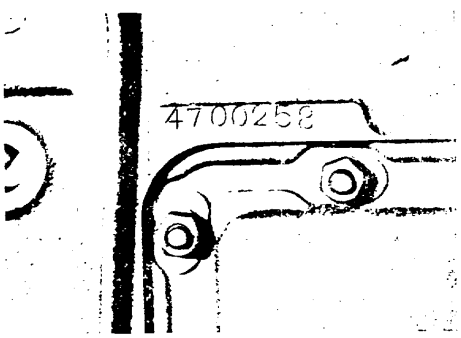
## Engine Number

Three systems of engine numbering have been used.

On very early engines. the serial number consisted of seven digits commencing with the figure. 4.

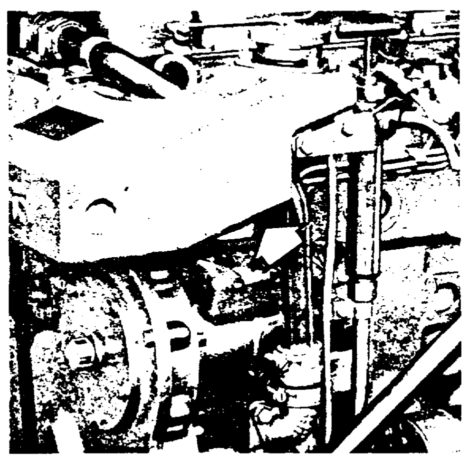
With later engines. the number consisted of figures and letters, e.g.. 236:251. The first three figures represent the capacity of the engine in cubic inches. the letter "1 " denotes the online was built in the United Kingdom and the last group of figures comprises the engine serial number,

On current engines. the number can consist or up to fifteen letters and figures a typical number being LD14739U510336D and will be found stamped on the cylinder block just above the fuel pump.




Engine Number Location
(Earlier 4.236 engines)


Engine Number Location
(Later 4.236 engines)



Engine Number Location
(Current 4.236 Engines)

**Contents**

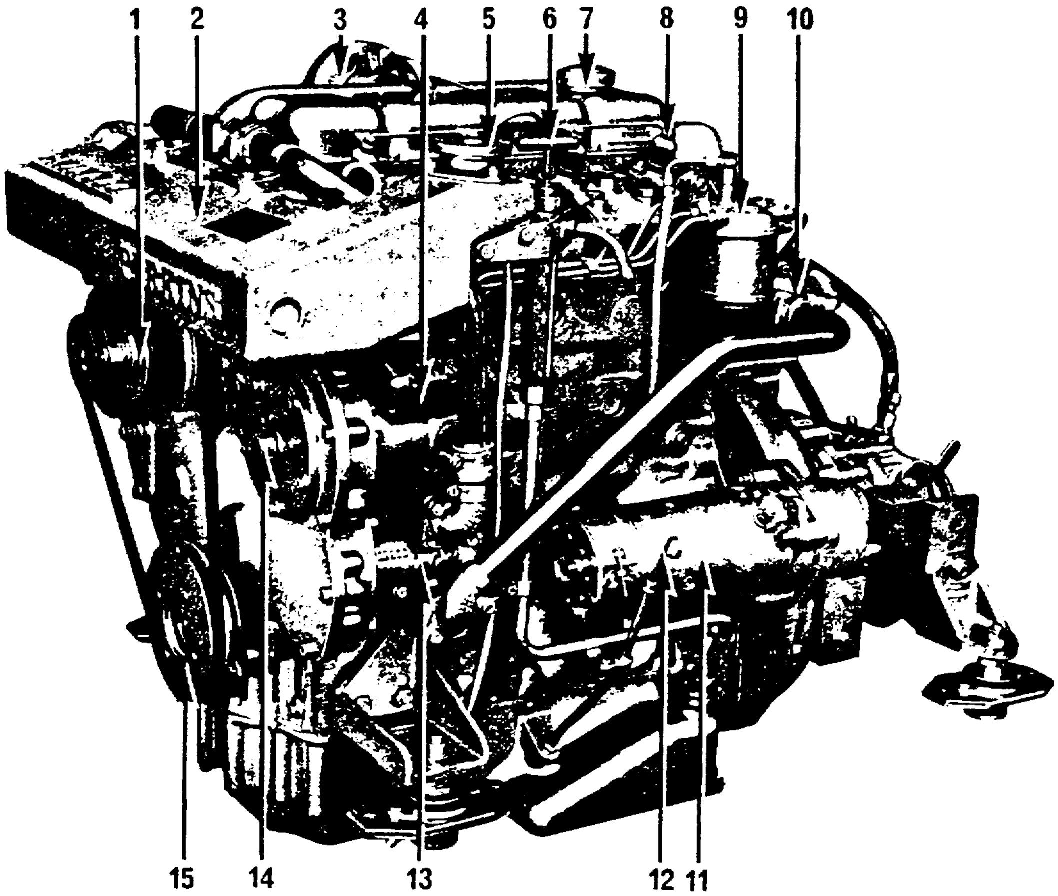
This publication is produced by the Technical Publications Department of Perkins Engines Ltd. and every endeavour is made to ensure that the information contained in this manual is correct at the time of publication. but due to continuous developments. the manufacturers reserve the right to make alterations without notice.

This engine manual is to guide you in dismantling and re-assembly - for information regarding the **application** of the engine, the reader should refer to the Perkins **"MARINE INSTALLATION MANUAL"** Publication No. 801SER 11811157.

## SECTION A
## Engine Views

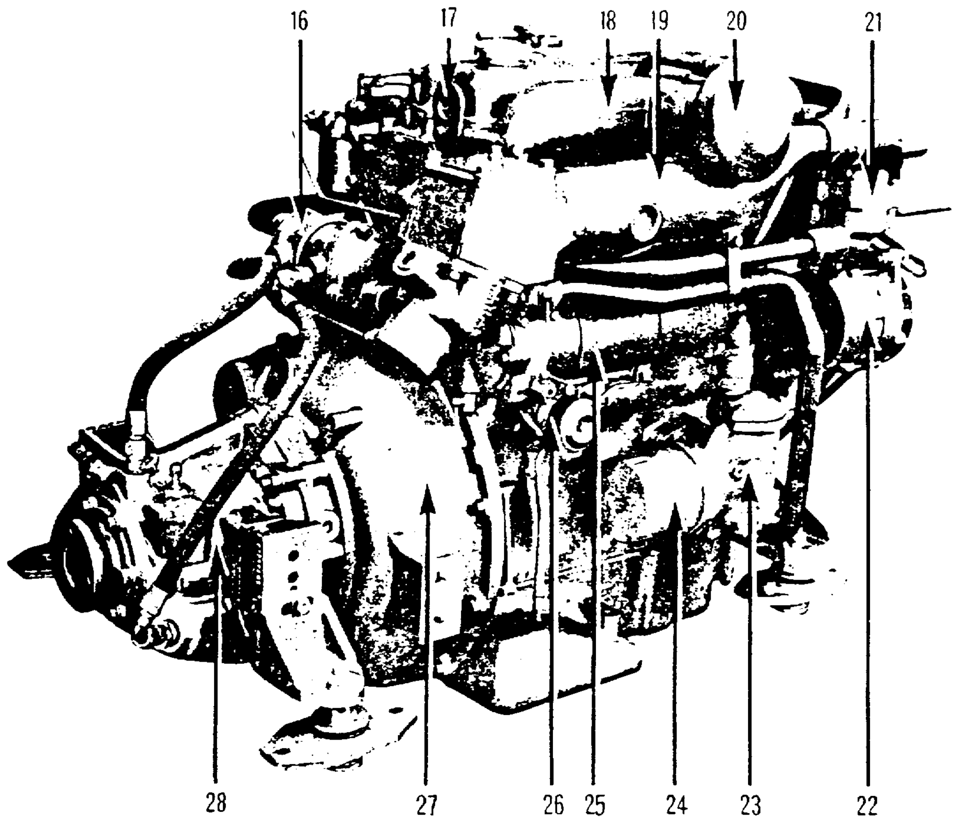
Perkins Engines are built to individual requirements to suit the applications for which they are intended and the following engine views do not necessarily typify any particular specification.

**ENGINE VIEWS-A.2**




Lowline 4.236M Engine

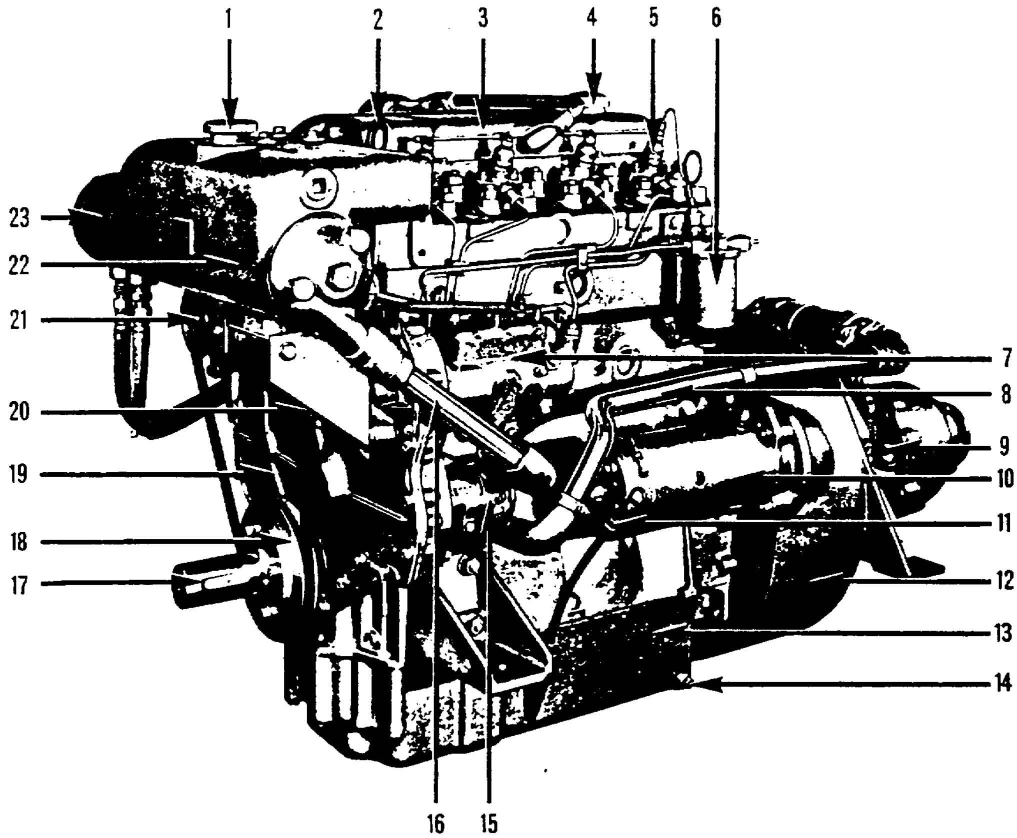
1. Fresh Water Pump Pulley.
2. Fresh Water Header Tank.
3. Air Filter.
4. Fuel Injection Pump.
5. Fresh Water Filler Cap.
6. Lubricating Oil Drain Pump.
7. Lubricating Oil Filler Cap.
8. Atomiser.
9. Fuel Oil Filter.
10. Gearbox Oil Cooler.
11. Starter Motor.
12. Lubricating Oil Dipstick
13. Sea Water Pump.
14. Tachometer Drive Connection.
15. Crankshaft Pulley.




Lowline 4.236M1 Engine

16. Gearbox Oil Cooler.
17. Engine Rear Lifting Eye.
18. Induction Manifold.
19. Water Cooled Exhaust Manifold.
20. Air Filter.
21. Thermostat Housing.
22. Alternator.
23. Engine Oil Cooler.
24. Spin-on Lubricating Oil Filter.
25. Heat Exchanger.
26. Fuel Oil Lift Pump.
27. Flywheel Housing.
28. Borg Warner 71CR Gearbox.

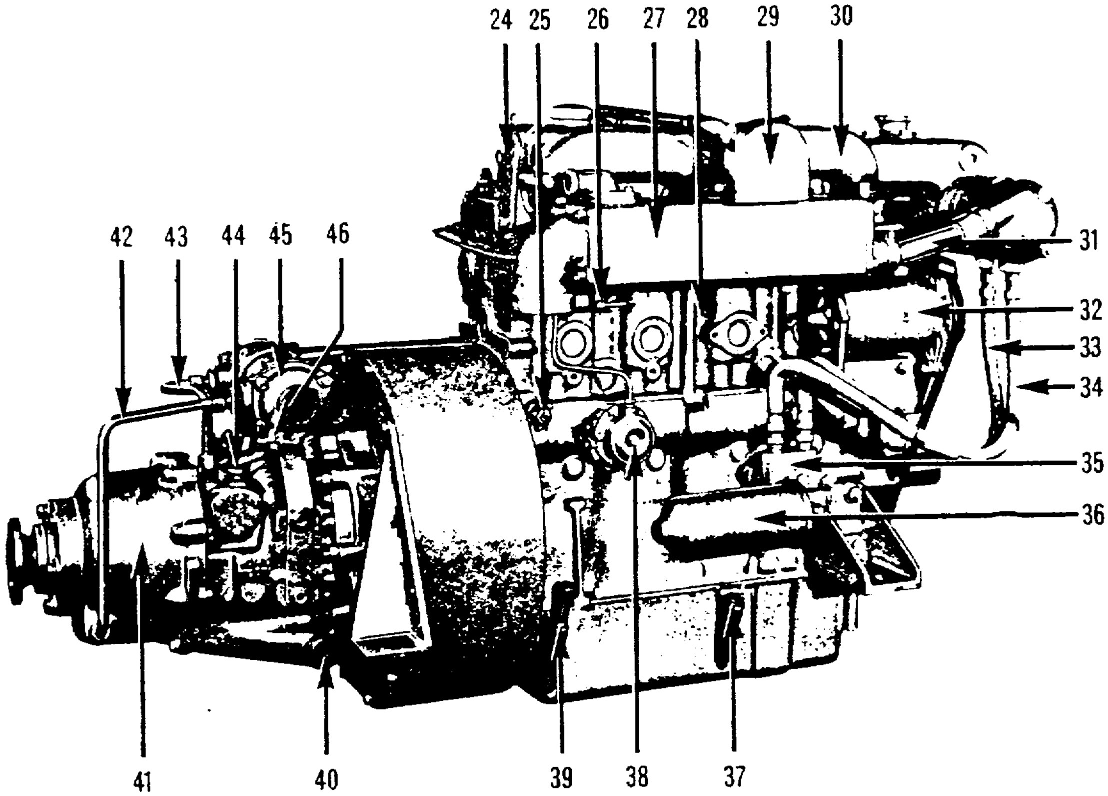
**ENGINE VIEWS-A.4**




4.236M Engine

1. Coolant Filler Cap
2. Front Lifting Eye
3. Rocker Cover
4. Lubricating Oil Filler Cap
5. Atomiser
6. Fuel Oil Filter
7. Fuel Injection Pump
8. Water Pipe from Gearbox Oil Cooler to Sea Water Pump.
9. Gearbox Filler Plug and Dipstick
10. Starter Motor.
11. Engine Oil Dipstick
12. Flywheel Housing
13. Lubricating Oil Sump.
14. Lubricating Oil sump Drain Plug.
15. Sea Water Pump.
16. Water Pipe Sea from Sea Water Pump to Heat Exchanger.
17. Power Take Oil from Front of Crankshaft.
18. Crankshaft Pulley
19. Timing Case Cover
20. Engine Tachometer Drive
21. Dynamo Pulley
22. Heat Exchanger

23 Engine Oil Cooler




4.236M Engine

24. Rear Lifting Eve.
25. Cylinder Block Drain Tap.
26. Exhaust Manifold Drain Tap.
27. Exhaust Manifold.
28. Cylinder Block.
29. Air Filter.
30. Induction Manifold.
31. Water Pipe from Heat Exchanger to Exhaust Manifold.
32. Dynamo.
33. Oil Pipe to Cooler.
34. Oil Pipe from Cooler.
35. Oil Filter Adaptor
36. Lubricating Oil Filter.
37. Alternative Dipstick Position.
38. Fuel Lift Pump.
39. Sump Draining Connection.
40. Gearbox Oil Drain Cap.
41. Reduction Gear Housing.
42. Oil Inlet Pipe from Cooler.
43. Oil Pipe to Cooler.
44. Gearbox Breather.
45. Gearbox Oil Cooler.
46. Gearbox Oil Cooler Water Drain Tap.

## Engine Date

| | |
|---|---|
| Type ...... ...... ...... ...... ...... | Four Stroke - Direct Injection |
| Nominal Bore (see Page B.2) ...... ...... ...... | 3.875 in (98,43 mm) |
| Stroke ...... ...... ...... ...... ...... | 5 in (127 mm) |
| No. of Cylinders .. ...... ...... ...... ...... | 4 |
| Cubic Capacity .... ...... ...... ...... ...... | 236 in' (3,86 litres) |
| Compression Ratio ...... ...... ...... ...... | 16: 1 |
| Firing Order ...... ...... ...... ...... ...... | 1, 3. 4, 2 |
| Rotation ...... ...... ...... ...... ...... | Left Hand (viewed from rear) |
| Valve Tip Clearance ...... ...... ...... ...... | 0.012 in (0.30 mm) cold |
| Engine Weight ..... ...... ...... ...... ...... | 1100 lb (499 kg) with Borg Warner D.D. |
| ...... ...... ...... ...... ...... | 1145 lb (519 kg) with Borg Warner Reduction |
| ...... ...... ...... ...... ...... | Gear |

## Details of Ratings

| | |
|---|---|
| Pleasure (High Speed) ...... ...... ...... ...... | 84 bhp (62.6 kW) at 2800 rev/min |
| Pleasure ...... ...... ...... ...... ...... | 76 bhp (56.6 kW) at 2503 rev/min |
| Commercial ...... ...... ...... ...... ...... | 69 bhp (50.7 kW) at 2250 rev/min |
| Commercial (Heavy Duty).... ...... ...... ...... | 54 bhp (40.3 kW) at 1800 rev/min |

## De-Rating for Altitude

This is not usually necessary for the 4.236 marine engine. A small loss of power will occur when temperature and humidity conditions are particularly adverse and allowance for this should be made when designing the propeller.

When the engine is required to operate on a lake more than 4,000 feet above sea level, contact Technical Services Department, Perkins Engines Ltd., Peterborough or one of those Overseas Companies listed on Page 11.

| Recommended Torque Tensions | lbf ft | kgf m | Nm |
|---|---|---|---|
| Cylinder Head Nuts or Setscrews ... ... | 100 | 13,8 | 136 |
| Connecting Rod Nuts | | | |
| Cadmium Plated (silver finish) ... ... ... | 75 | 10,4 | 102 |
| Phosphated (black finish)... ... ... ... | 95 | 13,1 | 129 |
| Main Bearing Setscrews | | | |
| (prior to Eng. No. 236U82408) ... ... ... | 150 | 20,7 | 203 |
| Main Bearing Setscrews | | | |
| (commencing Eng. No. 236U82408) ... ... | 180 | 2,8 | 244 |
| Idler Gear Hub Setscrews. ... ... ... | 30 | 4,1 | 41 |
| Flywheel Setscrews | 80 | 11 | 108 |
| Camshaft Gear Retaining Setscrew ... ... ... | 50 | 6,9 | 68 |
| Crankshaft Dog Nut or Retaining Screw | 300 | 42 | 406 |
| Lub. Oil Filter Setscrews ... ... ... | 30 | 4,2 | 41 |
| Atomiser Securing Nuts | 12 | 1.7 | 16 |
| Dynamo Pulley Retaining Nut ... ... ... | 20 | 2.8 | 27 |
| Alternator Pulley Retaining Nut (7/16 in) | 30 | 4,1 | 41 |
| Alternator Pulley Retaining Nut (9/16 in) ... ... ... | 30 | 4,1 | 41 |
| Alternator Pulley Retaining Nut (5/8 in) ... ... ... | 42 | 5,8 | 57 |
| Balancer Retaining Setscrews ... ... ... | 36 | 5,0 | 49 |
| High Pressure Fuel Pipe Nuts ... ... ... | 15 | 2,1 | 20 |
| Thermostart... ... ... ... ... | 10 | 1,4 | 14 |
| Thermostart Adaptor ... ... ... ... | 10 | 1,4 | 14 |

## Manufacturing Data and Dimensions

All threads used, except perhaps on proprietary equipment are Unified Series and America Pipe series. The crankshaft and pulley retaining setscrew are thread 7/8 in U.N.F. of T.P.I.

The following data of clearances and tolerances are given as a guide for personnel engaged upon major overhauls and the figures are those used in the factory for production methods.

The figure quoted in the dimensions column represent the minimum and the maximum sizes to which parts may be accepted when new.

The difference between these maximum and minimum figures is know as the manufacturing tolerance and this is necessary as an aid to manufacturing and its value is an expression of the desired quality of manufacture.

For example, where the outside diameter of a crankshaft main journal is quoted as 2.9985/2.999 in (76,16/76,18 mm) then the manufacturing tolerance is 0.0005 in (0.0127 mm).

During the overhaul of an engine it is reasonable to expect the use of personal initiave. It is obviously uneconomical to return worn component parts into service to involve labour cost again at an early date.

### Cylinder Block

| | |
|---|---|
| Total Height of Cylinder Block between Top and Bottom Faces ...... ...... ...... ...... | 17.367/17.375 in (441,12/441,33 mm) |
| Parent Bore Dia. for Cylinder Liner (Cast Iron) ...... | 4.0615/4.0625 in (103,16/103,19 mm) |
| Main Bearing Parent Bore Dia. ...... ...... ...... | 3.166/3.167 in (80,42/80,44 mm) |
| Camshaft Bore Dia. No. 1 for Bush (where fitted) ... | 2.1875/2.1887 in (55,56/55.59 mm) |
| Camshaft Bearing Bush Internal Dia. fitted... ...... | 2.0000/2.0017 in (50.8/50.84 mm) |
| Camshaft Bore Dia. No. 1 ...... | 2.00/2.001 in (50,80/50,83 mm) |
| Camshaft Bore Dia. No. 2 ...... ...... ...... | 1.990/1.9918 in (50,55/50,59 mm) |
| Camshaft Bore Dia. No. 3 ...... ...... ...... | 1.970/1.9718 in (50,04/50,08 mm) |

### Cylinder Liners (Cast Iron)

| | |
|---|---|
| Type ...... ...... ...... ...... ...... | Dry-Interference Fit |
| Interference Fit of Liner ...... ...... ...... ...... | 0.003/0.005 in (0,08/0,13 mm) |
| Inside Dia. of Liner after finish boring ...... ...... | 3.877/3.878 in (98,48/98.50 mm) |
| Height of Liner above Cylinder Block Face.... ...... | 0.028/0.035 in (0.71/0.89 mm) |
| Maximum Oversize (Rebore) ...... ...... ...... | +0.030 in (0,76 mm) |
| Overall Leneth of Liner ...... ...... ...... ...... | 9.005/9.015 in (228.7/229,0 mm) |

### Pistons

| | |
|---|---|
| Type ...... ...... ...... ...... ...... | Cavity in Crown |
| Overall Height (Skirt to Crown) ...... ...... ...... | 4.767 in (121.08 mm) |
| Piston Skirt Dia. (Across Thrust)..... ...... ...... | 3.8699/3.8707 in (98,29/98,32 mm) |
| Piston Crown Dia. (Across Thrust).. ...... ...... | 3.8508/3.8528 in (97.80/97.85 mm) |
| Piston Height in Relation to Cylinder Block Top Face (prior to Engine Nos. 236U135765 or 236U147150L) ...... ...... ...... ...... | 0.003/0.010 in (0,08/0,25 mm) ABOVE |
| Piston Height in Relation to Cylinder Block Top Face (commencing Engine Nos. 2361'135765 or 236U1147150L ...... ...... ...... ...... | 0.016/0.024 in (0.41/0.61 mm) ABOVE |
| Bore Dia. for Gudgeon Pin.. ...... ...... ...... | 1.37485/1.37505 in (34.92/34.93 mm) |
| Compression Ring Groove Width-Numbers 1, 2,. 3... | 0.0057 0.0967 in (2.43/2.46 mm) |
| Scraper Ring Groove Width-Numbers 4 and 5 ...... | 0.2525 0.2535 in (6.41/6.44 mm) |
| Weight of Piston ...... ...... ...... ...... | 2 lb 91/8, oz. - 1/4 oz (1.165 kg - 7 g) |

**Piston Rings**

| | |
|---|---|
| Top-Compression ...... ...... ...... ...... | Chromium Plated-Parallel Face |
| Second and Third-Compression ...... ...... ...... | Internally Stepped |
| Fourth-Scraper .... ...... ...... ...... ...... | Conformable Scraper |
| Fifth-Scraper ...... ...... ...... ...... ...... | Maxigroove |
| Compression Ring Width..... ...... ...... ...... | 0.0928/0.0938 in (2,36/2,.38 mm) |
| Groove Width ...... ...... ...... ...... ...... | 0.0957/0.0967 in (2,43/2,46 mm) |
| Ring Clearance in Groove.... ...... ...... ...... | 0.0019/0.0039 in (0,05/0,10 mm) |
| Scraper Ring Width ...... ...... ...... ...... | 0.249/0.250 in (6,33/6,35 mm) |
| Ring Clearance in Groove.... ...... ...... ...... | 0.0025/0.0045 in (0,06/0,11 mm) |
| Ring Gap-Chrome Compression...... ...... ...... | 0.016/1.024 in (0,41/0,61 mm) |
| Ring Gap-Internally Stepped Compression... ...... | 0.012/0.020 in (0,30/0,51 mm) |
| Ring Gap-Maxigroove Scraper ...... ...... ...... | 0 012/0.020 in (0,30/0,51 mm) |

**Gudgeon Pin**

| | |
|---|---|
| Type ...... ...... ...... ...... ...... | Fully Floating |
| Outside Dia. of Gudgeon Pin ...... ...... ...... | 1.3748/1.3750 in (34,92/34,93 mm) |
| Length of Gudgeon Pin ...... ...... ...... ...... | 3.297/3.312 in (83,74/84,12 mm) |
| Fit in Piston Boss. ...... ...... ...... ...... | Transition |

**Small End Bush**

| | |
|---|---|
| Type ...... ...... ...... ...... ...... | Steel backed, Lead Bronze Lined |
| Length of Small End Bush ... ...... ...... ...... | 1.316/1.336 in (33,43/33,93 mm) |
| Outside Dia. of Small End Bush...... ...... ...... | 1.535/1.5365 in (38,99/39,02 mm) |
| Inside Dia. before Reaming. ...... ...... ...... | 1.359/1.363 in (34,52/34,62 mm) |
| Inside Dia. after Reaming ...... ...... ...... | 1.37575i1.3765 in (34,94/34,96 mm) |
| Clearance between Small End Bush and Gudgeon Pin | 0.00075:0.0017 in (0,02/0,04 mm) |

Connecting Rod

| | |
|---|---|
| Type ...... ...... ...... ...... ...... | "H" Section |
| Cap Location to Connecting Rod...... ...... ...... | Serrations |
| Big End Parent Bore Dia. ...... ...... ...... | 2.6460/2.6465 in (67,21/67,22 mm) |
| Small End Parent Bore Dia. ...... ...... ...... | 1.53125/1.53225 in (38,90/38,92 mm) |
| Length from Centre Line of Big End to Centre Line of Small End.. ...... ...... ...... ...... | 8.624/8.626 in (219,05/219,10 mm' |
| Big End Bolt Dia... ...... ...... ...... ...... | 0.500 in (12,7 mm) |
| Thread of Bolt ...... ...... ...... ...... | U.N.F. |

## TECHNICAL DATA-B.4

### Connecting Rod Alignment

Large and small end bores must be square and parallel with each other within the limits of ±0.010 it (0,254 mm) measured 5 in (127 mm) each side of the axis of the rod on test mandrel as shown in Fig. B.1 With the small end bush fitted, the limit of ±0.010 in (0.254 mm) is reduced to ±0.0025 in (0,06 mm).

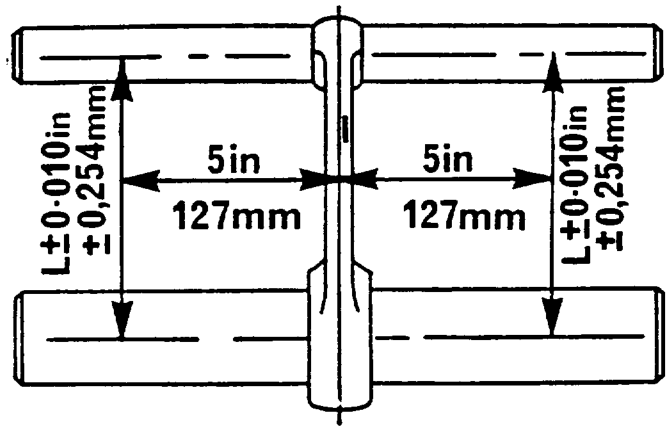



*Fig. B.1.*

### Crankshaft

| | |
|---|---|
| Overall Length ...... ...... ...... ...... | 24.01/24.04 in (609,85/610,62 mm) |
| Main Journal Dia.. ...... ...... ...... ...... | 2.9984/2.9992 in (76,16/76,18 mm) |
| Main Journal Length-Nos. 1 ...... ...... ...... | 1.453/1.473 in (36,91/37,41 mm) |
| Main Journal Length Nos. 2, 4 and 5 ...... ...... | 1.545/1.549 in (39,24/39.34 mm) |
| *Main Journal Length-Nos. 3 ...... ...... ...... | 1.738/1.741 in (44.15/44.22 mm) |
| *Main Journal Fillet Radii ...... ...... ...... | 0.145/0.156 in (3,68/3,96 mm) |
| Crankpin Dia ...... ...... ...... ...... | 2.4988/2.4996 in (63,47/63,49 mm) |
| Crankpin Length.. ...... ...... ...... ...... | 1.5885/1.5915 in (40,35/40,42 mm) |
| *Crankpin Fillet Radii ...... ...... ...... | 0.145/0.156 in (3,68/3,96 mm) |
| *Surface Finish-All Journals ...... ...... ...... | 16 micro inches (0,4 microns)- maximum |
| Main Journal and Crankpin Regrind Undersizes ...... | 0.010, 0.020 and 0.030 in (0,25, 0,51 and 0,76 mm) |
| Oil Seal Helix Dia. (rope seal only) ...... ...... | 3.124/3.125 in (79,35/79,38 mm) |
| Oil Seal Helix Width (rope seal only) ...... ...... | 0.050/0.080 in (1,27/2,03 mm) |
| Oil Seal Helix Depth (rope seal only) ...... ...... | 0.004/0.008 in (0,10/0.20 mm) |
| Flange Dia. ...... ...... ...... ...... | 5.247/5.249 in (133.27/133.32 mm) |
| Flange Width ...... ...... ...... ...... | 0.500 in (12,70 mm) |

**Crankshaft (Contd.)**

| | |
|---|---|
| Spigot Bearing Recess Depth ...... ...... ...... | 0.781 in (19,84 mm) |
| Spigot Bearing Recess Bore ...... ...... ...... | 1.849/1.850 in (46,98/47,00 mm) |
| Crankshaft End Float ...... ...... ...... ...... | 0.004/0.015 in (0,102/0,38 mm) |

*Fillet radii and surface finish must be maintained during crankshaft regrinding. Length of No. 3 main journal not to exceed 1.759 in (44,68 mm) after regrinding. Width of crankpins must not exceed 1.5965 in (40,55 mm) after regrinding. Where necessary use oversize thrust washers to bring crankshaft end float within the correct limits.

**Crankshaft Thrust Washers**

| | |
|---|---|
| Type ...... ...... ...... ...... ...... | Steel Backed, Lead Bronze Faced |
| Position in Engine ...... ...... ...... ...... | Centre Main Bearing |
| Thrust Washer Thickness (STD) ...... ...... | 0.089/0.091 in (2,26/2,31 mm) |
| Thrust Washer Thickness (O/S) ...... ...... ...... | 0.0965/0.1005 in (2,45/2,55 mm) |
| Thrust Washer Outside Dia. ...... ...... ...... | 4.088/4.098 in (103,84/104,90 mm) |
| Thrust Washer Inside Dia. ...... ...... ...... | 3.420/3.430 in (86,87/87.12 mm) |

**Main Bearings**

| | |
|---|---|
| Type ...... ...... ...... ...... ...... | Pre-Finished, Steel Backed, Aluminum Tin Faced |
| Shell Width-Nos 1, 2, 4 and 5 ...... ...... | 1.245/1.255 in (31,62/31,88 mm) |
| Shell Width-Nos. 3 ...... ...... ...... ...... | 1.435/1.445 in (36,45/36,70 mm) |
| Outside Dia. of Main Bearing ...... ...... ...... | 3.167 in (80.41 mm) |
| Inside Dia. of Main Bearing. ...... ...... ...... | 3.0010/3.0026 in (76,23/76,27 mm) |
| Main Bearing Running Clearance ...... ...... | 0.0018/0.0042 in (0,05/0,11 mm) |
| ! Shell Thickness.. ...... ...... ...... ...... | 0.0822/0.0825 in (2,088/2,096 mm) |

**Connecting Rod Bearings**

| | |
|---|---|
| Type ...... ...... ...... ...... ...... | Pre-Finished, Steel Backed, Aluminum Tin Faced |
| Shell Width ...... ...... ...... ...... ...... | 1.245/1.255 in (31,62/31,88 mm) |
| Outside Dia. of Con. Rod Bearing ...... ...... | 2.6465 in (67,22 mm) |
| Inside Dia. of Con. Rod Bearing ...... ...... | 2.5008/2.5019 in (63,52/63,55 mm) |
| Con. Rod Bearing Running Clearance ...... ...... | 0.0012/0.0031 in (0,03/0,08 mm) |
| Shell Thickness ...... ...... ...... ...... | 0.0723/0.0726 in (1,836/1,844 mm) |

**TECHNICAL DATA-B.6**

**Camshaft**

| | |
|---|---|
| No. 1 Journal Length | 1.2055/1.2155 in (30,62/30,87 mm) |
| No. 1 Journal Dia. | 1.9965/1.9975 in (50,71/50,74 mm) |
| No. 1 Cylinder Block Camshaft Bore Dia. | 2.000/2.001 in (50,8/50,83 mm) |
| No. 1 Journal Running Clearance | 0.0025/0.0045 in (0,06/0,11 mm) |
| No. 2 Journal Length | 1.625 in (41,27 mm) |
| No. 2 Journal Dia. | 1.9865/1.9875 in (50,46/50,48 mm) |
| No. 2 Cylinder Block Camshaft Bore Dia. | 1.990/1.992 in (50,55/50.60 mm) |
| No. 2 Journal Running Clearance | 0.0025/0.0053 in (0,06/0,14 mm) |
| No. 3 Journal Length | 1.15625 in (29,37 mm) |
| No. 3 Journal Dia. | 1.9665/1.9675 in (49,95/49,98 mm) |
| No. 3 Cylinder Block Camshaft Bore Dia. | 1.970/1.972 in (50,04/50,09 mm) |
| No. 3 Journal Running Clearance | 0.0025/0.0053 in (0,06/0,14 mm) |
| Cam Lift | 0.3045 in (7,73 mm) |
| Oilways for Rocker Shaft Lubrication | No. 2 Journal |

**Camshaft Thrust Washer**

| | |
|---|---|
| Type | 360º |
| Thrust Washer Outside Dia. | 2.872/2.874 in (72,95/73,00 mm) |
| Cylinder Block Recess Dia. for Thrust Washer | 2.875/2.885 in (73,03/73,28 mm) |
| Clearance Fit of Washer in Recess | 0.001/0.013 in (0,03/0,33 mm) |
| Thrust Washer Inside Dia. | 1.750 in (44,45 mm) |
| Thrust Washer Thickness | 0.216/0.218 in (5,47/5,54 mm) |
| Cylinder Block Recess Depth for Thrust Washer (Earlier Type). | 0.152/0.154 in (3,86/3,91 mm) |
| Thrust Washer Protrusion beyond Cylinder Block Face (Earlier Type) | 0.062/0.066 in (1,53/1,68 mm) |
| Cylinder Block Recess Depth for Thrust Washer (Later Type) | 0.187/0.190 in (4,75/4,83 mm) |
| Thrust Washer Protrusion beyond Cylinder Block Face (Later Type) | 0.026/0.031 in (0.66/0,79 mm) |
| Camshaft End Float | 0.004/0.016 in (0,10/0.41 mm) |

**Valve Timing**

Refer to Page K.7.

**Cylinder Head**

| | |
|---|---|
| Cylinder Head Length | 19.875 in (454,02 mm) |
| Cylinder Head Depth | 4.0625 in ± 0.015 in (103,20 mm ± 0,38 mm) |
| Skimming allowance on Cylinder Head Face | 0.012 in (0,31 mm) |
| Min. Cylinder Head Depth after Skimming | 4.0355 in (102,51 mm)* |
| Max. Nozzle Protrusion after Skimming | 0.175 in (4,44 mm) |
| Leak Test Pressure | 30 $lb/in^2$ (2,11 $kgf/cm^2$) - 207 $kN/m^2$ |
| Valve Seat Angle | 45° |
| Valve Bore in Cylinder Head | 0.37425/0.37525 in (9,51/9,53 mm) |

*Minimum Cylinder Head Depth quoted is nominal and Skimming Allowance must be governed by the Maximum Nozzle Protrusion Permissible.

**Exhaust Valves**

| | |
|---|---|
| Valve Stem Dia. . ...... ...... ...... ...... | 0.372/0.373 in (9,45/9,47 mm) |
| Clearance Fit of Valve in Head ...... ...... ...... | 0.00125/0.00325 in (0,03/0,08 mm) |
| Valve Head Dia. ...... ...... ...... ...... | 1.438/1.442 in (36,54/36,64 mm) |
| Valve Face Angle. ...... ...... ...... ...... | 45° |
| Valve Head Depth below Cylinder Heal Face (prior to Eng. Nos. 236U135765 or 236U147150L) | 0.029/0.039 in (0,74/0,99 mm) |
| Valve Head Depth below Cylinder Head Face (commencing.Engine Nos. 236U135765 or 236U147150L) ...... ...... ...... ...... | 0.042/0.052 in (1,07/1,32 mm) |
| Valve Head Depth below Cylinder Head Face (all types) Service* ...... ...... ...... ...... | 0.055 in (1,40 mm) maximum |
| Overall Length of Valve ...... ...... ...... | 4.847/4.862 in (123,11/123,49 mm) |
| Service Valve Stem Oversizes ...... ...... ...... | 0.003, 0.015 and 0.030 in (0,08, 0,38 and 0,76 mm) |
| Sealing Arrangement ...... ...... ...... | Rubber Deflectors |

*Where engines conform to the BSAU141a 1971 regulations, then the valve depth production limits should not be exceeded.

**Inlet Valves**

| | |
|---|---|
| Valve Stem Dia. ...... ...... ...... ...... | 0.3725/0.3735 in (9,46/9,48 mm) |
| Clearance Fit of Valve in Head ...... ...... ...... | 0.00075/0.00275 in (0,02/0,07 mm) |
| Valve Head Dia. ...... ...... ...... ...... | 1.742/1.746 in (44,25/44,36 mm) |
| Valve Face Angle. ...... ...... ...... ...... | 45° |
| Valve Head Depth below Cylinder Head Face ...... | 0.035/0.045 in (0.89'1,14 mm) |
| Valve Head Depth below Cylinder Head Face - Service* ...... ...... ...... ...... ...... | 0.061 in (1,55 mm) |
| Overall Length of Valve , ...... ...... ...... | 4.831/4.846 in (122,71/123,09 mm) |
| Service Valve Stem Oversizes ...... ...... ...... | 0.003, 0.015 and 0.030 in (0.08. 0.38 and 0.76 mm) |

'Where engines conform to the BSAU141a 1971 regulations, then the valve depth production limits should not be exceeded.

**Inner Valve Springs**

| | |
|---|---|
| Fitted Length ...... ...... ...... ...... | 1.5625 in (39,7 mm) |
| Load at Fitted Length ...... ...... ...... ...... | 15.4 Ibf ± 2 lbf (7 kgf ± 0,91 kgf) |
| Fitted Position ...... ...... ...... ...... | Damper Coils to Cylinder Head |

**Outer Valve Springs**

| | |
|---|---|
| Fitted Length ...... ...... ...... ...... | 1.780 in (45,22 mm) |
| Load at Fitted length ...... ...... ...... ...... | 40 lbf ± 2 Ibf (18,1 kgf ± 0,91 kgf) |
| Fitted Position ...... ...... ...... ...... | Damper Coils to Cylinder Head |

**Tappets**

| | |
|---|---|
| Overall Length ...... ...... ...... ...... | 2.96875 in (75,41 mm) |
| Outside Dia. Tappet Shank . ...... ...... ...... | 0.7475/0.7485 in (18,99/19,01 mm) |
| Cylinder Block Tappet Bore Dia. ...... ...... | 0.750/0.7512 in (19,05/19,08 mm) |
| Tappet Running Clearance in Bore ...... ...... | 0.0015/0.0037 in (0,04/0,09 mm) |
| Outside Dia. of Tappet Foot ...... ...... ...... | 1.1875 in (30,16 mm) |

**Rocker Shaft**

| | |
|---|---|
| Overall Length of Shaft ...... ...... ...... | 16.78125 in (426,24 mm) |
| Outside Dia. of Shaft ...... ...... ...... ...... | 0.7485/0.7495 in (19,01/19,04 mm) |

**Rocker Levers**

| | |
|---|---|
| Inside Dia. of Lever Bore ...... ...... ...... | 0.7505/0.7520 in (19,06/19.10 mm) |
| Lever Clearance on Rocker Shaft .... ...... ...... | 0.001/0.0035 in (0,03 /0,09 mm) |

## TECHNICAL DATA-B.8

**Valve Clearances**

Clearances between Valve Stem and Rocker Lever.. 0.012 in (0,300 mm) Cold

**TIMING GEARS**

**Camshaft Gear**

| | |
|---|---|
| Number of Teeth.. ...... ...... ...... | 56 |
| Inside Dia. of Gear Boss ...... ...... ...... | 1.375/1.376 in (34,93/34,96 mm) |
| Outside Dia. of Camshaft Hub ...... ...... ...... | 1.3751/1.3757 in (34,93/34,95 mm) |
| Transition Fit of Gear on Camshaft Hub ...... ...... | 0.0007/0.0009 in (0,017/0,022 mm) |

**Fuel Pump Gear**

| | |
|---|---|
| Number of Teeth.. ...... ...... ...... | 56 |
| Inside Dia. of Gear Bore ...... ...... ...... | 1.750/1.751 in (44,45/44,47 mm) |
| Fuel Pump Hub Dia ...... ...... ...... | 1.748/1.7488 in (44,40/44,42 mm) |

**Idler Gear and Hub**

| | |
|---|---|
| Number of Teeth.. ...... ...... ...... | 63 |
| Inside Dia. of Gear (bushes fitted)... ...... ...... | 1.9998/2.0007 in (50,79/50,82 mm) |
| Outside Dia. of Gear Hub ...... ...... ...... | 1.996/1.9975 in (50,70/50.72 mm) |
| Running Clearance of Gear on Hub.. ...... ...... | 0.0023/0.0047 in (0,06/0,12 mm) |
| Idler Gear Width Including Bushes ... ...... ...... | 1.1865/1.1875 in (30,14/30,16 mm) |
| Hub Width ...... ...... ...... ...... | 1.1915/1.1945 in (30,26/30,33 mm) |
| Idler Gear End Float ...... ...... ...... | 0.004/0.008 in (0,10/0,20 mm) |

**Crankshaft Gear**

| | |
|---|---|
| Number of Teeth.. ...... ...... ...... | 28 |
| Gear Bore ...... ...... ...... ...... | 1.875/1.876 in (47,63/47,65 mm) |
| Crankshaft Dia. for Gear ...... ...... ...... | 1.875/1.8755 in (47,63/47,64 mm) |

**Timing Gear Backlash**

All gears ...... ...... ...... ...... 0.003 in (0.08 mm) minimum

**LUBRICATION SYSTEM**

Lubricating Oil Pressure Normal oil pressure at max. engine speed and

| | |
|---|---|
| ...... ...... ...... ...... | normal operating temperature 30/60 lbf/in- |
| ...... ...... ...... ...... | (2,1/4.2 kgf/cm:) - 207/414 kN/$m^2$ |
| ...... ...... ...... ...... | Lubricating Oil Capacities |
| Sump ...... ...... ...... ...... | 14.5 IMP pints - 8.2 litres - 8.7 US quarts |
| Total ...... ...... ...... ...... | 16.5 IMP pints -9.4 litres -9.9 US quarts |

Sump

| | |
|---|---|
| Dipstick Position.. ...... ...... ...... | Direct into sump, port side below fuel injection pump. |
| Strainer Location.. ...... ...... ...... | On Suction Pipe of Lubricating Oil Pump. |

**Lubricating Oil Pump Clearances**

**Pump Part No. 41314054 (Concentric)**

| | |
|---|---|
| No. of Lobes on Inner Rotor ...... ...... ...... | Three |
| No. of Lobes on Outer Rotor ...... ...... ...... | Four |
| Inner Rotor to Outer Rotor ...... ...... ...... | 0.001/0.003 in (0,03/0,08 mm) |
| Inner Rotor End Clearance ...... ...... ...... | 0.0015/0.003 in (0,04/0,08 mm) |
| Outer Rotor End Clearance ...... ...... ...... | 0.0005/0.0025 in (0,01/0,06 mm) |
| Outer Rotor to Pump Body ...... ...... ...... | 0.011/0.013 in (0,28/0,33 mm) |

**Pump Part No. 41314061 (Hobourn Eaton)**

| | |
|---|---|
| No. of Lobes on Inner Rotor ...... ...... ...... | Four |
| No. of Lobes on Outer Rotor ...... ...... ...... | Five |
| Inner Rotor to Outer Rotor ...... ...... ...... | 0.001/0.006 in (0,03/0,15 mm) |
| Inner Rotor and Outer Rotor End Clearance . ...... | 0.001/0.005 in (0,03/0,13 mm) |
| Outer Rotor to Pump Body ...... ...... ...... | 0.0055i0.010 in (0,14/0,25 mm) |

**Oil Pump Drive Gear**

| | |
|---|---|
| Number of Teeth.. ...... ...... ...... ...... | 19 |
| Inside Dia. of Gear Bore ...... ...... ...... | 0.497/0.4978 in (12,62/12,64 mm) |
| Outside Dia. of Oil Pump Shaft ...... ...... ...... | 0.4990/0.4995 in (12,67/12,69 mm) |
| Interference Fit of Gear on Shaft ...... ...... | 0.0012/0.0025 in (0,03/0,06 mm) |
| Clearance between Drive Gear and Pump Body ...... | 0.003/0.007 in (0,08/0,18 mm) |

**Oil Pump Idler Gear**

| | |
|---|---|
| Number of Teeth.. ...... ...... ...... ...... | 20 |
| Inside Dia. of Gear Bore ...... ...... ...... | 1.000/1.0012 in (25,40/25,43 mm) |
| Outside Dia. of Gear Bush ...... ...... ...... | 1.000/1.0008 in (25,40/25,42 mm) |
| Inside Dia. of Gear Bush ...... ...... ...... | 0.8750/0.8763 in (22,23/22,26 mm) |
| Outside Dia. of Idler Gear Shaft ...... ...... | 0.8737/00.8742 in (22,19/22,20 mm) |
| Running Clearance of Gear on Shaft ...... ...... | 0.0008/0.0026 in (0,02/0,07 mm) |
| Idler Gear End Float ...... ...... ...... ...... | 0.002/0.016 in (0,05,/0,41 mm) |

**Relief Valve**

| | |
|---|---|
| Type ...... ...... ...... ...... | Spring Loaded Plunger |
| Pressure Setting.. ...... ...... ...... ...... | 50/60 Ib/in- (3,5/4.2 kgf, cm$^2$:) - 345/414 kN/m$^2$ |
| Length of Plunger. ...... ...... ...... ...... | 0.9375 in (23.81 mm) |
| Outside Dia. of Plunger ...... ...... ...... | 0.5585/0.5595 in (14,19/14,21 mm |
| lnside Dia. of Valve Housing Bore ... ...... ...... | 0.5605/0.5625 in (14,23/14.30 mm) |
| Clearance of Plunger in Bore ...... ...... ...... | 0.001 /0.004 in (0,03.0,10 mm) |
| Outside Dia. of Spring ...... ...... ...... ...... | 0.368./0.377 in (9,35/9,58 mm) |
| Spring-Free Length ...... ...... ...... ...... | 1.5 in (38,10 mm) |
| Spring-Solid Length ...... ...... ...... ...... | 0.745 in (18,92 mm) Maximum |

**Lubricating Oil Filter**

| | |
|---|---|
| Type of Filter ...... ...... ...... ...... ...... | Full Flow |
| Element Type ...... ...... ...... ...... | Paper or Spin-on Canister |
| By-Pass Valve Setting ...... ...... ...... ...... | Opens between 8/17 lbf/in$^2$ (0.5/1.2 kgf. cm<br>55,117 kN :m pressure differential |

**COOLING SYSTEM**

| | |
|---|---|
| Type ...... ...... ...... ...... | Indirect Fresh/Sea Water Cooling utilizing Heat Exchanger |
| Engine Fresh Water (Closed Circuit Capacity) ...... | 26 pt (14,8 litre) Including Heat Exchanger |

**Thermostat**

| | |
|---|---|
| Type ...... ...... ...... ...... | Wax Capsule |
| Opening Temperature ...... ...... ...... ...... | 177º-183°F (80°-84°C) |
| Fully Open at ...... ...... ...... ...... | 208°F (980C) |
| Valve Lift ...... ...... ...... ...... | 0.312/0.469 in (7,94/11,91 mm) |

## TECHNICAL DATA-B.10

**Water Pump (Fresh Water)**

| | |
|---|---|
| Type ...... ...... ...... ...... ...... | Centrifugal |
| Outside Dia. of Shaft for Pulley ...... ...... ...... | 0.7492/0.7497 in (13,03/13,04 mm) |
| Inside Dia. of Pulley Bore ...... ...... ...... | 0.7508/0.7516 in (19,07/19,09 mm) |
| Transition Fit of Pulley on Shaft ...... ...... ...... | 0.0011/0.0024 in (0,03/0,06 mm) |
| Outside Dia. of Shaft for Impeller..... ...... ...... | 0.6262/0.6267 in (15,90/15,92 mm) |
| Inside Dia. of Impeller Bore ...... ...... ...... | 0.6249/0.6257 in (15,87/15,89 mm) |
| Interference Fit of Impeller on Shaft ...... ...... | 0.0005/0.0018 in (0,01/0,05 mm) |
| Outside Dia. of Impeller ...... ...... ...... | 3.094/3.096 in (78,58/78,63 mm) |
| Impeller Blade to Body Clearance ...... ...... | 0.027/0.035 in (0,68/0,89 mm) |
| Water Pump Seal Type ...... ...... ...... | Synthetic Rubber, Carbon Faced |
| Outside Dia. of Water Pump Seal for Pump Bore .... | 1.435/1.436 in (36,45/36,47 mm) |
| Inside Dia. of Seal for Impeller Shaft ...... ...... | To suit 0.625 in (15,875 mm) Dia. shaft |
| Bearing Seal Type ...... ...... ...... ...... | Felt, impregnated with Water Repellent Oil |
| Bearing Seal Thickness ...... ...... ...... ...... | 0.219 in (5,56 mm) |
| Outside Dia. of Seal ...... ...... ...... ...... | 1.375 in (34,93 mm) |
| Inside Dia. of Seal ...... ...... ...... ...... | 0.922 in (23,41 mm) |

**Water Pump (Sea Water)**

| | |
|---|---|
| Type ...... ...... ...... ...... ...... | Centrifugal |

**FUEL SYSTEM**

**Fuel Oil Specifications**

| | | |
|---|---|---|
| United Kingdom | BS.2869:1967 | Class A. or A.2 |
| United States | V-F-800a<br>A.S.T.M./D975-66T | Grades DF-A, DF-1 or DF-2.<br>Nos. 1-D or 2-D |
| France J.O. 14/9/57 | | Gas Oil or Fuel Domestique |
| India IS: 1460/1968 | | Grade Special or Grade A |
| Germany | DIN-51601 (1967) | - |
| Italy | CUNA-Gas Oil NC<br>630-01 (1957) | - |
| Sweden | SIS. 15 54 32 (1969) | - |
| Switzerland | Federal Military Spec.<br>9140-335-1404 (1965) | - |

Fuel oils available in territories other than those listed above which are to an equivalent specification may be used.

**Fuel Lift Pump**

| | |
|---|---|
| Type of Pump ...... ...... ...... ...... | A.C. Delco V.P. Series |
| Method of Drive ...... ...... ...... ...... | Eccentric on Camshaft |
| Delivery Pressure ..... ...... ...... ...... ...... ...... ...... ...... | 2 $^{3/4}$ to 4¼ lbf/in$^2$ (0.19/0,30 kgf/cm$^2$) - 19/29 kN/m$^2$: |
| Pump to Cylinder Block Gasket Thickness ...... | 0.025 in (0,64 mm) |
| Spring Colour Code ...... ...... ...... ...... | Green |

**Fuel Filter (Final)**

| | |
|---|---|
| Element Type ...... ...... ...... ...... | Paper |
| Valve Type ...... ...... ...... ...... ...... | Gravity Vent Valve |

**Fuel Injection Pump**

| | |
|---|---|
| Make ...... ...... ...... ...... ...... | C.A.V. |
| Type ...... ...... ...... ...... ...... | D.P.A. (Mechanically Governed) |
| Pump Rotation ...... ...... ...... ...... | Clockwise |
| Plunger Dia. ...... ...... ...... ...... ...... | 8,5 mm |
| Timing Letter (Mechanical) ...... ...... ...... | "C" |
| No. 1 Cylinder Outlet ...... ...... ...... ...... | "W" |

**Engine Checking and Fuel Pump Marking Angles, Static Timing**

The correct marking angles and static timing can be found by reference to the prefix letters and figures of the setting code adjacent to the word "set" on the fuel pump identification plate. Engine checking and fuel pump marking angles are for use with timing tool MS67B and adaptor PD67B—1.

| **Prefix Letters** | **Engine Checking Angle (Degrees)** (with engine at TDC compression) | **Fuel Pump Marking Angle (Degrees)** | **Static Timing** (BTDC-Degrees) | **Piston Displacement** |
|---|---|---|---|---|
| AS62 | 279 | 292 | 26 | 0.322 in (8,18 mm) |
| BS44 | 281 | 296 | 30 | 0.425 in (10,79 mm) |
| BS49 | 281 | 292 | 22 | 0.230 in (5,84 mm) |
| BS34 | 281 | 292 | 22 | 0.230 in (5,84 mm) |
| BS62 | 281 | 292 | 22 | 0.230 in (5,84 mm) |
| BS64 | 281 | 292 | 22 | 0.230 in (5,84 mm) |
| LS43 | 284 1/2 | 296 | 30 | 0.230 in (6.35 mm) |
| LS44 | 281 | 296 | 23 | 0.425 in (10,79 mm) |
| LS45 | 284 1/2 | 296 | 23 | 0.250 in (6.35 mm) |
| LS49 | 284 1/2 | 296 | 23 | 0.250 in (6.35 mm) |
| LS50 | 284 1/2 | 296 | 23 | 0.250 in (6.35 mm) |
| LS52 | 284 1/2 | 296 | 23 | 0.250 in (6.35 mm) |
| LS55 | 284 1/2 | 296 | 25 | 0.250 in (6.35 mm) |
| LS57 below 2160 rev/min | 284 1/2 | 296 | 23 | 0.250 in (6.35 mm) |
| LS57 above 2160 rev/min | 283 1/2 | 296 | 25 | 0.295 in (7,49 mm) |
| LS61 | 284 1/2 | 296 | 23 | 0.250 in (6.35 mm) |
| LS62 | 283 1/2 | 296 | 25 | 0.295 in (7.49 mm) |
| LS63 | 284 1/2 | 296 | 23 | 0.250 in (6.35 mm) |
| LS66 | 281 | 292 | 22 | 0.230 in (5.84 mm) |
| LS67 | 284 1/2 | 296 | 23 | 0.250 in (6.35 mm) |
| MS67 | 279 | 292 | 26 | 0.322 in (8,18 mm) |
| PS45 | 281 | 292 | 22 | 0.230 in (5,84 mm) |
| PS48 | 281 | 292 | 22 | 0.230 in (5,84 mm) |
| PS51 | 281 | 292 | 22 | 0.230 in (5,84 mm) |
| PS54 | 281 | 292 | 22 | 0.230 in (5,84 mm) |
| PS55 | 283 | 292 | 18 | 0.156 in (3,96 mm) |
| PS61 (Exceptions below) | 281 | 292 | 22 | 0.230 in (5,84 mm) |
| PS61/850/4/3120 | 280 1/2 | 292 | 23 | 0.250 in (6.35 mm) |
| PS61/850/7/3120 | 280 1/2 | 292 | 23 | 0.250 in (6.35 mm) |
| PS61/850/9/2400 | 280 1/2 | 292 | 23 | 0.250 in (6.35 mm) |
| PS62 | 281 | 292 | 22 | 0.230 in (5,84 mm) |
| PS66 | 281 | 292 | 22 | 0.230 in (5,84 mm) |
| WS62 | 280 | 292 | 24 | 0.275 in (6,98 mm) |
| WS66 | 280 | 292 | 24 | 0.275 in (6,98 mm) |
| XS55E | 281 | 293 | 24 | 0.275 in (6,98 mm) |
| ZS51E | 278 1/4 | 291 | 25 1/2 | 0.311 in (7,90 mm) |

**TECHNICAL DATA—B.12**

**Atomisers**

| | |
|---|---|
| Make ...... ...... ...... ...... ...... | C.A.V. |
| Atomiser Body ...... ...... ...... ...... | BKBL 67S5151 |
| Atomiser Nozzle ...... ...... ...... ...... | BDLL 150S6556 |
| Minimum Working Pressure ...... ...... ...... | 170 atmospheres (176 kgf/cm2 - 2500 lbf/in$^2$) |
| Setting Pressure ...... ...... ...... ...... | 175 atmospheres (181 kgf/cm2 -2570 lbf/in$^2$) |
| Identification Code ...... ...... ...... ...... | "CU" |

| | |
|---|---|
| Make ...... ...... ...... ...... ...... | C.A.V. |
| Atomiser Body ...... ...... ...... ...... | BKBL 67S5299 |
| Atomiser Nozzle ...... ...... ...... ...... | BDLL 150S6649 |
| Minimum Working Pressure ...... ...... ...... | 195 atmospheres (201 kgf/cm$^2$ - 2870 lbf/in$^2$) |
| Setting Pressure ...... ...... ...... ...... | 210 atmospheres (217 kgf/cm$^2$ - 3090 lbf/in$^2$) |
| Identification Code ...... ...... ...... ...... | "FC" |

**ELECTRICAL SYSTEM**

**Dynamo**

| | |
|---|---|
| Make ...... ...... ...... ...... ...... | Lucas |
| Type ...... ...... ...... ...... ...... | C40A. 2 Pole, 2 Brush<br>Shunt Wound. Voltage Control |
| Rotation ...... ...... ...... ...... ...... | Clockwise Positive Earth |
| Output ...... ...... ...... ...... ...... | 11 A maximum |
| Dynamo Cut-in Speed ...... ...... ...... ...... | 525—625 rev/min |

**Alternator**

| | |
|---|---|
| Make ...... ...... ...... ...... ...... | C.A.V. or Lucas |
| Type ...... ...... ...... ...... ...... | AC5 or 11AC |
| Maximum Output AC5 12 volt (hot) ...... ...... | 55A at 13.5 volts |
| Maximum Output AC5 24 volt (hot) ...... ...... | 31A at 27.5 volts |
| Maximum Output 11AC 12 volt (hot) ...... ...... | 43A at 13,5 volts |
| Cutting in Speed 12 and 24 volts AC5 ...... ...... | 1125 rev/min |
| Cutting in Speed 11AC ...... ...... ...... ...... | 1000 rev/min |

**Starter Motor**

| | |
|---|---|
| Make ...... ...... ...... ...... ...... | C.A.V. |
| Type ...... ...... ...... ...... ...... | CA 45 D12-2M |
| Max. Current ...... ...... ...... ...... ...... | 900 A |
| Starter Cable Resistance ...... ...... ...... | 0.0017 ohms |
| No. of Teeth on Pinion ...... ...... ...... ...... | 10 |
| Rotation ...... ...... ...... ...... ...... | Clockwise |

**Starting Aid**

| | |
|---|---|
| Make ...... ...... ...... ...... ...... | C.A.V. |
| Voltage ...... ...... ...... ...... ...... | 12 Volt |
| Maximum Current Consumption ...... ...... ...... | 12.5/13.5 A at 1 1.5 V |
| Flow Rate through Thermostart ...... ...... ...... | 3.5/5.0 ml/min |
| Height of Reservoir above center of Thermostart ..... | 4.5—10 in (12—25 cm) |

NOTE: The Manufacturers reserve the right to alter this specification without notice.

**BALANCER UNIT**

| | |
|---|---|
| Front Dia. of Shafts (Driving and Driven)...... ...... | 1.2484/1.2490 in (31,71/31.73 mm) |
| Inside Dia. of Front Balance Frame Bushes ...... | 1.2510/1.2526 in (31.78/31.82 mm) |
| Running Clearance of Shafts in Bushes ...... ...... | 0.002/0.0042 in (0.05/0.11 mm) |
| Rear Dia. of Shafts (Driving and Driven)...... ...... | 0.9987/0.9992 in (25,37/25.38 mm) |
| Inside Dia. of Rear Balance Frame Bushes ...... | 1.001/1.0022 in (25.43/25,46 mm) |
| Running Clearance of Shafts in Bushes ...... ...... | 0.0018/0.0035 in (0,05/0,09 mm) |

| | |
|---|---|
| Shaft Dia. for Balance Weights ...... ...... ...... | 1.0622/1.0630 in (26,98/27,00 mm) |
| Bore Dia. of Balance Weights ...... ...... ...... | 1.0625/1.0637 in (26,99/27,02 mm) |
| Fit of Balance Weights on Shafts ...... ...... | —0.0005/+0.0015 in (—0,01/+0,04 mm) |
| Spigot Dia. of Balance Weights ...... ...... | 2.4988/2.500 in (63,47/63,50 mm) |
| Recess Dia. in Balance Weight Gears ...... ...... | 2.500/2.501 in (63,50/63,53 mm) |
| Fit of Gear on Balance Weight ...... ...... | —0.000/+0.0024 in (—0.00/+0,06 mm) |
| Dia. of Shaft for Lub. Oil Pump Gear ...... ...... | 0.4215/0.4235 in (10,71/10,76 mm) |
| Bore Dia. of Lub. Oil Pump Drive Gear ...... ...... | 0.425/0.426 in (10,79/10,82 mm) |
| Clearance Fit of Gear on Shaft ...... ...... ...... | 0.0015/0.0045 in (0,04!0.11 mm) |
| Depth of Lub. Oil Pump Body ...... ...... ...... | 0.999/1.002 in (25,38/25,45 mm) |
| Width of Lub. Oil Pump Drive Gears ...... ...... | 0.998/1.000 in (25,35/25,40 mm) |
| End clearance of Lub. Oil Pump Gears when 0.004 in (0,102 mm) joint is fitted ...... ...... ...... | 0.003/0.008 in (0.08/0.20 mm) |
| Shaft Dia. for Lub. Oil Pump Driven Gear ..... ...... | 0.4382/0.4386 in (11.13/11.14 mm) |
| Bore Dia. of Lub. Oil Pump Driven Gear ...... ...... | 0.4389/0.4396 in (11.15/11.17 mm) |
| Running Clearance of Oil Pump Driven Gear ...... | 0.0003/0.0015 in (0.01/0.04 mm) |
| Hub Dia. for Idler Gear ...... ...... ...... | 1.4984/1.4990 in (38.06/38,08 mm) |
| Bore Dia. of Idler Gear Bush ...... ...... ...... | 1.500/1.5016 in (38.10/38.14 mm) |
| Running Clearance of Idler Gear on Hub...... ...... | 0.001/0.0032 in (0.03/0,08 mm) |
| Idler Gear End Float ...... ...... ...... ...... | 0.008/0.014 in (0.20/0,36 mm) |

Note: Later balancer units have needle type bearings and all current balancer units have reversed weight roller bearings.

## Service Wear Limits

The following "wear limits" indicate the condition when it is recommended that the respective items should be serviced or replaced.

| | | |
|---|---|---|
| Cylinder Head Bow ...... | Transverse | 0.003 in (().08 mm) |
| | Longitudinal | 0.006 in (0.15 mm) |
| Maximum Bore Wear (when reboring or new liners are necessary).. ...... ...... ...... ...... | | 0.008 in (0,20 mm) |
| Crankshaft Main and Big End Journal, Wear, Ovality ...... ...... ...... ...... ...... | | 0.0015 in (0,04 mm) |
| Maximum Crankshaft End Float ...... ...... ...... | | 0.015 in (0,38 mm) |
| Valve Stem to Bore/Guide Clearance ...... | Inlet | 0.005 in (0,13 mm) |
| | Exhaust | 0.006 in (0,15 mm) |
| Valve Head Thickness at outer edge ...... ...... | | 1/32 in (0,79 mm) |
| Rocker Clearance on Rocker Shaft ...... ...... | | 0.005 in (0,13 mm) |
| Camshaft Journals, Ovality and Wear ...... ...... | | 0.002 in (0,05 mm) |
| Camshaft End Float ...... ...... ...... ...... | | 0.020 in (0,51 mm) |
| Idler Gear End Float ...... ...... ...... ...... | | 0.010 in (0,25 mm) |

**Preparation for Starting**

Check the radiator water level.

Check the engine sump oil level.

See that there is fuel oil in the tank.

Check that the starter battery is fully charged and that all electrical connections are properly made and all circuits in order.

**Starting the Engine**

**If the engine is warm,** turn starter switch in a clockwise direction to the "HS" position (see Fig. C.1).

As soon as the engine starts. release the switch to the "R" position.

Be sure that the starter pinion and engine have stopped rotating before re-engaging the starter motor, otherwise damage may result.

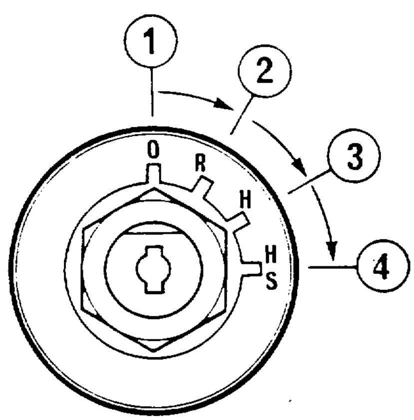



*Fig. C.1*

1. Off Position.
2. Run Position.
3. Heat Position.
4. Heat and Start Position.

**If weather is cold**, turn starter switch to the "H" position (see Fig. C.1) and hold it there for fifteen to twenty seconds.

Then turn the starter switch to the "HS" position, thereby engaging the starter motor.

If the engine does not start after twenty seconds, return the switch to the "H" position for ten seconds and then re-engage the starter motor by switching to the "HS" position.

As soon at the engine starts, release the switch to the "R" position.

**Earlier Heat Start Switch**

The cold start switch supplied with earlier engines is shown in Fig. C.2.

With this type of switch, starting a warm engine is effected by turning the switch in a clockwise direction to the "S" position.

In cold weather, the switch should be turned to the "H" position for fifteen to twenty seconds and then to the "HS" position in order to engage the starter motor.

As soon as the engine starts, the switch should be returned to the "0" position.

When this type of switch is used, it was sometimes customary to have a separate switch for the electrical circuits and this should be turned on before starting the engine and turned off after stopping the engine.

**Starting the Engine (Alternative Method)**

With some engines. a different starter switch may be found and the cold start aid operated by means of a separate push button switch.

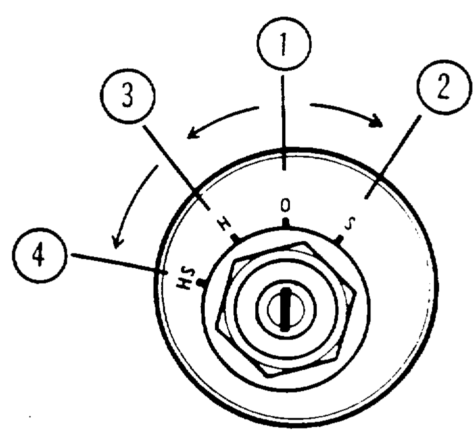



*Fig. C.2*
Earlier Heat/Start Snitch.

1. Off Position.
2. Start Position
3. Heat Position.
4. Heat and Start Position.

The cold starting procedure is however the same, i.e.,

Switch on by turning the starter switch in a clockwise direction to the first position.

Press the heater button for fifteen to twenty seconds and then, with the heater button still pressed, turn the starter switch in a further clockwise direction to engage the starter motor. As soon as the engine starts. release both starter switch and heater button.

**Cold Starting Aid**

The cold start unit comprises a tubular valve body carried in a holder which screws into the inlet manifold, and surrounded by a heater coil, an extension of which forms an igniter coil. The valve body houses a needle, the stem of which holds a ball valve in position against its seating.

The whole is surrounded by an open perforated shield. Fuel oil from the container enters through an adaptor.

When the unit is cold, the ball valve is held closed. On switching on the coil, the valve body is heated and expands. opening the ball valve and permitting the entry of fuel. The fuel is vaporized be the heat of the valve body and when the engine is cranked and air is drawn into the manifold, the vapor is ignited by the coil extension and continue to burn, thus heating the inlet air.

When the coil is switched off, the flow of air in the manifold cools the valve body rapidly and the valve closes.

The cold start aid is a sealed unit and cannot be dismantled. If the unit ceases to function, it must be renewed.

**To Stop the Engine**

A spring loaded stop control i. located near the engine controls and functions by cutting off the fuel at the fuel injection pump.

To operate, pull (he knob and hold in this position until the engine ceases to rotate. Ensure that the control returns to the run position, otherwise difficulty may be experienced in restarting the engine Some engines, may have an electric solenoid stop control on the fuel injection pump operated by a switch on the control panel

Turn start switch to the “O” position.

**Things to Note**

Always be sure that the starter pinion has stopped revolving before re-engaging the starter, otherwise the ring or pinion may be damaged.

Ensure that the electrical connection to the cold starting aid is correctly made.

Always ensure that, if a reservoir is used to feed fuel to the starting aid, it is fully primed and is not leaking. On later engines, the starting aid fuel feed is taken directly from the fuel filter.

In the event of difficult starting, check that fuel is reaching the cold starting aid in the induction manifold by unscrewing the inlet fuel connection.

If fuel is reaching it satisfactorily, then it may be that the cold starting aid itself is not working correctly. This can be checked by removing the air cleaner and watching the cold starting aid whilst the equipment is used. When the starting switch is turned to the "heat" position, the element should become red hot, and on engagement of the starter motor, it should burst into flame.

4.236 Marine engines are fitted with efficient cold starting equipment and no responsibility can be accepted for any damage caused by unauthorized starting aids.

To present thermostart damage, it is essential that the thermostart is not operated **DRY.** After any operation which allows fuel to drain from the thermostart feed pipe, the pipe must be disconnected at the thermostart and all air bled from the pipe before the thermostart is operated.

Where a thermostart starting aid has to be replaced, care must be taken not to exceed the torque figure quoted on Page B.1. Excessive torque loading can crack the insulator adaptor causing an electrical short and hard starting characteristics.

**Running-in Procedure**

It is not necessary to gradually run-in a new or factory rebuilt engine and any prolonged light load running can in fact prove harmful to the bedding in of piston rings and liners.

Full load can be applied on a new or factory rebuilt engine as soon as the engine is used, **provided that the engine coolant is first allowed to reach a temperature of at least 140°F (60°C).**

## Preventive Maintenance

If a Perkins marine diesel engine is to give long and trouble free service, it is imperative that it be maintained in accordance with the following Periodical Attentions :—

It is good engineering practice to check for water, fuel and lubricating oil leaks and the tightness of nuts, setscrews and hose clips at each servicing period.

It should be noted that the maintenance periods given are on the assumption that the fuel and lubricating oils used are to the specifications given in this workshop manual.

### Daily or Every 8 hours (whichever occurs first)

Check coolant level.
Check sump oil level.
Check gearbox oil level.
Check oil pressure.

### Every 125 hours or 2 months (whichever occurs first)

Clean air intake gauzes or screens.
Grease tachometer angle drive connections (where nipple fitted).

### Every 250 hours or 4 months (whichever occurs first)

Drain and renew engine lubricating oil using an approved oil — see appendix.
Renew lubricating oil filter element or canister.
Check drive belt tension.
Clean water trap.
Lubricate dynamo rear bush (where fitted).

### Every 500 hours or 12 months (whichever occurs first)

Renew final fuel filter element.
Clean lift pump sediment chamber.
Drain and clean fuel tank.
Renew gearbox lubricating oil (Borg Warner).

### Every 2,500 hours

Arrange for examination of proprietary equipment, i.e., Starter motor, dynamo, alternator, oil cooler, etc.
Service atomisers.
Check and adjust valve clearance (see Page E.8).

**Note:** Whilst a lubricating oil drain plug is fitted, it is not normally possible to drain the oil in the Marine installation. Instead, a sump draining connection is fitted, to which a hand operated pump (supplied as an optional extra) can be attached, for the purpose of pumping out the lubricating oil when necessary.

The sump draining connection is situated on the starboard side of the engine.

With 4.236 low-line engines, the sump drain pump is a standard fitment.

### POST-DELIVERY CHECKOVER

After a customer has taken delivery of his Perkins Marine Diesel engine. it is advisable. in his own interest. that a general checkover of the engine be carried out after the first 25/50 hours in service.

It is also recommended that the following procedure be adopted where an engine has been laid up for a considerable period before it is again put into service.

The checkover should comprise the following points :—

1. Drain lubricating oil sump and re-fill up to the full mark on the dipstick with new clean oil (Do not overfill). When the sump is drained and it is possible to gain access to the sump strainer, it should be removed and cleaned.

2. Renew clement or canister of lubricating oil filter.

3. Check external nuts for tightness.

4. Warm up engine and then shut down : remove rocker assembly. Retighten cylinder head nuts setscrews in the correct sequence as given in Fig. E.11 and to the correct torque as given on Page B.1. The correct procedure for retightening of the cylinder head nuts, setscrews is given on Page E.8. Replace rocker assembly.

5. Check and adjust valve clearances (0.012 in or 0,30 mm cold) see Page E.8.

6. Check fuel pipes from tank to fuel injection pump for leaks.

7. Check for lubricating oil leaks, and rectify if necessary.

8. Check cooling system for leaks and tighten

hose clips where necessary and inspect header tank water level.

9. Check water pump belt for tension.

10. Carry out test to check general performance of engine.

11. Check engine mounting bolts for tightness.

Thereafter maintenance periods should be in accordance with the instructions given on this page.

It is assumed that electrical equipment will have already been checked for such points as dynamo rate of charge, effectiveness of connections and circuits, etc.

**PROTECTION OF AN ENGINE NOT IN SERVICE**

The recommendations given below are to ensure that damage is prevented when an engine is removed from service for an extended period. Use these procedures immediately the engine is removed from service. The instructions for the use of POWERPART products are given on the outside of each container.

1. Thoroughly clean the outside of the engine.

2. Where a preservative fuel is to be used. drain the fuel system and till with the preservative fuel. **POWERPART Lay-Up 1** can be added to the normal fuel to change it to a preservative fuel. If preservative fuel is not used, the system can be kept charged with normal fuel, but this will have to be drained and discarded at the end of the storage period together with the fuel filter element.

3. Run the engine until it is warm. Correct any fuel, lubricating oil or air leakage. Stop the engine and drain the lubricating oil sump.

4. Renew the lubricating oil filter canister or element.

5. Fill the sump to the full mark on the dipstick with clean new lubricating oil or with a correct preservative fluid. **POWERPART Lay-Up 2** can be added to the lubricating oil to give protection against corrosion during the period in storage. If a preservative fluid is used, this must be drained and normal lubricating oil used when the engine is returned to service.

6. Drain the cooling system, see Page C.5. To give protection against corrosion, it is better to fill the cooling system with a coolant that has a corrosion inhibitor. If frost protection is needed, use an antifreeze mixture. If no frost protection is needed, use water with an approved corrosion inhibitor mixture.

7. Run the engine for a short period to send the lubricating oil and coolant around the engine.

8. Remove the atomisers and **spray POWERPART Lay-Up 2** into each cylinder bore. If this is not available, clean engine lubricating oil will give a degree of protection. Spray into the cylinder bores 140 ml (1/4 pint) of lubricating oil divided evenly between the four cylinders.

9. Slowly turn the crankshaft one revolution and then install the atomisers complete with new seat washers.

10. Remove the air filter and **spray POWERPART Lay-Up 2** into the induction manifold. Replace air filter and seal with waterproof tape.

11. Remove the exhaust pipe **Spray POWERPART Lay-Up 2** into the exhaust manifold. Seal the manifold with waterproof tape.

12. Remove the lubricating oil filler cap. Spray **POWERPART Lay-Up 2** around the rocker shaft assembly. Fit the filler cap.

13. Disconnect the battery and put it into safe storage in a fully charged condition. Before the battery is put into storage, give the battery terminals protection against corrosion**. POWERPART Lay-Up 3** can be used on the terminals.

14. Seal the vent pipe of the fuel tank or the fuel filler cap with waterproof tape.

15. Remove end plate from sea water circulating pump and lubricate the interior with glycerine or MARFAK 2HD grease, or remove the impeller for the lay-up period. Always use a new joint when refitting backplate.

16. Remove the drive belt and put into storage.

17. To prevent corrosion, spray the engine with **POWERPART Lay-Up 3.** Do not spray inside the alternator cooling fan area.

**NOTE:**
**Before the engine is started after a period in storage, operate the starter motor with the engine stop control in the "off" position until oil pressure shows on the gauge or the oil warning light goes out. If a solenoid stop control is used, this will have to be disconnected for this operation.**

If the engine protection is done correctly according to the above recommendations, no corrosion damage will normally occur. Perkins Engines Ltd., are not responsible for any damage that occurs in relation to a service storage period.

**ENGINE COOLANT**

The quality of the coolant used can have a large effect on the efficiency and life of the cooling system. The recommendations given below can be of assistance in the maintenance of a good cooling system with frost and/or corrosion protection.

1. Where possible, use clean soft water.

2. If an antifreeze mixture is used to prevent frost damage, it must have an ethylene glycol (ethanediol) base. An antifreeze that is to one of the standards given below or to an equal standard is acceptable if the pH value is kept within the range of 7.0-8.5 when diluted.
   U.K. BS 3151:1959
   'Ethanediol Antifreeze Type B with Sodium Benzoate and Sodium Nitrate Inhibitors'.
   U.S.A. ASTM 03306-74
   'Ethylene Glycol Base Engine Coolant'.
   Australia AS 2108-1977
   'Antifreeze Compounds and Corrosion Inhibitors for Engine Cooling Systems'.

When Perkins POWERPART Antifreeze is used, the correct mixtures of antifreeze and water are as given below. Perkins POWER PART Antifreeze fully passes the above standards.

| Lowest Temp. of Protection Needed | % Volume of POWERPART Antifreeze | Mixture-Ratio by Vol. POWERPART Antifreeze: Water |
|---|---|---|
| -12°C( 10°F) | 25 | 1:3 |
| -18°C( 0°F) | 33 | 1:2 |
| -25°C (-13°F) | 40 | 1:1.5 |
| -37°C (-34°F) | 50 | 2:1 |
| -60°C (-76°F) | 66 | 2:1 |

The quality of the antifreeze coolant must be checked at least once a year, for example, at the start of the cold period.

3. When frost protection is not necessary, it is still an advantage to use an approved antifreeze mixture as this gives protection against corrosion and also raises the boiling point of the coolant. A minimum concentration of 25% by volume of antifreeze is necessary, but it is our recommendation that a 33% concentration by volume is used.

   If an antifreeze is not used, add a correct corrosion inhibitor mixture to the water.

   Change the water/corrosion inhibitor mixture every six months or check according to the inhibitor manufacturer's recommendations.

**Note:**
**Some corrosion inhibitor mixtures contain soluble oil which can have an adverse effect on some types of water hose.**

If the correct procedures are not used, Perkins Engines Ltd. can riot be held responsible for any frost or corrosion damage.

To Drain the Cooling System

1. Remove filler cap from header-tank.

2. Drain water from header tank and engine cylinder block by opening all drain cocks and plugs. The cylinder block may be flushed back through the drain points with the thermostat removed. If it is decided to refill the fresh water system with antifreeze or corrosion inhibitor, see this page.

3. If the engine is to be layed up for the winter season, the raw water system should also be drained. Before commencing draining, the sea cock should be turned off and then all drain cocks opened and plugs removed. The removal of the sea water hose at the lowest point of the engine will assist in complete drainage of the raw water.

4. If the engine is to be left drained during freezing conditions, 1/2 pint (250 ml) of undiluted antifreeze should be added to the oil coolers to prevent freezing should any water drain into the coolers if the boat is moved.

**fault finding chart**

| **Fault** | **Possible Cause** |
|---|---|
| Low cranking speed | 1, 2, 3, 4. |
| Will not start | 5, 6, 7, 8, 9, 10, 12, 13, 14, 15, 16, 17, 18, 19, 20, 22, 31, 32, 33. |
| Difficult starting | 5, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 18, 19, 20, 21, 22, 24, 29, 31, 32, 33. |
| Lack of power | 8, 9, 10, 11, 12, 13, 14, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 31, 32, 33. |
| Misfiring | 8, 9, 10, 12, 13, 14, 16, 18, 19, 20, 25, 26, 28, 29, 30, 32. |
| Excessive fuel consumption | 11, 13, 14, 16, 18, 19, 20, 22, 23, 24, 25, 27, 28, 29, 31, 32, 33. |
| Black exhaust | 11, 13, 14, 16, 18, 19, 20, 22, 24, 25, 27, 28, 29, 31, 32, 33. |
| Blue/white exhaust | 4, 16, 18, 19, 20, 25, 27, 31, 33, 34, 35, 45, 56. |
| Low oil pressure | 4, 36, 37, 38, 39, 40, 42, 43, 44, 53, 58. |
| Knocking | 9, 14, 16, 18, 19, 22, 26, 28, 29, 31, 33, 35, 36, 45, 46, 59. |
| Erratic running | 7, 8, 9, 10, 11, 12, 13, 14, 16, 20, 21, 23, 26, 28, 29, 30, 33, 35, 45, 59. |
| Vibration | 13, 14, 20, 23, 25, 26, 29, 30, 33, 45, 48, 49. |
| High oil pressure | 4, 38, 41. |
| Overheating | 11, 13, 14, 16, 18, 19, 24, 25, 45, 47, 50, 51, 52, 53, 54, 57. |
| Excessive crankcase pressure | 25, 31, 33, 34, 45, 55. |
| Poor compression | 11, 19, 25, 28, 29, 31, 32, 33, 34, 46, 59. |
| Starts and stops | 10, 11, 12. |

**KEY TO FAULT FINDING CHART**

1. Battery capacity low.
2. Bad electrical connections.
3. Faulty starter motor.
4. Incorrect grade of lubricating oil.
5. Low cranking speed.
6. Fuel tank empty.
7. Faulty stop control operation.
8. Blocked fuel feed pipe.
9. Faulty fuel lift pump.
10. Choked fuel filter.
11. Restriction in air cleaner or induction system.
12. Air in fuel system.
13. Faulty fuel injection pump.
14. Faulty atomisers or incorrect type.
15. Incorrect use of cold start equipment.
16. Faulty cold starting equipment.
17. Broken fuel injection pump drive.
18. Incorrect fuel pump timing.
19. Incorrect valve timing.
20. Poor compression.
21. Blocked fuel tank vent.
22. Incorrect type or grade of fuel.
23. Sticking throttle or restricted movement.
24. Exhaust pipe restriction.
25. Cylinder head gasket leaking.
26. Overheating.
27. Cold running.
28. Incorrect tappet adjustment.
29. Sticking valves.
30. Incorrect high pressure pipes.
31. Worn cylinder bores.
32. Pitted valves and seats.
33. Broken, worn or sticking piston ring/s.
34. Worn valve stems and guides.
35. Overfull air cleaner or use of incorrect grade of oil.
36. Worn or damaged bearings.
37. Insufficient oil in sump.
38. Inaccurate gauge.
39. Oil pump worn.
40. Pressure relief valve sticking open.
41. Pressure relief valve sticking closed.
42. Broken relief valve spring.
43. Faulty suction pipe.
44. Choked oil filter.
45. Piston seizure/pick up.
46. Incorrect piston height.
47. Sea cock strainer or heat exchanger blocked.
48. Faulty engine mounting (Housing).
49. Incorrectly aligned flywheel housing or flywheel.
50. Faulty thermostat.
51. Restriction in water jacket.
52. Loose water pump drive belt.
53. Choked gearbox or engine oil cooler.
54. Faulty water pump.
55. Choked breather pipe.
56. Damaged valve stem oil deflectors (if fitted).
57. Coolant level too low.
58. Blocked sump strainer.
59. Broken valve spring.

## CYLINDER HEAD MAINTENANCE

The number of hours run has no bearing on when to overhaul the cylinder head on the 4.236 marine engine as carbon beyond a superficial coating does not form and accumulate on the cylinder head and pistons as is the case with a petrol engine.

Ease of starting and performance are the determining factors, therefore the cylinder head should only be removed when it is absolutely necessary.

Before commencing to overhaul the cylinder head ensure that all joints, gaskets and parts expected to be required are available.

### To Remove the Cylinder Head

1. Drain coolant from heat exchanger, cylinder block and exhaust manifold jacket (See engine photographs for location of drain points).

2. Disconnect the battery terminals to eliminate the possibility of a short circuit.

3. Disconnect the exhaust pipe from the exhaust manifold. Blank off the end of the exhaust pipe to prevent objects being dropped into it.

4. Disconnect sea water inlet and outlet connections from heat exchanger and exhaust manifold jacket, and connection between heat exchanger and fresh water pump.

5. Disconnect the lub. oil pipes from the lub. oil cooler.

6. Remove the heat exchanger securing setscrews and withdraw the heat exchanger.

7. Disconnect and remove the atomiser leak-off pipe assembly. Blank off the ports on the top of the atomisers.

8. Remove the fuel pipe from the fuel filter to the fuel injection pump inlet, also the fuel pipe from the fuel filter to the fuel injection pump outlet. Blank off the exposed parts.

9. Disconnect the fuel pipe from the fuel lift pump outlet to the fuel filter. Remove the two setscrews which secure the fuel filter to the cylinder head and withdraw the filter from the engine.

10. Remove the breather pipe from between the cylinder head cover and the induction manifold.

11. Disconnect and remove the high pressure fuel pipes from the fuel injection pump and atomisers. Blank off the exposed ports. Release and remove the nuts securing the atomisers and carefully extract the atomisers from the cylinder head (see Fig. E.1).

12. Disconnect the fuel pipe and electrical lead at the thermostart unit.

13. Remove the air filter. Remove the induction and exhaust manifolds.

14. Detach the rocker cover from the engine by removing the four screws which secure it to the cylinder head.

15. Remove the four rocker bracket securing nuts and washers, and remove the rocker assembly from the cylinder head (see Fig E.2). Remove the push rods.

16. Release and remove the cylinder head nuts or setscrews in the reverse order of the tightening sequence shown in Fig. E.1).

17. Remove the cylinder head. Do not insert a screwdriver or any other sharp instrument between the cylinder head and block. When removed place the cylinder head on a flat surface, preferably wood, to avoid damage.

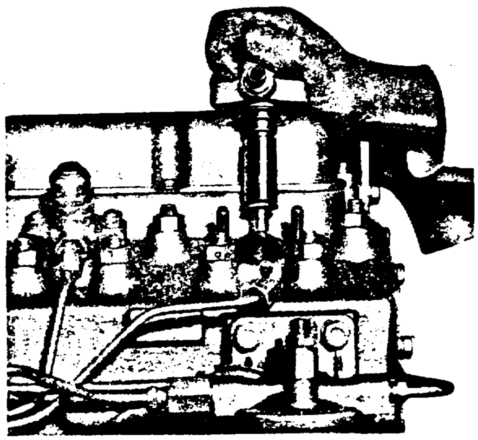


*Fig. E.1.*
*Removing an Atomiser.*

**To Remove the Valves**

Originally, all valves were numbered 1.1, 2.2, 3.3, and 4.4 with a corresponding number adjacent to each valve face (see Fig. E.31. This practice has now ceased and where these valves are to be used again. then they should be suitably marked to ensure that they are replaced in their respective positions.

1. Place the cylinder head on the bench with the gasket face downwards.

2. Compress the spring caps and springs with a suitable valve spring compressor as shown

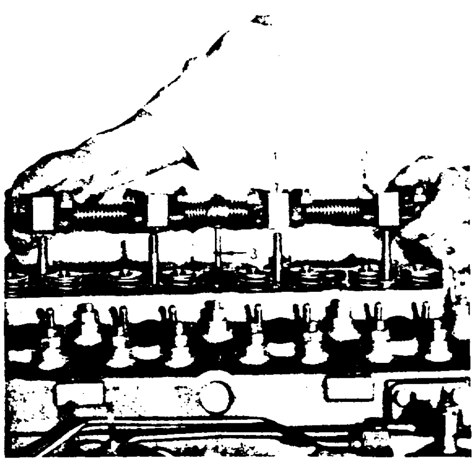


*Fig. E.2.*
*Removing the Rocker Shaft Assembly.*
1. Rocker Shaft Bracket.
2. Rocker Lever.
3. Oil Feed Connection.

in Fig. E.4 and remove the two half conical collets from each valve.

3. Remove the spring caps, springs and rubber oil deflectors from the valve stems, thus liberating the valves which can be taken out when the cylinder head is turned over.

**Cleaning**

It is essential that absolute cleanliness is observed during the following instructions to prevent the possibility of damage resulting from particles of hard carbon falling into the engine, thereby causing damage to cylinder liners, pistons and bearings, etc.

1. Carefully remove all traces of carbon from the cylinder head taking care not to scratch or burr the machined faces.

2. If the water jacket of the cylinder head shows signs of excessive scale, a proprietary brand of descaling solution should be used.

3. Blank off the rocker oil feed oil-way between numbers 2 and 3 cylinders to prevent the ingress of carbon particles and carefully remove the carbon from the pistons and cylinder block face again taking care not to scratch or burr the machined surfaces.

4. After valve seat machining and valve grinding operations have been carried out, all parts should be thoroughly washed in a suitable cleaning fluid.

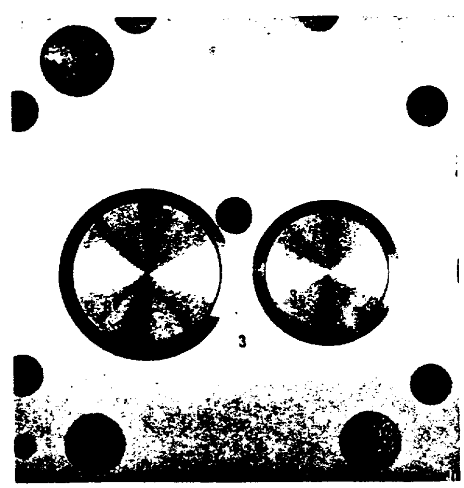



*Fig. E.3.*
*Numbering of Valves*

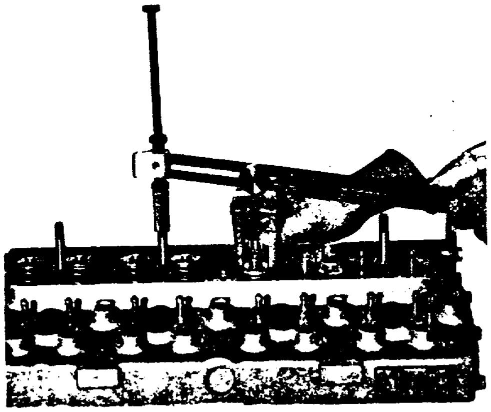


*Fig. E.4.*
*Removing the Valve Collets.*

**Valve Guides**

Detachable valve guides are not fitted, the valve bores being machined direct into the cylinder head.

When wear takes place in the valve bores restoration of the original clearance between the valve stem and its accommodating bore is accomplished by fitting valves with oversize stems. Three service valves are available, for both inlet and exhaust, with oversize stems of 0.003, 0.015 and 0.030 in. (0.08, 0.38 and 0.76 mm) respectively.

In order to fit the 0.015 and 0.030 in oversize valves, the bores in the cylinder head must be reamed with a piloted reamer to ensure that the valve position relative to the valve seat is maintained. Suitable reamers for carrying out this operation can be obtained from Messrs. V. L. Churchill and Co. Ltd.

When the above operation has been completed, check to ensure that the clearance between the valve bore in the cylinder head and the valve stem is within the limit of 0.0015 in to 0.0035 in (0.038 to 0.089 mm).

**Valves and Valve Seats**

There will be little wear of the valve stems provided that lubrication has always been adequate.

Check the valve stems for wear and their fit in the bores. If the stems are worn fit new valves.

Examine the valve faces for pitting or distortion. Valve refacing should be carried out on a suitable grinding machine to an angle of 45°.

When fitting new valves ensure that the valve head depth relative to the cylinder head face is not less than that quoted on Page B.7. Maximum depth should not exceed 0.061 in (1,55 mm) for inlet and 0.055 in (1,4 mm) for exhaust. Check this measurement by placing a straight edge across the face of the cylinder head and with feeler gauges measure the distance between the straight edge and valve head (see Fig. E.5).

The valve seats in the cylinder head should be reconditioned in the orthodox way, by means of cutters or specialized grinding equipment, to an angle of 450.

As narrow a valve seat as possible should always be maintained, therefore, care should be taken to ensure that a minimum of metal is removed.

*Fig. E.5.*
*Checking Valve Depths.*

## Hand Grinding

The efficiency of a diesel engine depends largely on the maintenance of good compression, therefore when grinding in valves, make certain that no signs of pitting are left on the seatings. At the same time care should be taken to avoid unnecessary grinding away of the valve seat.

1. With the valve removed apply a thin coating of medium or fine grinding paste according to the surface condition of the seat and replace the valve in its guide.

2. Lightly rotate the valve using a suitable suction tool in alternate directions, raising the valve from its seat from time to time and turning it continuously to ensure a concentric seat.

3. Add more grinding paste if necessary and continue the operation until an even grey matt finish is obtained.

4. After grinding operations have been completed. check the valve head depths relative to the cylinder head face to ensure that they are within the specified limit below the head face (see Page B.7).

5. Thoroughly wash off the cylinder head with cleaning fluid and ensure that all traces of grinding paste have been removed.

## Valve Seat Inserts

Valve scat inserts are not fitted to 4.236 marine engines during production. It is, however. permissible to fit inserts to valve seats where it is considered necessary, i.e. if the existing seat is damaged or worn to such an extent that recutting and lapping would place the valve depth relative to the cylinder head face beyond the maxi mum limits as given on Page B.7.

When fitting inserts ensure that genuine Perkins Parts are used.

1. Using the appropriate size piloted reamer 0.015 in (0,38 mm), or 0.030 in (0,76 mm) according to the condition of the valve bores in the cylinder head-ream out the valve bores.

**NOTE**

**It is well to remember that the appropriate oversize stem replacement valves will be needed when this operation has been carried out on guideless cylinder heads.**

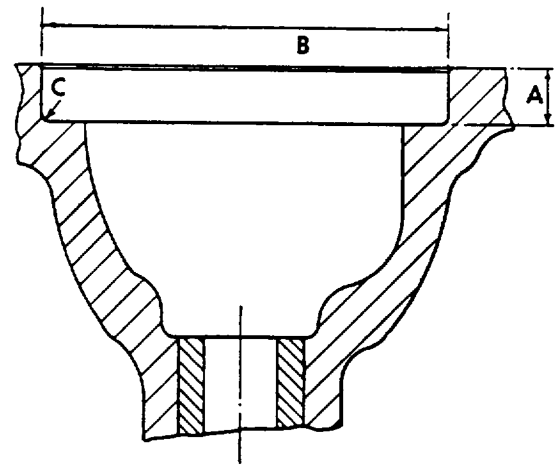



*Fig. E.6.*
*Valve Seat Cutting Dimensions.*

**Inlet**
A.—0.283/0.288 in (7,19/7,31 mm)
B.—2.0165/2.0175 in (51,22/51.24 mm)
C —Radius 0.015 in (0,38 mm) max

**Exhaust**
A.—375 to .380 in
B.—1.678 to 1.679 in
C.—Radius 015 in (max.)

2. Using the new valve bore as a pilot, machine the recess in the cylinder head face to the dimensions shown in Fig. E.6.

3. Remove all machining swarf and thoroughly clean the insert recess (removing any burrs which may be present), and once more using the valve bore as a pilot, press the insert home using the inserting tool (see Fig. E.7) using a steady pressure with either a hand or hydraulic press.

   This tool will ensure squareness which is essential whilst the insert is being pressed home.

   The insert must not, under any circumstances. be hammered in, neither should any lubrication be used.

4. Visually inspect to ensure that the insert has been pressed fully home, i.e. is flush with the bottom of the recess.

5. Once again using the valve bore as a pilot, machine the "flare" to the dimensions given in Fig. E.8.

6. Remove all machining swarf and any burrs which may be present.

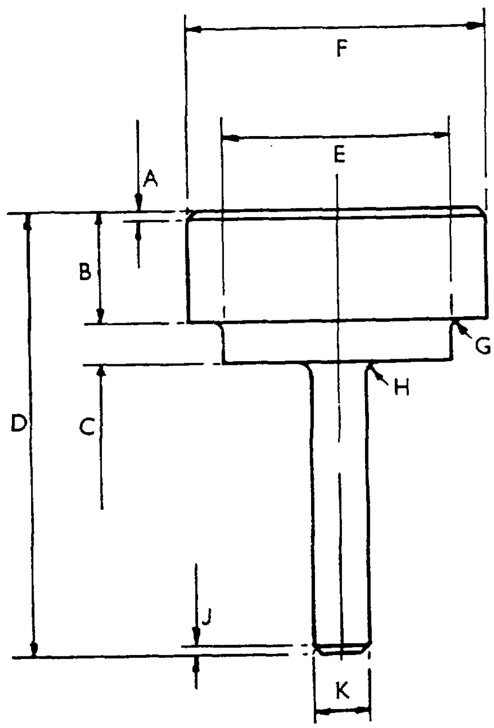



*Fig. E.7. Press Tool for Valve Seat Inserts.*

| **Inlet** | **Exhaust** |
|---|---|
| A— 1/16 in (1,59 mm) at 45° | A— 1/16 in at 45° |
| B— 3/4 in (19,05 mm) | B— 3/4 in |
| C— 0.250 in (6.35 mm) | C— 0.3125 in (7,29 mm) |
| D— 3 in (76.20 mm) | D— 3 In |
| E— 1.582 1.583 in (40,18:40,21 mm) | E— 1.248/1.249 in 31,70/31,72 mm) |
| F— 2.009'2.019 in (51,03/51,28 mm) | F— 1.670/1.680 in (43,32/43,76 mm) |
| G— 1/32 in (0,79 mm) radius | G— 1/32 in radius |
| H— 1/16 in (1.59 mm) radius | H— 1/16 in radius |
| J— 1/16 in (1,59 mm) at 45° | J— 1/16 in at 45° |
| K— 0.372:0.373 in (9,45i/9,47 mm) | K— 0.372/0.373 in |

7. Re-cut the valve seat at an included angle of 900 as in normal procedure, so that the valve head depth below the cylinder head face is within the production limits given on Page B.7.

**NOTE**

**If the cylinder head face has been skimmed since the fitting of valve seat inserts, then the following action is permitted :**

(a) If the insert is in a serviceable condition, machine to the dimensions given in Fig. E.8 and continue as in stages 6 and 7.

(b) If the insert is damaged or unserviceable through wear, remove the insert and replace with a new one, but before fitting, the back of the insert should be surface ground, removing the equivalent depth of material to that removed by the skimming of the cylinder head face. Do not forget to re-chamfer the insert as it was prior to grinding, i.e. 0.020/0.030 in (0,508/0,762 mm) at 450°. Then proceed as in stages 3 — 7.

**Valve Springs**

Valve springs deteriorate because of fatigue resulting from the combined effect of heat and the normal working of the springs. After a period the spring becomes weak and is then prone to failure. This, of course, applies to all types of engines.

A new set of springs should be fitted whenever the engine undergoes a major overhaul.

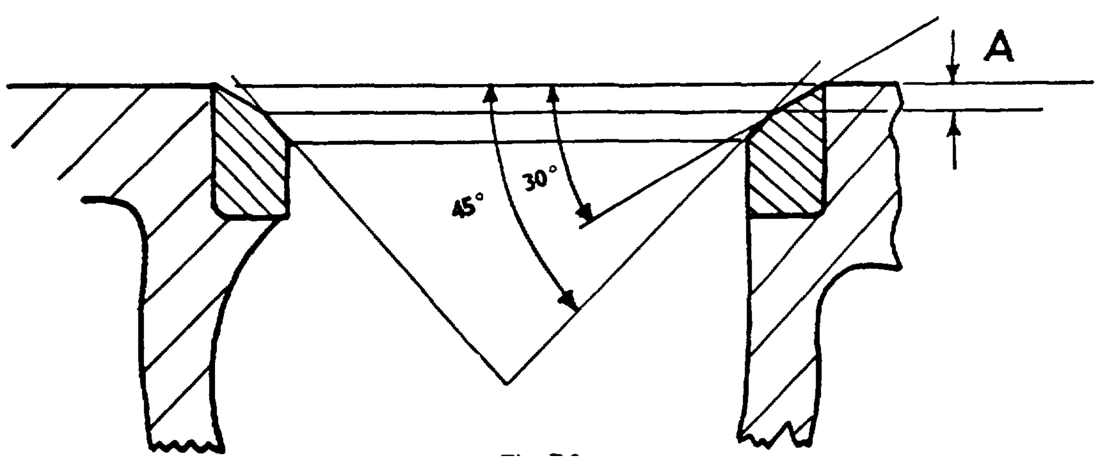



*Fig. E.8.*
*Showing Flare to be cut at 30°.*
*A-0.100 to 0.105 in (inlet), 0.094 to 0.099 in (exhaust).*

## CYLINDER HEAD—E.6

When carrying out a top overhaul only, examine the valve springs carefully with particular regard to squareness of ends and pressures developed at specified lengths, the details of which can be found in the Technical Data Section.

### Rocker Shaft Assembly

To Dismantle:—

1. Remove the circlips and washers from each end of the rocker shaft.
2. Withdraw the rocker levers, springs and support brackets from the shaft.
3. Remove the locating screw from the rocker oil feed connection and withdraw the connection from the shaft. Wash all parts thoroughly in cleaning fluid. Examine the rocker lever bores and shaft for wear. The rockers should be an easy fit on the shaft without excessive side play.

### To Reassemble

1. Fit the oil feed connection to the rocker shaft and secure with the locating screw, ensuring that the screw enters the locating hole in the shaft.
2. Refit the support brackets, springs, and rocker levers to the shaft in the order shown in Fig. E.2. The support brackets are interchangeable and when fitting them ensure that the securing stud holes are to the right viewing the shaft from the front end, with each pair of rockers inclined away from each other at the valve end.
3. Fit the securing washer and circlip at each end of the rocker shaft.

### Push Rods

Check the push rods for straightness. If any are bent, fit replacement push rods.

To fit a replacement push rod, (excepting numbers 1 and 8) with the rocker shaft assembly in position proceed as follows:—

1. Ensure that the valve concerned is closed.
2. Slacken off the valve adjusting screw and slide the rocker lever sideways until the push rod can be withdrawn from the engine.
3. Fit the new push rod and re-adjust the valve clearance.

To fit a replacement push rod to numbers 1 and 8 tappets proceed as follows :—

1. Ensure that the valve concerned is closed.
2. Slacken off the valve adjusting screw.
3. Remove the circlip and washer securing the rocker lever to the shaft and remove the lever from the shaft. The push rod can now be withdrawn from the engine.
4. Fit the replacement push rod. Refit the rocker lever, washer and circlip to the rocker shaft.
5. Re-adjust the valve clearance.

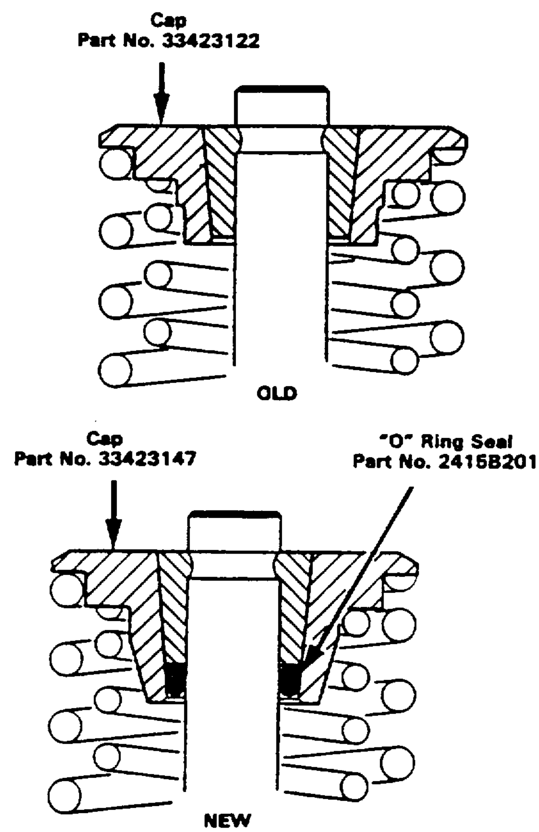



*Fig. E.9.*
*Valve Cap Sealing Arrangement*

To Re-Assemble the Cylinder Head

1. Ensure that the cylinder head and valves etc. are perfectly clean.
2. Lightly oil the valve stems to provide initial lubrication.
3. Insert each valve in its correct bore.
4. Fit the valve oil deflector rubbers with the open end towards the cylinder head.

5. Locate the spring seat locating washers, valve springs and spring retainers in their correct positions on the valve stems.

6. Using a suitable valve spring compressor (See Fig. E.4) compress each valve spring in turn and fit the valve collets.

**Note:**
**As from Engine No. LD U778518H, 'O' ring seals have been fitted in the valve spring caps under the collets. The valve spring caps have been changed which have a deeper body so that the seal can be fitted as shown in Fig. E.9. The new caps are fitted to both valves, but the seals are fitted to exhaust valves only.**

### To Refit the Cylinder Head

Before assembling the cylinder head to the engine it is extremely important to ensure that the cylinder block and cylinder head faces are perfectly clean. Care must be taken to ensure that the rocker assembly oil feed passage in the cylinder head is free from obstruction.

Whenever the cylinder head is removed, it should **not** be refitted with the old gasket, whatever the gasket condition.

**IMPORTANT:** Always ensure the correct gasket is fitted. The thickness of gaskets varies according to the piston height as given on Pace B.2 and exhaust valve depths as given on Page B.7 and if the correct gasket is not used, then piston/valve contact may result.

1. Current type cylinder head gaskets should be fitted DRY. On no account should jointing compound be used.

   Before placing gasket over cylinder head studs, ensure it is correctly positioned. Gaskets are marked to indicate how they should be fitted.

2. Place the cylinder head in position on the cylinder block. Lightly oil threads and tighten nuts/setscrews progressively (in 3 stages) in the order shown in Fig. E.11 to a torque of 100 lb ft (13,8 kgf m) — 136 Nm. The final stage should be repeated to ensure that no loss of tension has occurred earlier in the tightening sequence.

3. Fit the push rods in their respective positions and assemble the rocker shaft assembly to the cylinder head. Ensure that a new rubber sealing ring is fitted to the rocker oil feed connection and that it is correctly positioned before tightening down the rocker shaft assembly.

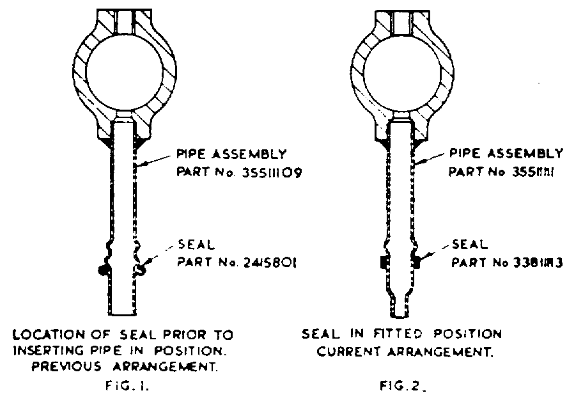



*Fig E.10.*
*Showing location of "O" Ring prior to fitting Rocker Shaft.*

When fitting the seal to the rocker oil feed connection, the seal should be positioned immediately below the 'bottom convolution so that when the pipe is inserted into the cylinder head. the "0" ring will roll up and over the lower convolution and locate itself between the two convolutions. With current engines, the seal should be fitted to butt up against the lower convolution (see Fig. E.10).

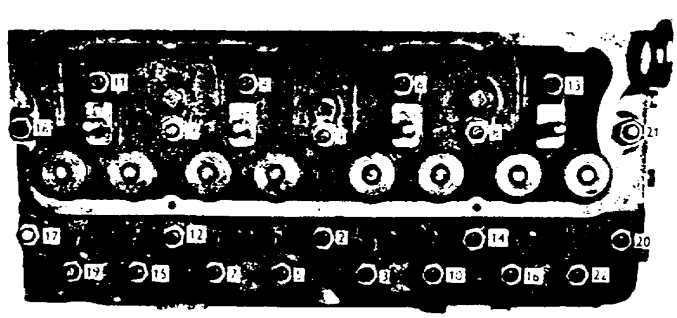


*Fig. E.11.*
*Cylinder Head Nut Tightening Sequence.*

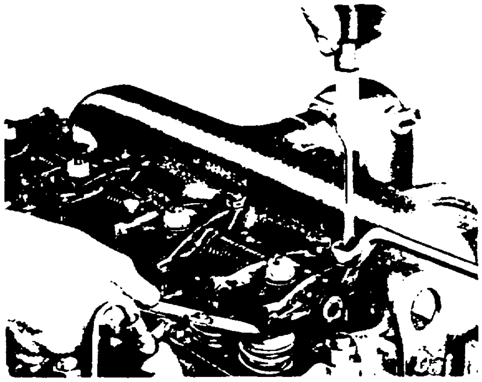


*Fig. E.12.*
*Adjusting Valve Clearance.*

4. Adjust valve clearances to 0.012 in (0.30 mm) in the following manner:—
   (a) With the valves rocking on No. 4 cylinder, set the clearances on No. 1 cylinder.

   (b) With the valves rocking on No. 2 cylinder, set the clearances on No. 3 cylinder.

   (c) With the valves rocking on No. 1 cylinder, set the clearances on No. 4 cylinder.

   (d) With the valves rocking on No. 3 cylinder, set the clearances on No. 2 cylinder.

Using a new joint, lit the rocker cover and secure with four plain washers, spring washers and screws.

5. Assemble the inlet and exhaust manifolds to the cylinder head using new joints and caskets. Connect the electrical lead and fuel feed pipe to the thermostart unit.

6. Refit the atomizers with new copper sealing washers and tighten down the securing nuts evenly ensuring the atomizer is squarely on its seat. Refit the high pressure fuel pipes to the injection pump and atomizer, (see Pages N.9 and N.13).

7. Fit the breather pipe assembly to the cylinder head cover.

8. Refit the fuel filter to the cylinder head securing it with the two setscrews and spring washers. Refit the fuel pipe connecting the lift pump outlet to the fuel filter.

9. Fit the fuel pipe connecting the fuel filter to the injection pump inlet also the pipe connecting the injection pump outlet to the fuel filter.

10. Refit the atomizer leak-off pipe assembly.

11. Fit the heat exchanger and secure with the setscrews.

12. Reconnect the lubricating oil pipes to the lubricating oil cooler.

13. Reconnect the water connection between the fresh water pump and the heat exchanger, also the sea water connections between the heat exchanger and exhaust manifold jacket.

14. Using a new gasket, connect the exhaust pipe to the exhaust manifold.

15. Refit the air filter and connections. Fit the water outlet hose. Re-connect the battery terminals.

16. Fill the cooling system with clean water ensuring that the drain taps are turned off. Check for water leaks.

17. Bleed the air front the fuel system as detailed on Page N.14 and start the engine.

18. Run the engine until normal operating temperature is attained and retighten the cylinder head nuts/setscrews, in sequence Fig. E.11, and to the correct torque as given on Page B.).

**Note:**
**When retightening cylinder head nuts/setscrews, the engine coolant outlet temperature should not be less,, than 170° F (77° C).**
**If the nut setscrew moves when retightened, then tighten up to the torque quoted on Page B.1.**
**If the nut setscrew does not move before the correct torque is achieved. then slacken off 1/12 to 1/6 of a turn (30° to 60°) and retighten to the correct figure**
**After retightening all the nuts/setscrews, the first 10 positions should be rechecked without further slackening off to ascertain they are still tightened to the torque quoted.**

19. Reset the valve clearance to 0.012 in (0.3,0 mm) cold (see item 4). Fit the cylinder head cover ensuring that there are no oil leaks at the joint.

**Note:**
**After the first 25/50 hours running, the rocker assembly should be removed and the cylinder head nuts/setscrews again retightened to the correct torque and the sequence shown in Fig. E.11. Ensure the correct procedure is followed as in above 18. Replace rocker assembly and set valve clearance to 0.012 in (0.30 mm) with the engine cold.**

**As from Engine Nos. 236U135765 and 236U147150L, engines are built to conform to BSAU141a 1971 regulations and should only be fitted with the later cylinder head and cylinder head gasket. The valve depths should also conform to the Production limits as given on Page B.7.**

To Remove Pistons and Connecting Rod Assemblies

1. Remove the cylinder head (see Page E.1).

2. Remove the lubricating oil sump.

3. Turn the engine crankshaft until two big ends are at bottom center then remove the nuts from the big end bolts.

4. Remove the big end caps, bearing shells and big end bolts.

**Note:**

**If the bearing shells removed are serviceable, care must be taken to refit them in their original positions.**

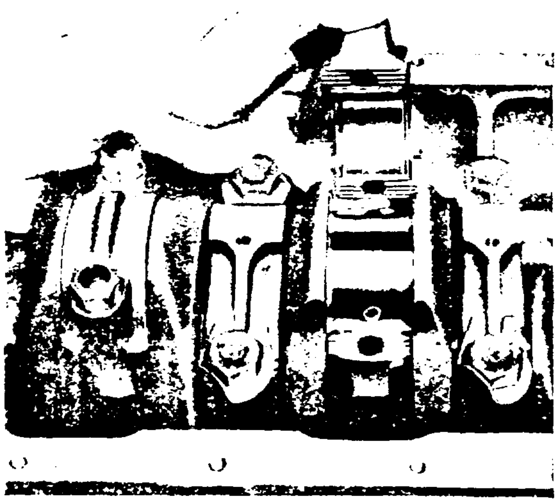


*Fig. F.1.*
*Removing a Big End Bearing Cap.*

5. Push pistons and connecting rods out of the top of the cylinders (Refer Fig. F.2).

6. Turn the engine crankshaft until the next two big ends are at bottom center and repeat removal operations.

**Note:**
**Carbon deposits around the top of the cylinder bores should be removed before**

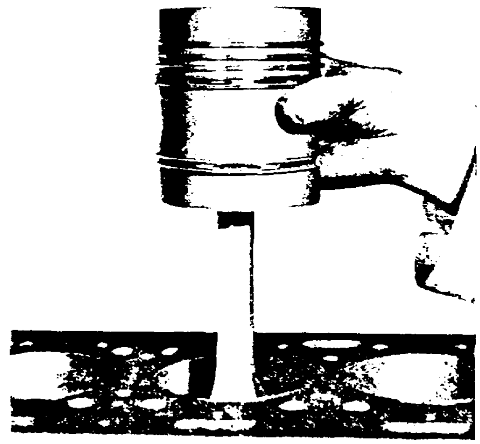


*Fig. F.2.*

*Removing Piston and Connecting Rod Assembly from Cylinder Bore.*

**attempting to remove the pistons. Keep each piston and connecting rod assembly separate, each to each as marked.**

**To Remove Pistons and Rings from Connecting Rods**

1. Remove the three compression rings and the two scraper rings from each piston.

2. Remove tile circlips retaining the gudgeon pin. using circlip pliers, and withdraw the gudgeon pin. If the gudgeon pin is tight in the piston bore, warm the piston in clean liquid to a temperature of 100°/120°F (40°/50°C) and the gudgeon pin will then he easily pushed out.

**Inspection**
1. Thoroughly clean all the dismantled components.

2. Examine the pistons for scoring. Check the clearance of the piston rings in their respective ring grooves (see Technical Data).

3. Check the fitted gap of the compression and scraper rings. In worn cylinders the gap should be checked at the bottom of the cylinder. For details of ring gap dimensions (see Technical Data).

4. Check the fit of the gudgeon pin in the piston bore and in the small end bush of the connecting rod. The pin is a transition fit in the piston, i.e. within the limits of —0.00015 in (0.004 mm) to +0.00025 in (0,006 mm). The clearance dimension between the gudgeon pin and the small end bush of the connecting rod is between 0.00075 in (0.019 mm) and 0.0017 in (0,04.3 mm). For details of piston bore, gudgeon pin and small end bush bore diameters see Technical Data. To renew the small end hush, press out the old bush using a suitable tool. Remove any sharp edges around the small end parent bore. Press in the new bush, ensuring that the oil hole in the hush coincides with the hole in the connecting rod. Ream out the

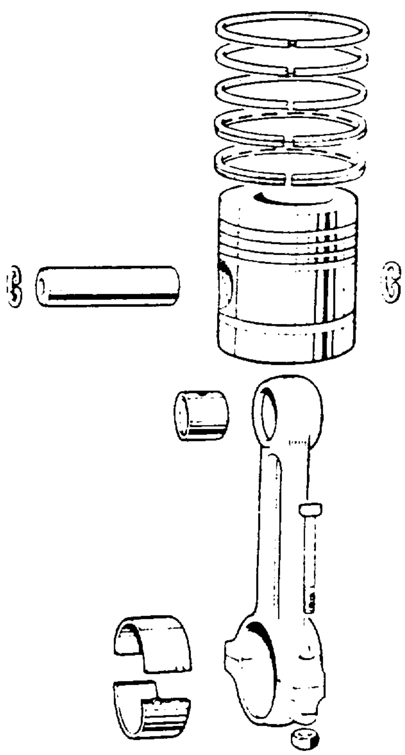


*Fig. F.3.*
*Exploded view of Piston and Connecting Rod Assembly.*

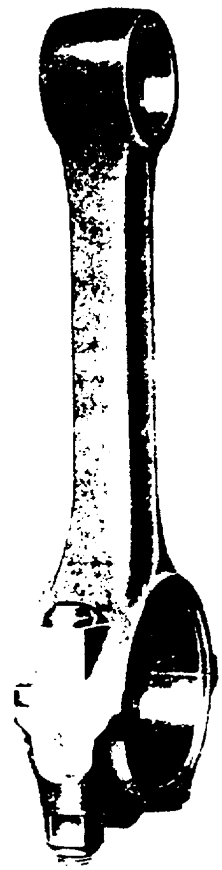


*Fig. F.4.*
*Numbering of Connecting Rods and Caps.*

new hush to suit the gudgeon pin and check the connecting rod for parallelism (see Technical Data).

5. Examine the big end bearing shells for wear and scoring. Also examine the crankpins and if necessary, remove the crankshaft, regrind the crankpins and fit undersize bearing shells. These are available in undersizes of 0.010 in (0.25 mm), 0.020 in (0,51 mm) and 0.030 in (0,76 mm). For details of crankshaft removal see Page H.31.

6. If the engine has been in service for a lengthy period, it is advisable to fit new piston circlips even if the old ones do not appear to be strained or damaged.

**To Assemble the Pistons and Rings to the Connecting Rods**

If the original pistons are being used they must be assembled to the same connecting rods, i.e. the piston stamped 1 on the crown must be fitted to the rod marked 1. For markings of pistons and connecting rods see Figs. F.4 and F.6.

1. Warm the piston in clean liquid to a temperature of 100°/120°F (40°/50°C). It will he noted that the cavity in the piston crown is off-set towards one side of the piston. Therefore, place the piston on the connecting rod with the cavity towards the side of the rod which carries the rod and cap identification numbers. Insert the gudgeon pin and fit the retaining circlips ensuring that they are seating correctly in the piston grooves.

2. Check the fitted ring gap of the compression and scraper rings (see Technical Data).

**Note:**
**When checking fitted ring gap in worn cylinders, the ring should be checked at the bottom of the cylinder.**

3. Fit the piston rings to the piston in the following order:

Slotted Scraper—
below the gudgeon pin.
Spring Expanded Oil Control—
above the gudgeon pin.
Internally Stepped Compression—
third groove.
Internally Stepped Compression—
second groove.
Chromium Plated Compression—
top groove.

**Note:**
**When fitting internally stepped compression rings, ensure that the "step" is towards the piston crown.**

**To Fit the Pistons and Connecting Rods to the Cylinder Bore**

1. Before fitting the piston and connecting rod assemblies to their respective cylinder bores. thoroughly clean and liberally coat each bore with clean engine oil.

2. Using a suitable ring guide (see Fig. F.5), insert the pistons and connecting rods into the top of the cylinder bores, ensuring that

*Fig. F.5.*
*Piston Fitting with the aid of an adjustable ring clamp.*

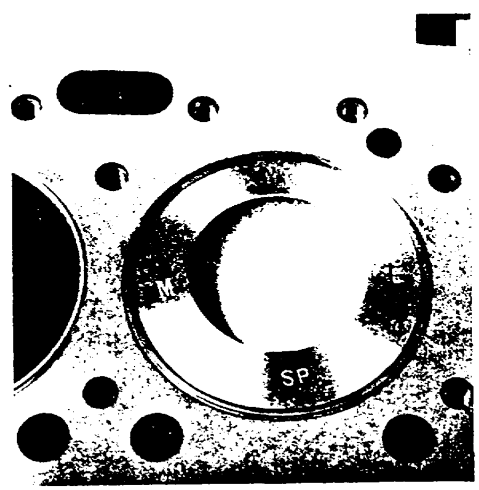



*Fig. F.6.*
*Showing markings on Piston*

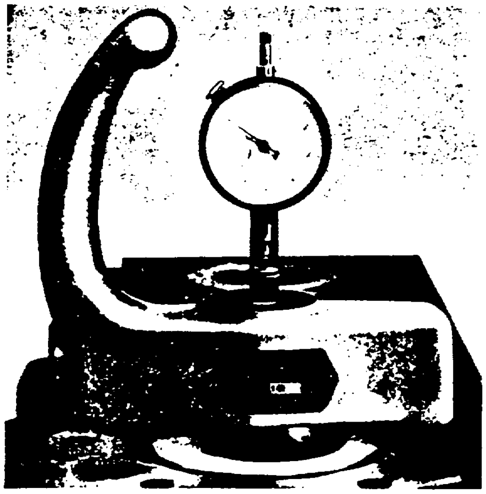


*Fig. F.7.*

*Checking Piston Height In relation to Cylinder Block Top Face*

the piston and rod numbers relate to the cylinder into which they are being fitted. Ensure that with the rod identification number opposite to the camshaft, the word "Front" marked on the piston crown is towards the front of the engine. If not, remove the piston from the connecting rod and refit correctly as previously detailed.

3. Turn the crankshaft until the appropriate crankpin is at bottom center, draw the connecting rod to the bearing shell, locating it in the tag slot.

4. Refit the other correct half bearing shell to the cap, again locating it in the tag slot, and refit the cap and bearing shell ensuring that the numbers stamped on the rod and cap coincide. Refit the two connecting rod bolts with the flat on the head of each bolt located against the milled shoulder on the rod. Secure with two new nuts to a torque wrench setting as given on Page B.1.

5. Refit the lubricating oil sump (see Page L.5).

6. Refit the cylinder head (see Page E.6).

**Fitting New Pistons**

When fitting new pistons it is essential to see that the piston and connecting rod are assembled correctly before fitting them to the engine, see "To Assemble the Pistons and Rings to the Connecting Rod."

Ensure that genuine Perkins parts are used, so that the new piston height will, when assembled, in the engine, comply with the tolerances as listed in "Technical Data" - Page B.2.

**NOTE:**

**As from Engine Nos. 236U135765 and 236U147150L, the pistons must be topped to the correct height above the cylinder block face as given on page B.2.**

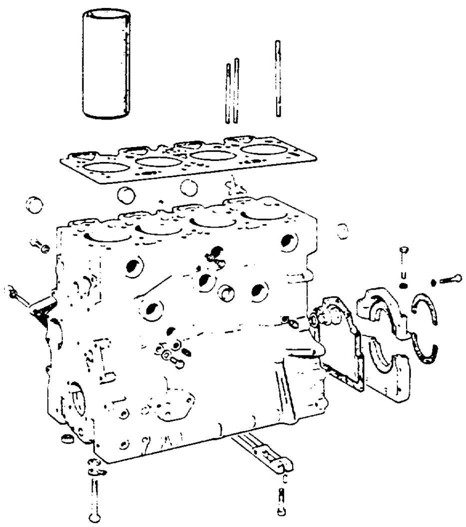


*Fig. G.1.*
*Exploded view of Cylinder Block Assembly.*

**To Renew Bush in No. 1 Camshaft Bore**

Current 4.236 marine engines have a bush fitted into No. 1 camshaft bore in the cylinder block.

A prefinished bush is available to replace a worn bush.

The worn bush may be extracted and replaced by a new one. making sure that the oil holes in the bush and cylinder block correspond.

**CYLINDER LINERS**

Cast iron interference fit dry liners are fitted to the 4.236 marine engine. These liners may be rebored to 0.030 in (0.76 mm) oversize, but during this operation it is most important to ensure that the true alignment of the bores relative to the crankshaft axis is maintained.

**To Renew Cylinder Liners**

1. Remove all engine components from the cylinder block (see appropriate sections for removal of these).

2. Remove the cylinder head studs from the cylinder block.

3. The liners are pressed out through the top of the cylinder block using a shouldered metal disc slightly smaller on the outside diameter than the parent bore size. Ensure that no damage is caused to the parent bore.

4. Ensure that the cylinder bores are perfect, clean and free from burrs etc.

5. Thoroughly wash oil any grease etc. from the new liner with cleaning fluid, and dry thoroughly. When fitting replacement liners ensure that the correct type is used.

6. Lubricate the outside diameters of the liner with clean oil and press them in until 0.028 0.035 in (0,71/0,89 mm) of the liner Is protruding above the cylinder block face. Shin washers or a solid stop washer 0.028 0.035 in (0,71/0,89 mm) thick should be used when pressing the liners into the cylinder block In order to give the necessary protrusion

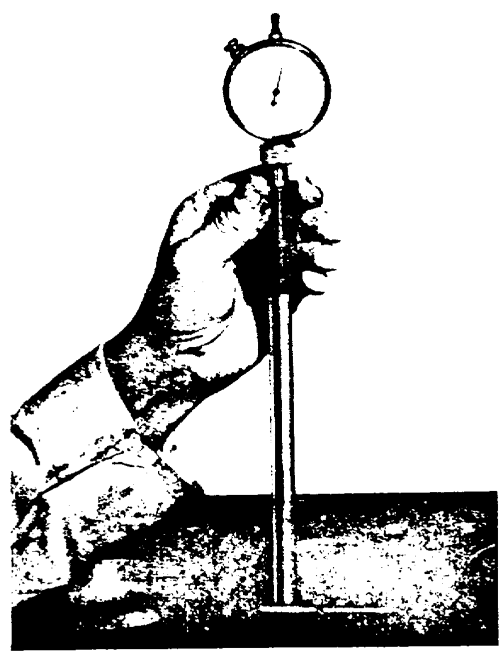


*Fig. G.2.*
*Dimensional check of Cylinder Bore*

*Fig. G.3.*
*Checking Cylinder Liner Protrusion above top face of Cylinder Block.*

7. Bore and finish hone the liners to the dimension given in "Technical Data." The above liner protrusion may create difficulties where boring equipment is mounted on the top face of the cylinder block. This may be overcome by making a parallel plate to fit between the boring bar and cylinder block face. Such a plate should be thicker than .035 in (0,89 mm) and have holes bored in it to give clearance around the protruding liners.

8. Assemble the engine components to the cylinder block (see the appropriate sections for assembly of these).

**Oversize Cylinder Liners**

Oversize outside diameter cylinder liners are available for fitment in service where the standard parent bore is enlarged to remove damage.

They are available as follows:-

| Oversize | Description |
|---|---|
| 0.005 in (0,13 mm) | Cast Iron Flangeless-bore and hone |
| 0.010 in (0.25 mm) | Cast Iron Flangeless-bore and hone |

Where a parent bore is reclaimed in service, it should be machined to the dimension by adding the appropriate liner oversize to the parent bore diameter given on Page B.2. The top of the parent bore must be re-chamfered after machining.

Where 0.005 in and 0.010 in oversize liners are fitted, the liner oversize should be stamped on the cylinder block top face between the liner and the edge of the cylinder block.

## CRANKSHAFT AND MAIN BEARINGS

The crankshaft runs in five pre-finished replaceable shell bearings lined with aluminum tin.

Crankshaft end float is controlled by four thrust washers which are located on both sides of the center main bearing housing. 0.0075 in (0,19 mm) oversize thrust washers are available which may he combined with standard thrust washers to give an adjustment of 0.0075 in (0.19 mm) or when used on both sides of the bearing housing, give an adjustment of 0.(15 in (0.,38 mm).

The main bearings are located in position by tabs fitting into slots machined in the bearing housings.

**Note:**
**Main bearing cap setscrew tabwashers have been deleted on later engines. It is therefore no longer necessary to replace these tabwashers when fitting main hearing cap setscrews. The tightening torque for these setscrews remains unchanged.**

### To Remove Main Bearings and Thrust Washers

Under normal circumstances, by the time the main bearings, require renewing the crankshaft will need to be removed for regrinding. However,

*Fig. H.1.*
*Removing a Main Bearing Cap.*

*Fig. H.2*
*Removing a Main Rearing Shell with the Crankshaft "in situ."*

removal of main bearing and thrust washers can he carried out without withdrawn the crankshaft. Proceed as follows : —

1. Remove the sump. sump strainer and the oil pump suction and delivery pipes (see page L.3).

2. Remove the two setscrews securing the main bearing cap. Only remove one bearing cap at a time.

3. Slacken the setscrews on the remaining bearing caps. To gain access to the rear main bearing setscrews, the rear main bearing bridge piece must be removed. This is secured by two recessed setscrews to the cylinder block and the two lower rear main oil seal housing securing setscrews. Access to the front main bearing setscrews can be achieved by removing the lubricating oil pump (see Page L.3).

4. Remove the lower half of the bearing from the bearing cap and with a suitable piece of thin hard wood push out the top half of the bearing by rotating it on the crankshaft, apply the wooden strip to the opposite side

of the one with the tag (see Fig. H.2). **Note: If the original bearings are to be refitted, identify each bearing half to its respective position.**

5. If the thrust washers require removal, it is necessary to remove the center main bearing cap. Remove the two bottom half thrust washers from the recesses in the center main bearing cap. The two top half thrust washers should be removed by sliding round from one side, using a suitable piece of thin hard wood, until withdrawal can be effected. Identify each thrust washer half to its relative position.

**To Refit Main Bearings and Thrust Washers**

1. Refit the main bearing half to the bearing cap locating it in the tag slot. Liberally oil the other half of the bearing, insert it plain end first and slide it around the crankshaft journal until the locating tag locates in its slot. Oil the cap half of the bearing and refit the cap securing with the two setscrews and shim washers. Tighten the setscrews to a torque setting as given on Page B.1.

**Note:**
**Make sure that the bearing caps are fitted to their original positions. Each cap is numbered to correspond with its engine position commencing with No. 1 at the front of ,he engine. Each cap is also marked with a serial number as stamped on the cylinder block bottom face. These should read in line (see Fig. H.3).**

2. Tighten the setscrews on the remainder of the bearing caps, which were slackened off, ensuring they are tightened to the correct torque setting.

3. To refit the thrust washers, liberally oil the two upper halves with lubricating oil and slide them into the recesses provided on either side of the main bearing housing. The steel side of the thrust washers should be towards the bearing housing and the cap. Position the two lower halves on either side of the bearing cap and refit the cap. Secure with the setscrews tightened to the torque setting given on Page B.1.

4. Check the crankshaft end float to ensure that a clearance of 0.004/0.015 in (0.102/0.38 mm) exists.

5. Refit the rear main bearing bridge piece together with new joints between the cylinder block and bridge piece and new sealing rubbers at the bridge piece ends (see Fig. H.6). Secure the bridge piece to the cylinder block with the two recessed screws and fit the two setscrews securing the rear main bearing oil seal housing to the bridge piece.

6. Refit the oil pump as detailed on Page L.5.

7. Refit the oil delivery and suction pipes to the oil pump.

8. Refit the sump strainer and sump.

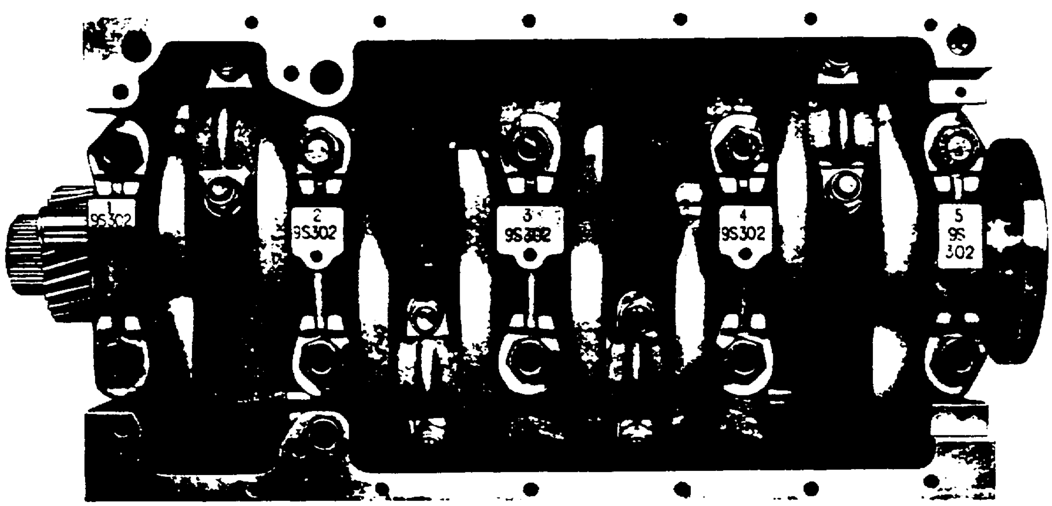



*Fig. H.3.*
*View of Crankcase showing Serial Numbers and Identification Numbers.*

### To Remove the Crankshaft

To carry out this operation, it will be necessary to remove the engine from the application and mount it in a suitable dismantling stand.

If the original components are to be refitted they should be suitably marked for re-assembly to their original positions.

1. Remove the sump, sump strainer and the oil pump suction and delivery pipes.
2. Remove the timing gears and timing case. (See Page K.3).
3. Remove the starter motor, flywheel and flywheel housing.
4. Remove the connecting rod caps and big end bearings (See Page F. 1).
5. Remove the rear main oil seal housing.
6. Take off the rear main bearing bridge piece.
7. Remove the oil pump from the front main bearing cap (See Page L.3).
8. Remove main bearing cap setscrews.
9. Remove the main bearing caps and half bearings.
10. Lift out the crankshaft and remove the other half bearings.

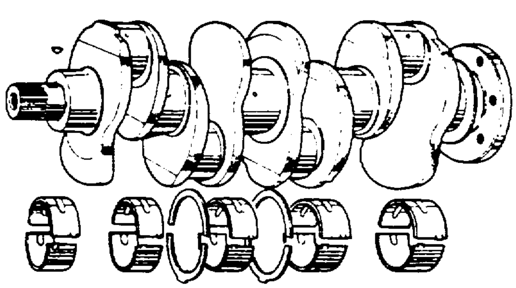


*Fig. H.4.*
*Exploded view of Crankshaft and Main Bearings.*

### Regrinding the Crankshaft (see Data, Page H.8)

Before regrinding the crankshaft, the following points should be checked to ensure it is suitable for further machining.

(a) The crankshaft should be crack-detected before regrinding. It must, of course, be remembered to demagnetize the crankshaft after crack detecting, in order to remove any polarization which may be present.

(b) The main journal and crankpin diameters should be checked to ascertain the next appropriate size to which the crankshaft can be reground, i.e., —0.010 in (—0.25 mm), —0.020 in (—0,51 mm) or —0.030 in ( —0.76 mm). If the crankshaft requires to be reground below -0.030 in (-0,76 mm) it is recommended that a new crankshaft be fitted. See "Technical Data" for crankshaft regrind dimensions.

(c) The dimensions given in "Technical Data' for the crankpin width apply only to a standard crankshaft. It will be appreciated that this dimension may increase as the crankpins are reground. but after regrinding the maximum width should not exceed 1,635 in (41,53 mm). During regrinding, all the limits must be adhered to, and the main journals and crankpins must be free from grinding marks.

After regrinding, the sharp corners on the oil holes should be removed and the crankshaft crack detected again and demagnetized.

**Note:**

**It is important that the radii on the main journals and crankpins are maintained. If these are neglected, a fracture is liable to occur.**

### To Refit the Crankshaft

1. Ensure all oilways are free from obstruction.
2. Check the main bearing setscrews for stretch or damage to the threads. In no case should setscrews other than those supplied by the engine manufacturer be used as they are of a special heat treated high grade steel.

3. Clean the bearing housings and place the top half bearings in position. Liberally oil the bearings with clean oil.

4. Place the crankshaft in position.

5. Oil the two upper thrust washer halves and slide them into the recesses provided on either side of the center main bearing housing.

6. Fit the lower halves of the main hearings to the hearing caps. Oil the hearings and place the caps in their respective positions ensuring that the lower halves of the thrust washers are correctly positioned on either side of the center main bearing cap. When replacing the main bearing caps, ensure that they are fitted in their respective positions, also that they are fitted the correct way round. The caps are numbered, No. I commencing at the front of the engine. Each cap is also marked with a serial number as stamped on the cylinder block bottom face. These should read in line (See Fig. H.3).

7. Examine main bearing setscrews for damage of threads, etc., replace where necessary. It is no longer necessary to fit tab washers to main bearing setscrews.

8. Evenly tighten the main hearing setscrews to a torque wrench setting as given on Page B.1.

9. Check the crankshaft end float to ensure that a clearance of 0.002/0.015 in (0,05/0,38 mm) exists. Oversize thrust washers may be fitted (see Fig. H.5)

10. Refit the connecting rod caps and big end bearings (See Page F.4).

11. Refit the rear main bearing bridge piece to the cylinder block together with new joints and sealing rubbers (see Fig. H.6). Ensure that the rear face of the bridge piece is in alignment with the rear face of the cylinder block (see Fig. H.7).

12. Fit new sealing strips to the rear main bearing oil seal housings and refit the housings as described in Rope Type Crankshaft Rear End Oil Seal. With lip type seals, refit oil seal housing as described in Lip Type Crankshaft Rear End Oil Seal.

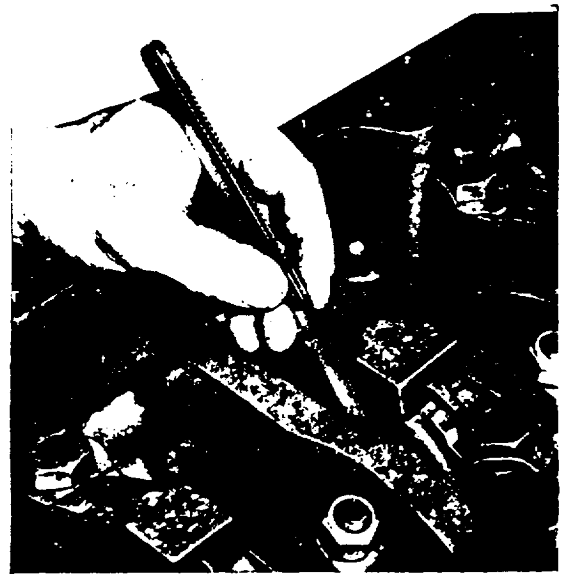


*Fig. H.5*
*Checking the Crankshaft End Float.*

13. Refit and correctly align tile flywheel housing as described on Page P.3. Refit the flywheel and starter motor.

14. Refit the oil pump, timing case and timing gears (see Page L.5 and K.,3)

15. Refit the sump, sump strainer and the oil pump suction and delivery pipes.

**ROPE TYPE CRANKSHAFT REAR END OIL SEAL**

The housing consists of two halves bolted around the rear of the crankshaft which has a shallow spiral oil return groove machined in it to a depth of 0.004/0.008 in (0,10/0.20 mm). The bore of the housing is machined to accommodate a rubber cored asbestos strip. The strip consists of two sections, one for each half of the oil seal housing.

When fitting the seal the following procedure should be adopted:—

1. Set up a half housing in the vice with the seal recess uppermost.

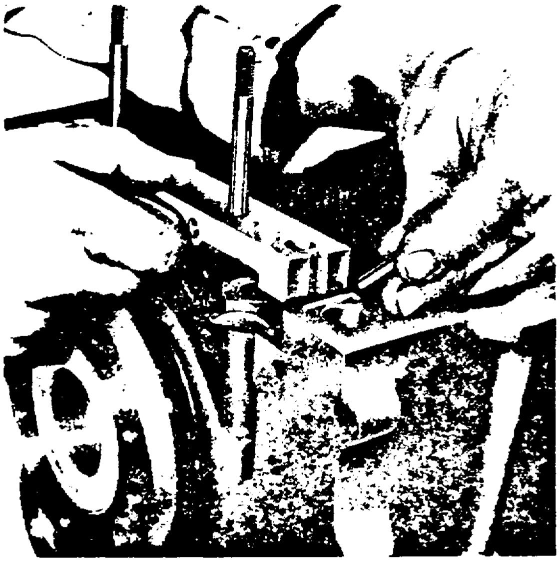


*Fig. H.6.*
*Refitting the Cylinder Block Bridge-Piece.*

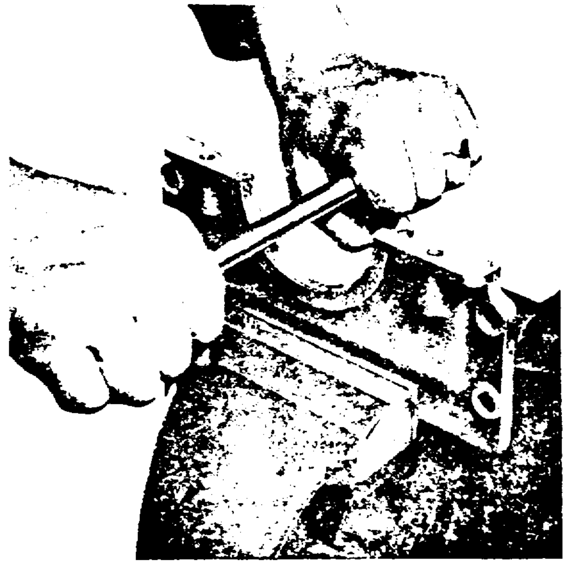


*Fig. H.8.*
*Bedding in the Rear Main Oil Seal.*

2. Settle approximately 1 in (25 mm) of the strip, at each end, into the ends of the groove ensuring that each end of the strip projects 0.010/0.020 in (0,25/0,50 mm) beyond the half housing joint face. Allow the middle of the seal to bulge out of the groove during this operation.
3. With the thumb or Linger press the remainder of the strip into the groove, working from tile centre, then use any convenient round bar to further bed in the strip by rolling and pressing its inner diameter as shown in Fig. H.8. This procedure takes advantage of the friction between the strip and the groove at the ends, to compact the rope whilst ensuring that the projections of the end faces of the rope remain as set.
4. Fit the sealing strip to the other half housing in a similar manner.
5. Remove all traces of the old joint from the cylinder block rear face and tit a new joint treated with a suitable jointing compound.
6. Lightly coat the faces of the housing with a suitable jointing compound.

*Fig. H.7.*
*Aligning Bridge-Piece to Block Face.*

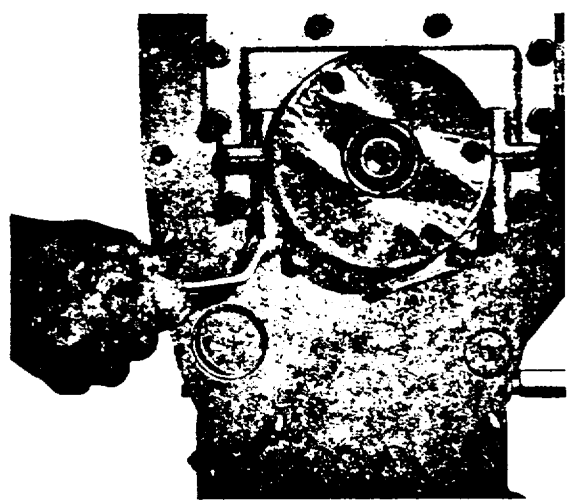


*Fig. H.9. Oil Seal Housing securing Setscrews.*

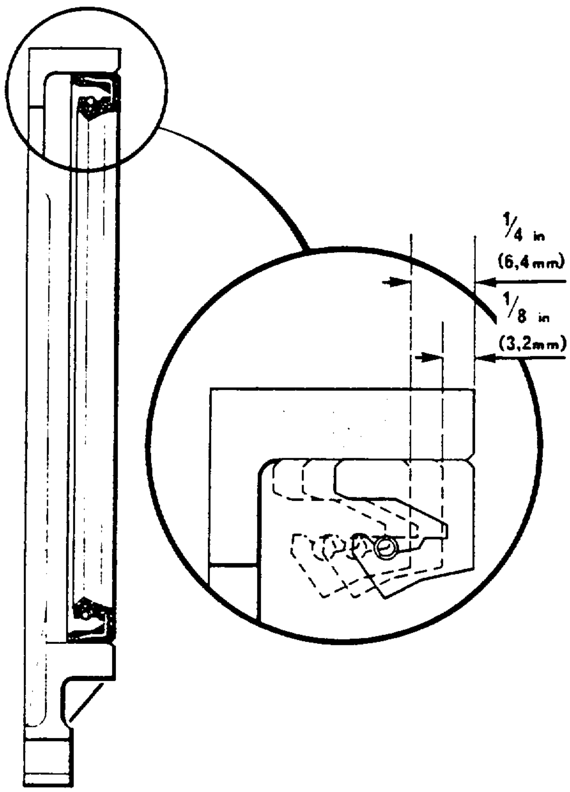



*Fig. H.10.*
*Three Positions for Lip*
*Type Rear Main Oil Seal.*

7. Spread a film of graphite grease over the exposed inside diameter surface of the strip.
8. Assemble the half housings around the crankshaft rear journal and fasten together by the two setscrews (see Fig. H.9).
9. Swivel the complete seal housing on the shaft to bed in the strips, and to establish that the assembly turns on the shaft.
10. Bolt the seal housing in position on the block and the rear main bearing cap bridge piece and finally tighten with setscrews and spring washers.

**LIP TYPE CRANKSHAFT REAR END OIL SEAL**

On some engines, a circular, spring loaded, lip seal is fitted, which locates on the periphery of the flange of the crankshaft. On production, this seal is fitted with its rear face flush with the rear face of the single piece housing.

This type of seal is easily damaged and extreme care should be taken when handling and fitting it to its housing or to the crankshaft. Any visual damage across the lip of a new seal will cause leakage and prevent bedding in of the new seal.

The seal is designed to function correctly with the direction of rotation of the engine and for identification purposes, the seal is marked with an arrow.

On production the seal is fitted with its rear face flush with the rear face of the housing. In service, when a new seal is to be fitted to a worn crankshaft, it should be pressed further into the housing, in the first instance to 1/8 in (3,2 mm) or, if this position has been used, to 1/4 in (6,4 mm) from the rear face of the housing — see Fig. H.10.

If all three positions have been used, it may be possible to machine the worn sealing area of the crankshaft flange, but not the spigot area on which the flywheel locates — see Fig. H.11. When a new seal is fitted to a new or reconditioned crankshaft, it should be fitted with its rear face flush with the housing.

Before fitting the seal in the housing, carefully examine the seal for damage, especially on the lip and outside diameter.

Using clean engine lubricating oil, lubricate the outside diameter of the seal and the inside diameter of the housing.

Press the seal into the housing to the required position, taking care that the seal is entered and pressed in squarely, otherwise damage to the outside diameter of the seal may occur, or if it is not square in the housing when fitted to the engine it may leak.

The seal and housing should be fitted, using seal guide PD 145 (Churchill Tool) as follows: —

Clean the faces of the cylinder block and oil seal housing, and the outside diameter of the crankshaft flange.

Check that the seal and the outside diameter of the crankshaft flange are not damaged. Where a new seal has been fitted, check that it is in the correct position as previously detailed.

Ensure that the two dowels are fitted in the cylinder block. Coat both sides of the housing with Perkins (Hylomar) Jointing Compound and position the joint over the dowels in the block.

Using clean engine lubricating oil, lubricate the crankshaft flange, the seal and the seal guide. The lubrication of the seal is necessary to prevent damage that may be caused by initial dry running.

Position the seal and housing on the seal guide, locate and guide on the crankshaft flange and gently press the seal and its housing into position on the flange, locating the housing on its dowels.

Withdraw the guide and secure the housing with setscrews and washers.

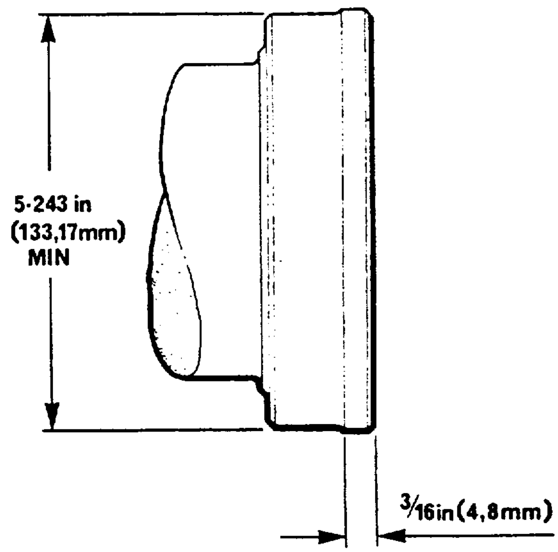



*Fig. H.11.*
*Regrinding of Crankshaft Flange for Lip Type Rear Oil Seal.*

**FOR CRANKSHAFT REGRINDING DATA SEE NEXT PAGE (H8).**

**Crankshaft Regrinding Data**

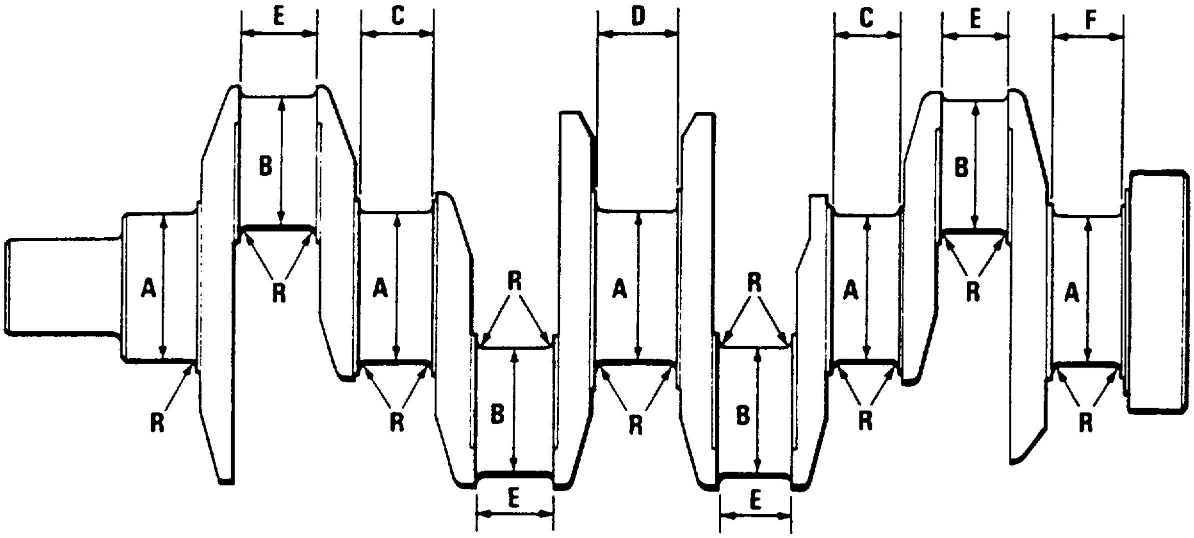



*Fig. H.12.*

| | 0.010 in (0.25 mm) Undersize | 0.020 in (0.51 mm) Undersize | 0.030 in (0.76 mm) Undersize |
|---|---|---|---|
| A | 2.9884/2.9892 in (75,91/75.93 mm) | 2.9784/2.9792 in (75.65/75.67 mm) | 2.9684/2.9692 in (75.40/75.42 mm) |
| B | 2.4888/2.4896 in (63.22/63.24 mm) | 2.4788/2.4796 in (62.96/62.98 mm) | 2.4688/2.4696 in (62.70/62.72 mm) |

C 1.554 in (39.47 mm) maximum
D 1 759 in (44.68 mm) maximum
E 1.5965 in (40.55 mm) maximum
F 1.554 in (39.47 mm) maximum
R 0.145,0.156 in (3.68:3.96 mm) all journals and crankpins.
Surface finish, journals and crankpins 16 micro inches (0.4 microns) maximum C.L.A.
Surface finish, fillet radii 32 micro inches (0,8 microns) C.L.A.

Magnetic crack detection D.C. Flow - 2 amps A.C. Current - 1600 amps.

Limits of taper and out of round of pins and journals:

Taper 0.00035 in (0,009 mm) Out of Round 0.0004 in (0.010 mm)

Maximum Run-out with the crankshaft mounted on the end main journals.

Independent readings:

| Crankshaft pulley Diameter T.I.R. | Rear Oil Seal Diameter T.I.R. | Flywheel Flange Diameter T.I.R. |
|---|---|---|
| 0.002 in (0.05 mm) | 0.002 in (0.05 mm) | 0.002 in (0,05 mm) |

Journals T.I.R. - Run-out must not be opposed

| Number 1 | Number 2 | Number 3 | Number 4 | Number 5 |
|---|---|---|---|---|
| Mounting | 0.003 in (0.08 mm) | 0.006 in (0,15 mm) | 0.003 in (0.08 mm) | Mounting |

On certain applications a balancer unit is incorporated in the engine sump, from which the lubricating oil pump is driven.

It is important to note that, on some of these applications, a crankshaft is fitted which has no balance weights, as distinct from the crankshaft on other applications which incorporates balance weights which are forged in the manufacturing process.

When replacing a crankshaft, the correct type should be fitted as determined by the displaced crankshaft.

It is also important to note that balancer units vary according to which side of the engine, the lubricating oil filter is fitted. When replacing a balancer unit, always ensure that the correct type is being fitted.

**To Remove**

Remove the lubricating oil sump.

Remove the balancer unit assembly, complete with the lubricating oil pump.

**To Dismantle**

Remove the seven setscrews and washers securing the lubricating oil pump to the balancer unit.

Remove the oil pump complete with backplate and driving gear, if possible. Should the backplate and driving gear remain in position on the balance unit they must be removed separately.

From the front of the balancer unit, remove the idler gear hub retaining nut or setscrews.

Remove the idler gear hub, idler gear and thrust plate.

Remove the two socket headed grubscrews in each of the balance weights.

Press out each of the shafts in turn, towards the drive end, taking care that the keys in the shafts do not foul the bushes in the drive end of the balancer frame. Insufficient care could result in the bushes being damaged and this would mean replacement of the complete frame assembly.

Both balance weights may now be lifted from the balancer frame, complete with their respective gears.

Should it be necessary to renew either the balance weights or coupling gears, remove the three socket headed capscrews in each balance weight assembly and take off the coupling gears.

Remove the two thimbles which locate between the frame and cylinder block.

Remove the seven plugs from the oilways in the balance frame and clean out the oilways.

**Important**

**When refitting the socket headed capscrews which secure the coupling gears to the balance weights, also the socket headed grubscrews in the balance weights and the idler gear and hub securing stud, "Loctite" grade A, should be used on the threads in the following manner: —**

**Use of "Loctite"**

Thoroughly clean both male and female threads with a suitable degreasing fluid (not kerosene), allowing 15 minutes for it to dry. It is recommended that, where possible. "Locquic" Q Activator be used for this purpose as it will considerably reduce the curing time.

Apply a light coating of "Loctite" grade A, to both male and female threads, fit the stud or screw and tighten to the .specified torque.

A curing period of 24 hours (1 hour if "Locquic" Q Activator has been used) at room temperature must now be allowed before the engine is started.

**To Re-assemble the Unit**

**Note**

**Replacement bushes for the balancer frame are not serviced separately and if wear is evident, a replacement balancer frame assembly must be obtained, complete with bushes already line-bored. Some later balancer units may have needle bearings fitted in place of bushes and are not interchangeable with bushes.**

Where needle race bearings are fitted, then the balancer unit drive and driven shafts, needle bearings, keys and oil pump gears must be changed after 5,000 hours operation.

Current balancer units have reversed balance weights where the gears are fitted to the rear of the weights instead of the front as shown in Fig. J.1. and thicker section roller race bearing are fitted.

**BALANCER UNIT - J.2**

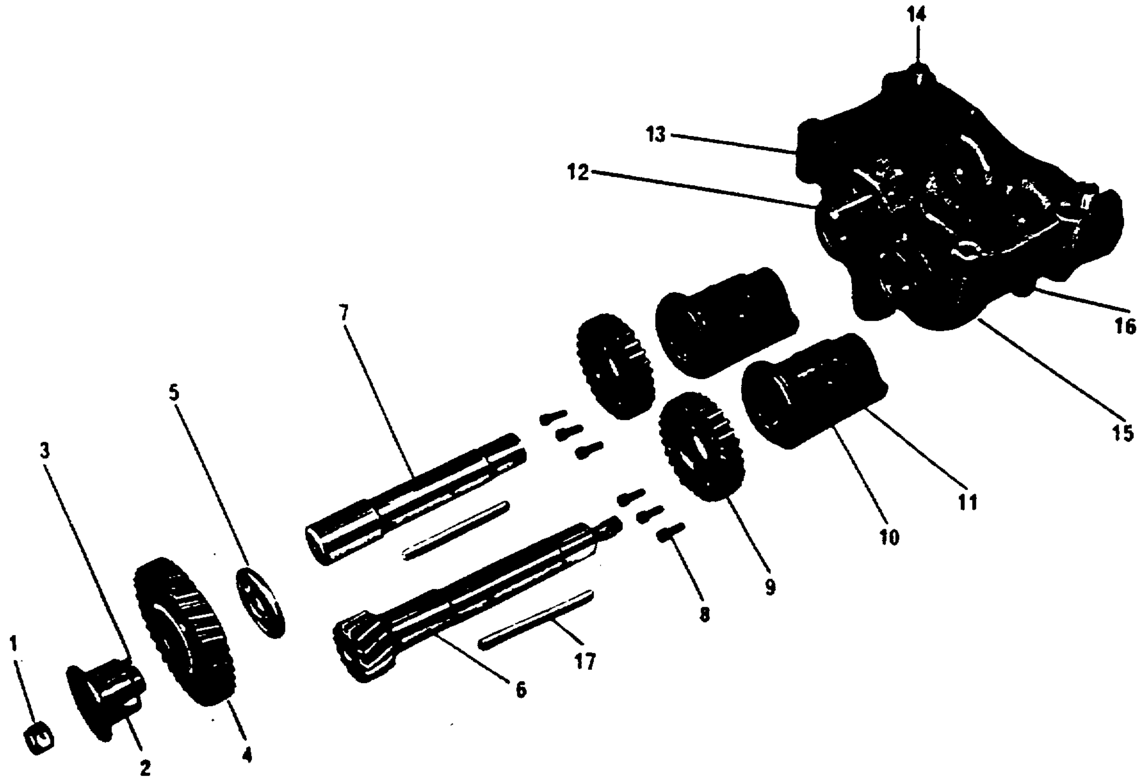



*Fig. J.1.*
*Exploded View of Balancer Unit*

| | | |
|---|---|---|
| 1. | Idler Gear Hub Retaining Nut or Setscrew (later engines) | 1 |
| 2. | Idler Gear Hub | 1 |
| 3. | Idler Gear Hub Dowel | 1 |
| 4. | Idler Gear Assembly (complet e with bush) | 1 |
| 5. | Idler Gear Thrust Plate | 1 |
| 6. | Driving Shaft | 1 |
| 7. | Driven Shaft | 1 |
| 8. | Balance Weight Gear Retaining Screws | 6 |
| 9. | Balance Weight Gear | 2 |
| 10. | Balance Weight | 2 |
| 11. | Balance Weight Locating Screw | 4 |
| 12. | Idler Gear Hub Stud | 1 |
| 13. | Balance Weight Frame Plug | 5 |
| 14. | Frame to Cylinder Block Thimble | 2 |
| 15. | Frame Assembly (complete with bushes) | 1 |
| 16. | Balance Weight Frame Plug | 2 |
| 17. | Balance Weight Locating Key | 2 |

When replacing needle or roller race bearings, they should not be hammered in, but pressed in using a suitable dolly. Needle race bearings should be pressed in to a minimum of 0.008 in (0,20 mm) from the end of the housing. Thicker section roller race bearings should be pressed in so that a clearance of 0.030/0.040 in (0,76/1,02 mm) is left between the end faces of all bearings and inside face of the frame bosses.

Having renewed any part showing signs of wear, proceed as follows:—

Replace the seven plugs in the oil drillings of the balancer frame.

Should it have proved necessary to renew the idler gear and hub securing stud, fit the new stud, using "Loctite".

Should it have been necessary to remove the coupling gears from the balance weights, using "Loctite", re-assemble. finally tightening the socket headed capscrews to a torque of 11 Ibf ft (1.52 kgf m) - 15 Nm.

Where necessary, renew the shaft keys.

Stand the balancer unit on its lubricating oil pump end face.

Place the two balance weights complete with gears into the frame, coupling the gears so that when the shafts are partially entered, the keys are in the same relative position, i.e., both at top dead centre or both at bottom dead centre.

Ensure that each shaft is related dead centre to the bushes at the front end rear of the frame and press in until the drive shaft (with integral gear) is fully home and the end of the driven shaft is flush with the drive end face of the balancer frame.

Extreme care must be taken when pressing in the shafts, to prevent the keys from touching the drive end bushes (where fitted) or the needle bearings as they pass through. The slightest damage caused this way could result in seizure of the unit and severe consequential damage to the engine.

Using "Loctite", fit the two grubscrews to each balance weight and tighten to a torque of 7-1/2 Ibf ft (1,03 kgf m) - 10 Nm. Do not omit degreasing before using "Loctite".

Fit thrust plate, idler gear and hub so that the single centre punch mark on the idler gear registers between the two punch marks on the integral balance shaft gear. Ensure that the dowel in the hub locates in the corresponding hole in the balancer frame.

Fit the idler gear and hub retaining nut or setscrew and tighten to a torque of 40 Ibf ft (5.53 kgf m) - 54 Nm.

Revolve the unit by means of the idler gear to ensure that the action is quite free.

Place the oil pump back plate in position at the rear of the balancer unit.

Fit the oil pump drive gear onto the end of the balancer drive shaft.

Fit the oil pump idler gear onto the idler shaft in the pump and refit the pump housing to the balancer unit, securing with seven setscrews and washers to a torque of 21 lbf ft (2.90 kgf m} 29 Nm.

Revolve the balancer unit idler gear once more to ensure freedom.

Continue revolving the idler gear until the punch marks once more coincide. This may take several revolutions.

To Replace

Place the two locating thimbles into their bores and refit the balancer unit to the cylinder block, ensuring that the single centre punch mark on the crankshaft gear registers between the two punch marks on the idler gear of the balancer unit.

The balancer unit is now timed to the engine. When fitting the balancer unit to an engine where the front end has not been stripped, it will not be possible to observe the punch mark on the crankshaft gear for the purposes of timing the unit to the engine.

In this case, the engine should firstly be rotated so that either the piston of No. 1 or No 2 cylinder is at top or bottom dead centre. Bottom dead centre is preferable as any error greater than one gear tooth will cause a foul between the weights and the connecting rod in this position, making it obvious that the balancer unit has been timed wrongly.

Revolve the idler gear until the single centre punch mark on the idler gear registers between the two punch marks on the balancer shaft drive gear.

Suitably mark with chalk, a tooth of the drive to align with another chalk mark on the frame.

In this position, fit the balancer unit to the engine, checking that the weights have not moved by observing alignment of the chalk marks.

As a further check, observe that the single punch mark on the idler gear still registers between the two punch marks on the balancer shaft gear, **in alignment with the gear centres**. Accuracy in timing the balancer unit to the engine is essential as an error will cause serious consequential damage to the engine.

The ability to turn the engine over by hand is not necessarily proof that the balancer unit is correctly timed.

Secure the balancer unit to the cylinder block with four setscrews and washers, tightened to a torque of 36 lbf ft (4,98 kgf m) - 49 Nm.

After fitting the balancer unit to the cylinder block and especially in the case where a new balancer unit frame has been incorporated,. check to see that there is clearance between the balancer unit frame and No. 1 main bearing cap.

Refit the sump in the normal manner, as described in the relevant service literature.

**Running-In**

After renewing any parts, the balancer unit must be carefully run-in and this should be effected by firstly running the engine at fast idle for a period of half an hour, followed by a further half hour at 1,000 rev/min.

**NOTE**

**Replacement bushes are not serviced separately for the idler gear. A replacement idler gear, complete with pre-finished bush must be fitted.**

**The stud which secures the idler gear and hub to the balancer frame is available as a spare part but need not be removed from the balancer frame unless it requires replacing**.

## TIMING CASE AND DRIVE

### To Remove the Timing Case Cover

1. Slacken the dynamo/alternator mounting bolts, release the adjusting arm and ease the driving belt from the pulleys.
2. Remove the four setscrews which secure the power take-off shaft to the crankshaft pulley front face and remove the power take-off shaft.
3. Remove the tachometer drive and heat exchanger support bracket which are mounted on the face of the timing cover.
4. Remove the crankshaft pulley retaining setscrew and washer, and withdraw the pulley. Remove the setscrews and nuts which secure the timing case cover to the timing case. Withdraw the timing case cover taking care not to damage the crankshaft front oil seal which is located in the cover.

### To Renew the Crankshaft Front Oil Seal

1. Using a suitable dolly and press, remove the oil seal from the timing case cover.
2. Locate the new seal in the bore of the cover from the front.
3. Press the new seal into position until the front face of the heal is 1 in (6.35 mm) below the front face of the cover.

   The seal is designed to function correctly with the direction of rotation of the engine and for identification purposes, the seal is marked with an arrow.

   Earlier engines were fitted with a black nitrile seal and a crankshaft oil thrower.

   Current engines have a red silicone seal and ,the oil thrower is replaced with a distance piece. Under no circumstances should the latest red seal be fitted with an oil thrower.

### Tachometer Drive

The tachometer angle drive mounted on the timing case front cover should be greased with a high melting point grease in accordance with Preventive Maintenance given on Page C.3.

Grease starvation of the angle drive gears can result in overloading and subsequent failure, but overloading is more frequently caused by the flexible drive itself due to its corrosion resulting from the drive cable lying in bilge water or being allowed to arc on battery terminals etc. No bend in the flexible drive should be less than one foot radius.

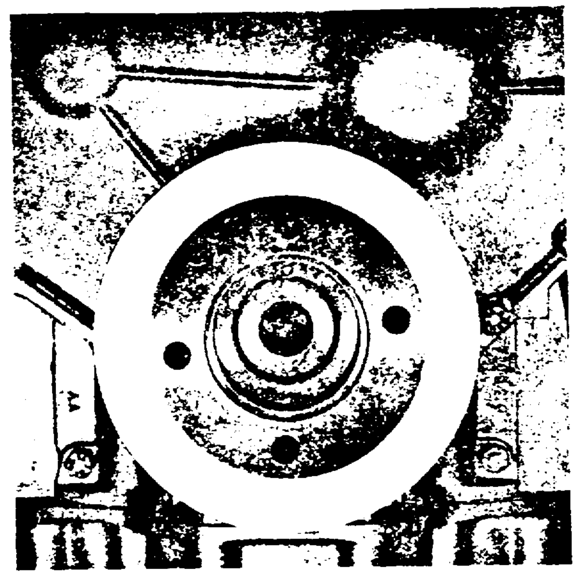


*Fig. K.1.*
*Showing markings for correct positioning of Crankshaft Pulley in relation to Crankshaft.*

With earlier engines. failure of the angle drive could result in fragments of the drive tag falling into the timing gear train and as a protective measure, a sleeve shield was introduced around the tachometer drive shaft and tag. It would be of advantage to introduce this safety shield on early engines whenever it becomes necessary to remove the timing case cover.

### To Refit the Timing Case Cover

1. Thoroughly clean the faces of the timing case front cover and timing case.
2. Position the timing case cover on the timing case by means of two opposite setscrews fitted loosely. Centralise the cover by locating the centralising tool PD.162 on the crankshaft and in the seal housing and tighten the assembly by means of the crankshaft pulley setscrew and washer — do not overtighten.

   Tighten all the timing case cover setscrews and remove the tool. If the centralising tool is not available, the crankshaft pulley can be used to centralise the cover but, as this method utilizes the inside diameter of the seal and the latest seal is soft, the cover may not be truly central and leaks may occur.

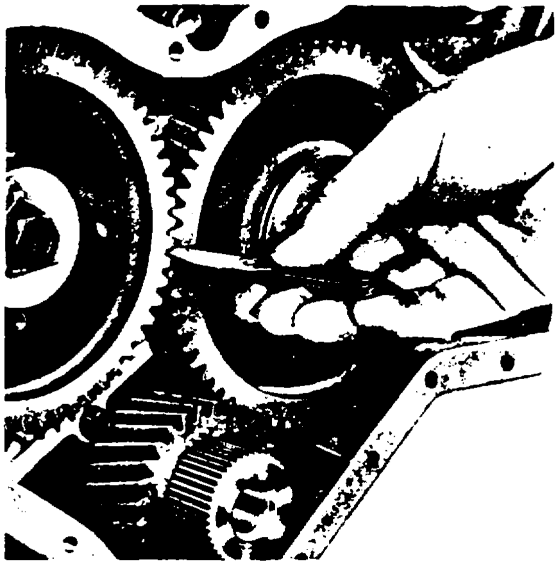


*Fig. K.2.*
*Checking Timing Gear Backlash.*

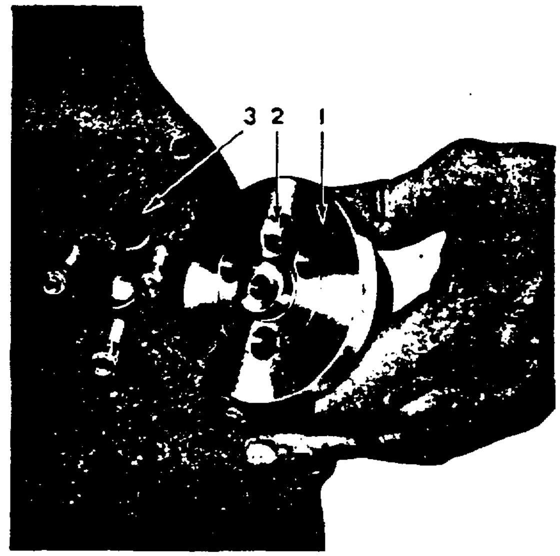



*Fig. K.3.*
*Idler Gear Hub Location.*
*1. Idler Gear Hub.*
*2. Oil Passage.*
*3. Oil Pressure Rail.*

3. Refit the heat exchanger support bracket and tachometer drive.
4. Refit the crankshaft pulley ensuring that the centre punch mark on the pulley coincides with the line on the front face of the crankshaft (see Fig. K.1). Fit the retaining setscrew and washer and tighten to a torque setting of 300 Ibf ft (42 kgf m) 410 Nm.
5. Refit the power take-off shaft to the crankshaft pulley and secure with the four setscrews.
6. Replace the dynamo/alternator and water pump driving belt over the respective pulleys and adjust as instructed on Page M.1.

**Checking the Timing Gear Backlash**

1. Remove the timing case cover as detailed on Page K.1.
2. Check the timing gear backlash as shown in Fig. K.2 using a clock gauge or feeler gauges. The backlash should be 0.003 in (0,08 mm) minimum.

**To Remove the Idler Gear and Hub**

1. Remove the timing case front cover as previously described in this Section.
2. Slacken and remove the three nuts securing the idler gear retaining plate to the idler hub and withdraw the retaining plate from its studs.
3. Remove the idler gear from the hub. The hub can now be withdrawn from its location in the timing case.
4. Clean and thoroughly examine the gear and hub for wear, cracks, and pitting, etc.
   **NOTE: - Replacement gears are supplied with the bushes fitted and machined to the dimensions given on Page B.8.**

**To Refit the Idler Gear and Hub**

1. After ensuring that the oilways in the hub are perfectly clean, refit the hub to its location in the timing case. The studs, on which the hub is located, are positioned so that the hub will fit in one position only, and the boss at the rear of the hub locates in a recess machined in the front face of the cylinder block (see Fig. K.3).
2. Remove the top cover and slacken off the rocker assembly securing nuts.
3. Turn the crankshaft to T.D.C. No. 1 and 4 cylinders, i.e., with the crankshaft gear keyway at the top of its periphery.
4. Refit the idler gear to its hub ensuring that the timing marks on the crankshaft, camshaft, fuel pump and idler gears are correctly aligned as shown in Fig. K.4.
5. Assemble the idler gear retaining plate to its studs and secure with the three setscrews tightened to a torque setting of 30 Ibf ft (4,1 kgf m).

Check idler gear end float as shown in Fig. K.5. The end float should be between 0.003/0.007 in (0,08/0,18 mm).

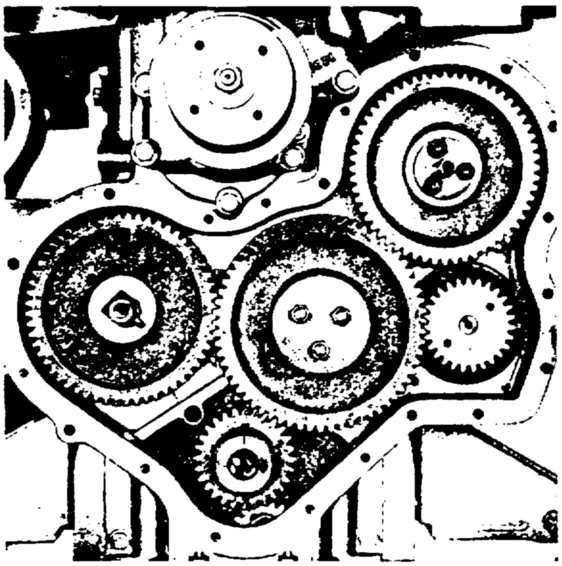


*Fig. K.4.*
*Showing Timing Marks on Drive Gear*

6. Tighten down the rocker assembly securing nuts and adjust the valve clearances to 0.012 in (0.30 mm) cold.
7. Refit the timing case front cover as previously detailed in this Section.

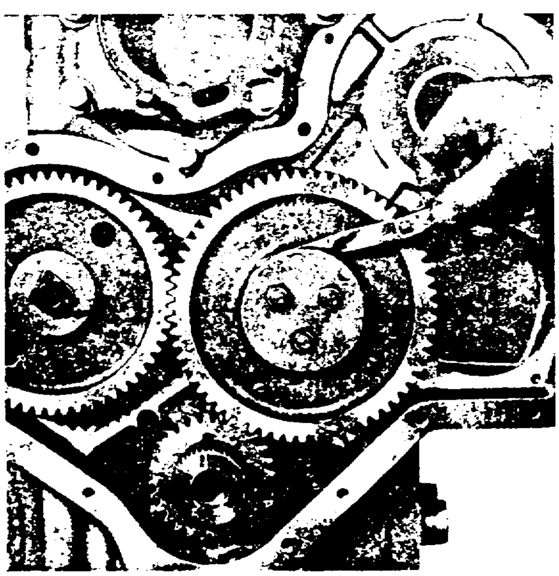


*Fig. K.5.*
*Checking Idler Gear End Float.*

**To Remove the Camshaft Gear**

1. Remove the timing case front cover as previously described in this Section.
2. Knock back the locking washer tab and remove the camshaft gear retaining setscrew, locking washer and camshaft gear retaining plate.

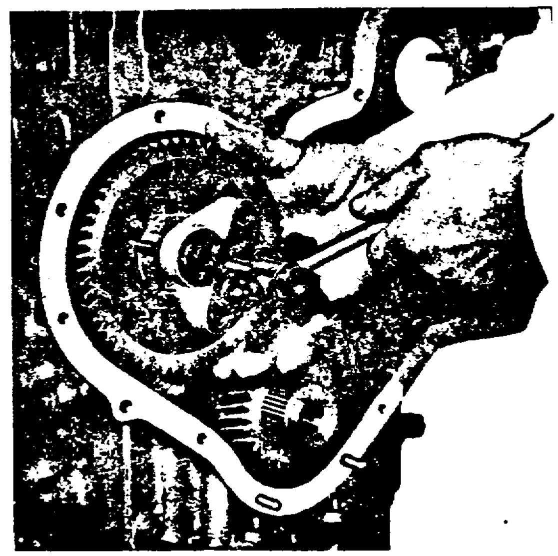


*Fig. K.6.*
*Camshaft Gear Removal*

3. Using a suitable extractor, remove the camshaft gear (see Fig. K.6).
4. Clean and thoroughly examine the gear for wear, cracks and pitting, etc.

**To Refit the Camshaft Gear**

1. Remove the idler gear as previously described in this Section.
2. Slacken off the rocker assembly securing nuts.
3. Refit the gear to the camshaft by drawing it onto the shaft with the retaining plate and setscrew.
4. Turn the engine until No. 1 piston is at T.D.C., i.e., with the crankshaft gear keyway at the top of its periphery.
5. Refit the idler gear to its hub ensuring that the timing marks on the crankshaft gear, fuel pump gear, camshaft gear and idler gear are correctly aligned as shown in Fig. K.4. Assemble the idler gear retaining plate to its studs, and secure with the three self locking nuts tightened to a torque setting of 30 lbf ft (4,1 kgf m)- 40 Nm.
6. Remove the camshaft gear retaining setscrew, fit a new lock washer, refit the setscrew,

tighten to a torque setting of 50 lbf ft 16.9 kgf m) - 68 Nm and secure the setscrew with the locking washer tab.

7. Refit the timing front case front cover as previously detailed in this Section.
8. Tighten down the rocker assembly securing nuts and adjust the valve clearances to 0.012 in (0,30 mm) cold.

**To Remove the Fuel Pump Gear**

1. Remove the timing case cover as previously described in this Section.
2. Turn the crankshaft until all the timing marks are correctly aligned (see Fig. K.4).
3. Remove the three setscrews and spring washers which secure the gear to the fuel pump.

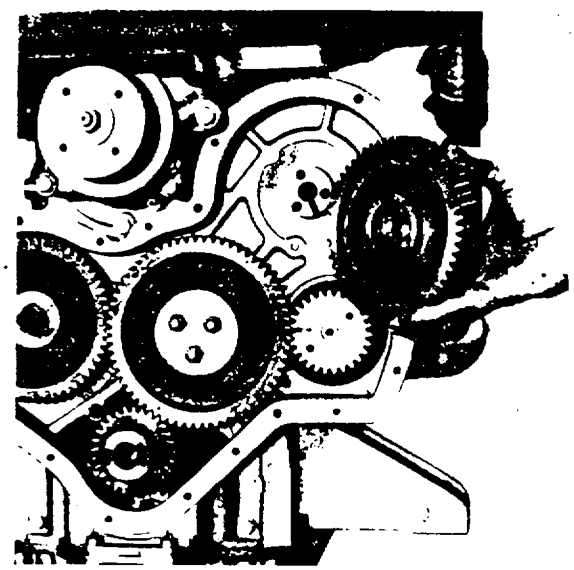


*Fig. K.7.*
*Removing the Fuel Pump Gear.*

4. Withdraw the gear from its dowelled location on the fuel pump.

**To Refit the Fuel Pump Gear**

1. Remove the idler gear from its hub.
2. Fit the fuel pump gear to the fuel pump drive shaft ensuring location of the dowel in the gear with the slot in the shaft.
3. Secure the gear with the three setscrews and spring washers.
4. Refit the idler gear to its hub as previously detailed ensuring that the timing marks are correctly aligned as shown in Fig. K.4.
5. Refit the timing case cover as previously detailed.

**To Remove the Timing Case**

1. Remove the timing case front cover and timing gears as previously described.
2. Remove the fuel and sea water pumps as described in the appropriate Sections.
3. Remove the nine setscrews and spring washers securing the timing case to the cylinder block.
4. Remove the four setscrews and washers securing the sump to the timing case.
5. Withdraw the timing case from the cylinder block taking care not to damage the sump joint.

**To Refit the Timing Case**

1. After ensuring that both the cylinder block and timing case faces are perfectly clean, fit the timing case to the cylinder block together with a new joint.
2. Secure the timing case with the setscrews and spring washers.
3. Secure the sump to the timing case with the four setscrews and spring washers.
4. Refit the fuel and sea water pumps as described in the appropriate sections.
5. Refit the timing gears and timing case front cover as previously described.

**Fitting New Timing Case**

In the event of a new timing case being fitted, this will not be marked with the scribed line for the correct alignment of the fuel injection pump.

To arrange this marking with the front cover, fuel pump and fuel pump gear removed, proceed as follows:—

1. Turn the engine to T.D.C.. number 1 cylinder compression stroke, with the timing marks on the camshaft gear, idler gear and crankshaft gear alined, crankshaft keyway upper-most.

   Remove collets, spring cap and spring from one of the valves from number 1 cylinder and allow the valve to rest on top of the piston. Care is necessary with this operation as the consequences of a valve dropping into a cylinder need not be described.

   With the aid of a clock gauge in contact with the tip of the valve stem now sitting on number 1 piston accurate T.D.C. can be established by rocking the piston over T.D.C. to obtain the highest clock reading. Zero the clock to the highest reading, rotate the engine anti-clockwise approx 0.100 in (2.54 mm), then rotate the engine in a clockwise direction until the clock gauge zeros. This

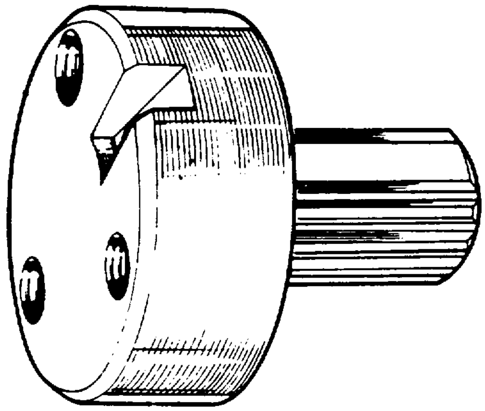


*Fig. K.8.*
*Adaptor PD67B-1.*

will ensure that all backlash is taken up at T.D.C. Refit valve spring cap and collets.

2. Fit adaptor PD67B-1 (see Fig. K.8) to the fuel pump gear so that dowel of gear locates in slot of adaptor and shaft of adaptor is towards rear of engine. Secure adaptor to gear using gear securing setscrews.

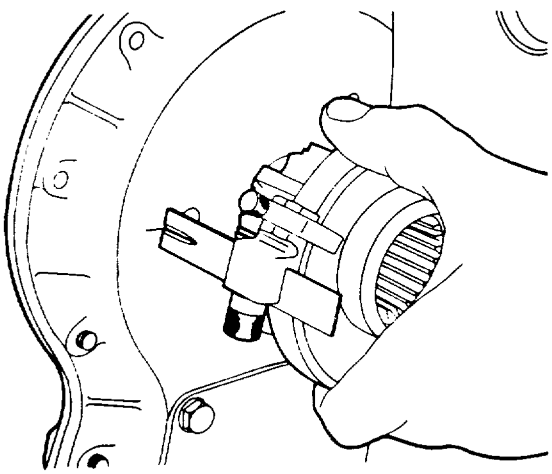


*Fig. K.9.*
*Marking Scribed Line on Rear of New Timing Case.*

3. Release screw (5) of timing tool MS67B (see Fig N.10) and remove splined shaft.
4. Ensure slotted pointer (2) of timing tool is positioned with slot to front of tool and chamfered sides of slot outwards. At this stage, slotted edge of pointer should be kept well back from front of body. Ensure that flat of washer fitted behind pointer securing screw (3) is located over pointer.
5. Release the bracket locking screw (4) and set bracket so that the chamfered edge is in line with the relevant engine checking angle (see Page B.11).
6. Pressing fuel pump gear and adaptor towards rear, with the fuel pump gear timing mark located correctly with the idler gear timing mark, locate splined shaft of adaptor into timing tool with master spline engaged and adaptor shaft in timing tool with rear face of adaptor abutting front face of timing tool.
7. Move tool forward, complete with gear so that register of tool locates in pump aperture of timing case. If pointer is 180° out, then engine is on wrong stroke and tool should be removed and engine set on correct stroke.

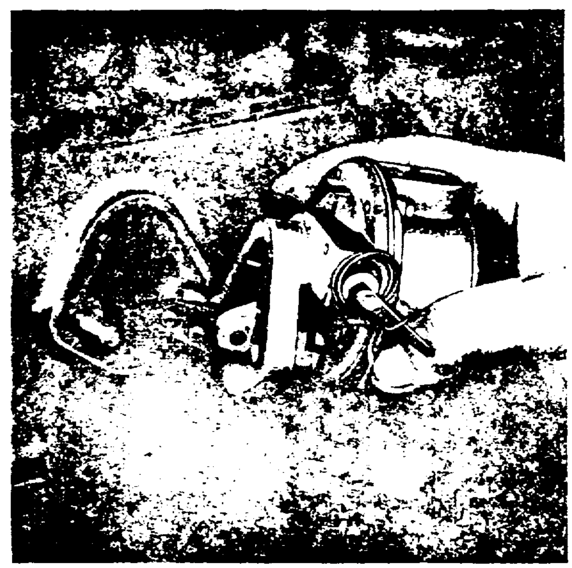


*Fig. K.10.*
*Removing the Fuel Lift Pump.*

8. Slide slotted pointer forward to reach rear face of timing case and lock in position.
9. Take up backlash by turning tool against normal direction of rotation (shown on pump nameplate) and mark the scribed line on the rear of the timing case to coincide with the centre of the slot in the pointer (see Fig. K.9).
10. Remove tool and adaptor from fuel pump gear and fit fuel pump to engine as detailed on Page N.6.

**To Remove the Camshaft and Tappets**

Camshaft end float is controlled by a thrust plate located in a recess machined in the front face of the cylinder block. The plate is dowelled to

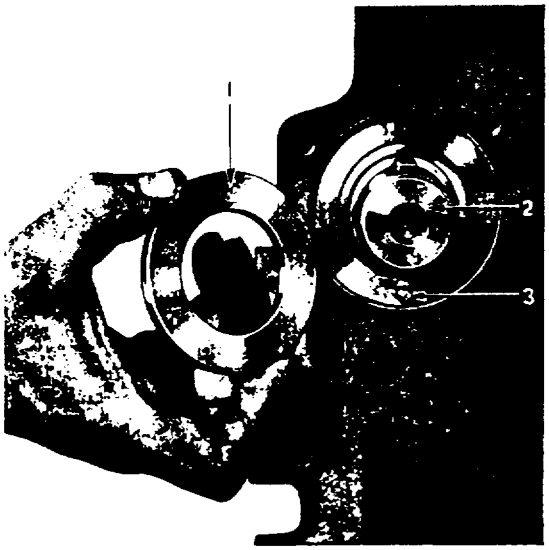



*Fig. K.11.*
*Removing Camshaft Thrust Washer.*
*1. Camshaft Thrust Washer.*
*2. Camshaft.*
*3. Thrust Washer Dowel Pin.*

prevent rotation and is held in position by the timing case.

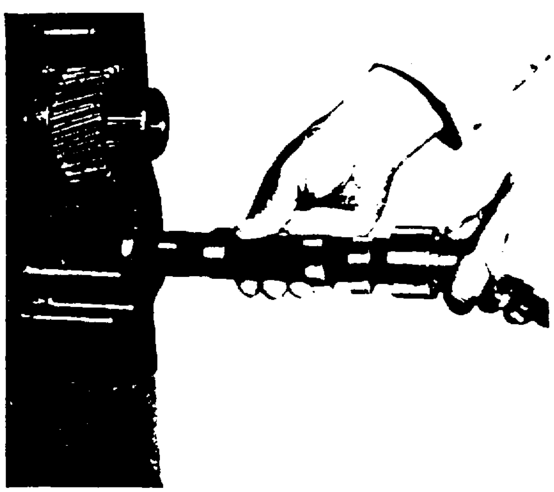


*Fig. K.12.*
*Removing the Camshaft.*

To remove the camshaft it is necessary to remove the engine from the application. After being removed the engine should be mounted in a suitable dismantling stand so that it can be turned upside down to prevent the tappets from falling into the sump when the camshaft is removed.

The removal procedure is as follows:—

1. Remove the engine from the application and mount in a suitable dismantling stand.
2. Remove the rocker cover, rocker assembly and push rods.
3. Remove the timing case front cover, timing gears and timing case as previously described.
4. Turn the engine over so that the sump is uppermost.
5. Remove the fuel lift pump (see Fig. K.10).
6. Remove the camshaft thrust plate from its location on the front of the cylinder block (see Fig. K.11).
7. Carefully withdraw the camshaft taking care not to damage the journals or cams (See Fig. K.12).
8. If desired the tappets may now be withdrawn after the sump has been removed (see Fig K.13).

**To Refit the Tappets and Camshaft**

1. If the tappets have been removed refit them in their locations (see Fig. K.13).

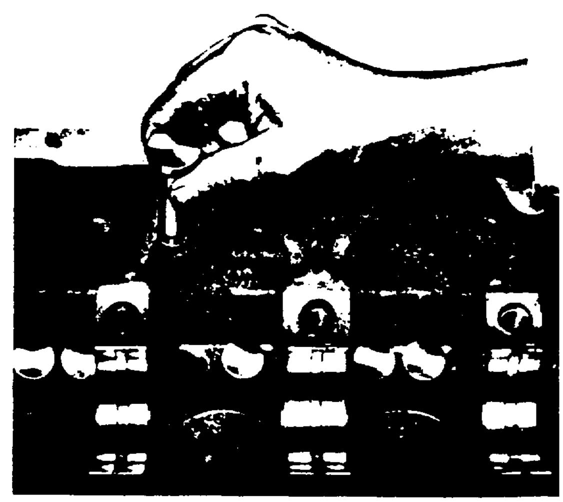


*Fig. K.13.*
*Removing a Tappet.*

2. Carefully refit the camshaft to the cylinder block taking care not to damage the journals or cams.
3. Fit the camshaft thrust plate to its location on the front face of the cylinder block ensuring that the plate is correctly positioned on the dowel. Check the thrust plate protrusion beyond the front face of the cylinder block. See "Technical Data."
4. Refit the sump, turn the engine upright and refit the fuel lift pump together with a new joint.
5. Using new joints, refit the timing case, timing gears and timing case front cover to the engine.
6. Refit the push rods and rocker assembly.

Adjust the valve clearances to 0.012 in (0,30 mm) cold. Refit the rocker cover together with a new joint.

7. Remove the engine from the dismantling stand and refit to the application.

## TIMING

### General

As timing gears are employed on the 4.236 marine engine, the factory setting remains constant. The following information is given as a general guide during an engine overhaul. It is well to remember that the removal of the cylinder head in no way affects either the fuel pump or valve timing.

### Timing Marks

When the engine is originally timed at the factory, certain marks are stamped on the gears, so that if for any reason the engine timing has to be disturbed, then to reset to the original timing is quite straight forward.

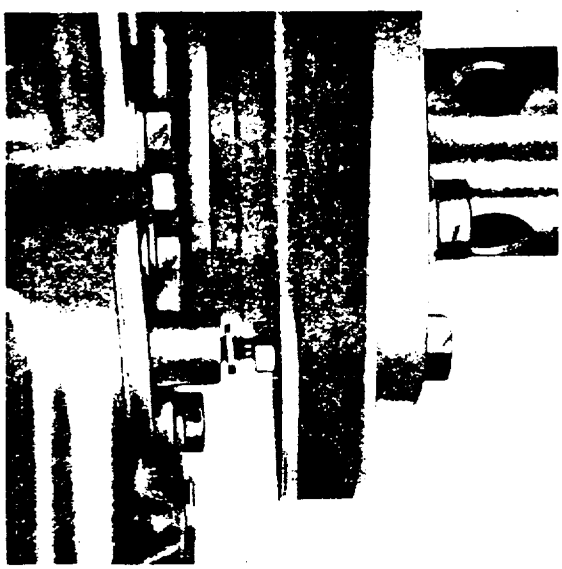


*Fig. K.14.*
*Showing Timing Pin located in Crankshaft Pulley.*

### Timing Pin

A timing pin is fitted at the bottom of the timing case cover on the starboard side. When it is unscrewed it locates in a hole machined in the rear face of the crankshaft pulley, when Nos. 1 and 4 pistons are at T.D.C. (see Fig. K.14).

Always return this pin. to its normal location immediately T.D.C. has been determined and before any attempt is made to turn or start the engine.

### To Reset Engine to the Original Timing

Before commencing the retiming procedure it is assumed that (a) the camshaft, fuel pump and idler gears have all been removed, and (b) the camshaft is free to turn by hand. (If the cylinder head assembly is still in position, it is advisable to remove the atomisers and rocker shaft to facilitate the retiming operations).

1. Turn the engine until the keyway in the front of the crankshaft is uppermost as shown in Fig. K.4. (This will bring Nos. 1 and 4 pistons to T.D.C.)
2. Fit the camshaft gear by drawing it onto its shaft using the retaining plate and setscrew. Lock the setscrew with the tabwasher.
3. Fit the fuel pump gear to the fuel pump drive shaft ensuring that the dowel is correctly located. Secure with the three setscrews and spring washers.
4. Replace the idler gear as previously detailed so that the timing marks are all correctly aligned as shown in Fig. K.4.
5. Check that the backlash between the timing gears is within the limits quoted on Page B.8.

**NOTE: When the timing has been reset, great care should be exercised when first turning the engine, for should the timing be incorrectly set, even by only one tooth, there is the possibility that a valve head will strike the piston crown.**

### For Checking Fuel Pump Timing, see Page N.6

### Checking Valve Timing

To check the valve timing proceed as follows:

1. Turn the crankshaft until the valves of No. 4 cylinder are 'on overlap'.
2. In this position set the valve clearance of No. 1 inlet valve to 0.047 in (1,2 mm).
3. Turn the engine slowly in the normal direction of rotation until the clearance of No. 1 inlet valve is just taken up. (In this condition it will just be possible to rotate No. 1 inlet valve push rod between the thumb and the forefinger).

4. Nos. 1 and 4 pistons will now be at T.D.C. if the timing has been correctly set.

   **NOTE: No adjustment is provided for valve timing, should the timing be incorrect and the camshaft gear has been correctly fitted to the camshaft hub, the error will probably be due to incorrect alignment of the original timing marks on the drive gears. Recheck as detailed on Page K.2.**

**When valve timing is originally set and checked during production a timing tolerance of plus or minus 2-1/2 (flywheel) degrees is allowed for item (4) above. When the timing has been correctly set, do not forget to reset No. 1 inlet valve clearance to the correct figure also to return the timing pin to its correct location if it has been used to check T.D.C.**

The importance of correct and clean lubrication cannot be stressed too highly and all references to engine oil should be taken to mean lubricating oil which falls within the specification given in the appendix. Care should be taken that the oil chosen is that specified for the climatic conditions under which the engine is operated.

The sump should be filled with a suitable grade of lubricant to the correct level but do not overfill above the full mark.

**Description**

The lubrication is of the forced feed type, the oil being circulated, under pressure, by a lobed rotor type oil pump which is mounted on the front main bearing cap and driven through an idler gear by the crankshaft gear. The oil is drawn through a sump strainer and a suction pipe before entering the pump itself. Oil is then pumped via a pipe to the relief valve housing and then through an internal drilling in the cylinder block to an externally mounted adaptor onto which is fitted the full flow type lubricating oil filter. This adaptor channels the oil first to and from the oil cooler section of the heat exchanger, by means of flexible pipes, then through this full flow lubricating oil filter back into the cylinder block. The oil passes via drillings within the cylinder block to the pressure rail (main oil gallery).

With lowline engines, the oil cooler and lubricating oil filter are an integral component fitted on the starboard side of the engine.

From the pressure rail the oil is fed through oilways in the crankcase webs to the five main bearings and then from these through oilways drilled in the crankshaft webs the oil passes to the big ends. An oil seal prevents oil leaking along the crankshaft at the rear end and oil thrown from this seal returns to the sump.

The three camshaft bearings are lubricated through oilways in the crankcase webs from numbers one, three and five main bearings.

The camshaft centre bearing supplies a controlled feed of oil through an oilway, in the cylinder block and cylinder head, to the rocker shaft assembly. This controlled feed is achieved by allowing oil under pressure to be forced to the rocker shaft only when the oilways in the camshaft journal and camshaft centre bearing are in line, this occurring once per camshaft revolution. Oil from the rocker shaft escapes through a small bleed hole in each rocker lever and lubricates the valves and guides by splash, the surplus oil being returned to the sump by gravity.

The idler gear and hub are pressure lubricated direct from the pressure rail. Oil enters the rear of the hub and passes through drillings in the hub to lubricate the idler gear bush and gear retaining plate. Timing gear teeth are splash lubricated by surplus oil from the front camshaft bearing idler gear hub and fuel pump hub.

Pistons, cylinder liners and connecting rod small end bearings are lubricated by splash and oil mist, also the cams and tappets of the valve mechanism.

## THE OIL PUMP

The oil pump is secured to the front main bearing cap by three setscrews, a protrusion of the idler gear shaft locating in a hole in the bearing cap to give positive location.

The bushed idler gear which is free to rotate on its shaft transmits the drive from the crankshaft gear to the oil pump gear.

The oil pump drive gear is pressed and keyed on to the pump driven shaft on the other end of which is pressed and pinned a three lobed rotor. This rotor meshes with a four lobed driven rotor, which is free to rotate in the cast iron pump body.

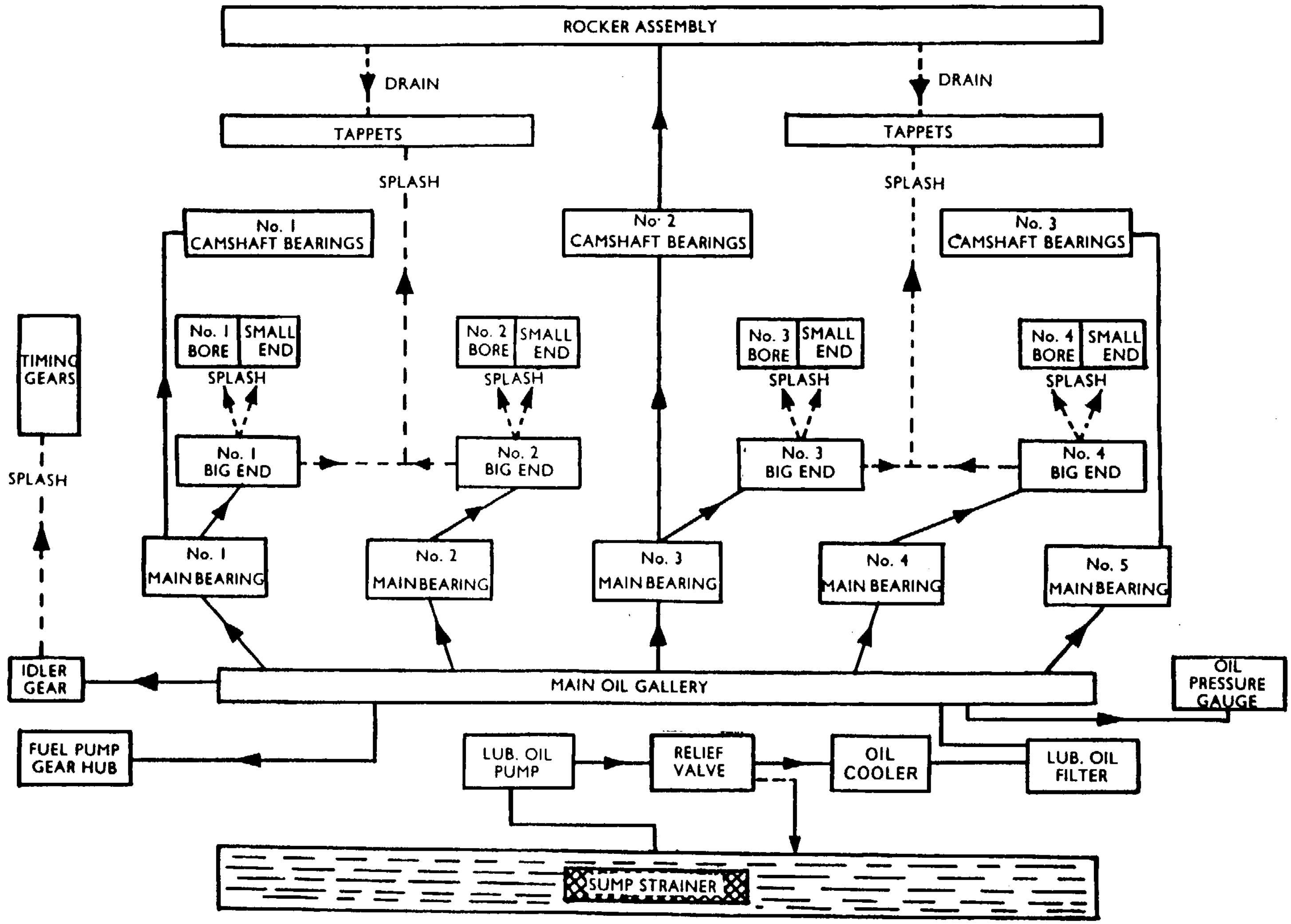



*Fig. L.1. Lubricating Diagram.*

As the pump rotors rotate, the pockets formed between the rotor lobes increase and then decrease in volume to propel the oil from the suction side to the pressure side of the pump.

**To Remove the Oil Pump**

1. Remove the sump securing setscrews and withdraw the sump from the engine. Remove the strainer from the suction pipe of the oil pump (see Fig. L.2). With lowline engines, the sump strainer is of a different pattern to that shown in Fig. L.2. but its removal is similar.
2. Disconnect and remove the suction pipe.
3. Disconnect and remove the oil delivery pipe between the pump and relief valve housing.
4. Remove the crankshaft pulley, timing case front cover, timing gears and timing case as described in the appropriate section.
5. Remove the idler gear circlip and idler gear (see Figs. L.3 and L.4).
6. Remove the three setscrews securing the pump to No. 1 Main bearing cap and with draw the pump from the cap (see Fig. L.5).

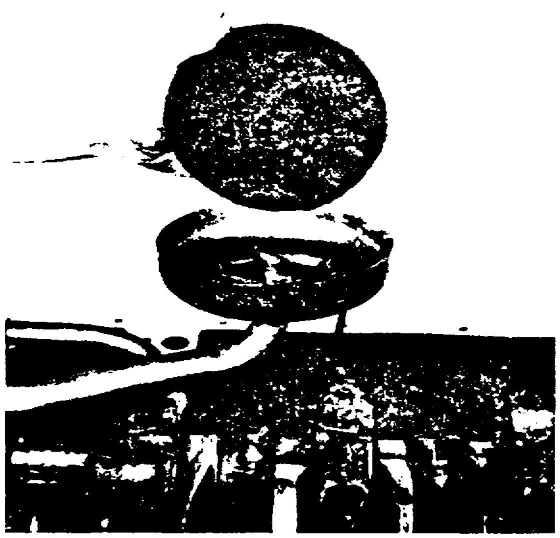


*Fig. L.2.*
*Removing Sump Strainer from Oil Pump Suction Pipe.*

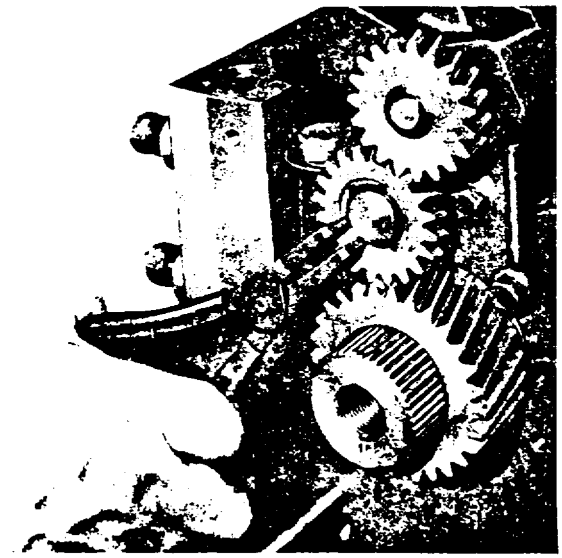


*Fig. L.3.*
*Removing the Oil Pump Idler Gear Retaining Circlip.*

**To Dismantle the Oil Pump**

1. With the pump assembly suitably held in a vice remove the oil pump drive gear retaining circlip (where fitted) and using a suitable extractor remove the drive gear.

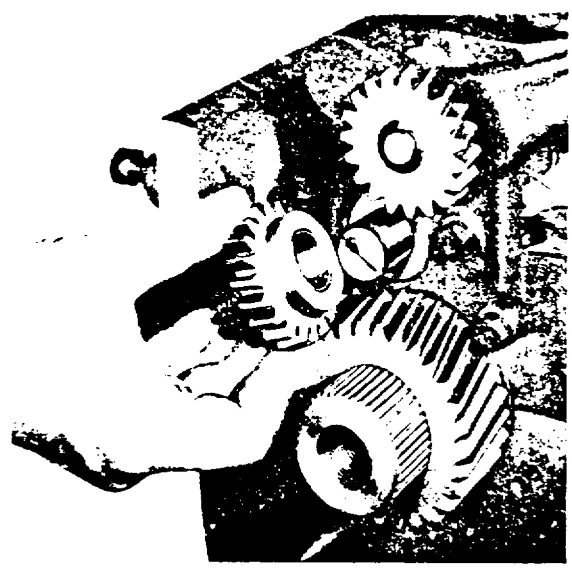


*Fig. L4.*
*Removing the Oil Pump Idler Gear*

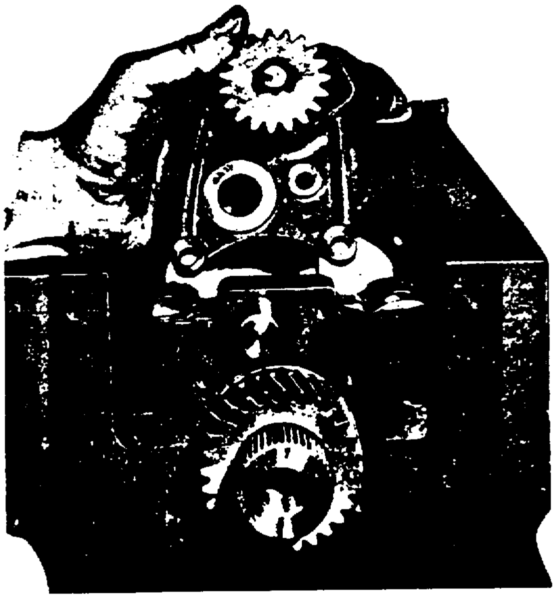


*Fig. L.5.*
*Removing the Lubricating Oil Pump.*

2. Remove the key from the keyway of the drive shaft.
3. Unscrew the three screws which secure the end plate to the pump and remove the plate.

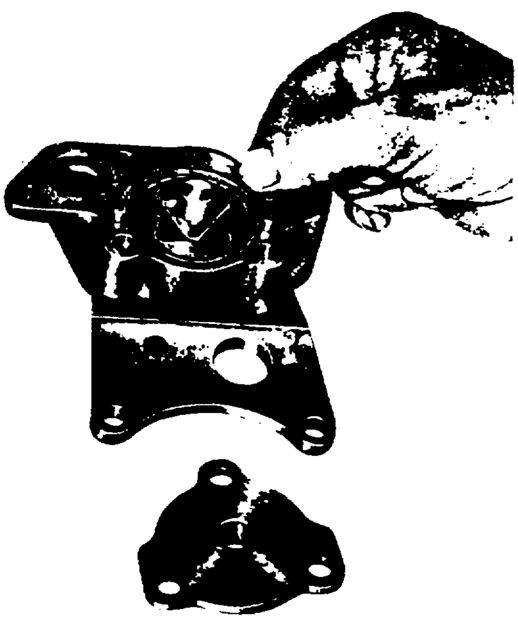


*Fig. L.6.*
*Removing the "O" Sealing Ring from the Oil Pump.*

4. Carefully remove the drive and driven rotors from the pump body.
5. Remove the "O" sealing ring from the pump body (where fitted). See Fig. L.6.

**Inspection**

1. After thoroughly cleaning all the parts they should be examined for signs of cracking, wear or corrosion.
2. Install the inner and outer rotors in the pump body, bearing in mind that the chamfered edge of the outer rotor enters the pump body first.
3. The clearances are checked as shown in Figs. L.7., L.8 and L.9.

**NOTE: The relevant clearances for these dimensional checks are given on Page B.8, they are the clearances applicable to a new pump and are intended to be used as a guide. Should a lubricating oil pump be worn to such an extent that it adversely effects the working oil pressure, then a replacement pump should be obtained. The component parts of the pump itself are not supplied individually,**

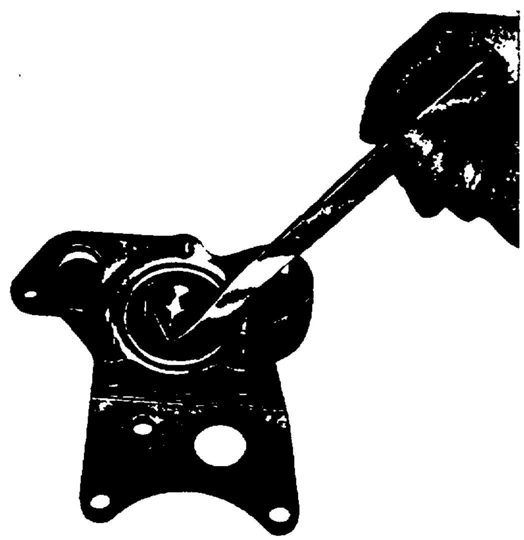


*Fig. L.7.*
*Checking Clearance between Inner and Outer Rotor.*

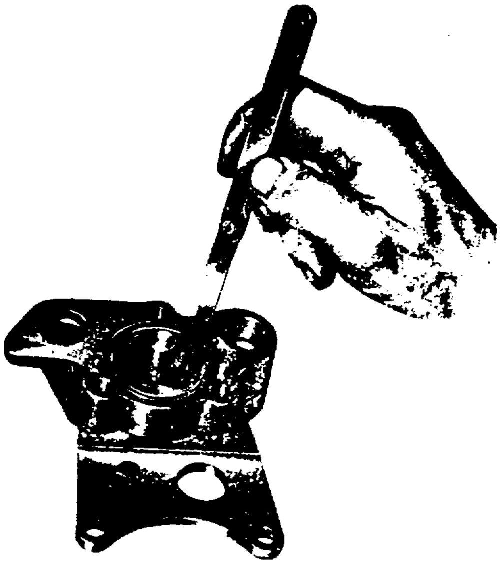


*Fig. L.8.*
*Checking the Clearance between the Outer Rotor and Oil Pump Body.*

therefore if any parts require renewing a replacement assembly should be fitted. It may be worth mentioning at this point that low oil pressure may not even be due to the oil pump, reference to the page covering Fault Diagnosis under the heading "Low Oil Pressure" may help to isolate the cause.

**To Assemble the Oil Pump**

1. Fit the drive and driven rotors to the pump body entering the chamfered end of the outer rotor to the body first. Refit end plate using a new "O" ring (where fitted). Secure the plate with the three screws.
2. Refit the key in the keyway of the drive shaft and refit the drive gear to the shaft. With earlier pumps, the boss on the drive gear was positioned towards the rear of the gear, the flat face of the gear being towards the circlip groove. The correct clearance for the gear was 0.003/0.007 in (0,08/0,18 mm) between the rear face of the gear and the pump body.
   With current pumps, the boss on the gear is positioned on the front of the gear and the correct clearance for the gear is 1.244/1.264 in (31.60/32,11 mm) when measured from the front face of the gear boss to the rear face of the pump mounting flange.

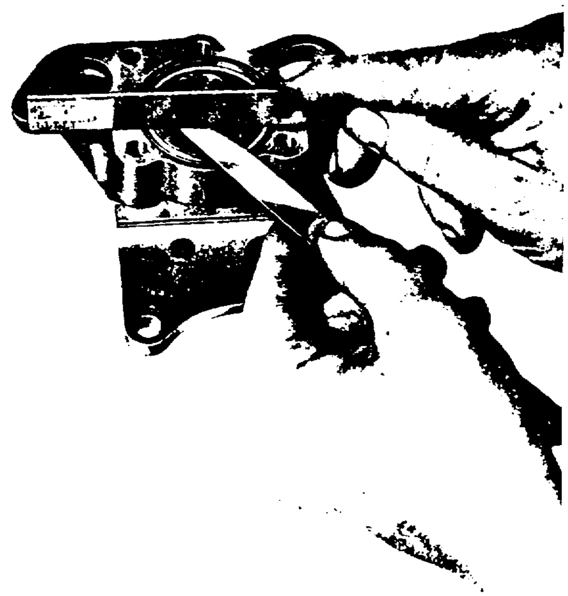


*Fig. L.9.*
*Checking Rotor End Clearance.*

3. Fit the drive gear retaining circlip (where fitted).

**To Refit the Oil Pump**

1. Prime the oil pump with clean lubricating oil.
2. Fit the oil pump to No. 1 main bearing cap and secure with the t three setscrews.
3. Refit the idler gear to the shaft with the recessed face towards the front and secure with the circlip. Check the idler gear end float which should be within the tolerance of 0.002/0.016 in (0,05/0,41 mm). Check the idler gear backlash which should be within the limit of 0.00610.009 in (0,15/0,23 mm).
4. Using new joints refit timing case, timing gears, timing case front cover and crankshaft pulley as described in the appropriate section.
5. Refit the oil delivery pipe between the oil pump and pressure relief valve housing.
6. Refit the suction pipe to the oil pump using a new flange seal.
7. Fit the sump strainer to the pump suction pipe, and using new joints, refit the sump to the engine and secure with the retaining setscrews. Refill the sump with clean oil of an approved grade.

## OIL PRESSURE RELIEF VALVE

The oil pressure relief valve is contained in a housing bolted to the bottom face of the cylinder block and is set to operate at 50/60 lbf/in$^2$ (3,5/4.2 kgf/cm$^2$) - 345/414 kN/m$^2$.

### To Remove and Dismantle the Relief Valve Assembly

1. Remove the sump securing setscrews and withdraw the sump from the engine.
2. Disconnect the oil pump delivery pipe at the relief valve end.
3. Remove the one or two setscrews (according to housing type) which secure the relief valve housing to the cylinder block and take off the relief valve housing.
4. Remove the splitpin from the end of the relief valve housing and withdraw the cap, spring and plunger. An exploded view of the relief valve assembly can be seen in Fig. L.11.
5. Thoroughly clean all parts. Inspect them for wear or damage and renew where necessary.

### To Assemble and Refit the Relief Valve Assembly

1. Fit the plunger, spring and cap to the relief valve housing and secure with the split pin.

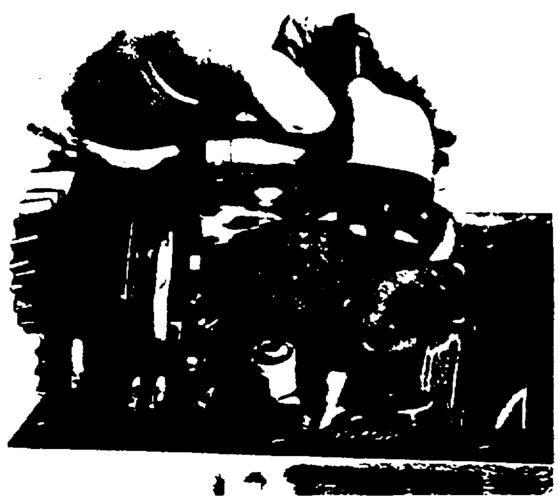


*Fig. L.10.*
*Removing the Oil Relief Valve Housing from the Cylinder Block.*

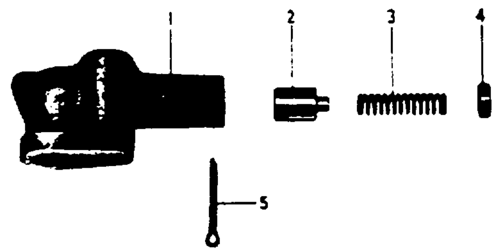



*Fig. L.11.*
*Exploded view of Oil Relief Valve.*
*1. Relief Valve Body.*
*2. Plunger.*
*3. Spring.*
*4. Spring Retaining Cap.*
*5. Splitpin.*

2. If a suitable test rig is available, check the pressure setting of the relief valve. The valve should lift between 50/60 lbf/in$^2$ (3,5/4.2 kgf/cm$^2$). If a test rig is not available, extreme caution is advised when starting the engine until it has been ascertained that the pressure relief valve is working correctly.
3. Using a new joint (where fitted) fit the relief valve housing to the cylinder block and secure with the setscrew(s).
4. Connect the oil pump delivery pipe to the relief valve housing.
5. Ensure that the sump strainer is correctly positioned on the oil pump suction pipe. Using new joints refit the sump to the engine and secure with the retaining setscrews. Refill the sump with clean oil of an approved grade.

## OIL PRESSURE

Always ensure that with the engine running, oil pressure is registering on the gauge or the oil pressure warning light is extinguished.

Pressures do vary according to climatic conditions and even between individual engines, but the oil pressure range at maximum working speed is given on Page B.8. The pressure will drop whilst the engine is idling and also a slight drop will be experienced when the oil is hot, this is quite normal. If, however, the oil pressure is suspected of being too high or too low then reference to the possible faults listed in Fault Diagnosis may prove helpful.

## LUBRICATING OIL FILTERS

To ensure cleanliness of the lubricating oil a sump strainer and a main full flow type of oil filter are fitted.

The sump strainer consists of a gauze wire container which is fitted over the end of the lubricating oil pump suction pipe. All oil must pass through this strainer before it reaches the oil pump, this ensures that no foreign matter reaches the pump which could cause any damage. It is recommended that this strainer is removed and thoroughly cleaned every time the sump is removed.

The main full flow type oil filter is mounted externally on the side of the cylinder block. All the oil passes through this filter after it leaves the pump, but before it reaches the bearings. This filter utilizes a replaceable paper filter element on earlier engines or a spin-on canister type having an integral element on later engines and no attempt should be made to clean it. It should be replaced by a new one in accordance with Preventive Maintenance recommended on Page C.3.

### To Renew Spin-on Oil Filter Canister

1. Unscrew filter canister from side of oil cooler (see Fig. L.12).
2. Discard old canister.
3. Clean head of oil cooler.
4. Using clean engine oil, liberally oil top seal of replacement canister.
5. Fill new canister with clean lubricating oil allowing time for the oil to filter through the element. Screw replacement canister on to end of the oil cooler until the seal just touches cooler head. Then tighten as per instructions on canister. Where a tool is available tighten to 15 Ibf ft (2,07 kgf m) - 20 Nm.
6. Run engine and check for leaks.

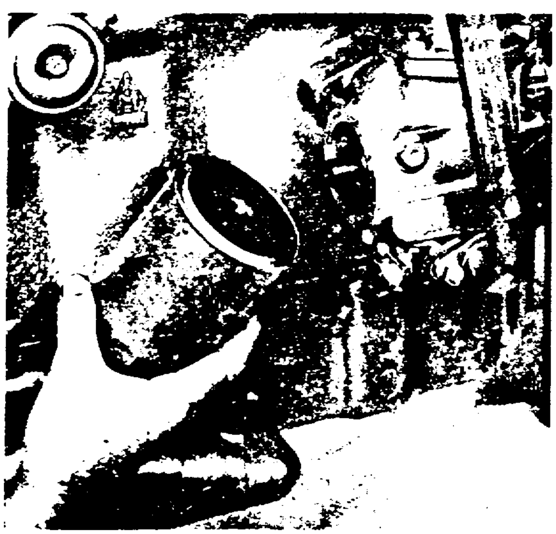


*Fig. L.12.*
*Removing Lubricating Oil Spin-on Canister.*
*(lowline engines)*

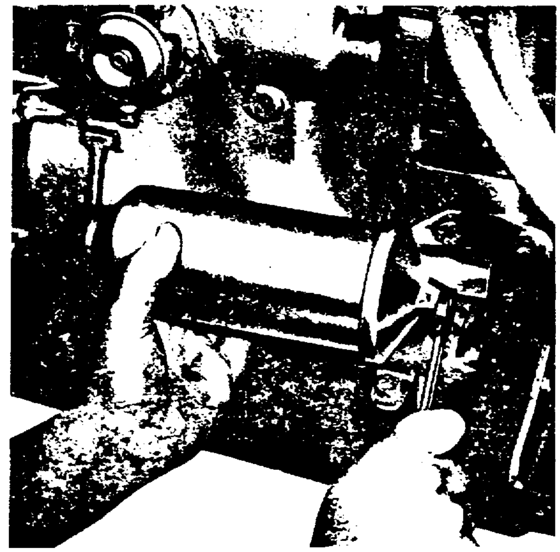


*Fig. L.13.*
*Removing the Lubricating Oil Filter Bowl Securing Screw.*
*(Replaceable element type)*

**NOTE: Oil filter canisters have internal valves to prevent oil drain back and a special tube stack is fitted, so always ensure that the correct replacement is fitted.**

### To Remove the Filter Element (earlier engines)

1. Clean the exterior of tile filter bowl.
2. Unscrew the filter bowl securing bolt as shown in Fig. L.13. A suitable container should be placed beneath the filter to catch the oil in the bowl as the securing bolt is slackened.
3. Ease the filter bowl clear, lift out the old element and discard.

**NOTE: Ensure that the top edge of the filter bowl is not damaged in any way during handling, otherwise it may be difficult to obtain an oil tight seal when it is refitted, even when using a new sealing ring.**

### To Renew the Filter Element (earlier engines)

1. Clean out the filter bowl using cleaning fluid.
2. Fit the new element so that it locates correctly on the spring loaded guide in the base of the container.
3. Fit the new container seal in the filter head ensuring that it is correctly located in its groove.

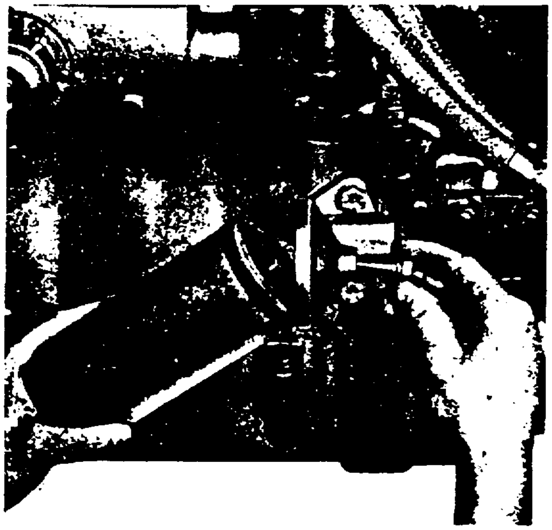


*Fig. L.14.*
*Removing the Lubricating Oil Filter Bowl.*
*(Replaceable element type)*

4. Offer the bowl to the head casting squarely and firmly, locate the securing bolt and tighten carefully. Ensure that the top edge of the filter bowl is central on the seal within the head casting recess.
5. Tighten the securing bolt. Do not overtighten.
6. After the engine has been run and the filter assembly checked for oil leaks, restore the oil in the sump to the correct level.

**To Remove the Oil Filter from the Engine (earlier engines)**

1. Withdraw the two setscrews securing the filter to the cylinder block and remove the filter assembly.

**To Refit the Oil Filter to the Engine (earlier engines)**

1. Ensure that the cylinder block face and filter mounting face are clean and that all traces of the old joint have been removed.
2. Using a new joint secure the oil filter to the cylinder block with the two setscrews and tighten to a torque wrench reading of 30 lbf ft (4.1 kgf m) - 41 Nm.
3. Check the sump level after running the engine and top lip as necessary.

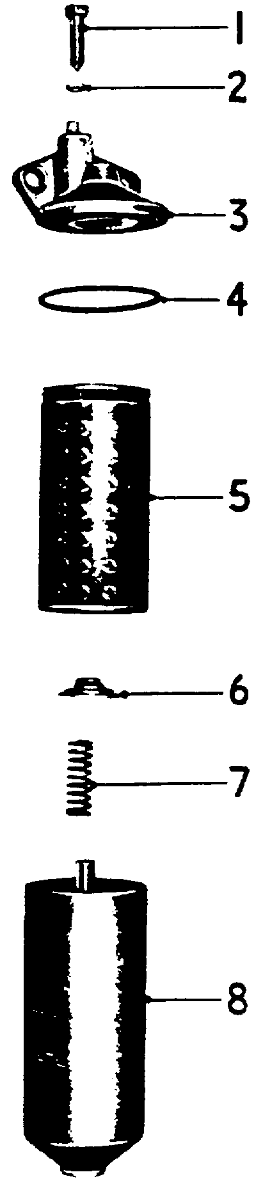



*Fig. L.15.*
*Exploded View of Lub. Oil Filter.*
*(Replaceable element type)*

1. *Bowl Retaining Setscrew.*
2. *Retaining Setscrew Washer.*
3. *Filter Cover.*
4. *Bowl Sealing Ring*
5. *Element.*
6. *Element Seating Washer.*
7. *Spring.*
8. *Bowl.*

The 4.236 Marine engine is indirectly cooled. This type of system employs two separate water circuits. One is a fresh water (closed) circuit which circulates within the cylinder block and head, the other is a sea or river water (open) circuit which circulates externally round the engine. Heat is interchanged between circuits via a heat exchanger unit.

**Lowline Engines**

A neoprene impeller type water pump is used to circulate the coolant on the open side of the system. The raw water is drawn in through the gearbox oil cooler to the water pump. From the pump, it is delivered to the heat exchanger mounted on the starboard side of the engine and then to the oil cooler where the engine oil passes over a series of tubes running the length of the unit. It is through these tubes that the coolant is passed. From the engine oil cooler, the raw water is finally discharged through the exhaust manifold water injection bend.

Circulation of the closed fresh water system is effected by a centrifugal water pump mounted on the front of the cylinder block and is belt driven from the crankshaft. Water is drawn from the header tank mounted on the front of the engine to the cylinder block where both the head and block are cooled by thermosyphon action. The water then passes to the thermostat. When the engine is cold and the thermostat fully closed, the water bypasses the thermostat to a double entry elbow mounted on the heat exchanger via a copper pipe. From the double entry elbow, the water passes to the rear of the exhaust manifold. As the engine warms up, the thermostat will start to open allowing the warm cooling water to bleed through the heat exchanger through the double entry elbow joining up with the bypass cooling water. The water then passes through the exhaust manifold to the header tank. As the water temperature rises to its allowed maximum, the thermostat gradually opens until it is in the fully open position, the bypass flow is cut off and the full cooling water flow passes through the heat exchanger and passes through the exhaust manifold and back to the header tank. The amount of water passing through the bypass and through the heat exchanger will depend on the opening position of the thermostat.

The header tank is fitted with a pressurized finer cap.

The water pumps for each circuit are described individually later in this section.

**Standard Engines**

With earlier standard engines, the header tank mounted at the front of the engine incorporates both the engine fresh water heat exchanger and the engine oil cooler. A pressurized filler cap is fitted.

The coolant on the open side of the system is drawn in through the gearbox oil cooler to the water pump. From the water pump, it is delivered to the combined heat exchanger and engine oil cooler in the header tank where fresh water and oil in their respective compartments pass over a series of tubes running the length of the unit. It is through these tubes that the coolant on the open side is passed. From the combined heat exchanger and oil cooler. the water is then passed to the water cooled exhaust manifold and is then finally discharged overboard.

Circulation of the closed fresh water system is effected by a centrifugal water pump mounted on the front of the cylinder block and is belt driven from the crankshaft. Water is drawn from the combined header tank heat exchanger and is delivered to the cylinder block where both the head and block are cooled by thermosyphon action. After circulation, the water is finally discharged at the front of the cylinder head through the thermostat housing to the header tank/heat exchanger.

The water pumps for each circuit are described individually later in this section.

The operating temperatures of the closed water system at the outlet should be in the region of 190°F (88°C).

A thermostat is fitted in the water outlet connection, which enables the engine to reach its most efficient working temperature in the shortest possible time by restricting coolant flow. When the correct temperature is reached, the thermostat valve opens and allows the water to circulate normally. Where a pressurized system is used, the coolant temperature will be slightly higher.

**To Adjust the Dynamo/Alternator and Water Pump Belt**

The belt tension should be adjusted so that it is possible to depress the belt, without undue pressure, approximately 3/8 in (10 mm) on the longest unsupported length of the belt (see Fig. M.1).

To prevent premature wear and eventual failure, correct tension of this belt should be maintained by periodical checking and adjustment every 250 hours.

Excessive belt tension, and consequent overloading of the dynamo/alternator and water pump bearings, is detrimental to both belt and bearings and may cause complete failure of one or both of these components.

Insufficient belt tension, allowing belt slip, will impair the efficiency of the engine cooling system and adversely affect dynamo/alternator output.

Belt adjustment is obtained by altering the position of the dynamo/alternator in the following manner.

1. Slacken off the dynamo/alternator adjusting lever setscrew, the adjusting lever to timing case setscrew and the dynamo/alternator to bracket support bolts.
2. The dynamo/alternator is now free to be moved on its support bracket towards or away from the engine to obtain the correct belt tension. Hold the dynamo/alternator in the desired position.
3. Tighten the adjusting lever setscrew, the lever to timing case setscrew and the dynamo/alternator to bracket support bolts.
4. Check that the tension is still correct.

**NOTE: When a new belt is fitted it is advisable to re-check the adjustment after a short running period. New belts are subject to initial stretch and early readjustment may be necessary.**

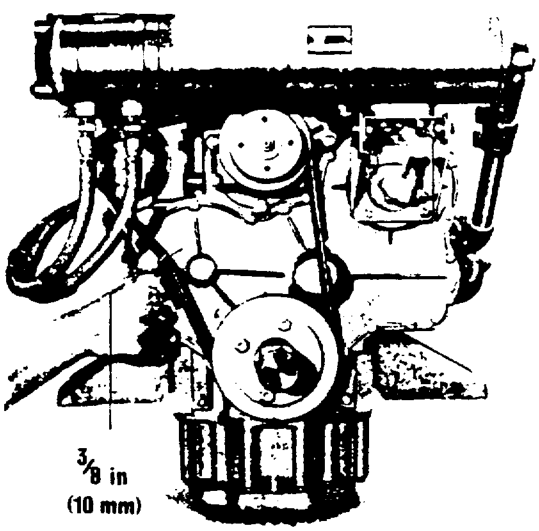



*Fig. M.1.*

**To Remove the Belt**

1. Slacken off the dynamo/alternator adjusting lever setscrew, the adjusting lever to timing case setscrew and the bracket support bolts. Pivot the dynamo/alternator towards the cylinder block.
2. Turn the engine by hand and work the belt off the water pump and dynamo/alternator pulleys.
3. Remove the belt from the crankshaft pulley.
4. Examine the belt for wear or fraying and renew as necessary.

**To Refit the Belt**

Refitting the belt is a reversal of the removal operations. Adjust the fan belt tension as detailed. If a new belt is fitted, check the tension after a few hours of running to ensure that any slackness due to initial stretching is corrected.

**FRESH WATER PUMP (Closed Circuit)**

This is of the centrifugal type, the pump shaft which rotates within two bearings is belt driven by means of a pulley pressed onto one end and secured with a self locking nut. The drive is transmitted through the shaft to an impeller which is pressed onto the other end of this shaft.

The impeller assists the circulation of the coolant around the system. Water is contained within the impeller chamber by means of a spring

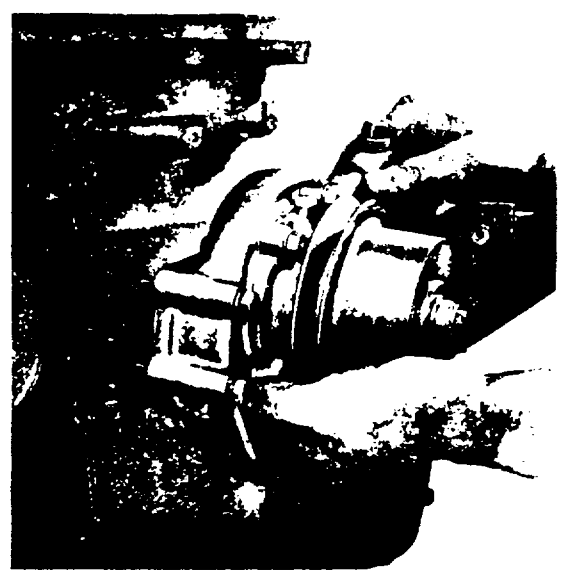


*Fig. M.2.*
*Removing the Water Pump.*

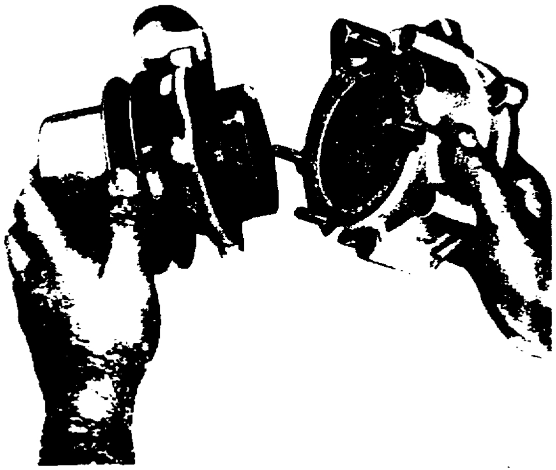


*Fig. M.3.*
*Separating the Front and Rear Pump Body Sections.*

loaded carbon-faced seal which registers against the inside (back) face of the impeller.

**To Remove and Refit Fresh Water Pump**

**Description**

1. Remove the dynamo/alternator and water pump driving belt.
2. Disconnect the inlet and outlet connections to the water pump.
3. Unscrew the five setscrews which pass through the pump and rear pump body into the cylinder block. Withdraw the pump from the engine (see Fig. M.2).
4. Separation of the front and rear pump body sections is achieved by removing the securing nuts and washers and gently tapping with a hide-faced hammer.
5. Refit the pump rear body and water pump in the reverse sequence ensuring that all joint faces are clean, and that new joints are fitted between the cylinder block and pump rear body, and between the rear body and water pump.
6. Refit the dynamo/alternator and water pump driving belt as detailed on Page M.1.

**Fresh Water Pump Seals**

Where ceramic counter face water pump seals are fitted, if the engine is run without coolant, even for a few seconds, the heat build-up between the carbon seal and ceramic counter face is very rapid, resulting in the cracking of the ceramic. This often creates the misunderstanding that the cause of leakage is due to the incorrect assembly of the sealing arrangement of the water pump.

*Fig. M.4.*
*Removing the Water Pump Pulley.*

**To Dismantle the Water Pump**

1. Unscrew the self locking nut securing the water pump pulley to the pump shaft and remove the nut with plain washer.
2. Using a suitable withdrawal tool, remove the pulley from the shaft (see Fig. M.4) and remove the pulley driving key from the shaft.
3. Press the water pump shaft, complete with impeller, out of the water pump body from the front of the pump.
4. Using a suitable press, remove the impeller from the pump shaft.
5. Remove the water seal from the pump shaft.
6. Remove the bearing retaining circlip from the front of the pump body using circlip pliers.
7. Press the two bearings and distance piece out of the pump body.
8. Finally, remove the front grease seal, seal retainer and flange from the pump body.

**Inspection**

1. Thoroughly wash all the water pump components in cleaning fluid and dry off.
2. Examine the pump body for cracks, damage or corrosion.
3. Examine the drive shaft for wear ensuring the inner diameters of the bearings are a perfect fit on the shaft. The shaft should be renewed if wear in this area is sufficient to allow the races to rotate on the shaft.

4. Remove rust and scale from the impeller and visually inspect for cracks or damage. Examine the impeller hub sealing face for excessive wear or scoring. Renew if unserviceable.
5. Examine the water seal for damage. Excessive wear, scoring or cracks in the carbon sealing face will necessitate renewal.
6. Inspect the bearings for pitting, corrosion or wear, and renew if necessary.

**To Re-Assemble the Water Pump**

1. Press the rear bearing on to the shaft, fit the bearing distance piece and then press on the front bearing. When fitting the bearings to the shaft, ensure that the shielded face of each bearing faces outwards towards the front and rear end of the shaft.
2. Fit the grease seal retaining plate in position against the back face of the rear bearing. This retaining plate is "dished" and when in position, the centre of the plate must not be in contact with the bearing.
3. Fit the felt seal and seal retainer housing so that these bear on the retaining plate.
4. Half fill the space between the two bearings with a high melting point grease and press the complete bearing and shaft assembly into the pump housing from the front end. Securely position the retaining circlip in the recess of the pump housing immediately forward of the front bearing.
5. Fit the water seal into the housing ensuring that the carbon face is positioned towards the rear. When fitted, the seal must rest squarely on its seat and not be canted in any way.
6. At this stage, the shaft should be turned by hand to ensure that no undue resistance to rotation exists.
7. Fit the driving pulley key and press on the pulley making sure that no rearward axial movement of the shaft is incurred.
8. Where ceramic counter face seals are fitted, fit seal to shaft with counter face towards water seal and rubber bonded holder towards impeller face.

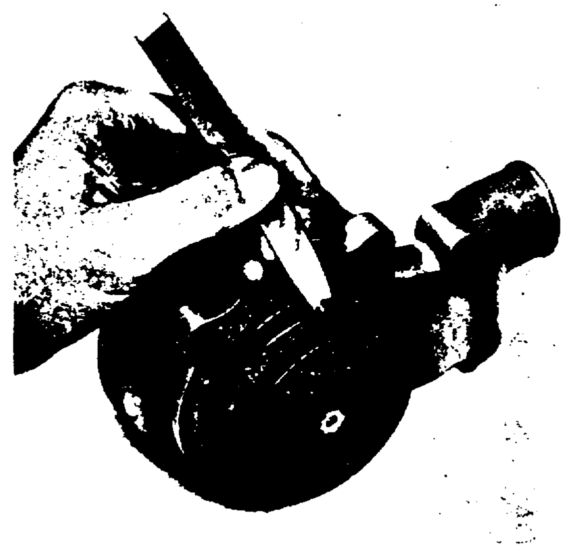


*Fig. M.5.*
*Checking Impeller to Water Pump Body Clearance.*

9. Press the impeller onto the shaft ensuring that a clearance of 0.012/0.032 in (0,30/0.81 mm) is maintained between the impeller vanes and the pump body (see Fig. M.5).
10. Refit the plain washer and pulley retaining self locking nut, tightening to a torque of 60 lbf ft (8,5 kgf m) - 84 Nm.

## SEA WATER PUMP (Open Circuit)

**Description**

This type of pump consists basically of a shaft, gear driven from the rear of the timing case, which rotates within bearings in a water tight housing. The shaft transmits the drive to a neoprene impeller mounted on the other end. This impeller is offset slightly to the water chamber in which it rotates. The impeller blades, being flexible have a trailing action when the pump is turned in the normal direction of rotation. This flexibility permits the impeller to operate offset to the centre of the water chamber and has the action of drawing in water through the suction (inlet) side of the pump in the large pockets between the impeller blades, when the impeller turns, the blades become more flexed and consequently the volume of the pockets between the blades decreases forcing the water now under pressure to escape as the blades uncover the outlet port on the pressure side of the pump.

The pump is self priming, but it is advisable to prime it when first commencing service or after the engine has been laid up for any considerable length of time. This is effected by disconnecting the pipe between the water pump and the heat exchanger at its upper end, filling it with water and then reconnecting it to the heat exchanger.

This pump should never be run in a dry condition and if the engine is to be withdrawn from service for any length of time, it will be necessary to pack the water pump with MARFAK 2HD grease. (Where this is not available, Glycerine may be used instead). This may be effected by removing the water pump end plate, giving access to the interior of the pump, which can then be packed with grease.

This treatment is usually effective for about three months, and should be repeated prior to recommencement of service if laid up for a longer period than this.

N.B. Due to considerable suction created by this type of pump, it is essential that where rubber hose pipe is employed on this side of the pump any 'runs' of hose should be reinforced internally, likewise at junctions the pipe ends should almost butt together to prevent either partial or complete collapse with subsequent overheating.

**To Remove the Pump**

1. Uncouple the inlet and outlet water connections.
2. Remove the nuts securing the pump to the back of the timing case.
3. Withdraw the pump complete with its driving gear from the studs. The pump may be replaced by reversing the above procedure.

**Dismantling the Pump**

1. Remove the water pump end cover plate.
2. Remove the impeller by means of a pair of pliers. If it is tight on the shaft, loosen it by holding the impeller and twisting the shaft backwards and forwards.
3. Loosen the cam locking screw a few turns, then lightly tap screw downwards to loosen the cam in the water pump body.

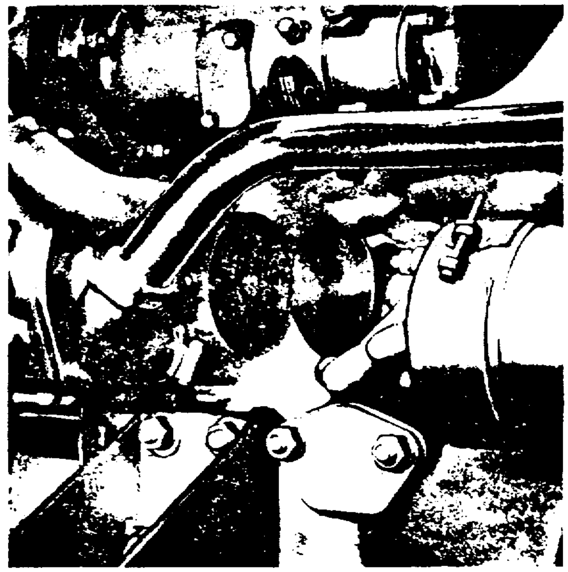


*Fig. M.6.*
*Removing Water Pump End Cover Plate*

4. Remove the cam locking screw and cam.
5. Remove wear plate from inside of impeller housing.
6. Remove the circlip on the water pump shaft and withdraw the spring loaded seal and seal seat.

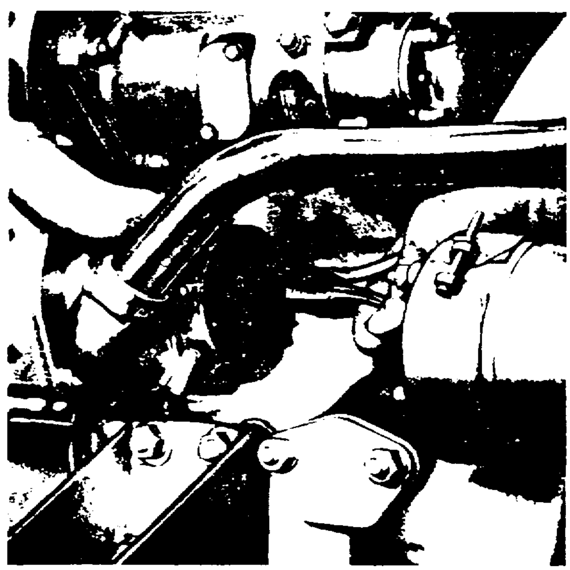


*Fig. M.7.*
*Removing Water Pump impeller*

*Fig. M.8.*
*Removing Sea Water Pump from back of Timing Case.*

It may be advisable to apply a soapy solution to the pump shaft in order to ease the seal past the circlip groove.

Should difficulty be experienced in gripping the seal with the fingers then two lengths of stiff wire or welding rod (3/64 in to 1/16 in dia.) with hooked ends (1/16 in to 3/32 in deep) can be utilized to secure the seal, one opposite the other, whereupon the seal can then be withdrawn.

Alternatively, slacken off the clamping device which secures the two halves of the pump together (bearing housing and impeller housing) and then proceed to separate them, thus exerting pressure on the seal from behind.

7. Remove the gear from the drive end of the pump shaft by means of a suitable puller.
8. Remove the outer retaining circlip from the bearing housing.
9. Withdraw the impeller housing from the bearing housing, firstly slackening off the clamping device.
10. Withdraw the slinger from the pump shaft.
11. A suitable press may then be used to press out the water pump shaft together with the water pump bearings.
12. Remove the bearings from the water pump shaft by means of a press. To re-assemble the water pump, the reverse order should be adopted.

When replacing the cam fitted in the impeller housing, be certain to coat the entire top surface, rear face and securing setscrew hole with a suitable jointing compound.

Note that the cam will go into position one way only.

Care should be taken, when replacing the rubber impeller, that all the blades lie in the same direction relative to rotation of the pump i.e., blades trailing.

When re-assembling, ensure that the rubber impeller is coated with MARFAK 2HD grease.

**NOTE:**

**If appreciable wear or scoring has taken place on the wear plate working face, it may be turned round so that the reverse side now becomes the working face. If this face in turn becomes worn, then a replacement wear plate should be fitted.**

**If appreciable wear or scoring has taken place on the end cover working face, it can be ground to restore flatness, providing that this operation is not carried out too many times. If a replacement end cover is fitted which does not carry the pump model number etc., then the original worn end cover should be fitted over the new part, utilizing longer setscrews.**

**The thickness of the end cover joint is critical. If it is damaged, it is important that the correct replacement joint, or one of similar thickness be fitted.**

### HEAT EXCHANGER AND OIL COOLER (lowline engines)

With lowline engines, the heat exchanger and oil cooler are two separate items both mounted on the starboard side of the engine. The oil cooler and spin-on lubricating oil filter are an integral unit.

Removal of both units is effected by removing the inlet and outlet water connections and removing the units from the cylinder block.

The dismantling of both units is similar. Remove the end covers and drive the tube stacks out of their respective housings. Cleaning of the tube stacks is the same as that recommended for the earlier combined heat exchanger and oil cooler as given on Page M.7.

When re-assembling, new "O" ring seals and joints should be fitted if they appear to be badly worn or deformed.

### HEAT EXCHANGER AND OIL COOLER (earlier engines)

The unit basically comprises: —

(a) An aluminum casing providing the header tank and a machined bore into which the heat exchanger tube stack is located.

(b) A smaller aluminum cylinder into which the oil cooler tube stack is located.

(c) Two tube stacks each comprising a multiplicity of small bore tubes running between two tube plates.

(d) Two sea water end covers.

(e) A tie rod which passes between the end covers and secures the assembly together.

**Dismantling**

When dismantling it is best to proceed in the order given below:

1. Remove the two sea water pipes from their respective end covers.

2. Disconnect the two oil pipes.

3. Remove the brass cap nut.

4. This end cover can now he removed.

5. The other end cover complete with tie rod can now be withdrawn. Care should be taken to support the oil cooler and the spacing ring after the tie rod has been removed, as this will not be attached in any way to the main casing.

6. The "O" seals can now be removed from the end of the tube stacks allowing the latter to be withdrawn from their respective casings.

7. The main aluminum casing can now be removed from the engine if necessary; this will entail disconnection of the fresh water flanges.

**Cleaning**

If the tube stack appears badly fouled up, the best method of cleaning is to use non caustic crystalline solvents approved by the manufacturers.

Usually, the fresh water side, i.e., the outside of the tubes are relatively clean as these are on the

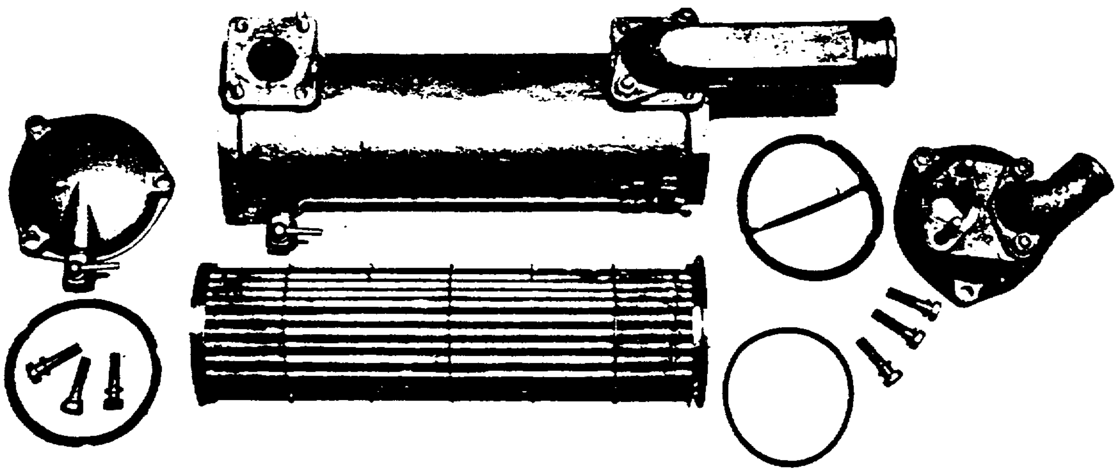


*Fig. M.9.*
*Exploded View of Heat Exchanger.*
*(lowline engines)*

closed water circuit. The inside of these tubes which have the raw water (sea water) passing through them are more likely to require cleaning.

If these are not badly scaled enough to require the solution treatment described above, they can be cleaned by pushing a length of 1/8 in (3.2 mm) diameter steel rod down the tubes to dislodge all foreign matter. It is important to note that when carrying out this exercise, the rod should be pushed through the tubes in the opposite direction to that in which the water flows. Do not use undue force to push the rod through the tubes.

The other components of the assembly should be cleaned before re-assembly and as these have no hidden features, no special instructions are considered necessary.

### Re-Assembly

If the main aluminum casing has been removed from the engine it is best to refit this to the engine first before re-assembling the heat exchanger itself, although, if conditions are too cramped, it is quite possible to completely re-assembly the heat exchanger first, and then re-attach it to the engine.

1. Place the two tube stacks in their respective casing and fit the "O" seals over each end. It is advisable to renew these seals if they appear badly worn or deformed.

2. The complete oil cooler should now be slid along the tie rod, taking care that the tube stack is located in the end cover.

3. The spacing ring should be replaced in position and the tie rod complete with oil cooler assembly fitted to the main casing.

4. The other end cover can be replaced and the cap nut complete with its copper and asbestos washer refitted. This cap nut should be tightened to a torque not exceeding 25 Ibf ft (3,5 kgf m) - 34 Nm.

### GEARBOX OIL COOLER

### To Remove

1. Uncouple inlet and outlet water connections to the oil cooler.

2. Remove inlet and outlet oil pipes.

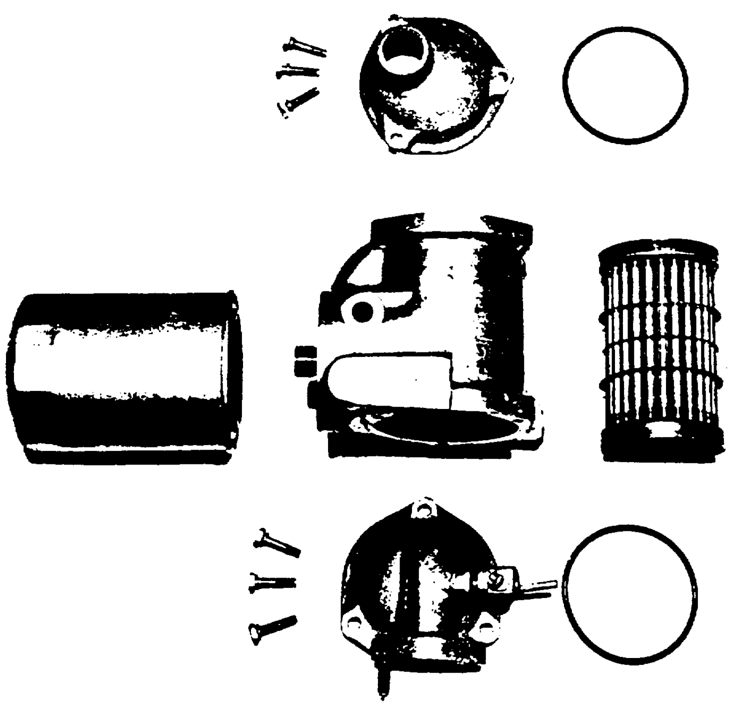


*Fig. M.10.*
*Exploded View of Lubricating Oil Cooler and Filter.*
*(lowllne engines)*

3. Remove oil cooler by unscrewing the two nuts on the ends of the oil cooler securing clamp.

   Replacement of the oil cooler is effected by reversing the above procedure.

**Dismantling**

1. Remove the oil cooler end covers by unscrewing the securing setbolts.

2. Remove the rubber "O" ring seals at each end of the cooler.

3. Drive tube stack out of oil cooler casing.

**Cleaning**

Under normal circumstances, the gearbox oil cooler will require little attention, providing the sea water strainer is efficient and is kept clean.

After a lengthy period of service, it may be necessary to clean the tube stack and this may be effected in a similar manner to that described for the combined heat exchanger and lub. oil cooler.

**Re-Assembly**

1. Place the tube stack in its casing and fit the "O" ring seals over each end cover. It is advisable to renew these seals if they appear to be badly worn or deformed.

2. The end covers and securing setscrews should now be replaced.

3. Tighten the securing setscrews.

## THERMOSTAT

**To Remove (lowline engines)**

1. Remove water connection between header tank and exhaust manifold. To effect this, it is necessary to slacken both hose clips and slide the hose towards the exhaust manifold. Removal of the two setscrews securing the water pipe to the header tank will then permit its removal.

2. Remove setscrews securing top cover of thermostat housing and remove cover.

3. Remove thermostat — see Fig. M.13.

**To Remove (earlier engines)**

1. Remove all water and lubricating oil connections to heat exchanger assembly.

2. Unscrew the four setscrews securing the heat exchanger assembly to the thermostat housing, thereby disclosing the thermostat.

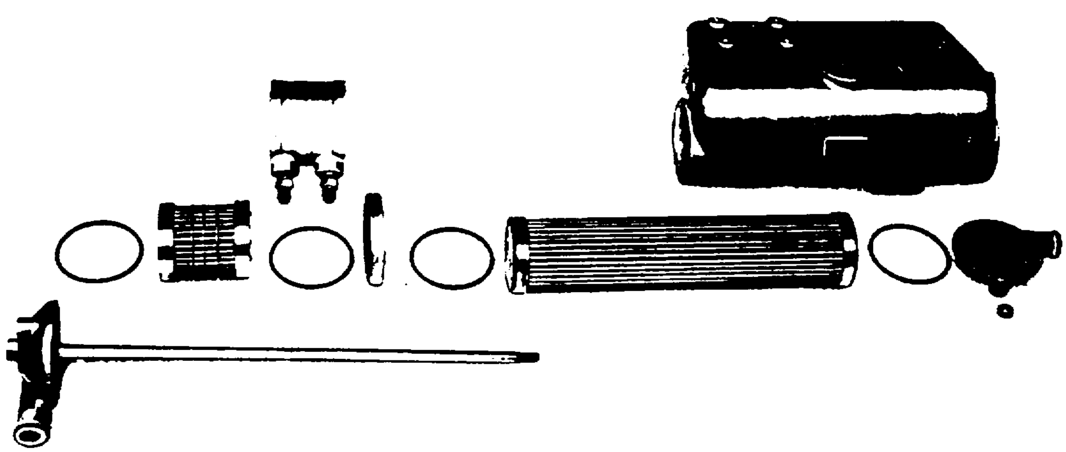


*Fig. M.11.*
*Exploded view of Heat Exchanger Assembly,*
*(earlier engines)*

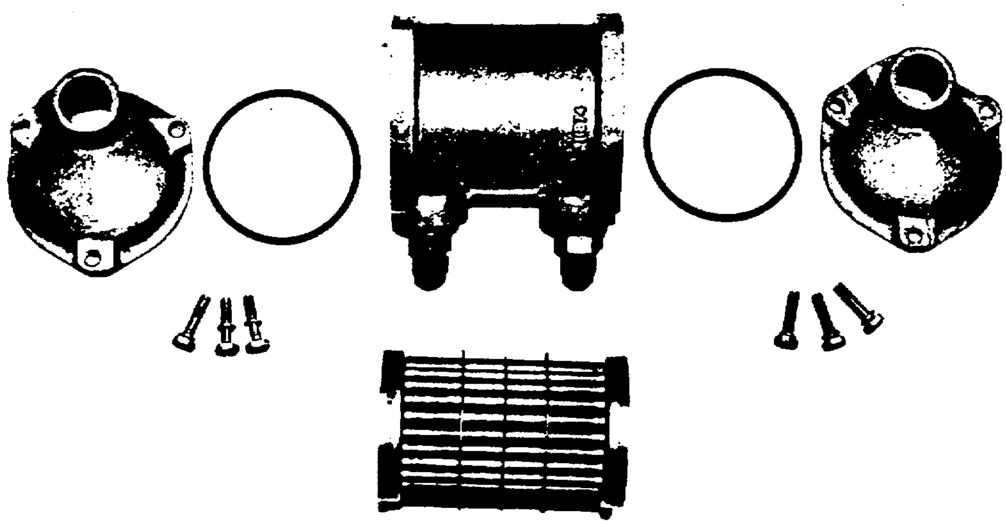


*Fig. M.12.*
*Exploded View of Gearbox Oil Cooler.*
*(lowline engines)*

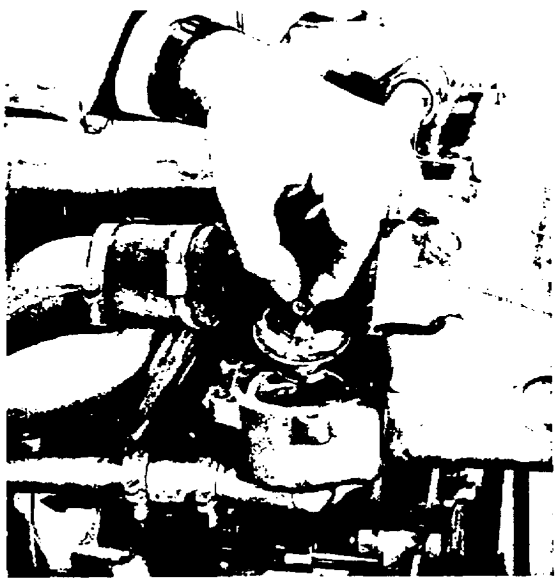


*Fig. M.13.*
*Thermostat Removal.*
*(lowline engines)*

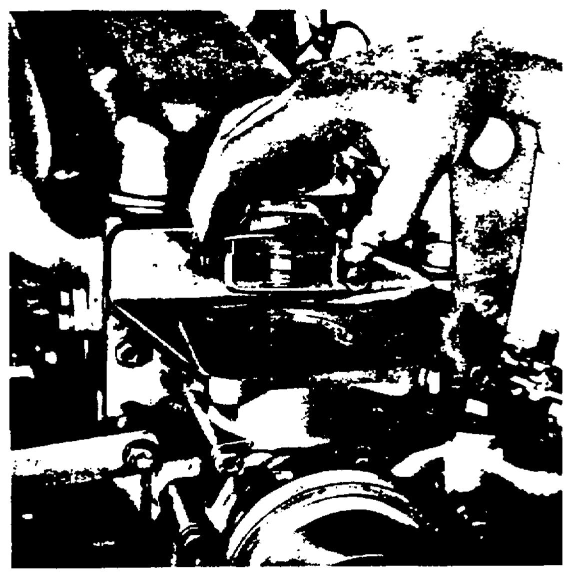


*Fig. M.14.*
*Thermostat Removal.*
*(earlier engines)*

3. Remove the thermostat — see Fig. M.14.

**Testing the Thermostat**

If it is suspected that the thermostat is not operating correctly it should be tested in the following manner:—

1. Immerse the thermostat in a suitable container of water and gradually heat. Check the water temperature at frequent intervals with an accurate thermometer. The valve should commence to open at the temperature stamped on the top face of the thermostat adjacent to the valve seat.

2. If the thermostat does not function properly, no adjustment is possible. Replace with a new unit.

## Introduction

The equipment for the supply, filtration and delivery of fuel to the engine consists of a fuel tank, a diaphragm type fuel lift pump, fuel filters, a distributor type fuel injection pump and four injectors. There is also a small reservoir to provide a gravity feed to the cold starting aid in the air intake manifold.

Air drawn into the engine through the induction manifold is filtered by a perforated mild steel gauze.

This method of filtration is satisfactory for all applications except canal, river or dockside work where dust or other foreign matter may be present in the atmosphere. In this case a dry type air cleaner with cleanable element is preferable.

As with all diesel engines, particular stress is laid on the importance of clean, filtered fuel oil if longevity and trouble-free operation is to be obtained.

### AIR FILTERS

The time period for cleaning air filters should be governed by the conditions under which the engine operates.

The correct maintenance of the air filter will greatly assist in reducing bore wear, thereby extending the life of the engine.

### FUEL FILTER

The fuel filter is of the paper element type, therefore, no attempt should be made to clean the element. It should be renewed when periodical maintenance is being carried out.

The filters fitted to earlier engines have a separate element positioned inside a bowl whereas filters fitted to later engines have an encapsulated element held between the filter head and the filter base.

The period for changing the element will largely depend upon the quality and condition of the fuel available. Under normal conditions the element should be renewed every 1,000 hours. This period should be decreased accordingly if unavoidable contamination of the fuel is being experienced.

## To Renew Earlier Type Filter Element

1. Thoroughly clean the exterior of the filter bowl and cover.

2. Unscrew the bolt in the centre of the filter top cover (see Fig. N.1).

3. Take the filter bowl and element assembly away from the filter cover (see Fig. N.2).

4. Throw away the dirty element. Remove the lower element scaling washer, seal seating and spring from the bowl.

5. Thoroughly clean the inside of the bowl particularly the centre tube.

6. Fit the spring and seal seating to the bowl. Examine the lower seal, renew if necessary and refit to the bowl. Place the new element in position in the bowl.

7. Ensure that the element to top cover and the bowl to top cover seals are in good condition, if not, replace with new seals.

8. Bleed the fuel system as detailed on Page N.9.

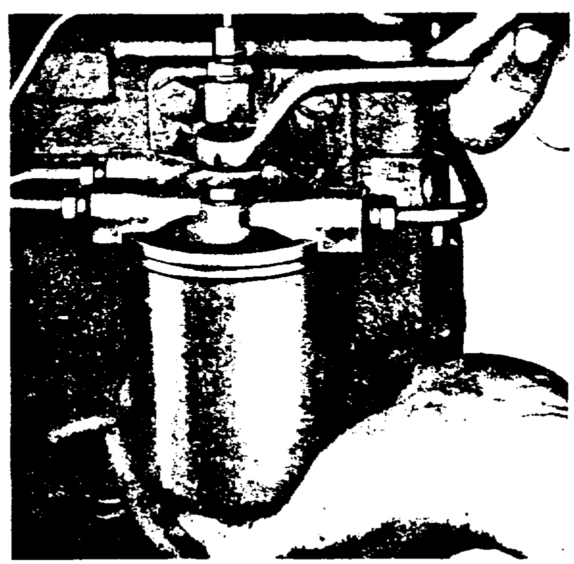


*Fig. N.1.*
*Removing the Fuel Filter Bowl Securing Bolt.*
*(Earlier Type)*

9. Refit the bowl to the top cover and secure with the centre bolt.

10. Vent the fuel system as detailed on Page N.15.

**To Renew Later Type Filter Element**

1. Thoroughly clean the exterior of the filter assembly.

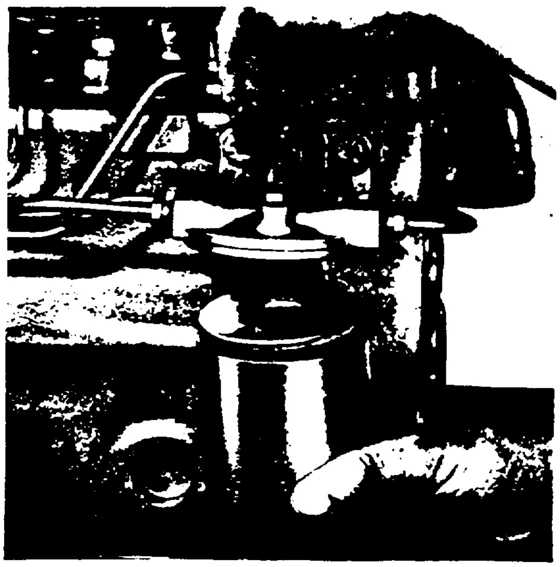


*Fig. N.2.*
*Removing the Fuel Filter Bowl.*
*(Earlier Type)*

3. Thoroughly clean the filter head and base.

4. Inspect the sealing rings and renew if damaged in any way.

5. Place the base squarely on the bottom of the new filter element and offer up the element squarely to the filter head so that the top rim of the element locates centrally against the sealing ring in the filter head.

6. Hold in this position whilst the securing setscrew is located and screwed home.

7. Bleed the fuel system as detailed on Page N.9.

*Fig. N.3.*
*Removing Fuel Filter Element*
*(Later Type)*

**FUEL LIFT PUMP**

**Testing the Pump in Position**

1. Disconnect the outlet pipe (lift pump to filter) leaving a free outlet from the pump.

2. Rotate the engine. There should be a well defined spurt of fuel from the outlet port once every two revolutions of the engine.

**Pressure Testing of Fuel Lift Pump in Position**

Fit a 0/10 lbf/in$^2$ (0/0,7 kgf/cm$^2$) - 0/70 kN/m$^2$ pressure gauge to the outlet of the pump. Ensure that there are no leaks at the connections between pump and gauge. Crank the engine for 10 seconds and note the maximum pressure on the gauge. If the pressure recorded is less than 75% of the minimum production static pressure shown below, then rectify the pump. Also observe the rate at which the pressure drops to half the maximum figure obtained when cranking has ceased. If less than 30 seconds, rectify the pump.

| | Min. Production Static Pressure | | | Min. Test Pressure (75% Min. Prod. Pres.) | | |
|---|---|---|---|---|---|---|
| | lbf/in$^2$ | kgf/cm$^2$ | kN/m$^2$ | lbf/in$^2$ | kgf/cm$^2$ | kN/m$^2$ |
| 4 bolt type | 6 | 0,42 | 41 | 4.5 | 0,31 | 31 |
| 2 bolt type | 2.75 | 0,19 | 19 | 2 | 0,14 | 14 |

**To Clean the Pump Chamber**

1. Remove the fuel lift pump cover and pulsator diaphragm by unscrewing and removing the cover screw (see Fig. N.4).

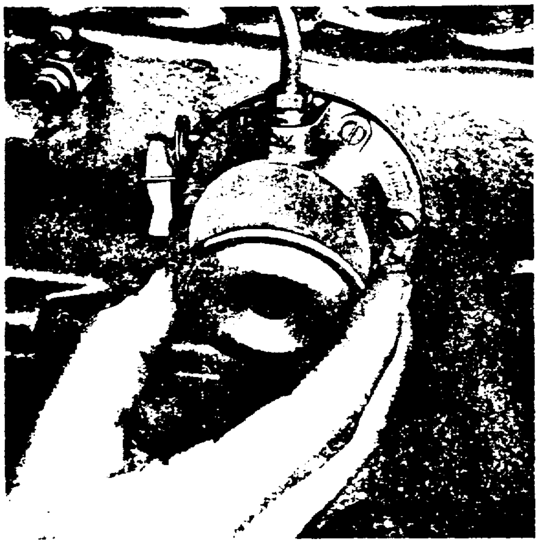


*Fig. N.4.*
*Fuel lift pump cover removal*

2. Clean the sediment chamber and check the pulsator diaphragm for condition. Renew if necessary.

3. Refit the pulsator diaphragm and cover. Tighten the securing screw just sufficiently to make a tight sealing joint.

4. Vent the fuel system as detailed on Page N.14.

**To Remove the Pump**

1. Disconnect the pipes from the inlet and outlet ports. Seal the ends of the pipes to prevent the entry of dirt, etc.

2. Remove the two setscrews securing the pump to the cylinder block and withdraw the pump and joint.

**To Dismantle the Pump**

1. Before dismantling, clean the exterior of the pump and make a file mark across the two flanges for guidance in re-assembling in the correct positions.

2. Remove the six securing screws and spring washers and separate the two halves of the pump.

3. Remove the diaphragm from the lower half of the body by unhooking it from the rocker arm link. The diaphragm spring can now be withdrawn from the body.

4. Drive out the rocker arm pivot pin from the body and withdraw the rocker arm, rocker arm spring and link from the body.

5. Dismantle the priming lever from the body by removing the lever retaining pin and withdrawing the lever and spring from the body.

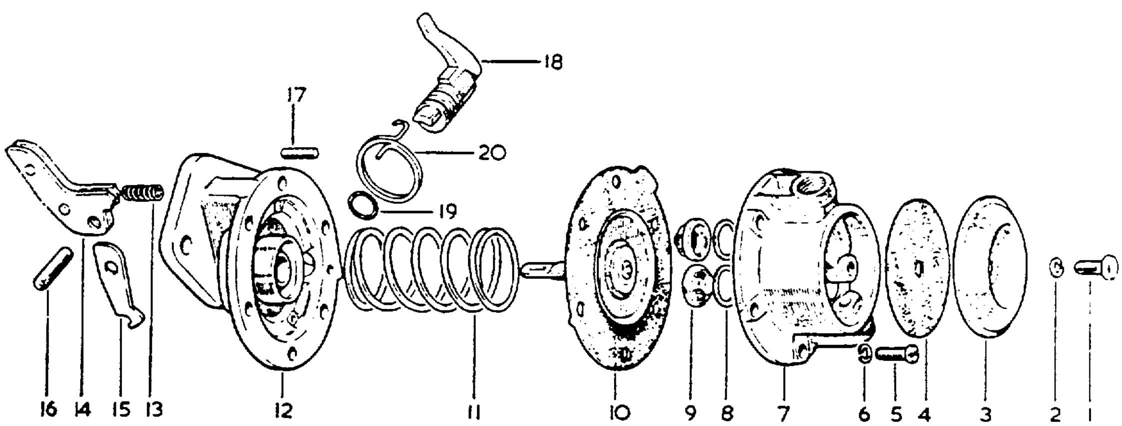



*Fig. N.5.*
*Exploded view of Fuel Lift Pump.*

1. Pulsator Cover Screw.
2. Pulsator Cover Washer.
3. Pulsator Cover.
4. Pulsator Diaphragm.
5. Cover Screw.
6. Cover Screw Washer.
7. Cover.
8. Valve Gasket
9. Valve Assembly.
10. Diaphragm Assembly.
11. Diaphragm Spring.
12. Body.
13. Rocker Arm Spring.
14. Rocker Arm.
15. Link.
16. Rocker Arm Pin.
17. Primer Pin.
18. Primer.
19. Sealing Ring.
20. Primer Spring.

6. Remove the valves from the upper body half by carefully levering from their locations. Remove the valve gaskets from the bottom of the recesses.

7. Remove the pump cover and pulsator diaphragm by unscrewing and removing the cover retaining screw.

**Inspection of Parts**

1. Thoroughly wash all parts in cleaning fluid.

2. Check the diaphragm for hardening or cracking and examine the pull rod for wear at the point where it connects with the rocker lever link. Renew the diaphragm and pull rod assembly if any of these signs are evident.

3. The diaphragm spring should be renewed if it is corroded or distorted. Ensure that if renewing the spring, the new spring has the same (green) colour identification.

4. The valves should be renewed unless in perfect condition. The two valves are identical and may be used for inlet or outlet (See Fig. N.5). It is advisable to renew the valve gaskets after dismantling.

5. Examine the rocker, arm, link, spring and pin for wear. If appreciable wear is evident new parts must be fitted.

6. Check the pulsator diaphragm for condition and renew if necessary.

7. Replace all gaskets and washers as routine procedure.

8. Examine the flanges of the two pump halves for distortion. If distorted lightly linish to restore flatness.

**To Re-Assemble the Pump**

1. Place the new valve gaskets in position in the valve recesses and fit the valves to the body. The inlet valve must be fitted so that the valve can open to admit fuel, i.e., the spring must protrude into pump chamber towards the diaphragm. The outlet valve must be fitted in the reverse position to the inlet valve, so that it allows flow of fuel out of the pump. To retain the valves in the casting, replace retaining plate or stake the casing in six places with a suitable punch.

2. Place the pulsator diaphragm in the pulsator cover and secure on the upper casting with the washer and screw.

3. Insert the rocker arm pin through its hole in the body, at the same time engaging the link and the rocker arm. During this operation ensure that the rocker arm spring is located properly in the pump body. Tap the rocker arm pin in until it is flush with the pump body. Stake the casting in three places each side to retain the pin.

4. Place the diaphragm spring in position in the pump body.

5. Place the diaphragm assembly over the spring, the pull rod being downwards, and centre the upper end of the spring in the lower diaphragm protector washer.

6. Press downward on the diaphragm and make sure that the downward tag on the lower diaphragm protecting washer is on the priming lever side of the body. This tag is required to be in the hole of the body ready for fitment of the priming lever. Engage the diaphragm pull rod with the link and at the same time permit the matching up of the holes in the diaphragm with those on the pump body flanges.

7. Push the rocker arm towards the pump until the diaphragm is level with the body flange. Place the upper half of the pump into its proper position as shown by the file mark on the flanges made prior to dismantling. Install the cover screws and washers and tighten only until the heads of the screws just engage the washer.

   Release the rocker arm and push on the spaded end of the rod so as to hold the diaphragm at the top of the stroke, and while so held tighten the securing screws diagonally and squarely.

   **NOTE: After assembling in the manner described, the edges of the diaphragm should be about flush with its two clamping flanges. Any appreciable protrusion of the diaphragm indicates incorrect fitting in which case especial care should be paid to maintaining pressure on the pull rod while the diaphragm screws are finally tightened.**

8. Fit primer to side of body and retain with the pin. Clip on priming lever spring.

9. Test the fuel lift pump to ensure that it is working correctly.

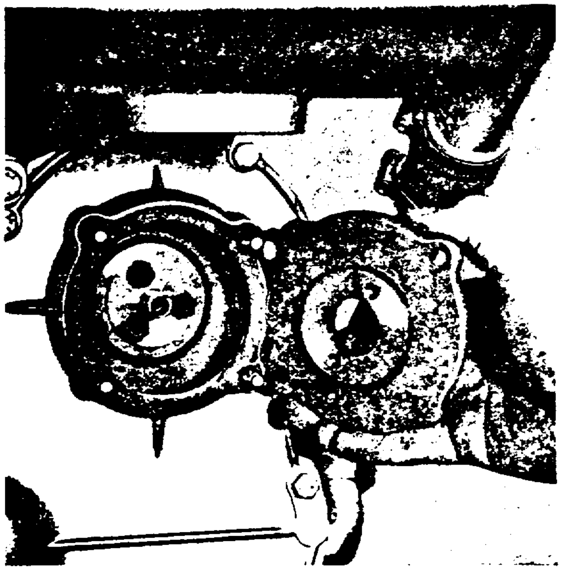


*Fig. N.6.*
*Inspection Cover removed to gain access to Fuel Pump Gear Securing Setscrews.*

**To Refit the Pump**

1. Using a new joint, refit the pump to the cylinder block and secure with the two nuts and spring washers.

2. Reconnect the fuel lines and vent the system of air as detailed on Page N.14

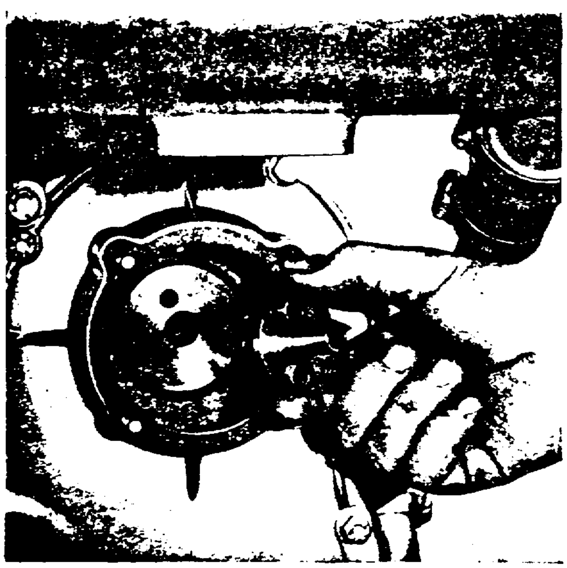


*Fig. N.7.*
*Removal of Fuel Pump Gear Setscrews and Tachometer Drive Shaft.*

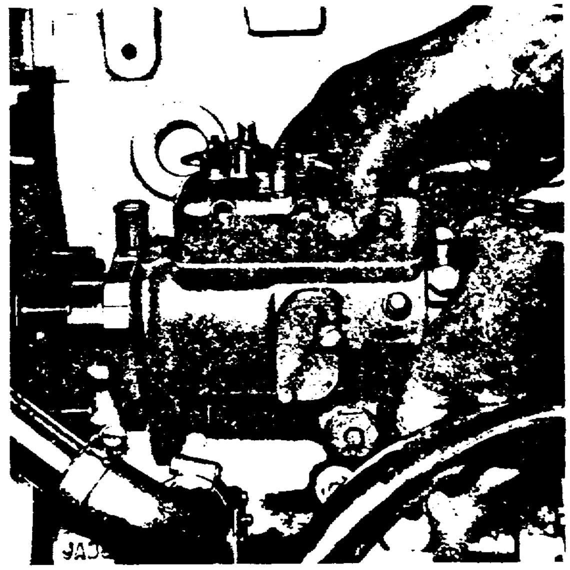


*Fig. N.8.*
*Removal of Fuel Pump.*

**FUEL INJECTION PUMP**

**Description**

The fuel injection pump is of the D.P.A. distributor type. It is a precision built unit incorporating a mechanical flyweight governor.

The pump is flange mounted and is driven front the engine timing case.

**IMPORTANT NOTE: Unless the necessary equipment and experienced personnel are available, dismantling of the fuel pump should not be attempted.**

**To Remove the Fuel Pump**

1. Remove the high pressure injection pipes from the pump and atomisers and blank off all ports to prevent the ingress of dirt.
2. Remove the low pressure pipes from the fuel pump inlet ports, again blanking off the open ports.
3. Disconnect the stop and throttle controls from the pump and remove the control return springs.
4. Remove the nuts and setscrews from the heat exchanger mounting bracket.
5. Remove the bracket complete with tachometer drive assembly and fuel pump gear cover plate.
6. Remove the three setscrews which secure the fuel pump gear to the fuel pump.

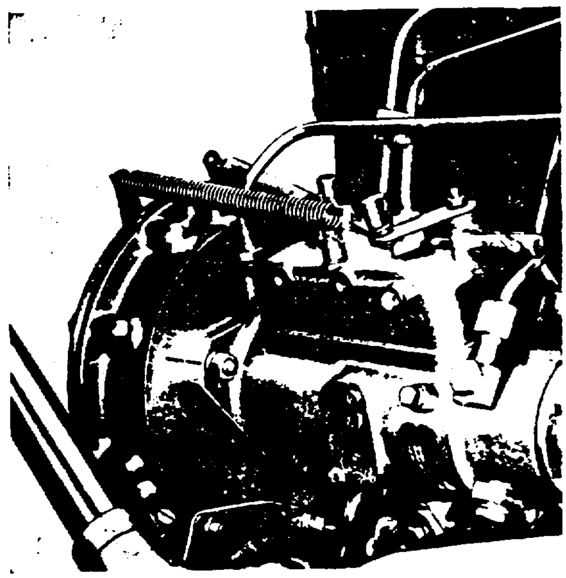


*Fig. N.9.*
*Timing Marks on Fuel Pump Flange and Timing Case.*

7. Remove the three nuts, spring washers and plain washers from the fuel pump securing studs. Withdraw the fuel pump from the timing case ensuring that when the fuel pump gear leaves the fuel pump shaft it stays in mesh with the idler gear otherwise the fuel pump timing will be affected.

**To Refit the Fuel Pump**

1. Offer up the fuel pump together with a new joint ensuring that the slot in the pump hub is aligned with the dowel in the fuel pump gear.
2. Position the pump so that the scribed line on the pump flange and the mark on the timing case are in alignment (see Fig. N.9). To check accuracy of scribed line on rear of timing case, this may be ascertained in accordance with the instructions for marking a new timing case as given on Page K.4. Fit the plain washers, spring washers and secure the pump to the timing case with the three nuts.
3. Secure the pump driving gear and tachometer drive adaptor to the fuel pump shaft with the three setscrews and spring washers, ensuring the dowel is properly located in its slot.
4. Using a new joint fit the fuel pump gear cover plate complete with tachometer drive assembly.
5. Refit the heat exchanger mounting bracket and secure with the setscrews and nuts.
6. Refit the low pressure pipes to the fuel pump inlet and outlet connections.
7. Refit the high pressure injection pipes between the atomisers and fuel pump.
8. Re-connect the throttle and stop lever controls and securely attach their respective return springs in position.
9. Vent the air from the fuel system as detailed on Page N.14.
10. Adjust the maximum speed and idling speed as detailed on Page N.8.
11. If the fuel pump timing is suspected of being inaccurate it should be checked and reset as follows:—

**To Check Marking Angle of Fuel Injection Pump using Tool MS67B**

1. Release screw (5, Fig. N.10) and position splined shaft with the small splined diameter to the rear to locate in the fuel pump drive shaft.
2. Ensure that the slotted pointer (2) is positioned with slot to rear of tool and chamfered sides of slot outwards. At this stage, slotted end of pointer should be kept well back towards the body of tool. Ensure that the flat in the washer fitted behind the pointer locating screw (3) is located over the side of pointer.
3. Release bracket screw (4) and set bracket so that the chamfered edge is in line with the relevant marking angle (see Page B.11).
4. Position timing tool, locating splined shaft in hub and slide tool towards pump to rest on end of hub and lock shaft in tool.

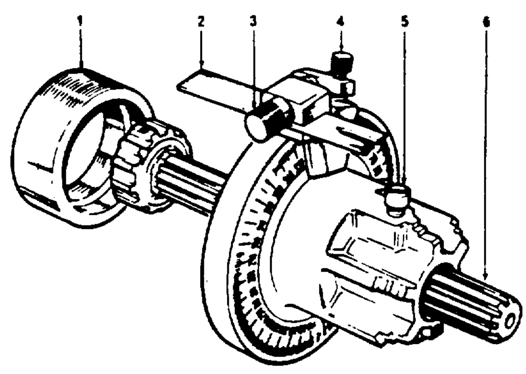



*Fig. N.10.*
*Fuel Pump Timing Tool MS67B.*

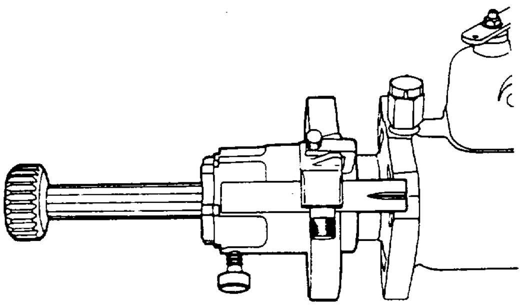


*Fig. N.11.*
*Checking Timing Mark on Fuel Pump Flange.*

5. Connect No. 1 outlet of pump body to an atomiser test rig and pump up to 30 atm (31 kgf/cm$^2$) or 440 lbf/in$^2$.
6. Turn pump in normal direction of rotation as shown on pump nameplate until it locks.
7. In this position, slide pointer forward until it is halfway over pump flange and check that timing mark is central to slot in pointer (see Fig. N.11).

Where no timing tool is available, the fuel pump timing may be checked as follows:—

On the fuel pump rotor, inside the fuel pump are a number of scribed lines, each one bearing an individual letter. A timing circlip with a squared end is positioned inside the pump and has to be set so that when the appropriate scribed line on the fuel pump rotor is aligned with the squared end of the timing circlip; this denotes the static point of injection.

To set the timing circlip, it is necessary to remove the pump from the engine and fix the position of the circlip by connecting No. 1 cylinder outlet connection (marked "W") to an atomiser tester and pump up to 30 atm (31 kgf,/cm$^2$ or 440 lbf/in$^2$). Turn the pump by hand

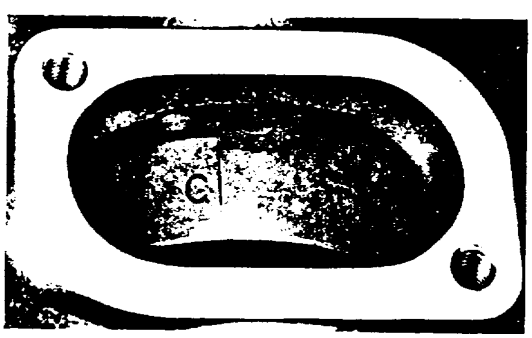


*Fig. N.12.*
*Timing Marks on Fuel Pump Rotor.*

in the normal direction of rotation until it "locks up". The squared end of the circlip should now be adjusted until it lines up with the letter "C" on the pump rotor.

To re-set the fuel timing the following procedure should be adopted:—

1. Ensure that the fuel pump circlip is correctly positioned as described previously.
2. Ensure that the fuel pump is correctly fitted with the scribed line on the mounting flange coinciding with the mark on the back of the timing case cover (see Fig. N.9).
3. Position the crankshaft so that No. 1 piston is at T.D.C. on compression stroke.
4. Remove the collets, spring cap and spring from one of the valves on No. 1 cylinder and allow the valve to rest on the top of the piston. Care is necessary with this operation as the consequences of a valve dropping into the cylinder need not be described.
5. With the aid of a clock gauge in contact with the end of the valve now sitting on the No. 1 piston it will be necessary to position the crankshaft so that the piston will be at the correct "Static Timing Position" (See Page B.11).
6. Remove the inspection plate on the fuel pump enabling the rotor to he seen.
7. With No. 1 piston at the static timing point In its compression stroke, the scribed line on the fuel pump rotor marked “C” should align with the squared end of the circlip (Refer to Fig. N.12).

   If it does not, then the necessary adjustment should he made by releasing the fuel pump, securing setscrews and turning the fuel pump on the slotted holes the required amount to bring the respective timing letter into alignment with the squared end of the timing circlip.
8. When the fuel pump timing is correct, refit the spring, spring cap and collets to the valve which has been used for the timing check and refit the pump inspection plate and timing case inspection plate. Re-seal the inspection plate.

**Maximum Speed Setting**

**IMPORTANT NOTE: The maximum speed screw seal of the original fuel pump must not be broken or tampered with in any way unless factory authority is first obtained. Failure to do so may result in the guarantee becoming void.**

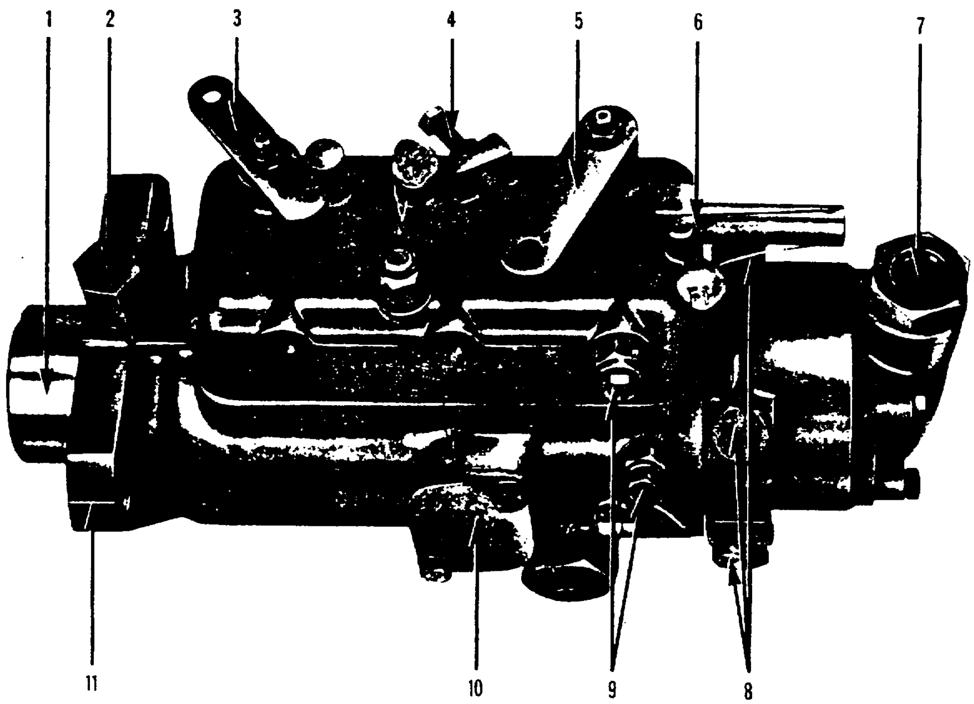



*Fig. N.13.*

1. Drive Shaft.
2. Fuel Outlet.
3. Stop Lever.
4. Idling Screw
5. Speed Control Lever.
6. Maximum Speed Screw.
7. Fuel Inlet.
8. Injector Pipe Connections
9. Bleed Screws.
10. Inspection Cover Plate.
11. Scribed Line.

When fitting a replacement fuel pump, or in the event of the maximum speed screw having been moved for any reason, the maximum no load speed must be checked and re-set as necessary.

The maximum no load speed will depend upon the type of application to which the engine is fitted, and for details of this, reference should be made to the code number stamped on the fuel pump data plate. The last four numbers in the code indicate the speed required, and in the case of the example quoted below, this would be 2660 rev/min.

**Code Example:—PS66/500/2/2660**

**NOTE: If the fuel pump data plate is damaged or defaced so as to make it impossible to read the code, or if the code is not stamped on the plate, you are advised to contact your nearest Perkins Distributor, or alternatively, Service Dept., Perkins Engines Limited, Peterborough, to obtain the correct maximum no load speed setting.**

To set the maximum no load speed the following procedure should be adopted:—

1. Check the fuel system for leaks and rectify as necessary. Ensure that no air is present in the system.
2. Run the engine at part throttle until full operating temperature has been reached.
3. Place a tachometer with a suitable extension and drive adaptor in the centre of the crankshaft pulley retaining screw.
4. Open the throttle until the maximum speed, given on the pump data plate, is obtained. If the speed will not reach this figure, turn the maximum speed screw anti-clockwise until the required speed is obtained. Should it be possible to obtain a higher speed, turn the maximum speed screw clockwise until the speed is reduced to the required figure. Re-seal the maximum speed screw.

**IMPORTANT.** Under no circumstances should the engine be allowed to operate at a higher speed than specified or severe damage to the engine may be the result.

### Idling Speed Setting

The engine idling speed is adjusted by the idling screw (see Fig. N.13).

With the engine warm, turn the screw clockwise to increase the engine speed and anti-clockwise to decrease.

The idling speed may vary, depending upon the type of craft to which the engine Is fitted. For details apply to the nearest Perkins Distributor, or alternatively, Service Dept., Perkins Engines Limited, Peterborough.

## ATOMISERS

### General

Each atomiser body consists of a steel body held to the cylinder head by means of a flange and two studs.

The joint between the atomiser and cylinder head is made by a copper washer between the lower face of the nozzle cap and the cylinder head.

When preparing to fit the atomiser into place in the cylinder head, care should be taken, that only the correct copper washer is used to make this joint. The metal of the cylinder head, the faces of the copper joint ring, and the corresponding face on the nozzle holder cap nut should be perfectly clean if a leak-proof joint is to result.

It is advisable to fit a new joint washer when the atomiser is replaced after having been removed for any reason.

Ensure that the old washer has been removed from atomiser or cylinder head.

This joint washer should be an easy, but not loose fit for the atomiser nozzle, and it is because this is such an important feature that the washers especially made for the purpose should be used and none other. On no account should ordinary sparking plug type washers be used.

The atomiser can now be fitted in place, care being taken to see that it is an easy fit in the cylinder head and on the holding-down studs, so that it can be placed down on the copper joint without force of any kind. The nuts on the flange should then be tightened down evenly in order to prevent the atomiser nozzle being canted and so "nipped" in the cylinder head.

The correct tightening torque for the atomiser securing nuts is 12 lbf ft (1,7 kgf m) - 16 Nm.

When fitting the leak-off pipes make sure new washers are used, and before tightening the banjo bolt make sure the washers are a good fit and are placed centrally, and remain central when tightening the bolt.

### MAINTENANCE

The following information is given for the guidance of those who wish to carry out their own atomiser maintenance using the basic test equipment, which would include an Atomiser Testing Pump and kit of tools. (Refer Figs. N.14 and N.17).

Atomisers should be taken out for examination at regular intervals. How long this interval should be is difficult to advise, because of the widely different conditions under which engines operate. When combustion conditions in the engine are good and the fuel tank and filtering system are maintained in first-class order, it is often sufficient if the atomisers are tested every 2,500 hours.

It is no use taking atomisers out of attention unless the equipment described above is available, or spare atomisers are at hand for substitution.

The nearer the ideal conditions of good fitting with adequate cooling and absolutely clean fuel are realized, the less attention the atomisers will need, and so the longer their efficient life. In this connection, since there is no other item of the equipment upon which the performance of an engine depends so much, it pays the user handsomely to see that the engine never runs with any of its atomisers out of order.

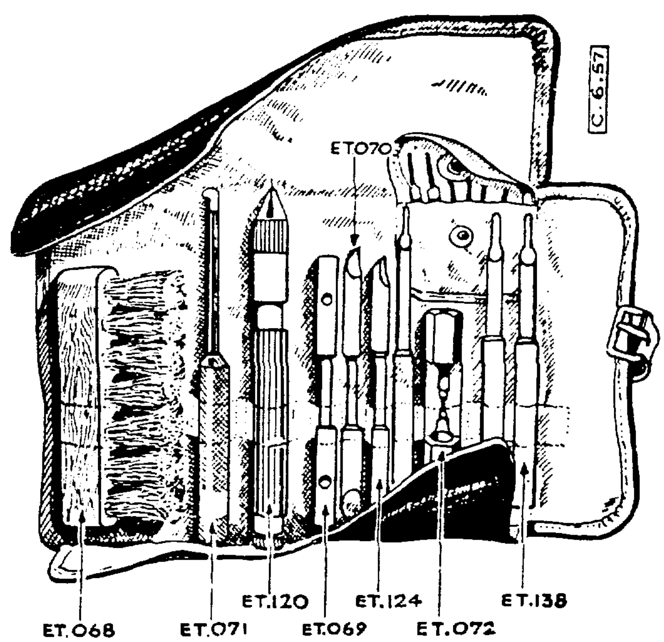



*Fig. N.14.*
*Complete Kit of Tools for use when cleaning and overhauling atomisers.*

## Troubles in Service

The first symptoms of atomiser troubles usually fail in one or more of the following headings:–

1. Misfiring.
2. Knocking in one (or more) cylinders.
3. Engine overheating.
4. Loss of power.
5. Smoky exhaust (black).
6. Increased fuel consumption.

Often the particular atomiser or atomisers causing trouble may be determined by releasing the pipe union nut on each atomiser in turn, with the engine running at a fast "tick-over." This will prevent fuel being pumped through the nozzle to the engine cylinder, thereby altering the engine revolutions. If after slackening a pipe union nut the engine revolutions remain constant, this denotes a faulty atomiser.

After stopping the engine the nuts from the flange of the doubtful atomiser should be removed and the complete unit withdrawn from the cylinder head and turned round, atomiser nozzle outwards and the unions retightened. After slackening the unions of the other atomiser pipes (to avoid the possibility of the engine starting), the engine should be turned until the nozzle sprays into the air, when it will be seen at once if the spray is in order. If the spray is unduly "wet" or "streaky" or obviously to one side, or the atomiser nozzle "dribbles," remove from the fuel pipe; the faulty atomiser should then be securely wrapped, preferably in grease-proof paper for attention on the maintenance bench.

**NOTE: Great care should he taken to prevent the hands or face from coming into contact with the spray, as the working pressure will cause the fuel oil to penetrate the skin with ease.**

## Preparation

The most suitable bench for atomiser maintenance is one that is zinc, linoleum or plastic covered, absolutely free from dust, dirt, filings, grease or acids, where no other work is done and where the use of cotton waste or fluffy rags is forbidden. It should also be provided with a small vice (the jaws being protected with clean soft copper or aluminum shields) and a dust-proof drawer for holding the nozzle cleaning tools.

An atomiser is good for service if, when operating the Atomiser Testing Pump at the recommended rate, it gives four effective sprays, each breaking into a very fine mist and the breaking pressure is not less than the working pressure, (refer page B.12) then the atomiser may be put back into service.

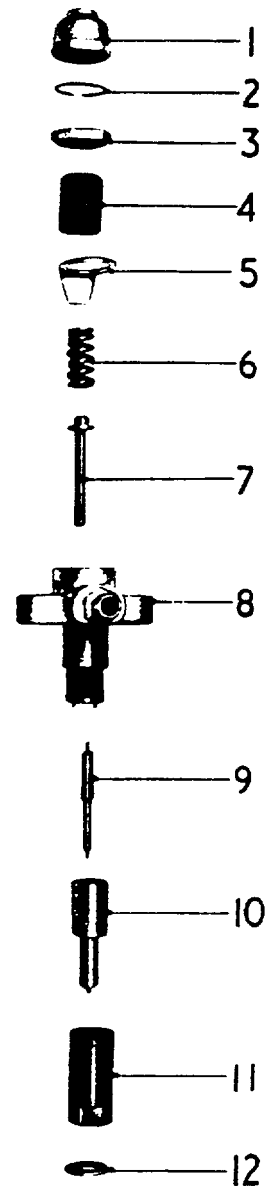



*Fig. N.15.*
*Exploded view of Atomiser.*

1. Nozzle Holder Cap Nut.
2. Cap Nut Washer.
3. Locknut.
4. Spring Cap.
5. Identification Tab Washer.
6. Spring.
7. Spindle.
8. Body.
9. Nozzle Needle.
10. Nozzle.
11. Nozzle Cap Nut.
12. Copper Washer.

An atomiser requires attention if (a), when proceeding as above it throws out "solid" wet jets and not broken up spray or, (b), if any of the holes are choked or partially choked so that the spray issues only from one or two holes in the nozzle, or (c), an irregular spray pattern is formed.

**Atomiser Dismantling**

The atomiser should be placed on a suitable holding plate, nozzle downwards, first remove the nozzle holder cap nut (1), slacken the locknut (3), release the nozzle spring tension by turning the spring cap (4) in an anti-clockwise direction. Reverse the position of the atomiser on the holding plate and remove the nozzle cap nut (11) and nozzle (10) taking care not to drop the nozzle needle onto the floor. Complete the dismantling by removing the spring cap, spring (6) and spindle (7). Inspect visually for signs of corrosion, distortion, etc. Keep all the dismantled parts together, if possible, in a tray to facilitate re-assembly after cleaning.

**NOTE: Do not lose the small steel shim washer fitted between the top of the spring and the spring cap.**

To hold the nozzle holder cap nut in a vice or to use badly worn or adjustable spanners is to invite trouble.

**Inspection**

The nozzle needle should be free from all traces of damage, it is important that it is not "blued" at the tip due to overheating. If the nozzle is "blued" or the seating has a dull circumferential ring indicating wear or pitting, the complete unit (nozzle and needle) should be set aside for attention by a depot or agent with specialized equipment available and a replacement nozzle assembly used

The stem of the nozzle needle should be clean and bright, free from high spots, bad scratches or dull patches, and the grooves free from foreign matter of any kind; similarly the nozzle needle bore in the nozzle body should be free from any of the above, the small drilled passages should be checked to see that they are clear.

**Cleaning**

Starting with the nozzle assembly, remove the needle from the nozzle body and by using the soft brass seat scraper (ET 070) any carbon which may be present on the nozzle body seat can be

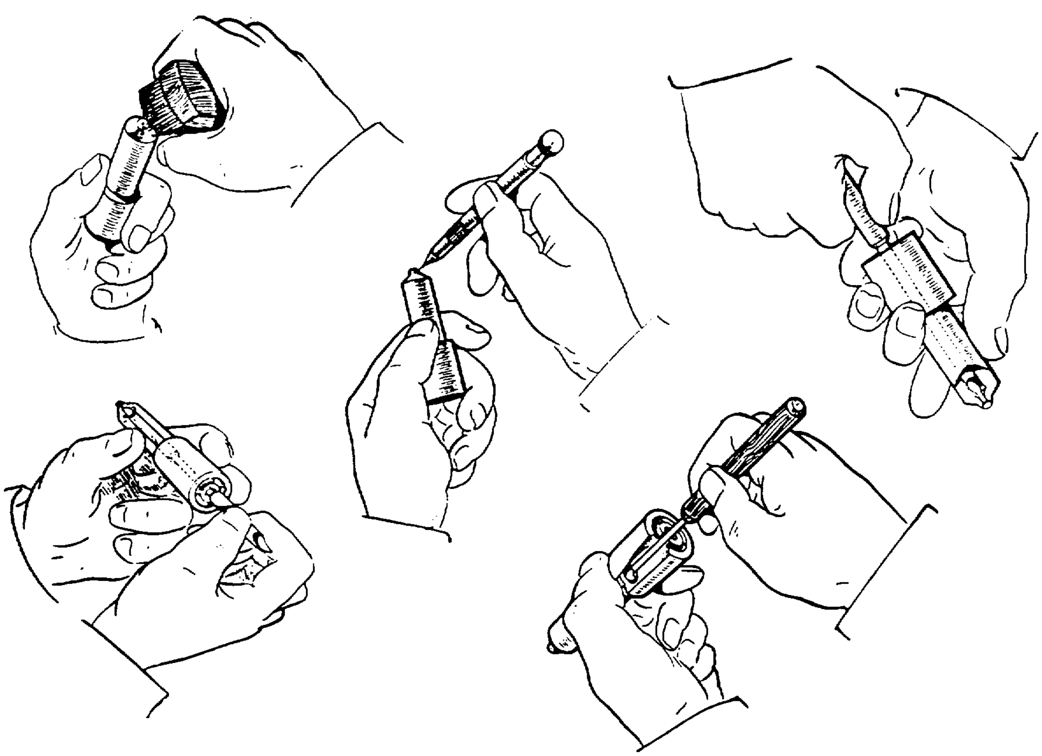


*Fig. N.16. Cleaning the Nozzle.*

removed. The gallery should now be cleaned with the aid of the special soft brass scraper (ET 071).

Brush all carbon from the nozzle tip using the brass wire brush contained in the recommended Nozzle Cleaning Kit shown in Fig. N.14. The four holes in the nozzle tip should be cleared by means of the probing tool (ET 120) fitted with the appropriate sized cleaning wire. If the size is not known, it can be ascertained by careful trial of wires in the holes. Extreme care must be taken, however, to obviate the danger of wire breaking off in the hole, as its removal is practically impossible and renders the nozzle unusable.

The cleaning wire should be fitted in the probe chuck so that there is approximately 1/16 in protrusion, thus giving maximum resistance to bending. Enter the wire into the hole, pushing and rotating gently until each hole in turn is cleared. Particular attention should be given to the nozzle needle seat. This and the smaller cylindrical portion above it, called the "stem" and "cone," can he cleaned with the fine brass wire brush. To ensure that the stem and cone in the nozzle body are free from carbon particles, the soft brass stem cleaner (ET 072) should be applied with a rotary action pressing between the fingers. After ensuring that the exterior of the atomiser nozzle is clean and free from carbon. the nozzle needle and nozzle body may be thoroughly washed in clean fuel oil, or an approved alternative, assembled together whilst submerged in the clean oil and left immersed until it is intended to re-assemble the atomiser. Should it be desired to store the nozzle assembly for any period of time, then the needle and nozzle should be lightly smeared with grease and stored away, preferably in a dust-proof drawer.

The atomiser body should now receive attention, it should be washed in clean fuel oil or an approved alternative. care being taken to ensure that the highly ground face is clean and free from scratches. This face must register with the atomiser nozzle flange cleanly and squarely to form a high pressure joint and must, therefore, be handled in such a way as to avoid damage to the surface. The exterior of the atomiser body, of course, should be cleaned thoroughly.

### Re-Assembly of Atomisers

The atomiser body and nozzle assembly may now be assembled carefully, after having immersed the pressure faces of each in clean fuel or an approved alternative, to ensure that these faces are absolutely clean. Place the atomiser body on the holding plate, pressure face uppermost, place the nozzle assembly in position (located by the dowel) and fit the nozzle cap nut, tighten carefully. Excessive tightening of this cap may result in distortion of the nozzle and its consequent

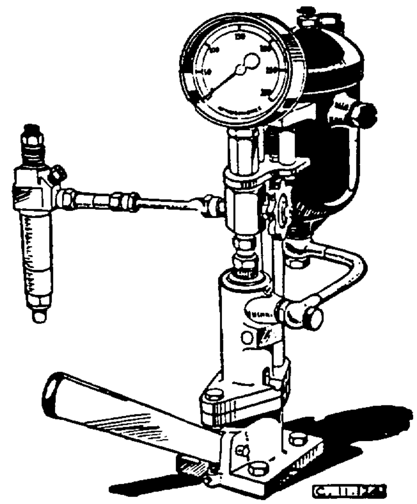


*Fig. N.17. Atomiser Testing Pump*

failure; care should be exercised that the leverage applied is not excessive. Reverse the atomiser on the plate and refit the spindle, spring and spring cap (ensure that the steel shim washer is correctly located in the top of the cap). Transfer the atomiser from the holding plate and fit to the Atomiser Testing Pump. Pump up slowly until fuel spurts out of the four nozzle holes and whilst still pumping slowly turn the spring cap, using a suitable screwdriver, in a clock-wise direction increasing the spring tension until the breaking pressure is that quoted against Setting Pressure on Page B.12.

The atomiser is good for service if, as previously mentioned. when the Atomiser Testing Pump is operated at approximately twenty strokes per minute, four effective and even sprays breaking into a very fine mist are obtained.

**NOTE: When testing atomisers for spray formation, as opposed to setting the nozzle breaking pressure, always isolate the pressure gauge by means of the valve fitted, to prevent possible damage caused by rapid fluctuations in pressure.**

### Pressure Setting

To set the pressure at which the nozzle should open, slowly move the hand lever downwards and carefully watch the pressure gauge for the highest recorded pressure before the needle "flicks," indicating the needle lifting off its seat. Any necessary adjustment is effected by loosening the locknut (3) and turning the spring cap (4) clock-wise to increase or anti-clockwise to decrease the breaking pressure. Tighten the locknut and re-check the pressure before removing from the Atomiser Testing Pump.

When the atomiser has been cleaned, reassembled, the breaking pressure set to the recommended figure and the spray formation found to be satisfactory, the following two checks may be carried out on the Atomiser Testing Pump before returning the atomisers to service.

**(1) Back Leakage**

Pump up sufficient pressure to raise the nozzle needle from its seat, pump again slowly to just below this pressure (approximately 160-165 atmospheres), then upon releasing the hand lever and allowing the pressure to fall naturally, record the time (with the aid of a stop-watch) taken for the pressure shown on the gauge to fall from 150 to 100 atmospheres. For a nozzle in good condition this time should not be less than 6 seconds.

When carrying out this test observe that no leakage occurs at the lapped pressure faces of the nozzle holder and nozzle body. Leakage may be external, when it is visible at the nozzle cap nut screw thread, or internal, in which case it cannot be readily distinguished from excessive leakage past the lapped portion of the needle. If leakage past the lapped portion is suspected, do not overtighten the cap nut in an effort to cure such leakage, but remove the nozzle and re-examine the pressure faces for signs of dirt or surface imperfections. Clean thoroughly, and if all appears in order, replace components and re-test.

If the pressure drop time is still low, this indicates excessive leakage past the lapped portion of the nozzle needle.

**(2) Seat Tightness**

Wipe nozzle tip dry, pump up the pressure to approximately 10 atmospheres below the nozzle opening pressure, the nozzle tip must remain substantially dry and there must be no tendency for blobs of fuel to collect or drip. A slight dampness may be ignored.

**NOTE: If, after carrying out the aforementioned atomiser maintenance, satisfactory results are not obtained, the nozzle assemblies concerned may still be fit for further service after reconditioning. This, however, requires specialized equipment and the complete nozzle assemblies should be forwarded to the nearest depot or workshop capable of undertaking such work, and a replacement unit obtained.**

A perfect atomiser, when tested by pumping fuel through it in the open air gives a short "pinging" sound as the fuel emerges from the holes. After the atomiser has been in service for some time, the "pinging" changes to a crackling sound. It is not until the atomiser sounds "dead" that its condition is likely to affect the running of the engine.

When replacing the atomiser in the cylinder head follow carefully the instructions for fitting given on Page N.8.

**Atomiser Identification**

Later atomisers have the identification letters "CU" rolled on the atomiser body.

With earlier atomisers, the identification letters were stamped on the tab washer fitted under the spring cap locknut.

**Fuel Pipes**

No two of the pressure pipes, from the fuel pump to the atomisers are alike. Keep this in mind when replacing.

Examine the olives at each end of the pipe. If the union nuts have at any time been overtightened there is a risk that the olives will have cracked or been unduly compressed. If so, leakage will result and a new pipe should be fitted.

High pressure fuel pipes are now supplied with formed ends in place of olives. Earlier pipes were supplied with olives fitted as shown in Fig. N.18. Originally, the olives were fitted in the reverse position but both positions are still satisfactory if undamaged.

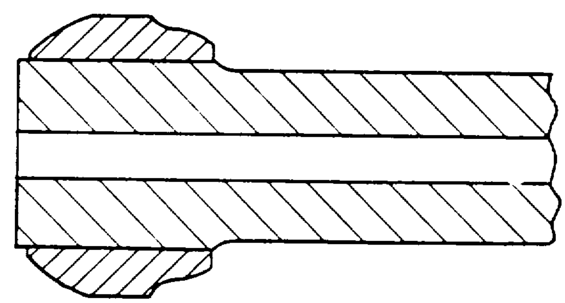


*Fig. N.18.*

In this connection bear in mind that the working pressure which these joints must sustain is several thousands pounds per square inch. Only a perfect joint is satisfactory.

Offer up the pipe to the fuel pump and atomiser unions to check that the pipe fits square at both ends. Do not fit one and then bend the pipe to square it with the other union.

When fitting the pipe tighten the unions alternately a little at a time, first one end and then the other.

The correct tightening torque for the high pressure fuel pipe nuts is 15 lbf ft (2,1 kgf m) - 20 Nm.

If the olives are in good condition, and the

*Fig. N.19*
*Unscrewing Vent Plug on lop of Filter Cover.*

pipe is square to the unions at each end as described previously, no force will be needed to make a good joint. Use only a standard open ended 5/8 in A.F. spanner.

If the union is tightened excessively the olive may collapse and split. The same danger exists if the pipe is not square to and central with the union.

When changing an atomiser always remove the pipe entirely. Never disconnect one end only, leaving the other end tight. Never bend the pipe.

## PRIMING THE FUEL SYSTEM

The air must be vented from the fuel system whenever any part of the system between the fuel link and injection pump has been disconnected for any reason, or when the system has been emptied of fuel.

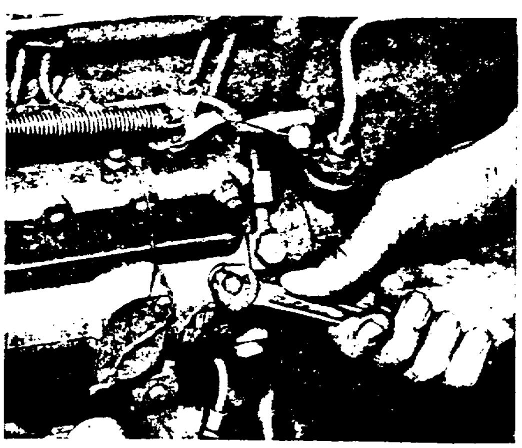


*Fig. N.20.*
*Slackening Vent Valve on Hydraulic Head Locking Screw.*

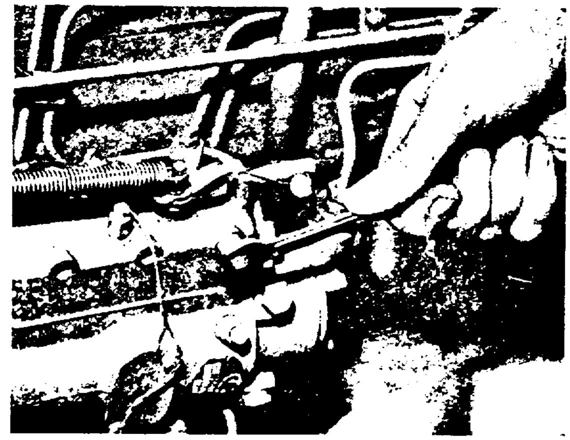


*Fig. N.21.*
*Slackening Air Vent Valve on Governor Control Cover.*

No attempt must be made to start the engine until the injection pump has been filled and primed as serious damage can be caused to the pump due to lack of lubrication.

The method of priming detailed below, ensures that only fuel which has passed through the paper filter element can reach the interior of the pump.

To bleed the system, proceed as follows:—

1. Unscrew by two or three turns, the vent plug on top of the fuel filter cover (not the return pipe to the tank). See Fig. N.1). Later type fuel filters are self venting and do not have a vent plug. Air vent the fuel filter by removing

*Fig. N.22.*
*Operating the Hand Priming Lever on the Fuel Lift Pump.*

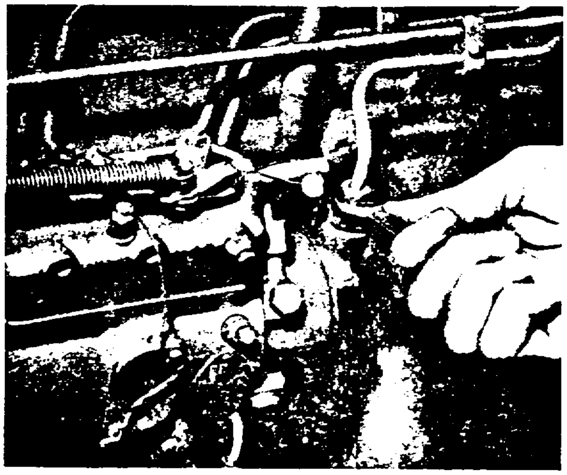


*Fig. N.23.*
*Slackening Union Nut at Pump Inlet.*

the excess fuel return pipe, to the fuel tank, from the filter head. Operate the fuel feed pump priming lever until fuel, free from air bubbles issues from the non return valve. Refit fuel return pipe.

2. Slacken the vent screw on the hydraulic head locking screw on the side of the fuel injection pump body. See Fig. N.20.
3. Slacken the air vent screw on the side of the governor control cover. See Fig. N.21.
4. Operate the priming lever of the fuel lift pump — see Fig. N.22 (note — if the cam on the engine camshaft driving the fuel lift pump is on maximum lift, it will not be possible to operate the hand primer and the engine should be turned one complete revolution) and when fuel, free from air bubbles issues from each vent point, tighten the connections in the following order.
   (a) Filter cover vent screw.
   (b) Head locking screw vent valve.
   (c) Governor cover vent valve.
5. Slacken the pipe union nut (see Fig. N.23) at the pump inlet, operate the priming device and retighten when oil, free from air bubbles issues from around the threads.
6. Slacken the unions at the atomiser ends of two of the high pressure pipes.
7. Set the accelerator at the fully open position and ensure that the "stop" control is in the "run" position.
8. Turn the engine until fuel oil, free from air bubbles, issues from both fuel pipes.
9. Tighten the unions on both fuel pipes, and the engine is ready for starting. If fuel has been drained from the thermostat feed pipe, the pipe must be disconnected at the thermostat and all air bled from the pipe before the thermostat is operated.

**Priming Procedure after changing a Filter Element**

1. With the vent plug on the filter cover removed, and the union at the filter end of the return pipe (filter to tank) slackened, operate the feed pump priming lever until oil, free from air bubbles, issues from the filter cover vent.
2. Replace the vent plug, and continue to operate the priming lever until oil, free from air bubbles, issues from around the threads of the return pipe union.
3. Tighten the return pipe union.
4. Slacken the union at the filter end of the filter to injection pump feed pipe, and operate the priming lever until oil, free from air bubbles, issues from around the union threads.
5. Tighten the feed pipe union. The pump and filter are now filled and primed and ready for further service.
6. Later type fuel filters may not have an air bleed plug. In this case remove the excess fuel return pipe, to the fuel tank, from the filter head. Operate the feed pump priming lever until fuel free from air bubbles issues from the non-return valve. Refit fuel return pipe. Continue from item 4.

## GEARBOX

The gearbox fitted to the 4.236 Marine engine is the earlier Borg Warner 71 CR or the later 10-17 type, hydraulically operated, direct drive type incorporating a reverse gear.

A Borg Warner 71 CR or the later 10-17 type gearbox with an epicyclic reduction gear can be supplied with the following ratios:– 1.523:1, 1.91:1, 2.1:1, 2.57:1, or 2.91:1. The output shaft of the gearbox or reduction gear is on the same centreline as the crankshaft.

For standard gearboxes and reduction gear, a left handed propeller is required, except with the 1.91:l reduction gear, which requires a right handed propeller. The 2.1:1 and 1.91:1 reduction gears can be used together in twin engined installations to give left and right handed propeller rotation.

The gearbox operating oil pressure should be 120/140 lbf/in$^2$ (8,4/9,8 kgf/cm$^2$) - 827/965 kN/m$^2$.

**IMPORTANT NOTE:**

**When filling the Borg Warner gearbox as fitted to the 4.236 Marine engine, Automatic Transmission Fluid Type 'A' must be used.**

The gearbox should be filled to the full mark on the dipstick and the unit turned over at low speed by idling the engine for a short period in order to fill all circuits including the cooler and cooler piping.

The oil level should then be checked immediately after shutting off the engine and sufficient oil added to bring the level to the full mark again.

When checking the gearbox oil level, the dipstick should be screwed fully home in order to obtain the correct reading.

## TO REMOVE THE GEARBOX

1. Remove lubricating oil pipes to and from gearbox oil cooler.
2. Remove water connections to and from gearbox oil cooler.
3. Remove gearbox oil cooler.
4. Uncouple propeller shaft from gearbox output shaft and move clear of box.
5. Remove nuts securing gearbox adaptor plate.
6. The gearbox can then be removed by withdrawing it to the rear.
7. Remove nuts securing gearbox adaptor plate to flywheel housing.
8. Remove adaptor plate.
9. The driving plate connecting the gearbox to the flywheel can now be removed. It should he noted that if either flywheel or flywheel housing .is removed, then it must be accurately aligned on replacement in accordance with the instructions on Pages P.2 and P.3.

## TO REFIT THE GEARBOX

Replacement of the gearbox is the reverse procedure to removal but the splines on the gearbox input shaft should be lubricated with anti-fretting grease before the unit is replaced.

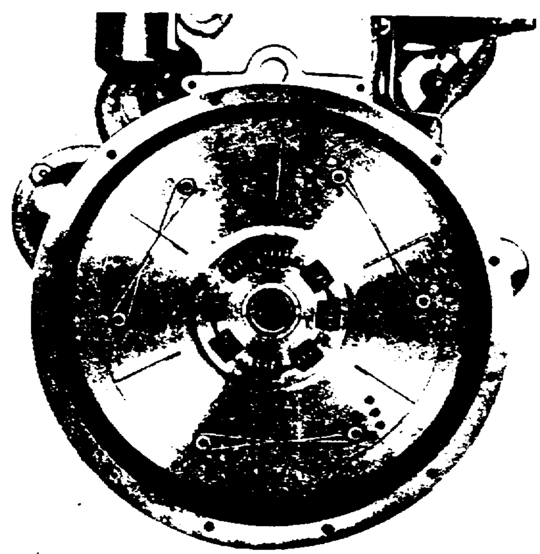


*Fig. P.1. Gearbox to Flywheel driving plate.*

## FLYWHEEL AND FLYWHEEL HOUSING

### To Remove the Flywheel

1. Remove the gearbox and adaptor plate.
2. Evenly unscrew the socket headed setscrews securing the driving plate assembly to the flywheel and detach the unit.
3. Knock back the tabs of the locking washers of the flywheel securing setscrews.
4. Remove the six setscrews and lift the flywheel from the crankshaft flange.

To facilitate the removal of the flywheel, it is recommended that two diametrically opposed securing setscrews are removed and in their place, screw in two suitably sized studs, finger tight only. The remaining setscrews can now be removed and the flywheel withdrawn under control.

### To Renew the Flywheel Ring Gear

1. Place the flywheel in a suitable container of clean cold water and support the assembly in the container by positioning four metal blocks under the ring gear. Arrange the flywheel assembly so that it is partly submerged in water with the ring gear uppermost. The complete ring gear must be above the water line and it is recommended that the bottom face of the ring be approximately 1/4 in (6.35 mm) above the water level. Heat the ring gear evenly around its circumference using oxy-acetylene welding equipment, thus expanding the ring, which will allow the flywheel to drop away from the ring gear. Lift out the flywheel and thoroughly dry it off.
2. Ensure that the registering faces of the flywheel and new ring gear are clean and free from burrs.
3. Heat the new ring gear to an approximate temperature of 475$^{o}$F (246$^{o}$C). Fit the gear over the flywheel with the lead-in on the teeth facing the front of the flywheel and allow the ring to cool in atmosphere.

### To Refit the Flywheel

1. It is most essential before fitting a flywheel that the crankshaft flange face and periphery are perfectly clean and free from burrs. The mating faces of the flywheel must also be absolutely clean and free from burrs.
2. It will be noted that there is a seventh untapped hole in the crankshaft flange, which is at bottom dead centre when the crankshaft is at T.D.C. Nos. 1 and 4 pistons. Mount the flywheel with the aid of guide studs to the crankshaft flange so that the untapped hole in the flange is in line with the seventh unused smaller hole in the flywheel. This ensures the flywheel timing marks are in a correct position in relation to the crankshaft.
3. Engage the six securing setscrews with three new locking washers and tighten to a torque wrench reading of 74/80 lbf ft (10,3/11,0 kgf m) - 99/108 Nm.
4. Set up a clock indicator gauge with the base secured to the flywheel housing or cylinder block and adjust the clock so that the plunger is contacting the periphery of the flywheel. Turn the crankshaft and check the run-out. The flywheel should run truly within 0.012 in (0.30 mm) total indicator reading.
5. Now adjust the clock gauge so that the plunger is at right angles to the crankshaft flange and rests on the vertical machined face of the flywheel, at the outermost point of the face (see Fig. P.2).
6. Turn the crankshaft and check the run-out, shown on the clock gauge, of the flywheel face which should be within 0.0005 in (0,013 mm) per inch (25,4 mm) of flywheel diameter, total indicator reading at right angles to the crankshaft axis.
7. When the flywheel has been checked for alignment lock the setscrews with the tab washers.
8. Refit the adaptor plate and gearbox, etc.

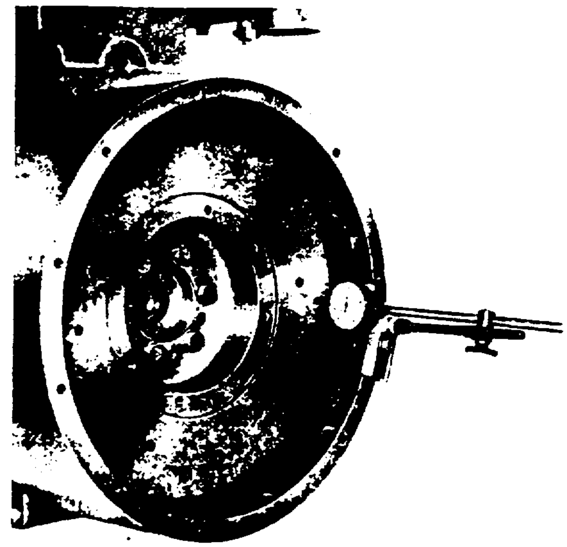


*Fig. P.2.*
*Checking Flywheel Back Face run-out.*

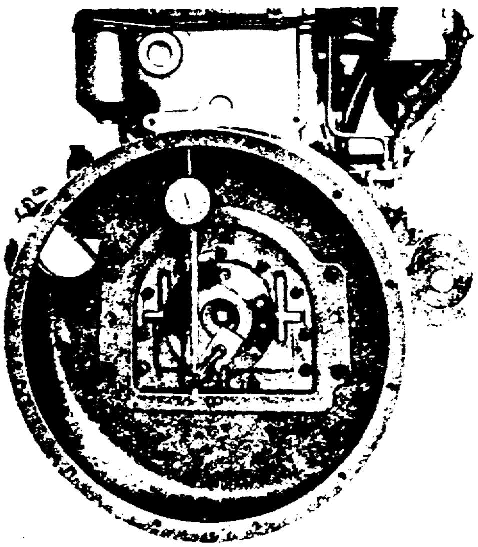


*Fig. P.3.*
*Checking Alignment of Flywheel Housing Bore.*

**To Remove the Flywheel Housing**

1. Remove the flywheel (see Page P.2).
2. Remove the starter motor.
3. Unscrew the nuts securing the flywheel housing to the cylinder block and tap the housing clear of the locating dowels.
4. Examine the housing for cracks or damage etc.

**To Refit the Flywheel Housing**

1. Ensure that the rear face of the cylinder block and the mating face of the flywheel housing are perfectly clean and free from burrs, etc.
   Check dowel location in block and housing, ream and fit oversize dowels where necessary.
2. Locate the flywheel housing carefully on the two dowels and refit the securing setscrews.
3. Mount a dial test indicator (clock) gauge with the base on the crankshaft flange and the gauge stylus on and perpendicular with the inner face of the housing aperture as shown in Fig. P.3. Rotate the crankshaft, the inner bore should be truly central with the crankshaft within the limits listed towards the end of this section.
4. With the gauge base still mounted in the same position adjust the stylus so that it is at right angles to tile vertically machined rear face of the flywheel housing as shown in Fig. P.4. Turn the crankshaft and check that this face is at right angles to the crankshaft axis to within the following limits.

| Diameter of Housing Bore | Max. Allowance |
|---|---|
| Up to 14 1/4 in (362 mm) | 0.006 in (0.15 mm) Total Indicator Reading |
| 14 1/4 to 20 1/8 in (362 to 511 mm) | 0.008 in (0.20 mm) Total Indicator Reading |
| 20 1/8 to 25 1/2 in (511 to 648 mm) | 0.010 in (0.25 mm) Total Indicator Reading |
| 25 1/2 to 31 in (648 to 787 mm) | 0.012 in (0.30 mm) Total Indicator Reading |

**NOTE: Any adjustments which may be necessary to bring the flywheel housing within the limits quoted must be carried out on the housing, under no circumstances may the rear face of the cylinder block be interfered with.**

5. When the housing is correctly aligned finally tighten the securing setscrews.
6. Refit the flywheel as previously described on Page P.2.

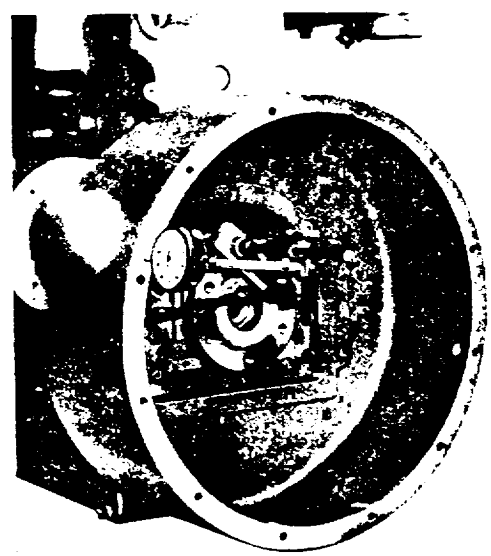


*Fig. P.4.*
*Checking Alignment of Flywheel Housing Face.*

## ALTERNATOR

### Models AC5 and 11AC

### 1. General

At the time of writing there are two types of alternator supplied with the 4.236 marine engine, namely the AC 5 with its associated 440 regulator, and the 11 AC with the 4 TR Control Box.

These are driven by the engine in the same manner as a D.C. Generator, namely, belt driven from the crankshaft pulley, but the advantage lies in their ability to provide higher maximum output at lower speeds, to cope with increased electrical load demanded by modem equipment. They are also much lighter in weight, output for output.

As opposed to the DC Generator in which the armature windings rotate inside a stationary field system, the alternator has a rotating field system inside a stationary generating winding. When the rotor rotates inside the stator, the output produced is alternating current (AC). This is unsuitable for charging the battery which requires direct current (DC), so it is rectified by means of diodes which converts it to uni-directional flow to the battery.

The alternator voltage output is maintained within close limits by means of a control box which is fully transistorized and functions as fast switches.

### 2. Precautions

As previously described the diodes in the alternator function as one-way valves and the transistors in the regulator/control box operate as fast switches. Both are accurate and sensitive.

They do not wear out and seldom require adjustment, but because they are sensitive to voltage changes and high temperature, the precautions are vital to prevent them from being destroyed.

(a) DO NOT disconnect the battery whilst the engine is running. This will cause a voltage surge in the alternator charging system that will immediately ruin the diodes or transistors.

(b) DO NOT disconnect a lead without first stopping the engine and turning all electrical switches to the off position.

(c) DO NOT cause a short circuit by connecting leads to incorrect terminals. Always identify a lead to its correct terminal. A short circuit or wrong connection giving reverse polarity will immediately and permanently ruin transistors or diodes.

(d) DO NOT connect a battery into the system without checking for correct polarity and voltage.

(e) DO NOT "flash" connections to check for current flow. No matter how brief the contact the transistors may be ruined.

### 3. Maintenance

The alternator charging system will normally require very little attention, but it should be kept free from build-up of dirt, and a check made if it fails to keep the battery charged.

(a) Regularly inspect the driving belts for wear and correct tension. It is important to ensure that all belts on a multiple belt drive have equal tension and are each carrying their share of the load. Slack belts will wear rapidly and cause slip which will not drive the alternator at the required speed. Drive belts which are too tight impose severe side thrust on the alternator bearings and shorten their life. Periodically ensure that the alternator is correctly aligned to the drive.

(b) Do not replace faulty belts individually in a multi-belt system. A complete matched set of drive belts must always be used.

(c) Keep the alternator clean with a cloth moistened in kerosene or cleaning fluids. Ensure that ventilation slots and air spaces are clear and unobstructed.

(d) Remove any dirt accumulated on the regulator/control box housing, and ensure that cooling air can pass freely over the casing.

**4. Fault Finding on AC5**

The AC 5 alternator is so designed that a flow of current indicated either by the extinguishing of the warning light, or as shown on the ammeter, is sufficient evidence that the system is in proper working order. Therefore, no open circuit, voltage or current output checks should be performed on the installation UNLESS:—

(a) The warning light fails to illuminate when the generator is stationary, and the switch is closed OR fails to become extinguished when the alternator is running.
(b) No charging current is shown on ammeter.
(c) The battery is flat.
(d) The battery is "boiling", indicating loss of voltage control.

If any of the above symptoms occur, the procedure indicated below should be followed.

(a) Connect a good quality moving coil voltmeter 0-50 volts range across the battery or regulator negative terminal, and one of the three positive terminals marked LO, MED, HI. Disconnect alternator output terminal. Fit a good quality moving coil 0-100 amp ammeter in series with the alternator terminal and output lead. The battery should be in a charged condition.
(b) Close the warning light switch (master electric switch on dashboard) when the warning lamp should light up.
(c) Switch on a 10-15 amperes load such as lights, fans, etc., for fifteen minutes.
(d) Start engine and run at fast idle speed when
    1. The warning light should go out.
    2. The ammeter records a small charge dc-pendant on engine speed.
(e) Increase engine speed momentarily to maximum speed, when the charging current should be about 30 Amperes for 24 Volt, and 53 Amperes for 12 volt systems.
(f) With the alternator running at approximately half speed, (engine speed about 1.500) rev/min) switch off electrical load. Depending on the connection selected for the positive sensing wire LO, MED or HI, the voltage should rise to between 26 and 28 volts on 24 volt systems and 13-14 volts on 12 volt systems and then remain constant. At the same time the current reading should drop appreciably.

Any variance in the above data could indicate a fault and the following procedure should be adopted before disconnecting any components.

The regulator is a sealed unit and is non-repairable and if found to be faulty it must be replaced.

**Warning Lamp does not light up when switched "On".**

Check the bulb.

If no fault

Check all wiring connections at regulator, alternator and battery.

If no fault

Switch off, disconnect "F" lead at regulator and connect it to the negative terminal.

Switch on. If warning lamp lights up, the regulator is faulty. If lamp fails to light up, the alternator is faulty.

**Warning Lamp does not go out and Ammeter shows no output when running.**

Check all regulator, alternator and battery connections.

If no fault

Switch off, disconnect "F" lead at regulator and connect to regulator negative terminal.

Switch on, and run at fast idle.

If no output, alternator is faulty.

If output appears, regulator is faulty.

**Warning Lamp does not go out when running and Ammeter shows reduced output with full output only at maximum speed or Warning Lamp goes out but Alternator delivers reduced output. Full output only at maximum speed.**

Alternator faulty. Remove from installation and apply open circuit diode check.

**Warning Lamp flashes intermittently and Ammeter needle oscillates when Battery is fully charged and no loads are switched in.**

Check for excessive resistance in regulator negative sensing lead.

If no fault, regulator is faulty.

**Batteries overcharging and Ammeter indicates high or full output all the time.**

Check regulator positive sensing lead and its connection at regulator.

If no fault, regulator is faulty.

## 5. Fault Finding on 11 AC

If the alternator does not produce its rated output of 43 amps for 12 volt and 23 amps for 24 volt circuit, the failure may be due to any unit or the associated wiring, and the following procedure should be followed.

**TEST 1.**

**Check the Field Isolating Relay**

Disconnect the earthed battery terminal and the cable from the alternator main output terminal. Connect a 0-60 DC ammeter between the terminal and disconnected cable. Link terminals 'C1' and 'C2' on the field relay. Reconnect the battery cable. Close the master switch and start engine and run at charging speed. If ammeter shows a charge the relay is faulty. or its wiring and connections.

If ammeter shows no charge, carry on with Test 2.

**TEST 2**

**Check the Alternator and Control Box**

Leave the test ammeter connected, and disconnect cables 'F' and '-' from control unit and join them together. Remove link from field relay terminals and ensure they are connected to 'C1' and 'C2'. Start engine and run at charging speed.

Ammeter should indicate current values of 35 amps or more for 12 volt circuit or 22 amps or more for 24 volt circuit. A zero or low reading indicates a faulty alternator.

If satisfactory output is recorded, a faulty control unit is indicated.

**TEST 3**

**Checking or Adjusting the Voltage Setting**

The regulator of the 4 TR control unit must be set on CLOSED CIRCUIT, when the alternator is under load. Also, the system must be stabilized before checking or resetting is carried out, and the battery must be in a well charged condition. Check the battery to control unit wiring, to ensure that the resistance of the complete circuit does not exceed 0.1 ohm. Any high resistance must be traced and remedied. Connect a test DC voltmeter (suppressed zero type) scale 12-15 volts for 12 volt installations or 24-30 volts for 24 volt installations, between the battery terminals, and note the reading with no electrical load. Disconnect battery earth cable and connect test ammeter between alternator main terminal and disconnected cable. Reconnect battery earth cable, and switch on an electrical load of approximately two amps. Start engine and run at about 2000 rev/min, for at least eight minutes. If the charging current is still greater than ten amps, continue to run engine until this figure is reached. Then compare the volt meter reading with the appropriate setting limits, as specified for the particular control unit as follows.

| | | |
|---|---|---|
| 12 V (37423)/(37449) | 13.9 | 14.3 volts |
| 24 V (37444)'(37502) | 27 9 | 28.3 volts |
| 12 V 37429 | 13.7 | 14.1 volts |

(Part no. marked on upper edge of the moulded cover of Control Unit).

If reading obtained is stable hut outside the appropriate limits the unit can be adjusted as follows.

ADJUSTMENT OF VOLTAGE SETTING

Stop the engine and remove the control unit from its mounting.. At the back of the unit is a sealed potentiometer adjuster. Carefully scrape away the sealing compound. Then start the engine, and while running the alternator at charging speed, turn the adjuster slot — CLOCKWISE to INCREASE the setting or ANTI-CLOCKWISE to DECREASE it — until the required setting is obtained.

Recheck the setting by stopping the engine, then start again and slowly "run-up" to charging speed. If setting is now correct, remount the control unit, disconnect test meters and restore original wiring connections. If, after adjustment, the voltmeter reading remains unchanged, or increases in an uncontrolled manner, then the control unit is faulty and a replacement must be fitted.

**TEST 4**

**Check of Alternator Output**

Disconnect battery earth cable, and connect test ammeter between the alternator main terminal and disconnected cables. Reconnect battery earth cable, and switch on the full electrical load and leave on for 3 or 4 minutes. Leave load on and start engine and run at approximately 2000 rev/min. The alternator output should balance the load, and at the same time show a charge to the battery.

**Check Warning Light Control**

If warning light does not function either by remaining "on" or "off", but the system is charging satisfactorily, connect voltmeter between the alternator "AL" terminal and earth. Reading should be 7.0-7.5 max (12 volt alternator) or 14.0-15.0 (24 volt alternator). Connect leads 'E' and 'WL' together. If warning lamp lights the warning light control is faulty and should be replaced.

**6. Fault Diagnosis Procedure for 11 AC**

**Alternator Fails to Charge**

(a) Check driving belt for correct tension and wear.
(b) Apply Tests 1 and 2.

**Low-Unsteady Charging Rate**

(a) Check driving belt for correct tension and wear.
(b) Check for high resistance at battery terminals and in the circuit wiring and connection. Check all connections made to earth.
(c) Apply Test 2.

**Flat Battery or Low State of Charge**

(a) CHECK condition of battery with hydrometer and high rate discharge tester.
(b) Check driving belt for correct tension and wear.
(c) Check that the field isolating relay contacts open when master switch is off; otherwise battery will discharge through rotor winding.
(d) Check that flat or low battery is not caused by insufficient alternator output caused by abnormal electrical loads by applying Test 4.

**Excessive Charge Rate to a Fully Charged Battery**

(a) Apply Test 3.

**Noisy Alternator**

(a) Alternator loose in mounting brackets.
(b) Worn, frayed or loose drive belt.
(c) Worn bearings, fully out of alignment.
(d) Rotor damaged or pulley fan loose on shaft.
(e) Open circuited, or short circuited rectified diodes, or stator winding open-circuit.
(f) Loose pulley.

## DYNAMO

### 1. General

The following information concerns the dynamo fitted as standard equipment to the earlier 4.236 marine engine, namely, the Lucas C40A model. If information concerning another type of dynamo is required, the relevant manufacturer should be contacted.

The C40A is a non-ventilated, shunt-wound two-pole two-brush machine arranged to work in conjunction with a compensated voltage control regulator unit. A hall bearing supports the armature at the driving end and a porous bronze bush at the rear supports the commutator end.

The output of the dynamo is controlled by the regulator unit and is dependent on the state of charge of the battery and the loading of the electrical equipment in use. When the battery is in a low state of charge, the dynamo gives a high output, whereas if the battery is fully charged, the dynamo gives only sufficient output to keep the battery in good condition without any possibility of overcharging. An increase in output is given to balance the current taken by lamps and other accessories when in use.

When fitting a new control box, it is important to use only an authorized replacement. An incorrect replacement can result in damage to the dynamo.

### 2. Routine Maintenance

**(a) Lubrication**

Every 250 running hours, inject a few drops of high quality S.A.E. 30 engine oil into the hole marked "OIL" at the commutator end bearing housing.

**(b) Inspection of Brushgear**

Every 2,500 running hours, the dynamo should be removed from the engine and the brushgear inspected by a competent electrician.

**(c) Belt Adjustment**

Occasionally inspect the dynamo driving belt, and if necessary, adjust to take up any slackness by turning the dynamo on its mounting. Care should be taken to avoid overtightening the belt (see Page M.1).

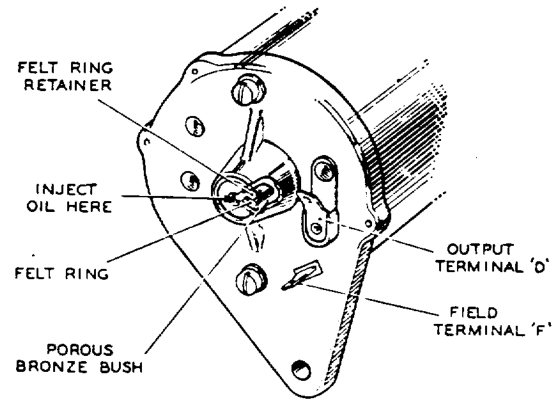



*Fig. Q.1.*
*Lubricator in Commutator End Bracket.*

### 3. Performance Data

The cutting in and maximum output speeds quoted below are production test figures and refer to cold machines with brushes only partly bedded.

Model C40A

Cutting-in Speed
1,100 rev/min (max.) at 13.0 dynamo volts.

Maximum Output:
11 amperes at 1,700 rev/min (max.) at 13.5 dynamo volts and a resistance load of 1.23 ohms.

Field Resistance:
6.0 ohms.

### 4. Servicing

**(a) Testing in Position to Locate Fault in Charging Circuit**

1. Inspect the driving belt and adjust if necessary.

2. Check the connections on the commutator end bracket. The larger connector carries the main dynamo output, the smaller connector the field current.

3. Switch off all lights and accessories, take off the cables from the terminals of the dynamo and connect the two terminals with a short length of wire.

4. Start the engine and set to run at normal idling speed.

5. Clip the negative lead of a moving coil type voltmeter, calibrated 0 - 20 volts, to one dynamo terminal and the positive lead to a good earthing point on the yoke.

6. Gradually increase the engine speed, when the voltmeter reading should rise rapidly and without fluctuation. Do not allow the volt meter reading to reach 20 volts, and do not race the engine in an attempt to increase the voltage. It is sufficient to run the dynamo up to a speed of 1,000 rev/min. If the voltage does not rise rapidly and without fluctuation the unit must be dismantled for internal examination, see Para 4(b). Excessive sparking at the commutator in the above test indicates a defective armature which should be replaced.

**(b) To Dismantle**

1. Take off the driving pulley.

2. Unscrew and withdraw the two through bolts.

3. Withdraw the commutator end bracket from the yoke.

4. Lift the driving end bracket and armature assembly from the yoke. Take care not to lose the fibre thrust washer from the commutator end of the shaft.

5. The driving end bracket, which on removal from the yoke has withdrawn with it the armature and armature shaft ball bearing, need not be separated from the shaft unless the bearing is suspected and requires examination, or the armature is to be replaced; in this event the armature should be removed from the end bracket by means of a hand press, having first removed the shaft key.

**(c) Brush Gear (Checking with yoke removed)**

1. Lift the brushes up into the brush boxes and secure them in that position by positioning the brush springs at the sides of the brushes.

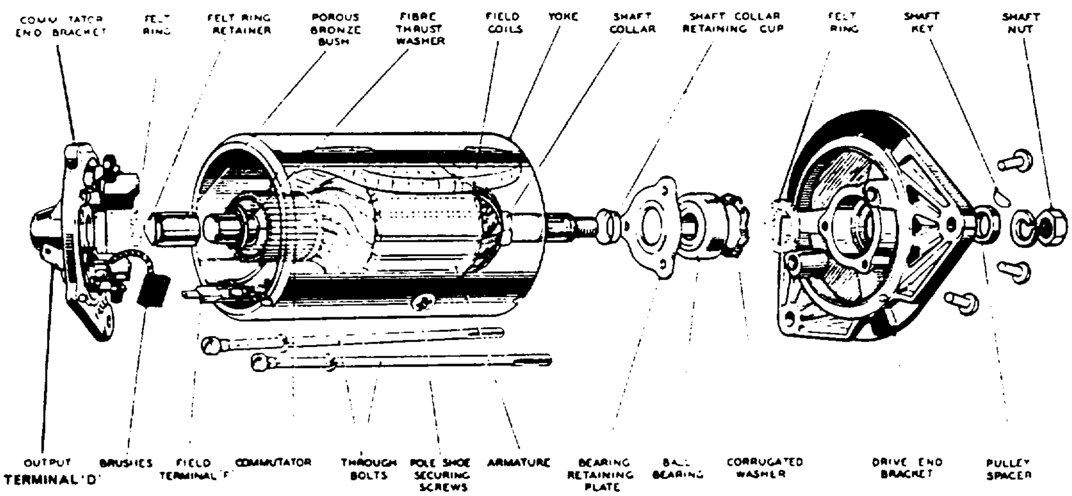



*Fig. Q.2.*
*Dynamo Dismantled.*

2. Fit the commutator end bracket over the commutator and release the brushes.

3. Hold back each of the brush springs and move the brush by pulling gently on its flexible connector. If the movement is sluggish, remove the brush from its holder and ease the sides by lightly polishing on a smooth file. Always refit the brushes in their original positions. If the brushes are badly worn, new brushes must be fitted and bedded to the commutator. The minimum permissible length of brush is 9/32 in (7,14 mm), i.e. when the spring arm reaches the brush box.

4. Measure the brush spring pressures, using a spring balance held radially to the commutator. The tension on the springs should be 30 ozf (0,85 kgf), maximum, when exerted on a new brush and 13 ozf (0,37 kgf), minimum, on a brush worn to 9/32 in (7,14 mm). Both pressures should be measured and defective springs replaced.

**(d) Commutator**

1. A commutator in good condition will be smooth and free from pits and burned spots. Two types of commutator, the moulded and the fabricated, will be found in service. Moulded commutators can be recognized by the exposed end being quite smooth, unlike that of the fabricated commutator from which a metal roll-over and an insulating cone protrude (see Fig. Q.3).

2. A moulded commutator can be re-skimmed during service but care must be exercised to ensure that the finished diameter is not less

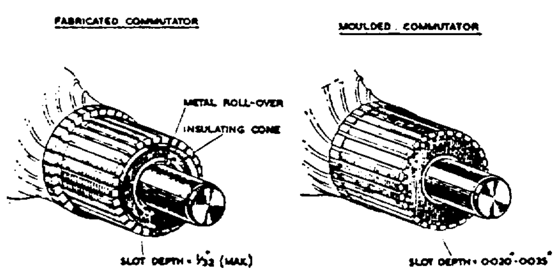



*Fig. Q.3.*
*Comparison of Fabricated and Moulded Commutators.*

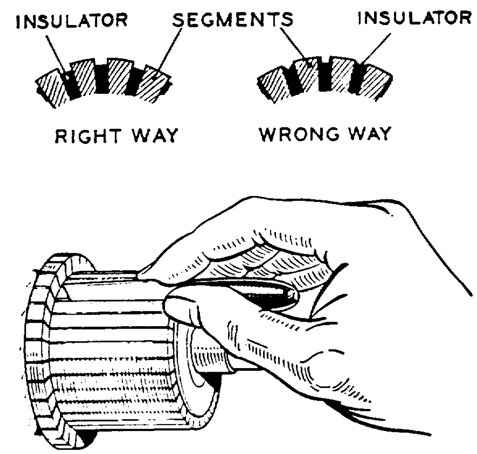



*Fig. Q.4.*
*Undercutting Insulators.*

than 1.450 in (36,83 mm). The process of re-skimming consists of rough turning (if necessary) followed by diamond turning. Whether or not rough turning is carried out depends upon the severity and unevenness of the wear which has taken place. A moulded commutator requires no undercutting in service, the production undercut being of sufficient depth to obviate any further need for this. The insulation slots, however, muss be kept clear of copper and carbon residue.

3. To remedy a worn fabricated commutator, undercut the insulators between the segments to a depth of 1,32 in (0,79 mm) using a hacksaw blade ground to the thickness of the insulator, then mount the armature, with or without the drive end bracket, in a lathe, rotate at high speed and take a light cut with a very sharp tool. Do not remove more metal than is necessary. Polish the commutator with very fine glass paper.

**(e) Armature**

Indication of an open-circuited armature winding will be given by burnt commutator segments. If armature testing facilities are not available, an armature can be checked by substitution.

To separate the armature shaft from the drive end bracket, press the shaft out of the drive end bracket bearing. When fitting the new armature, support the inner journal of the ball bearing, using a mild steel tube of suitable diameter, whilst pressing the armature shaft firmly home. See also Para 4 (h)1.

**(f) Field Coils**

Measure the resistance of the field coils, without removing them from the dynamo yoke, by means of an ohm meter connected between the field terminal and the yoke. The resistance is 6.0 ohms for the model C40A.

If an ohm meter is not available, connect a 12 volt d.c. supply between the field terminal and dynamo yoke with an ammeter in series. The ammeter reading should be approximately 2 amperes. Zero reading on the ammeter or an "Infinity" ohm meter reading indicates an open circuit in the field winding.

If the current reading is much more than 2 amperes, or the ohm meter reading much below 6 ohms, it is an indication that the insulation of one of the field coils has broken down.

In either event, unless a substitute dynamo is available, the field coils must be replaced. To do this, carry out the procedure outlined below, first noting to which end of the coil the field terminal is soldered.

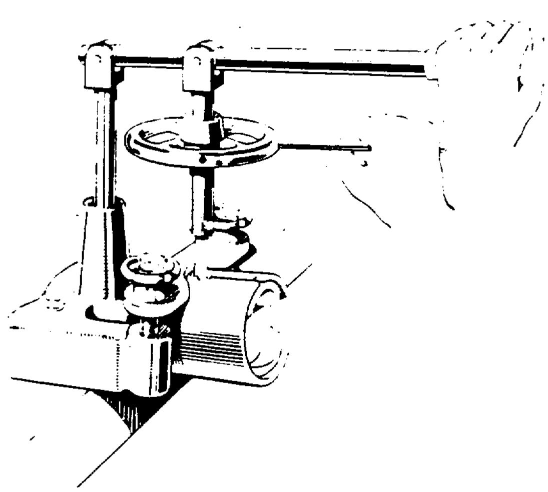


*Fig. Q.5.*
*Tightening Pole Shoe Retaining Screws.*

1. Drill out the rivet securing the field coil terminal assembly to the yoke and unsolder the field coil connections.
2. Remove the insulation piece which is provided to prevent the junction of the field coils from contacting with the yoke.
3. Mark the yoke and pole shoes so that the latter can be refitted in their original positions.
4. Unscrew the two pole shoe retaining screws by means of a wheel operated screw driver.
5. Draw the pole shoes and field coils out of the yoke and lift off the coils.
6. Fit the new field coils over the pole shoes and place them in position inside the yoke. Take care to ensure that the taping of the field coils is not trapped between the pole shoes and the yoke.
7. Locate the pole shoes and field coils by lightly tightening the fixing screws.
8. Fully tighten the screws by means of a wheel operated screwdriver.
9. Solder the original terminal and earthing eyelet to the appropriate coil ends.
10. Refit the insulating sleeve and re-rivet the terminal assembly to the yoke.
11. Refit the insulation piece behind the junction of the two coils.

**(g) Bearings**

Bearings which are worn to such an extent that they will allow side movement of the armature shaft must be replaced. To replace the bearing bush in a commutator end bracket proceed as follows:—

1. Remove the old bearing bush from the end bracket. The bearing can be withdrawn with a suitable extractor or by screwing a j inch tap into the bush for a few turns and pulling out the bush with the tap. Screw the tap squarely into the bush to avoid damaging the bracket.

2. Withdraw and clean the felt ring retainer and felt ring.

3. Insert the felt ring and felt ring retainer in the bearing housing, then press the new bearing bush into the end bracket, using a self-extracting tool of the type and in the manner shown in Fig. Q.6-the fitting pin or mandrel portion being of 0.5924 in (15,05 mm) diameter and highly polished. To withdraw the pin after pressing the bush fully home, turn the nut against the sleeve while gripping the squared end of the fitting pin. Porous bronze bushes must not be opened out after fitting, or the porosity of the bush may be impaired.

**NOTE:**
**Before fitting the new bearing bush it should be allowed to stand for 24 hours completely immersed in a good grade**

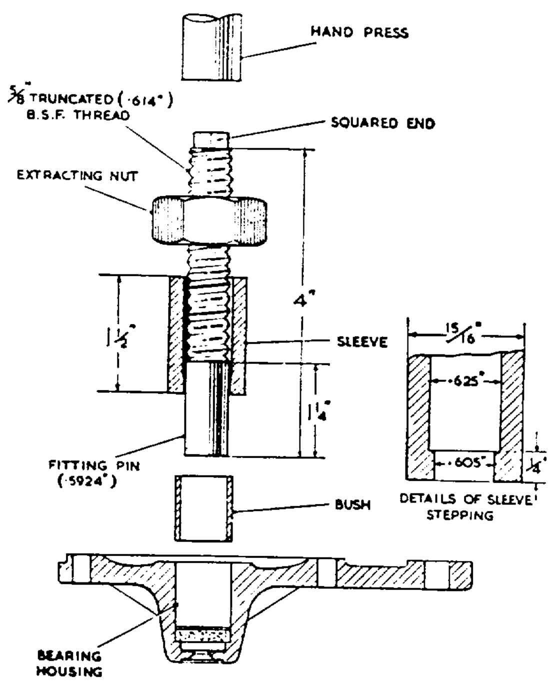



*Fig. Q.6.*
*Tool for fitting Commutator End Bracket Bush.*

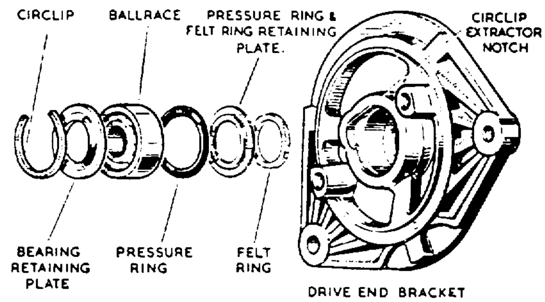



*Fig. Q.7.*
*Drive End Bracket with Circlip Retained Bearing.*

S.A.E. 30 engine oil: this will allow the pores of the bush to be filled with lubricant. The enclosed ball bearing at the driving end is replaced as follows:—

1. Drill out the rivets, or remove the screws whichever is applicable, which secure the bearing retaining plate to the end bracket and remove the plate.

2. Press the bearing out of the end bracket.

3. Remove and clean the corrugated washer and felt ring.

4. Before fitting the replacement bearing. see that it is clean and pack it with high melting point grease.

5. Place the felt ring and corrugated washer in the bearing housing in the end bracket.

6. Locate the bearing in the housing and press it home.

7. Fit the bearing retaining plate. Insert the new rivets from the pulley side of the end bracket and open the rivets by means of a punch to secure the plate rigidly in position. If secured by screws, fit the screws and tighten.

**Ball Race Bearing in Drive End Bracket**
**(Circlip Secured Assembly)**

This arrangement is shown in Fig. Q.7.

1. Insert the tip of a screwdriver in the extractor notch and prise free the circlip.

2. Remove the bearing retaining plate and press out the bearing.

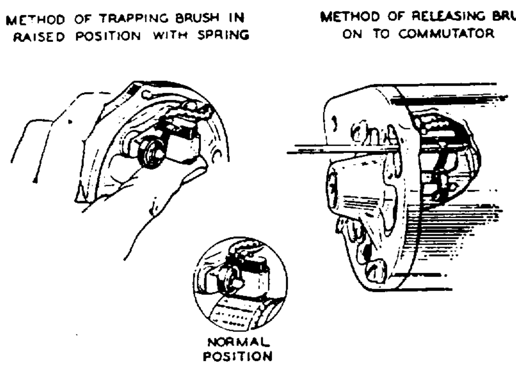



*Fig. Q.8.*
*Fitting Commutator End Bracket to Yoke.*

3. Ensure that the pressure and felt rings and the retaining plate do not fall out.

4. Check that the replacement bearing is clean and push it fully home with a hand press.

5. Replace the bearing retaining plate and after replacing the circlip in position, compress the whole assembly enough to allow the circlip to re-locate itself.

**(h) To Re-Assemble**

1. Fit the shaft collar retaining cup and drive end bracket to the armature shaft. The inner journal of the bearing must he supported by a tube, approximately 4 in (10(1 mm) long, 1/8 in (3 mm) thick and internal diameter 5/8 in (16 mm). Do not use the drive end bracket as a support for the bearing whilst fitting an armature.

2. Fit the yoke to the drive end bracket.

3. Push thc brushes up into the brush boxes and secure them in that position by positioning each brush spring at the side of its brush.

4. Fit the commutator end bracket on the armature shaft until the brush boxes are partly over the commutator. Place a thin screwdriver on top of each brush in turn and press the brush down on the commutator. The brush springs should then position themselves on top of the brushes.

5. Fit the commutator end bracket to the yoke so that the projection on the bracket locates in the yoke.

6. Refit the two through bolts. After assembly lubricate the commutator end bearing.

## STARTER MOTOR

### Model - CA45

**GENERAL DESCRIPTION**

Designed for flange mounting, the C.A.45 starter motor has a uniform cylindrical shape with no surface protrusions. This is because the solenoid and main switch assemblies are housed within the drive end-shield, around (i.e., co-axially with) the armature shaft.

The essential feature of the co-axial starter is that, **the pinion alone** moves axially to engage the engine flywheel. There is no longitudinal movement of the whole armature assembly, as in the axial types.

Smooth engagement of the pinion with the engine flywheel is constantly ensured by using two-stage operation of the solenoid and switch mechanisms. Thus the risk of damage to both pinion and flywheel, through faulty meshing. is practically eliminated.

In construction, the starter consists of three main sections. into which it can he easily dismantled.

1. The solenoid switch-gear and pinion assembly housed in the drive end-shield.

2. The armature. shaft and commutator assembly.

3. The yoke, pole-piece and field-coil assembly.

Ready access is possible therefore, to those parts most likely to require adjustment, such as the switchgear and commutator assemblies.

**OPERATING MECHANISM**

The starter is designed for working off a 12 volt supply, with 17 amps solenoid current.

The starter operating mechanism consists of the following main parts, viz.:

The solenoid (10) and resistor (9) (Fig. Q.9).

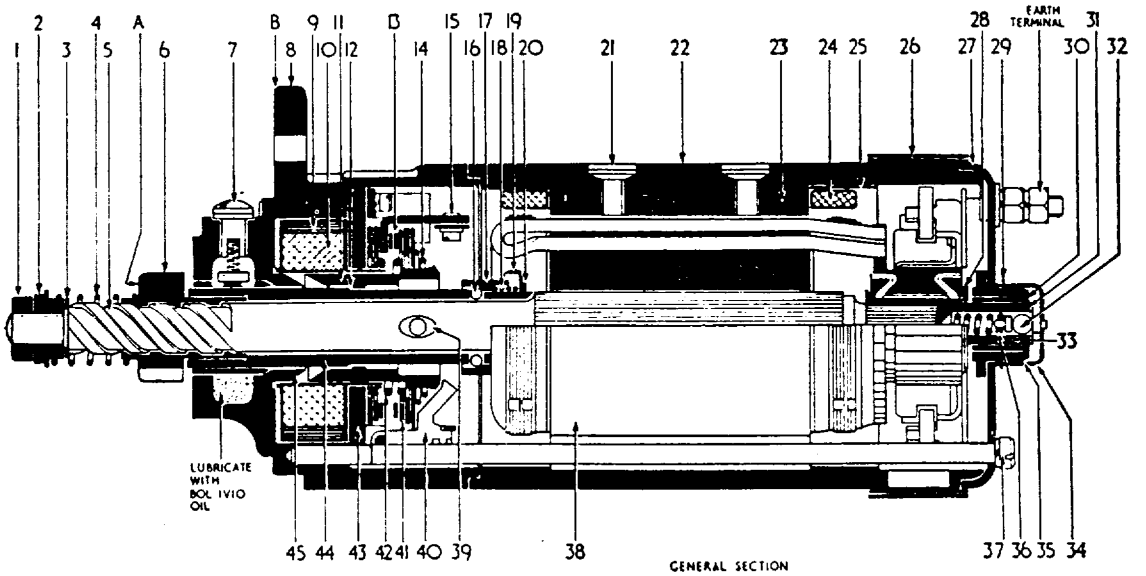



*Fig. Q.9.*
*Cross Section view of CA 45 Type Starter Motor.*

The pinion (6) and sleeve (44), mounted on the armature shaft (5).

The sliding plunger (11) mounted on the pinion sleeve.

First (13) and second (41) main switch contacts. The moving contacts are mounted on the plunger.

The contact trip-trigger (40).

The ball-locking collar (17) and trip-collar (19) both mounted on the pinion sleeve.

## OPERATION

Engagement of the pinion with the engine flywheel is made in two separate, but continuous stages.

### First Stage

When the starter switch-button is pressed, the solenoid (10), is energized. The magnetic field draws the sliding plunger (11) forward v, in (8 mm) to meet the shoulder (12), on the pinion sleeve (44).

The pinion, now pushed by the plunger, also moves forward, until the pinion nose commences to mesh with the engine flywheel.

Simultaneously, the moving contacts, mounted on the plunger, are also carried forward, causing the first set (13) to close. The second set (41) held by the trip-trigger (40) remain open until the first stage is completed. At this point, the plunger slides fully home against the stop (45) on the drive end shield.

The first pair of contacts having closed, battery current flows through the resistance (9) and armature field windings (24). Since the resistance allows a **limited** current only, to pass through the field windings. the armature rotates very slowly. The electrical circuit is shown schematically in Fig. Q.11. This completes the first stage of the operation.

### Second Stage

The pinion, already partially engaged and prevented from rotating by the engine flywheel will be gently pushed into full engagement by the helix on the slowly revolving armature shaft. However, just before complete engagement is reached, the trip-trigger (40) is lifted by the forward movement of the trip-collar (19) mounted on the pinion sleeve. This frees the second set of contacts (41), which now close. Closing of the contacts short circuits the resistor and allows full current to flow through the field windings. The armature now rotates under full power, with the pinion and engine flywheel fully engaged. This completes the second stage.

In order to avoid premature disengagement of the pinion before release of the starter button, a ball-locking device is positioned between the armature shaft and pinion sleeve. This consists of the following components:

Four steel balls (16) located in holes in the pinion sleeve.

A locking collar (17) mounted on the pinion sleeve.

The collar loading spring (18).

Four recesses (39) in the armature shaft.

The balls, set in holes in the pinion sleeve, are retained in position by the lock-collar, the inside bore of which, has a 450 chamfer, causing the balls to be pressed inwards against the armature shaft.

In the stationary position, the balls hold back the lock collar. When the pinion moves forward to the fully engaged position. the balls become opposite the recesses in the armature shaft sinking into them as the shaft revolves. Spring pressure pushes the collar over the top of the balls, locking them in the recesses. Thus any backward or forward movement of the pinion sleeve can no longer occur and the pinion is securely held in the fully engaged position as long as the starter button remains pressed.

Releasing the starter button cuts off the solenoid current. Under the combined pressure of the main contact and plunger springs (14) and (42). the plunger returns to its normal position. carrying with it the moving contact plate. Thus both sets of contacts open. With current cut, the rotation speed of the armature rapidly drops. The returning plunger pushes back the lock collar, releasing the balls and freeing the pinion sleeve. The engine flywheel speed now rapidly over-runs the pinion speed. This action, combined with the pressure of the return spring (4) throws the pinion out of mesh with the flywheel, returning the pinion to the disengaged position.

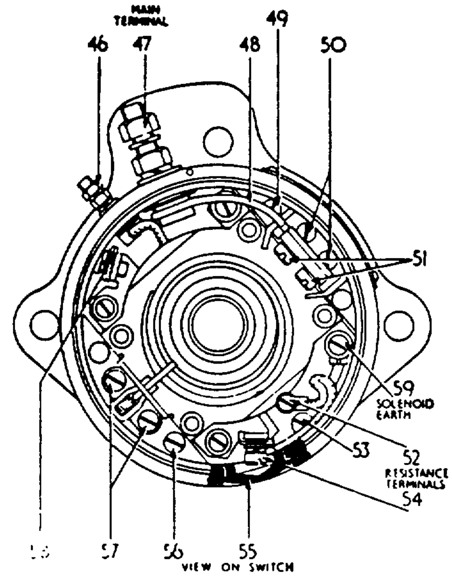



*Fig. Q.10.*

Any tendency of the pinion to wander forward under vibration resulting in damage to the contact and armature assembly, is prevented by pressure of the pinion return spring (4).

On rare occasions, badly worn pinion and flywheel teeth may meet face to face, preventing engagement and causing the pinion to remain stationary against the flywheel when the starter button is pressed. Special provision is made for overcoming this difficulty. At the commutator end of the armature, a steel ball thrust device is fitted.

This consists of a spring (36), guide (33), steel ball (32). and thrust-washer (30), against which the armature presses. The spring and ball are held in position by an end-cap (34) secured to the commutator end shield by a spring clip (29).

Should a face-to-face contact occur, the armature. under the influence of the helix, will be turned slightly and at the same time forced back against the spring: end movement of approximately 1/16 in (1,6 mm) is permitted. When the starter button is released the armature and pinion will come back to the normal disengaged position, but the radial position of the pinion will be slightly in advance of the previous position, so that the next engagement will be made quite smoothly. In order to maintain the required tolerances, shims (28) are fitted at the commutator end.

**Testing on the Application**

Ensure that the battery is in a charged condition.

Switch on the lamps and operate the starter button. If the starter fails to function, but the lights maintain full brilliance, check the switch and battery connections to the starter and all external leads. Sluggish action of the starter can be caused by a poor or faulty connection.

Difficulty in smooth engagement between starter and engine flywheel is probably due to dirt on the starter-shaft helices preventing free pinion movement. The shaft should be thoroughly cleaned with cleaning fluid followed by the application of a small quantity of Caltex Thuben 90 or SAE 90 oil.

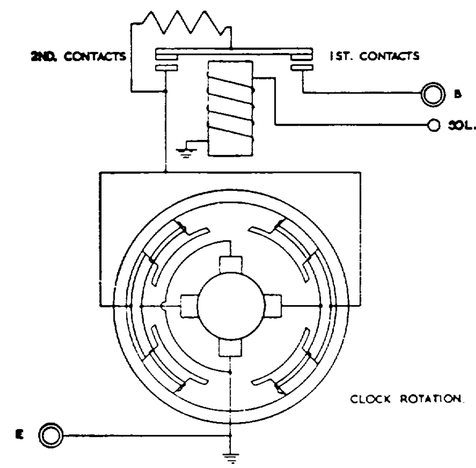



*Fig. Q.11.*
*Internal Wiring Diagram.*

## OPERATING THE STARTER

**When starting the engine the following points should be rigidly observed**

1. Press the starter button firmly and release it **immediately** the engine fires.

2. If the engine does not fire at once, let it come to rest before pressing the switch again.

3. Do **not** run the battery down by keeping the starter switch pressed when the engine refuses to start. Ascertain the cause.

4. Do **not** operate the starter when the engine is running as serious damage may occur to both starter and flywheel.

## MAINTENANCE

**LUBRICATION**

The large oil reservoir in the drive end shield need only be replenished during overhaul periods, when a supply of BOLIVIO oil should be added through the oil plug (7).

An oil impregnated sintered bronze bush is fitted at the commutator end, and needs no further attention.

**BRUSH GEAR AND COMMUTATOR**

Inspect the brushes at intervals of approximately 2.500 hours. See that they are free in their guides and that the leads are quite free for movement, by easing back the brush springs and pulling gently on the flexible connections. If a brush is inclined to stick, remove it from its holder and clean the sides with a petrol moistened cloth.

Be sure to refit the brushes in their original positions to retain the "bedding." The brushes should he well bedded (i.e. worn to the commutator periphery) but if not, wrap a strip of very fine glass or carborundum paper firmly around the commutator with the abrasive side outwards. With the brushes in position, rotate the armature by hand in the normal working direction of rotation; until the correct brush shape is obtained. If the brushes are worn down so that the springs are no longer providing effective pressure, they should be renewed. Check the brush spring pressure by hooking a spring balance under the spring lip.

The correct tension is 30—40 ozf (0,9—1,1 kgf).

It is essential that replacement brushes are the same grade as those originally fitted. Genuine spares should always be used. To remove the brushes, unscrew the four fixing screws. one to each brush. In re-assembling care must be taken to re-connect the field coil and interconnector leads, held by two of the fixing screws. Before inserting brushes in their holders, it is advisable to blow through the holders with compressed air or clean them with a cloth moistened with petrol.

The commutator should be clean, entirely free from oil or dirt. Any trace of such should be removed by pressing a clean dry **fluffless** cloth against it, while armature is hand rotated.

If the commutator is dirty or discolored, tilt the brushes and wrap a strip of fine glass or carborundum paper (not emery cloth) round the commutator, with the abrasive side inwards. Rotate the armature by hand until the surface is even. Clean with a petrol moistened cloth.

If repair is necessary to the commutator or switch gear etc., the starter must be dismantled. This should be done only in accordance with the method given.

**DISMANTLING THE STARTER**

(Figs. Q.9 and Q.10 refer).

Remove the starter from the engine, and proceed as follows:-

1. Unscrew the shaft lock-nut (1) (L.H. thread on clockwise rotation machine), remove pinion stop (2), shim washers (3) and return spring (4).

2. Remove the two cover screws (55) from the drive-end shield and unscrew the exposed field coil terminal screws (54) and (58).

3. Remove the commutator end cover-band (26).

4. Unscrew the brush-lead screws, ease off brush springs and lift brushes from the holders. Note that removing the brush screws also frees the field coil and interconnector leads.

5. Remove the spring-clip (29) and take off the end cap (34).

6. Remove the circlip (31), thrust washer (30), shim-washers (35), steel ball (32) and spring (36).

7. Unscrew and withdraw the two throughbolts (37) from the commutator end-shield (27).

8. Remove the commutator end-shield, and take off the shaft-shims (28).

9. The yoke (22), pole-pieces (23) and field coils (24) can now be removed as one assembly, leaving the armature completely exposed.

10. Unscrew the eight pole-shoe fixing screws (21) and take out the pole-pieces, and fieldcoils, taking care not to damage the leatheroid (25), inserted between the coils and yoke.

**DISMANTLING THE OPERATING MECHANISM**

1. Holding the pinion (6) and drive-end shield (8) rigid, release the ball lock and withdraw the shaft from the pinion sleeve (44), by rotating the armature in an anti-clockwise direction (clockwise on L.H. rotation machines).

   **Note—**

   **This may require a little more than the normal force, because of probable burring resulting from the action of the ball lock. Withdrawal of the shaft causes the four steel balls (16) to fall through to the inside of the pinion sleeve, and these should now be recovered.**

2. Using circlip pliers, remove the circlip (20) from the pinion sleeve-end.

3. Remove the trip-collar (19) and ball locking collar spring (18). Slide off the locking collar (17).

4. Withdraw the pinion (6).

5. Remove the two screws (51) from the main terminal connecting link (48). Loosen the main terminal (47) and remove the link.

6. Remove the resistance lead (52) from the moving contact plate.

7. Remove the two screws (57) holding the trip-gear and remove by threading the trigger (40) through the slot in the moving contact plate.

8. Remove the two screws (50) holding the stop plate and remove the plunger assembly (11).

9. Unhook the plunger spring (14) from the sliding plunger (11).

10. Take off the moving contact plate, remove the contact spring (42).

11. Remove both solenoid and main terminals (46) and (47) from the end-shield.

12. Unscrew the three solenoid end-plate fixing screws (49), (53) and (56). Take out the endplate (43) complete with the solenoid housing. If the plate offers resistance, screw in two 2BA screws, (approx. 2 in (50 mm) long) one into the trip gear fixing hole, the other into the stop-plate fixing hole. The end plate may then be easily extracted.
    **Under no circumstances should the solenoid windings and resistor assembly be disturbed or any damage done to the mica housing.**

## REPAIR AND TESTING INSTRUCTIONS
## COMMUTATOR

Examine commutator for wear which, if not severely pitted or grooved can be cleaned up with fine glass or carborundum paper (do not use emery cloth), whilst spun in a lathe. If however, the commutator is badly worn it should be skimmed, taking a very light cut, if possible with a diamond tool to provide the desired high quality finish.

The commutator insulating segments must not be undercut.

## ARMATURE COILS

The respective armature coils can be tested for continuity or short circuits by mounting the armature between centres and connecting the commutator to an ordinary battery through the medium of two brass or copper brushes mounted at an angle of 90° to each other. Contact is then made to any two adjacent commutator bars by means of hand spikes which are connected direct to a milli-volt meter.

A variable resistance should be included in the battery circuit capable of carrying the full output of the battery and adjusted to give 2 volts or less on the armature. The armature is then rotated until every commutator bar has been tested, the reading on the milli-volt meter in each case should read approximately the same; any big variation, indicating a fault in the coil connected to one of the commutator bars under test. A reduction in the milli-volt reading will be generally found due to a short circuit while an increased reading will indicate either an open circuit or a faulty connection.

In the event of an armature being found to be faulty, it should be returned direct to a C.A.V. Agent.

## ARMATURE SHAFT

Examine the elliptical recesses in the armature shaft for burrs caused by the steel balls and carefully file these off. Finally inspect the helices for any signs of damage. Thoroughly clean with a suitable cleaning fluid and lightly oil using Cal tex Thuben 90 or SAE 90 oil.

## FIELD COILS

These can be simply tested when in position for short circuits to the yoke and poles by means (of hand spikes connected to a mains supply and in series with a lamp of suitable voltage positioned on the live side of the system. One spike should be applied to the end of the winding and the other to the yoke. If the lamp does not light then insulation is intact. Take care to remove all other connections to the coils and insulate bare ends.

There is no easy way of testing internal shorts in the coils as the resistance is very low ; new coils should be tried if existing ones are suspect.

## BEARINGS

If either the commutator or drive end bearings are worn and need replacing, proceed as follows:

**(a) Commutator End Bearing**

1. Press the old bearing bush out of the end shield.
2. Press the new bearing into the end shield by using a stepped highly polished mandrel. A special fitting pin, with a dimension of 0.6263 in 0.0002 in (15,908 0,005 mm), is supplied by the makers. After assembly, the bore should be within the limits 0.6258 in to 0.6268 in (15,895 to 15,921 mm). **No machining should be attempted.**

**Note—**

**Before fitting a new bearing bush it should be completely immersed for 24 hours in clean thin engine oil.**

**(b) DRIVE END BEARING**

1. Press out the old bearing bush from the inside of the end-shield.

2. Press in new bush taking care to keep the lubricating wick away from the bore by using a split dolly. Finally set up the end-shield on a lathe and turn the bore using a spigot diameter as a register, to 1.126—1.137 in (28.6—28,62 mm).

## PINION

If the pinion teeth are badly worn, obtain a replacement and offer this up to the shaft to ensure freedom of movement. Should it be necessary they can be lightly lapped together.

## SOLENOID AND OPERATING MECHANISMS

Examine all moving parts for wear. Inspect the electrical leads for chafing and impaired insulation.

Examine the springs for possible fracture and replace as necessary. After any removal, the spring pressures should be checked before re-assembly In accordance with the following:-e

Ball-lock spring (18) (Fig Q.9)—11 lbf/in (1,97 kgf/cm)
Pinion return spring (4) — 8.6 lbf/in (1.54 kgf/cm)
Main contact (plunger) spring (14) 91/2 — 12 lbf (4,31—5,44 kgf) when compressed to 3/16 in (4,76 mm).
Contact return spring (42) 6—7 lbf (2,72— 3,18 kgf) when compressed to 1/4 in (6,35 mm).

## CONTACTS

Examine the "fixed " and "moving " contacts, and clean them with spirit or very fine carborundum paper.

If the contacts are badly burnt and pitted, they should be replaced. As replacements are not supplied ready machined, it will be necessary to face them when in position.

It is essential, when facing the "fixed" contacts, that they are kept to the angle shown in Fig. Q.12.

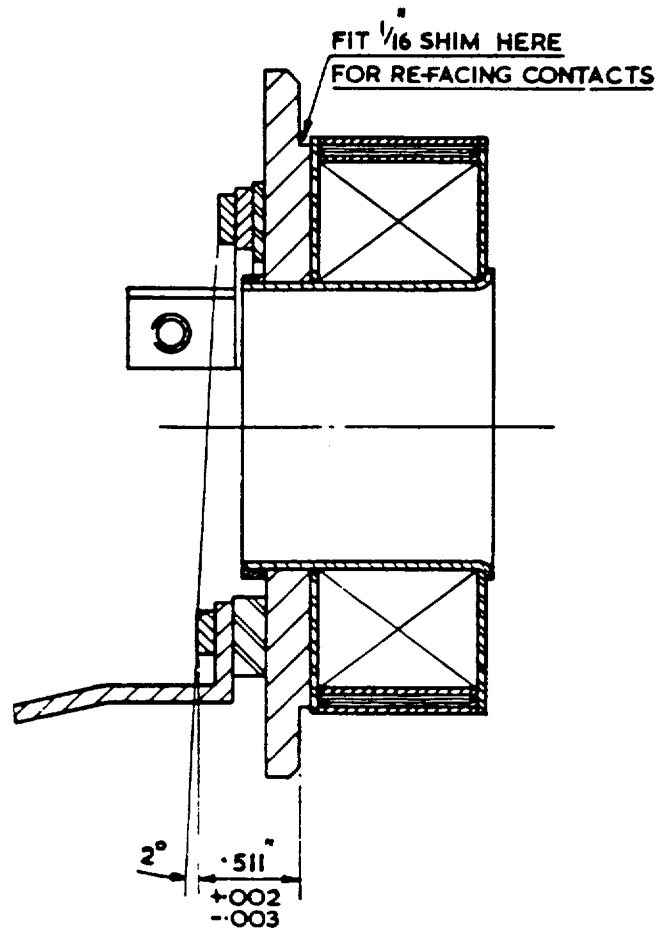



*Fig. Q.12.*

This can most easily he done by placing a 1/16 in (1,6 mm) shim behind the end-plate and the faceplate on the lathe. This will provide the required 2° angle.

Make sure that the shim is placed on the correct side.

Alternatively, if a number of refacing operations are likely to be dealt with, a suitable face-plate can be made up for attaching to the lathe. This should have one side machined to the 2° angle, as shown in Fig. Q.13. The end-plate of the solenoid can then be secured to it, and the contacts skimmed.

In facing the "moving" contacts, it is essential to keep to a dimension within the limits 0.250 in to 0.247 in (6,35 to 6,27 mm), between the rear side of the back-plate and the contact face.

Finally, when the two contacts are assembled, the distance between them on the first step, should be accurately maintained at 0.071 in to 0.056 in (1,80 to 1,42 mm). To compensate, shims may be added under the "fixed" contacts, prior to machining.

## ASSEMBLING THE STARTER

1. Assemble the pole-shoes and field-coils and fix into yoke with the aid of a pole-shoe expander and a wheel operated screw-driver. Care should be taken not to trap the leatheroil (25) Fig. Q.9 beneath the pole-pieces. See that the screw holes in the field coils are in their correct position for connecting to the brush boxes and solenoid switch.

## ASSEMBLING SWITCH

1. Screw the solenoid into the drive end-shield. Check that the solenoid end-plate is flush against the drive end-shield shoulder, and paint insulating varnish at live points near to earth to prevent tracking.
2. See that the solenoid earth lead is attached to the "fixed" contact screw (59). (Note that in "insulated return" machines, this lead is taken to a different point, viz, one side of connecting link bracket).
3. Assemble solenoid terminal (46) in drive end-shield and connect the solenoid lead to it. Assemble the positive main terminal (47) In position, but do not tighten.
4. Assemble the moving contact onto the plunger and see that the contact spring is correctly and firmly located. Ensure that the second turn of the spring cannot jump over the first coil, by pushing the plunger through the moving contact assembly, until it is fully compressed.
5. Place the plunger return spring (14) in position. Oil the plunger by lightly smearing with Caltex Thuben 90 oil. Insert the assembled contact and plunger into the solenoid. As the plunger is inserted, its locating shoulders must pick up with the return spring.

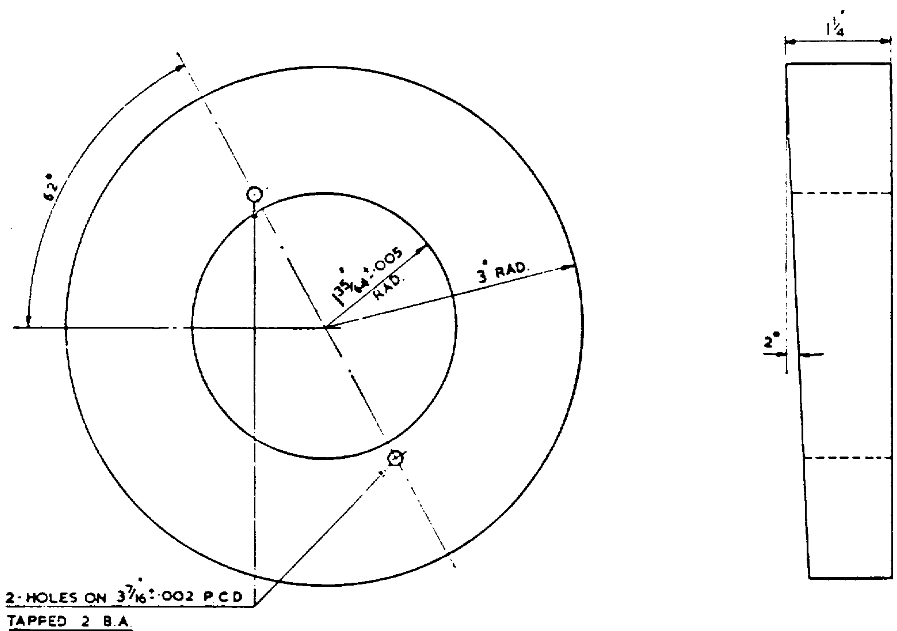



*Fig. Q.13. Face Plate.*

**ALTERNATIVE METHOD OF ASSEMBLY IN PLACE OF PARAGRAPH 3**

Assemble commutator shield, yoke, drive end and armature together temporarily without shims at the commutator end and measure distance between pinion face and flange with the shaft pushed towards the drive end. Dismantle starter and add shims inside commutator end shield on the shaft to give 1 in ± 0.002 in (47,63 ± 0.05 mm) between flywheel and starter flange face. Then assemble commutator end-shield and add shims on the shaft between commutator end shield and the shaft circlip so that the armature end float is 0.062 —0.072 in (1,57—1,83 mm). This gives the desired 1/16 in (1.6 mm) float on the armature assembly. A simple tool for this purpose is shown in Fig. Q.14. The measurement from the square base to the cross member is 1.877 in (47,68 mm) on one side and 1.900 in (48,26 mm) en the other, so that with feelers, the correct size shims can be ascertained.

**TEST PROCEDURE**

**TESTS ON COMPLETE STARTER**

1. **Ensure there is NO connection to the main terminal.**
2. Pull the pinion forward by hand, approximately 1/16 in (1,6 mm) and let go. The pinion should return to its original position.
3. Energize the solenoid, by means of a battery connected between the solenoid terminal (46) Fig. F.10 and the earth terminal on the commutator end-shield. The pinion must move forward 1 in (6,35 mm) minimum.
4. With the solenoid still energized, pull the pinion slowly forward by hand. The trip collar must act upon the trigger at least k in (3,18 mm) before the pinion reaches its stop. It is possible to feel this action taking place.
5. With the pinion at the end of its outward travel, the ball-lock device should now have come into operation, locking the pinion. There must be approximately 0.005 0.010 in (0,127 — 0,254 mm) play between the pinion and shaft stop.
6. Apply a spring load pressure of 30 lbf (13,6 kgf) to the pinion face, by means of a compression spring balance. The pinion must remain in the forward position.
7. Remove the solenoid connection. The pinion must now return to its normal position in one sharp movement.

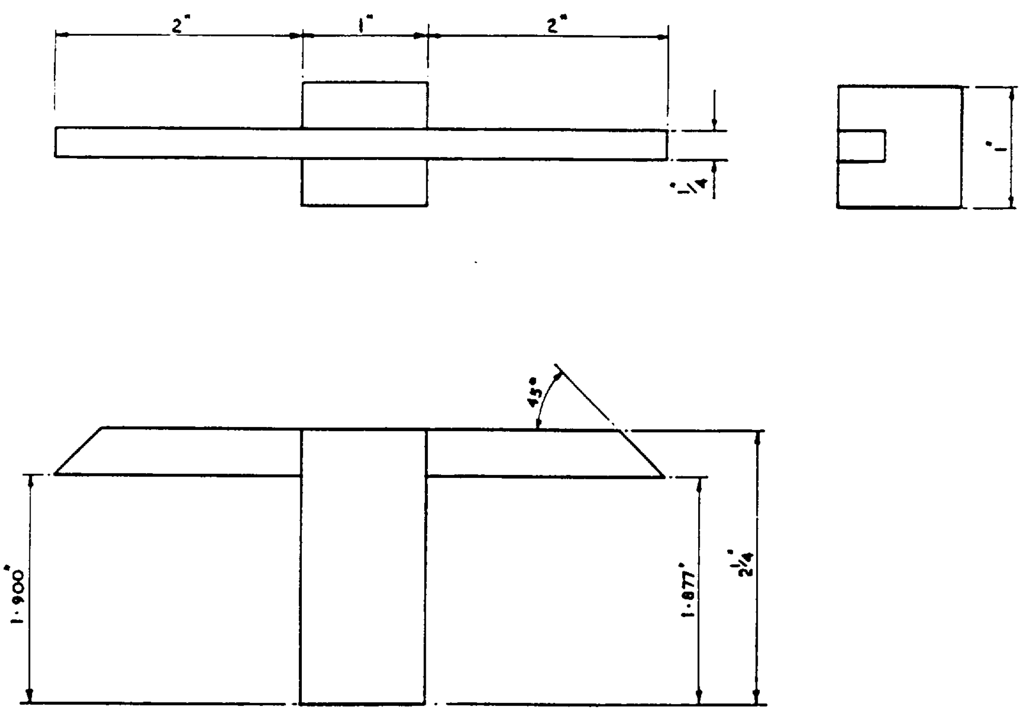



*FIG. Q.14.*

6. Thread the trigger (40) of the trip assembly, through the moving contact slot. Place the two fixing screws (57) into the trip support, press the plunger assembly downwards maintaining the pressure, whilst tightening the fixing screws.

7. Fix the contact stop-plate into position by means of the two screws (50). Secure the flexible resistance lead to the moving contact (52). **Ensure that the square-ended tag does not touch the back-plate**, and that the solenoid leads are outside this lead to prevent chafing.

8. Check that the plunger can he compressed at least 0.3125 in (7,94 mm) without the trip being released, and that the first contact makes between 0.057 in —0.081 in (1,45—2,06 mm) movement.

9. Insert the connecting link (48) between the positive terminal (47) and the fixed contact. Screw in the two screws (51) before tightening the positive terminal post (47).

## ASSEMBLING PINION

1. Unscrew and remove the oil-plug (7) and wick-spring. Push the wick temporarily out of the way to ensure free entry of the pinion sleeve.

2. Insert the pinion into the drive end-shield.

3. Fit the ball-lock collar (17) in place, with its spring, trip collar (19) and circlip. Ensure that the lock collar slides freely.

4. Using a medium grade grease, assemble the four steel balls (16) into the pinion-sleeve holes by inserting them through the sleeve bore. Press the balls firmly into the holes to allow free entry of the armature shaft.

## ASSEMBLING ARMATURE

1. When assembling the armature to the pinion, it should be noted that the helices are formed by a three start thread, and the correct thread must be selected so that the steel balls forming the lock will locate in the shaft recesses (39). To assist correct selection, both pinion and shaft ends have corresponding "pop" marks.
   Release the ball-lock by pulling the lock collar towards the commutator end and holding in this position push the pinion up to the shaft shoulder.

2. Assemble armature and drive end shield to yoke assembly, ensuring that dowel is correctly located.

3. Stand the above assembly vertical, with the flange resting on a support, and the pinion face resting on another support, 1 7/8 in ± 0.002 in lower (47,6 ± 0,051 mm). Place a straight-edge across the yoke face and build up with shims on shaft until a dimension of 0.285 in ± 0.020 in (7,24 ± 0,508 mm) between the commutator sleeve and the yoke face is obtained. This will give 1/16 in (1,6 mm) end movement of the shaft, when the commutator endshield is assembled.

4. Check that the commutator end-shield turns freely on the shaft and screw up the two through bolts (37).

5. If necessary, add shims between the commutator end-shield and the shaft circlip (31), to maintain a dimension of 1.872—1.877 in (47.55—47.68 mm), between the pinion nose (6A) and flange face (8B).

6. Place the shaft spring (36) in position, and insert the pad and ball. Replace the cover and clip into position. The end-shield should be stoned to remove any scoring etc., sustained in dismantling the end cover clip. Failure to do so, may result in damage to the sintered bronze bearing.

7. Complete the assembly by fitting brushes, field screws, pinion return-spring, stop, and shaft lock-nut.
   Screw the two cover-screws (55) into position, in the drive end-shield, and replace the commutator end cover-band accurately to exclude all dirt

8. Remove the shaft lock-nut, pinion stop, shim and spring. Pull the pinion forward about 1/4 in (6,35 mm).

9. Apply a spring load to the drive end of the shaft. The spring at the commutator end must start to compress between 13—19 lbf (5,9 to 8,6 kgf), reading to 19—25 lbf (8,611,34 kgf), after 1/16 in (1,6 mm) movement.

10. Replace shaft nuts, shim and spring.

**PERFORMANCE TESTS**

1. Brushes to be bedded over at least 75% of their area.

2. Fit the starter to a special flywheel rig and connect the power supply.

3. With a supply of 10 volts only, check that the starter fully engages with the flywheel.

4. With a 12 volts supply circuit, complete five operations under each of the following conditions, on a locked flywheel.
   (a) Distance between flywheel and pinion set at 0.068 in (1,73 mm).
   (b) Distance between flywheel and pinion set at 0.196 in (4.98 mm).

**PERFORMANCE FIGURES**

The figures obtained must be within the following limits.

1. Typical Lock Torque: 36.5 lbf ft (5 kgf m) with 950-1050 A at 6.0 V.

2. Typical Torque at 1250 -1300 rev/min: 12 lbf ft (1,7 kgf m) with 420 480 A at 9.5 V.

3. Typical Light Running Current: 100-120 A at 7,000 rev/min.

**INSULATION TEST**

1. Using a 500v megger, the following tests should show an insulation resistance of not less than I megohm.

2. Lift earth brushes and check the main terminal to earth.

3. With earth brushes still raised, check the positive brush to earth.

**Insulated Return Electrical System**

With this system, the thermostart starting aid is insulated from the induction manifold by an insulated "BLOCK" bush. When a thermostart unit or insulating bush is replaced, care must be taken not to exceed the torque figure quoted on Page B.1. Overtightening of these parts can crack the insulating bush and could cause hard starting and an electrical short.

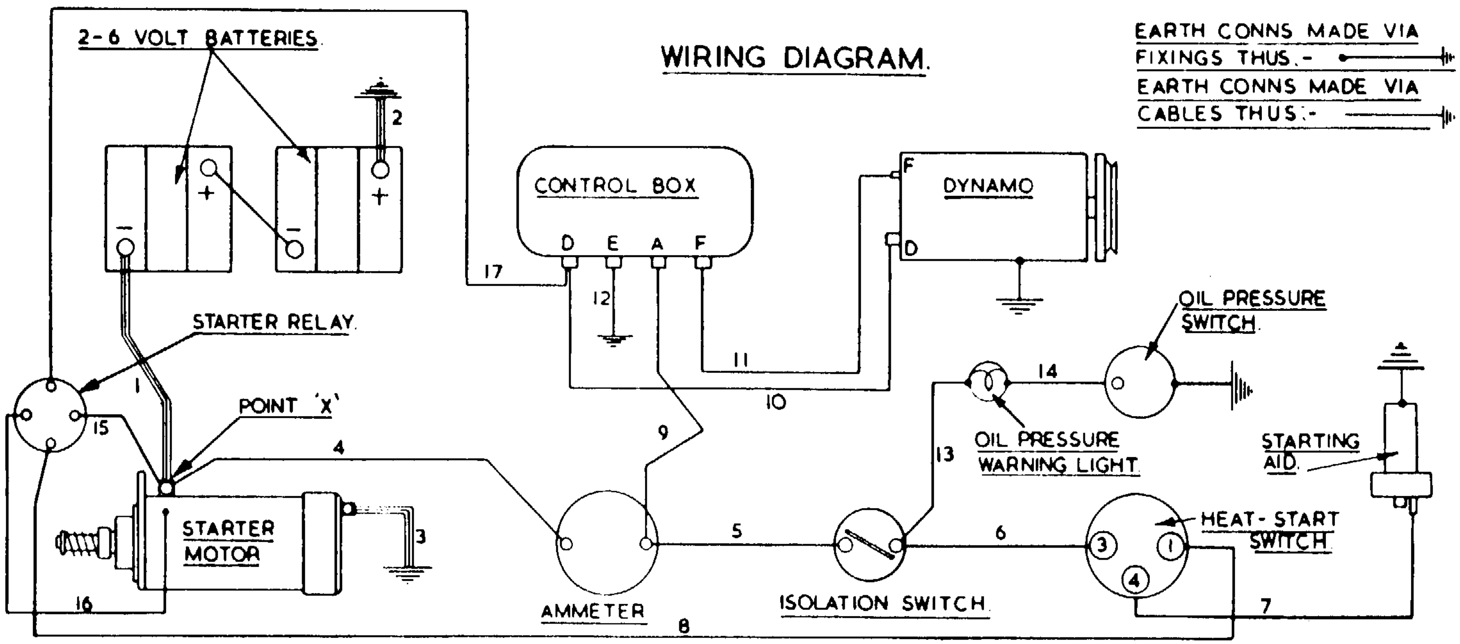



*Fig. Q.15. Typical Wiring Diagram.*
*(incorporating dynamo)*

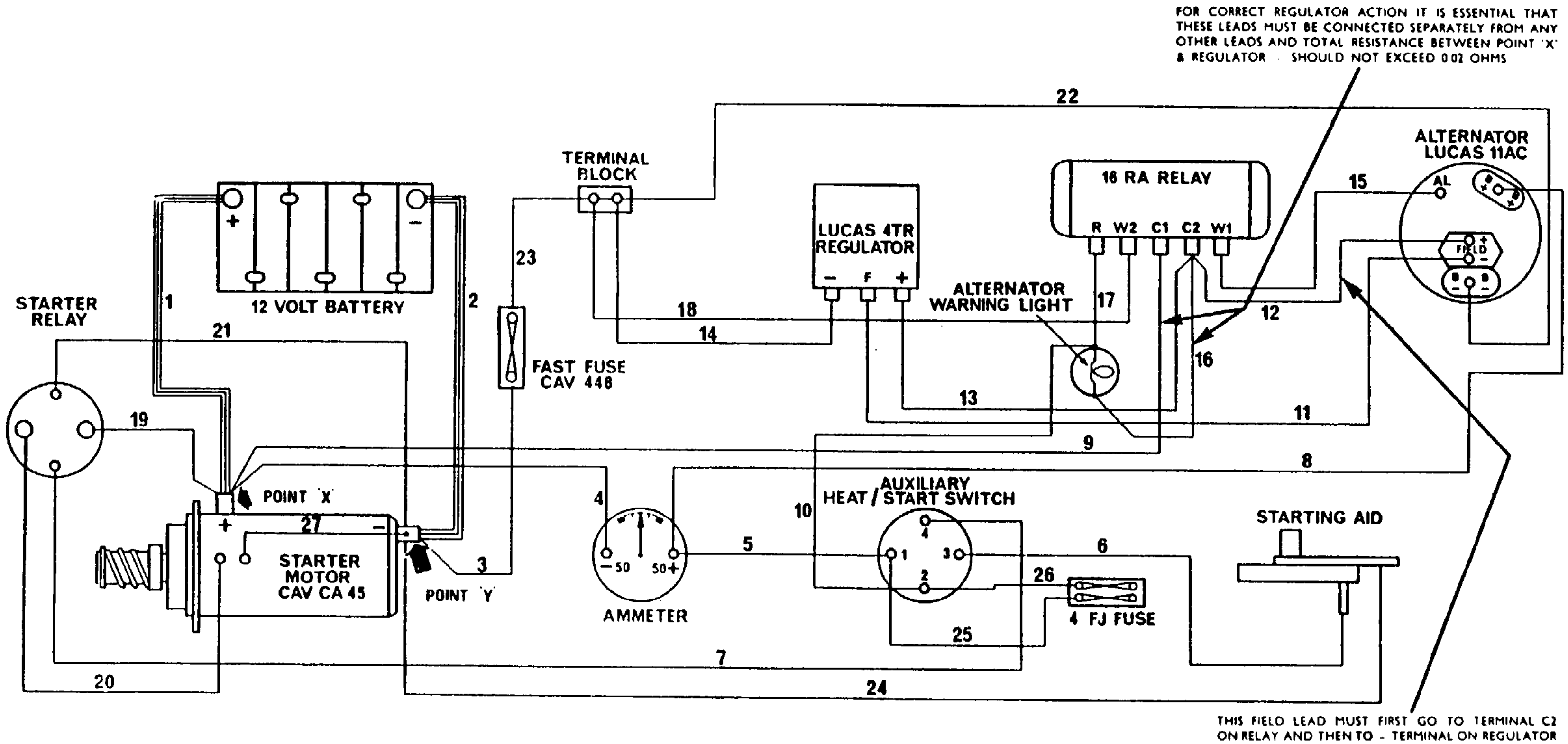



*Fig. Q.16.*
*Typical Wiring Diagram.*
*(incorporating alternator).*

## LUBRICATING OILS

Lubricating oils should meet the requirements of the U.S. Ordnance Specifications MIL-L-46152 or MIL-L-2104C. The lubricating oils for use in Perkins Diesel engines should have a **minimum** Viscosity Index of 80.

**Note:**

**Operators are advised not to use a lubricating oil to the MIL-L-T104C specification in 4.236 marine engines for the first 25/50 hours of operation.**

Some of these oils are listed below and on next page but any other oils which meet these specifications are also suitable.

### MIL-L-46152 Oils

| Company | Brand | S.A.E. Designation | | |
|---|---|---|---|---|
| | | 0°F (-18°C) to 30°F (-1°C) | 30°F (-1°C) to 80°F (27°C) | Over 80° F (27°C) |
| **B.P. Ltd.** | Vanellus M | 10W | 20W | 30 |
| | Vanellus M | | 20W/50 | 20W/50 |
| **Castrol Ltd.** | Castrol/Deusol CRX | 10W | 20 | 30 |
| | Castrol/Deusol CRX | 10W/30 | 10W/30 | 10W/30 |
| | Castrol/Deusol CRX | | 20W/50 | 20W/50 |
| | Deusol RX Super | | 20W/40 | 20W/40 |
| **A. Duckham & Co. Ltd.** | Fleetol HDX | 10 | 20 | 30 |
| | Fleetol Multi V | | 20W/50 | 20W/50 |
| | Fleetol Multilite | 10W/30 | 10W/30 | 10W/30 |
| | Farmadcol HDX | | 20 | 30 |
| | Hypergrade | | 15W/50 | 15W/50 |
| | Fleetmaster | | 15W/40 | 15W/40 |
| **Esso Petroleum Co. Ltd.** | Essolube XD-3 | 10W | 20W | 30 |
| | Essolube XD-3 | | 15W/40 | 15W/40 |
| **Mobil Oil Co. Ltd.** | Delvac 1200 Series | 1210 | 1220 | 1230 |
| | Delvac Special | 10W/30 | 10W/30 | 10W/30 |
| **Shell** | Rimula X | 10W | 20W/20 | 30 |
| | Rimula X | 10W/30 | 10W/30 | 10W/30 |
| | Rimula X | | 15W/40 | 15W/40 |
| | Rimula X | | 20W/40 | 20W/40 |
| | Rotella TX | 10W | 20W/2G | 30 |
| | Rotella TX | | 20W/40 | 20W/40 |
| **Total Oil Co. Ltd.** | Total Super HD | | 20W/20 | 30 |
| | Total HD2-M | 10W/30 | 20W/40 | 20W/50 |
| | Total HD3-C (Rubia S) | 10W | 20W/20 | 30 |
| | Total HD3-C (Rubia TM) | | 15W/40 | 15W/40 |
| | Total Universal Tractor Oil (Multagri) | | 20W/30 | 20W/30 |
| | Total Super Universal Tractor Oil (Multagri TM) | | 20W/30 | 20W/30 |

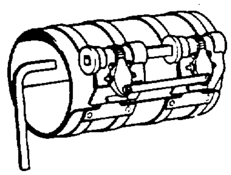
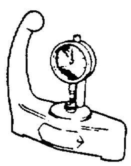
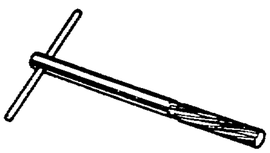
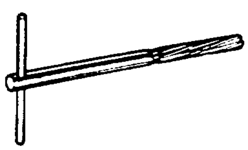
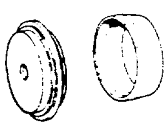
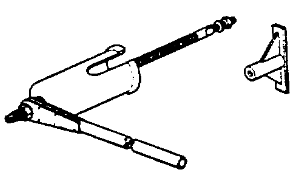
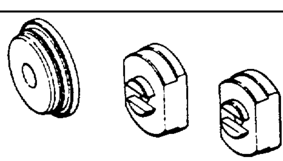
**MIL-L-2104C Oils**

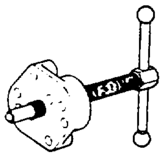
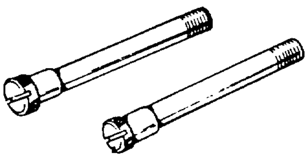
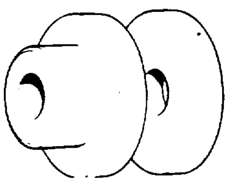
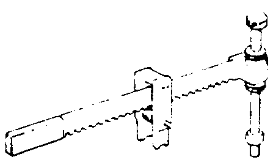
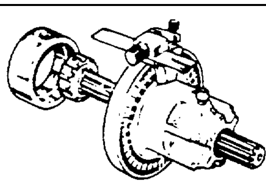
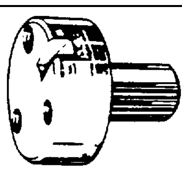
| Company | Brand | S.A.E. Designation | | |
|---|---|---|---|---|
| | | 0°F (-18°C) to 30°F (-1°C) | 30°F (-1°C) to 80°F (27°C) | Over 80° F (27°C) |
| **B.P. Ltd.** | Vanellus C3 | 10W | 20W/20 | 30 |
| **Castrol Ltd.** | Castrol/Deusol CRD | 10W | 20 | 30 |
| | Deusol RX Super | | 20W/40 | 20W/40 |
| | Agricastrol HDD | 10W | 20 | 30 |
| | Agricastrol MP | | 20W/30 | 20W/30 |
| | Agricastrol MP | | 20W/40 | 20W/40 |
| **A. Duckham & Co. Ltd.** | Fleetol 3 | 3/10 | 3/20 | 3/30 |
| | Farmadcol 3 | 3/10 | 3/20 | 3/30 |
| | Hypergrade | | 15W/50 | 15W/50 |
| | Fleetmaster | | 15W/40 | 15W/40 |
| **Esso Petroleum Co. Ltd.** | Essolube D-3HP | 10W | 20W | 30 |
| | Essolube XD-3 | 10W | 20W | 30 |
| | Essolube XD-3 | | 15W/40 | 15W/40 |
| **Mobil Oil Co. Ltd.** | Delvac 1300 Series | 1310 | 1320 | 1330 |
| **Shell** | Rimula CT | 10W | 20W/20 | 30 |
| | Rimula X | 10W | 20W/20 | 30 |
| | Rimula X | 10W/30 | 10W/30 | 10W/30 |
| | Rimula X | | 15W/40 | 15W/40 |
| | Rimula X | | 20W/40 | 20W/40 |
| | Rotella TX | 10W | 20W/20 | 30 |
| | Rotella TX | | 20W/40 | 20W/40 |
| **Total Oil Co. Ltd.** | Total HD3-C (Rubia S) | 10W | 20W/20 | 30 |
| | Total HD3-C (Rubia TM) | | 15W/40 | 15W/40 |
| | Total Super Universal Tractor Oil (Multagri TM) | | 20W/30 | 20W/30 |

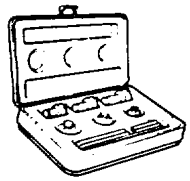
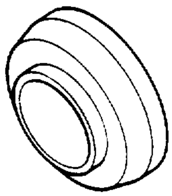
**The above specifications are subject to alteration without notice.**

**APPROVED SERVICE TOOLS**

Available from V. L. Churchill & Co. Ltd., Daventry, Northamptonshire, NN11 4NF, England.

| | Tool No. | Description |
|---|---|---|
|  | No. 8 | PISTON RING SQUEEZER |
|  | PD.418 | PISTON HEIGHT AND VALVE HEIGHT GAUGE<br>A simple method of quickly checking piston height and valve depth. |
|  | PD.137 | VALVE GUIDE REAMER<br>.015" o/size. |
|  | PD.138 | VALVE GUIDE REAMER<br>.030" o/size. |
|  | PD.145 | CRANKSHAFT REAR OIL SEAL REPLACER ADAPTOR<br>(LIP TYPE SEAL) |
|  | PD.150A | CYLINDER LINER REMOVER/ REPLACER (MAIN TOOL)<br>For Field Service replacement of single liners. Not advised for complete overhaul. For this work use adaptors with a hydraulic ram unit. |
|  | PD.150-1B | ADAPTORS FOR PD.150<br>Suitable for cylinders of 3.6" dia. and 3.87" dia. Removal and replacement. |

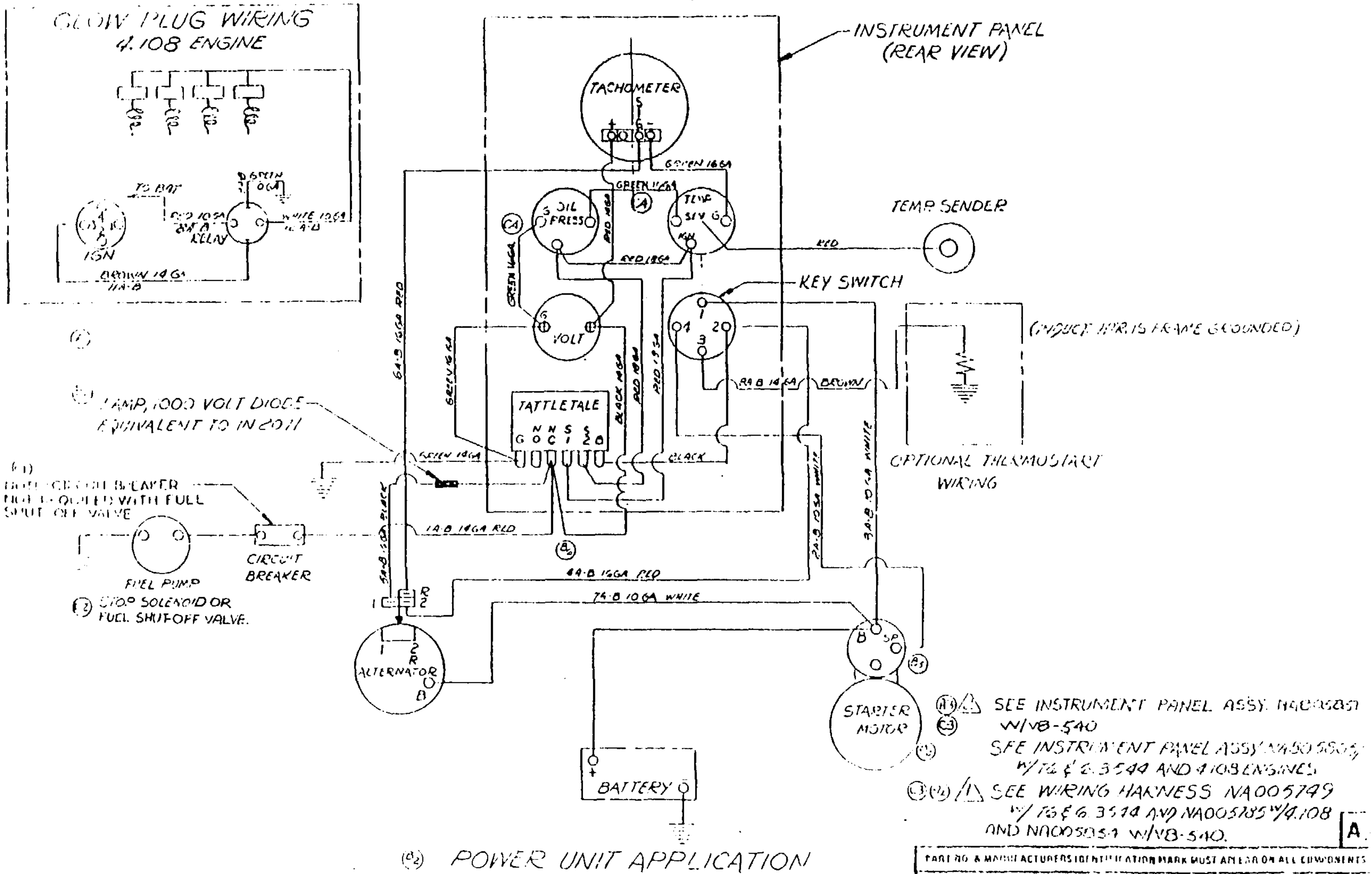
| | Tool No. | Description |
|---|---|---|
|  | 155B | BASIC PULLER<br>The cruciform head with multiple holes at different centres is used with adaptors listed below. |
|  | PD 155-1 | ADAPTORS FOR PD.155B<br>Used to remove water pump pulleys<br>Also suitable to remove Camshaft Gears. |
|  | 335 | CON ROD JIG & 336 MASTER ARBOR |
|  | 336-102 | ARBOR ADAPTOR<br>Used with 335. |
|  | 6118B | VALVE SPRING COMPRESSOR |
|  | PD.6118-4 | ADAPTOR FOR 6118B |
|  | MS.67B | TOOL FOR CHECKING FUEL INJECTION PUMP TIMING |
|  | PD.67B-1 | ADAPTOR FOR USE WITH MS.67B |

| | Tool No. | Description |
|---|---|---|
|  | MS.73 | VALVE SEAT CUTTERS<br>(For 45° Seats) |
|  | PD.162 | TIMING CASE COVER CENTRALIZING<br>TOOL |

HOLE CENTERS & PITCH CIRCLE DIAMETERS TO BE WITHIN ± 0,2 [0.008].
TOLERANCES ON MACHINED DIMENSIONS TO ± 0, 4 [0.010] UNLESS OTHERWISE SPECIFIED.
ALL FILLETS AND ROUNDS TO BE 3 [0.12] R UNLESS OTHERWISE SPECIFIED.
ANGULAR TOLERANCES TO BE ± 0° 30' UNLESS OTHERWISE SPECIFIED.
ALL DIMENSIONS IN MM [IN.].

REMOVE ALL BURRS & SHARP CORNERS

| | |
|---|---|
| ALTERATION NO. | A |
| ALTERATION NO. 2461 SEE OCT REVISIONS | B |
| ALTERATION NO. [illegible] | C |
| ALTERATION NO. | D |
| ALTERATION NO. | E |
| ALTERATION NO. | F |
| ALTERATION NO. | G |




WIRING DIAGRAM

INDUSTRIAL/MARINE APPLICATION

SHEET 1 of 3

SCALE: NONE

TD

A

PERKINS-WAYNE

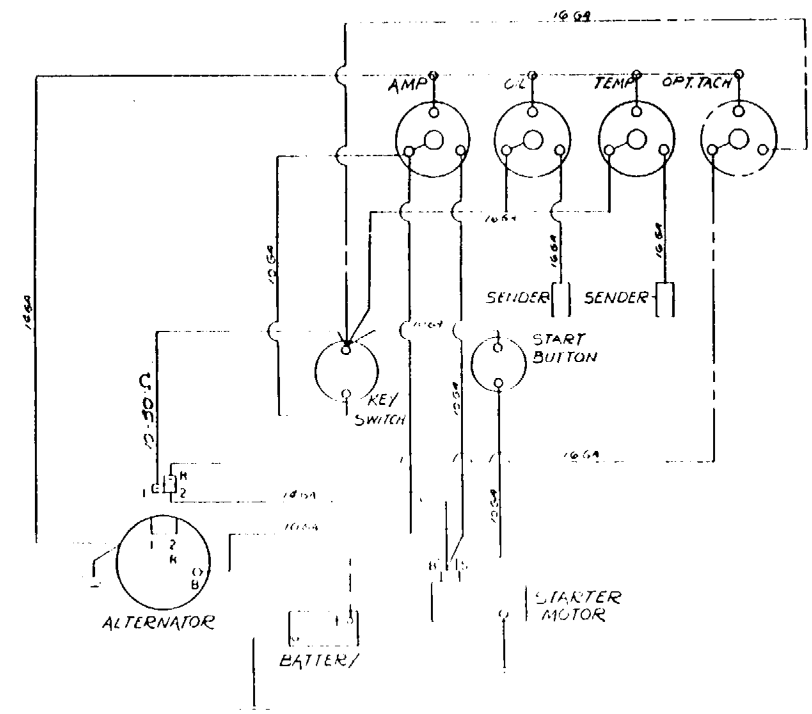
| ALTERATION NO. | A |
|---|---|
| ALTERATION NO. | B |
| ALTERATION NO. | C |
| ALTERATION NO. | D |
| ALTERATION NO. | E |
| ALTERATION NO. | F |
| ALTERATION NO. | G |

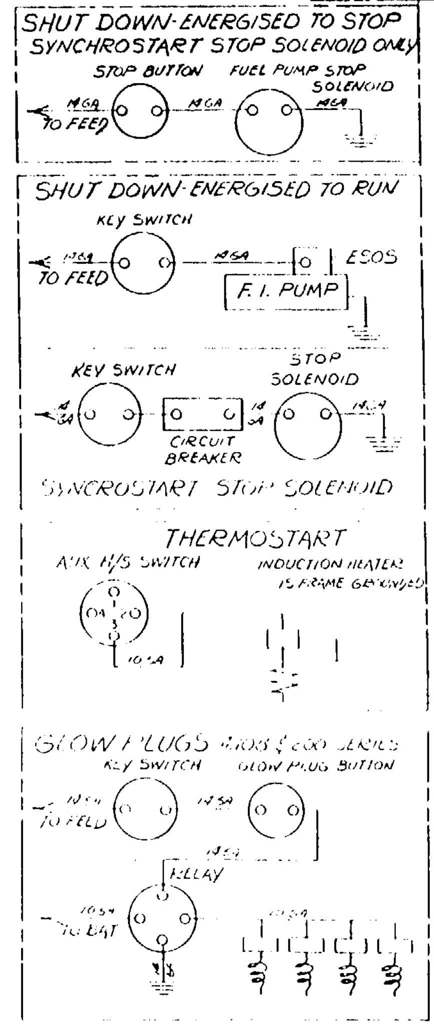
DRAWING NOT TO BE SCALED

INCH
M/M

HOLE CENTERS & PITCH CIRCLE DIAMETERS TO BE WITHIN ± 0,2 (0.008).
TOLERANCES ON MACHINED DIMENSIONS TO ± 0,4 (0.016) UNLESS OTHERWISE SPECIFIED.
ALL FILLETS AND ROUNDS TO BE 3 (0.12) R UNLESS OTHERWISE SPECIFIED.
ANGULAR TOLERANCES TO BE ± 0° 30' UNLESS OTHERWISE SPECIFIED.
ALL DIMENSIONS IN MM (IN.).

REMOVE ALL BURRS & SHARP CORNERS




GENERAL INDUSTRIAL APPLICATION



| | | |
|---|---|---|
| APPROVED FOR PROD | | 7-27-83 |
| DRAWN | RLR | 7-27-83 |
| CHECKED | AM | 7-26-83 |
| QC | | |
| APPL | JWS | 7-26-83 |

SURFACE TEXTURE SPECIFICATION TO ANSI - B46.1
∇ - MACHINE

FIRST USED ON -
INTRODUCTORY ALT - DCP 2461
SCALE - NONE
THIRD ANGLE PROJECTION

WIRING DIAGRAM
INDUSTRIAL/MARINE APPLICATIONS

SHEET 2 of 3

A2

PART NO & MANUFACTURERS IDENTIFICATION MARK MUST APPEAR ON ALL COMPONENTS

MATERIAL

TD

PRO NO

PART NO NA005750

# PERKINS-WAYNE

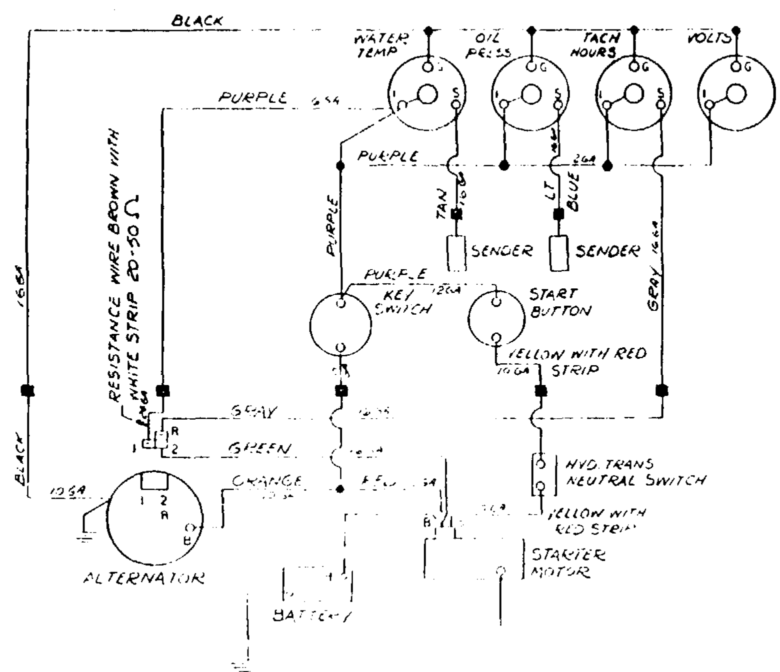
| ALTERATION NO. | |
|---|---|
| | A |
| | B |
| | C |
| | D |
| | E |
| | F |
| | G |

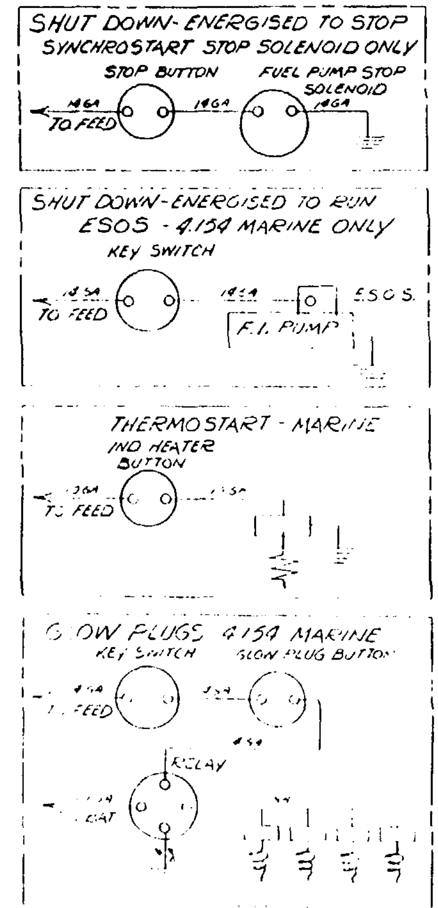
**DRAWING NOT TO BE SCALED**

INCH
M/M

HOLE CENTERS & PITCH CIRCLE DIAMETERS TO BE WITHIN ± 0,2 (0.008).
TOLERANCES ON MACHINED DIMENSIONS TO ± 0, 4 (0.016) UNLESS OTHERWISE SPECIFIED.
ALL FILLETS AND ROUNDS TO BE 3 (0.12)R UNLESS OTHERWISE SPECIFIED.
ANGULAR TOLERANCES TO BE ± 0° 30' UNLESS OTHERWISE SPECIFIED.
ALL DIMENSIONS IN MM (IN.).

**REMOVE ALL BURRS & SHARP CORNERS**




NOTE - - - - - NOT SUPPLIED BY PEI

■ PIN CONNECTORS
MALE FOR SINGLE PANEL NA004844
FEMALE FOR DUAL PANEL NA004843
USE WITH HARNESS'S
NA004854 - 4.108 (M) ENGINE
NA004855 - 4.236 (M) ENGINE

MARINE APPLICATION

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© PERKINS ENGINES INC

| | | |
|---|---|---|
| APPROVED FOR PROD | | |
| DRAWN | RLR | |
| CHECKED | RM | |
| QC | | |
| APPL | | |

SURFACE TEXTURE SPECIFICATION TO ANSI - B46.1
√ = MACHINE

FIRST USED ON
INTRODUCTORY ALT - DCP 2461
SCALE - NONE
THIRD ANGLE PROJECTION

WIRING DIAGRAM
INDUSTRIAL/MARINE APPLICATIONS

SHEET 3 of 3

A

PART NO & MANUFACTURERS IDENTIFICATION MARK MUST APPEAR ON ALL COMPONENTS

MATERIAL

TD
PRO NO
PART NO NAQ 50

## EXAMPLES OF SERVICE FACILITIES

### Service Publications

The following Service Literature may be purchased through your local Perkins Distributor.

Workshop Manuals

Operators Handbooks

Crankshaft Regrinding

Fault Finding Guide

Engine Brake Testing Data

Installation and Maintenance Guide for Static Standby Engines

Etcetera

### Service Instruction

**Perkins Engines, Inc.**
32500 Van Born Road
P.O. Box 697 • Wayne, Michigan 48184 • U.S.A.
Tel.. (313) 595-9600 • Telex: 23-4002

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**GENUINE**

**PERKINS PARTS**

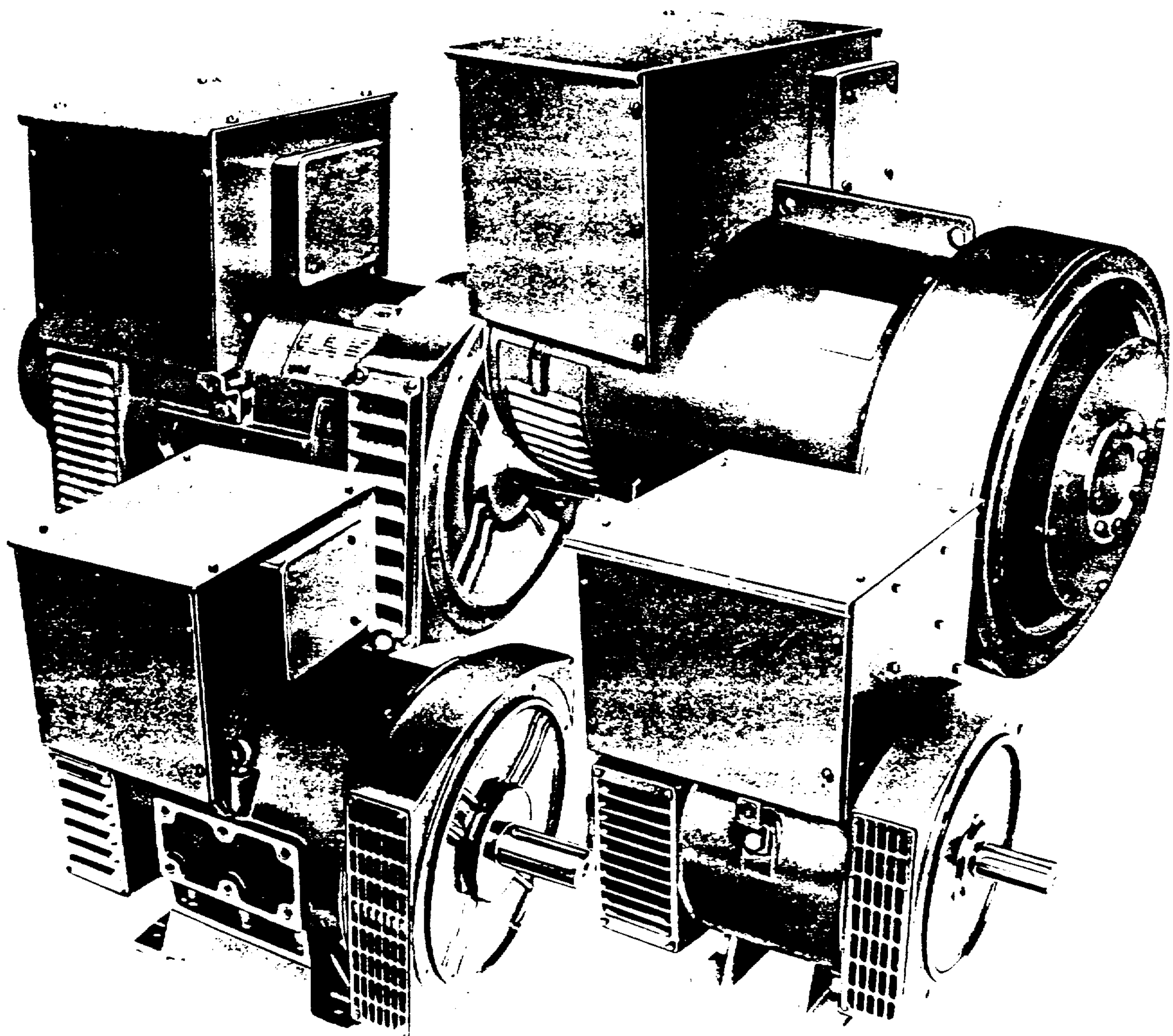
**To ensure you obtain the best results from your engine and to safeguard your own guarantee, fit only genuine Perkins Parts. These are readily obtainable throughout the world.**

## INDEX

'C' Range

NEWAGE STAMFORD

**FRAMES 1,2 &3**
**Series 4 A.V.R. Controlled**
**Operation & Maintenance Manual**
**Machine Designations-**
**PC164**
**SC and MSC 144, 244,344**



**Publication No. 1H - 059 1st Edition**

# CONTENTS

## SECTION ONE

## GENERAL DESCRIPTION

The Stamford 'C' range a.c. generator is a brushless, revolving field high performance machine. The frame sizes covered in this book are fitted with Series 4 excitation system on SC1 - 3 frame sizes and Series 6 excitation system on PC1 frame size. The machines are. 4 pole, A.V.R. controlled with a broad operating voltage range and with a 12 wire reconnectable facility. The standard windings listed below cover most world voltages.

| WDG. No. | FREQ | SERIES STAR | PARALLEL STAR | SERIES DELTA | SERIES ZIG-ZAG STAR | PARALLEL ZIG-ZAG | REMARKS |
|---|---|---|---|---|---|---|---|
| | | 3 ph. 4W. | 3 ph. 4W. | 3 ph. 4W.<br>1 ph. 2W. | 3 ph. | 1 ph 3W | |
| 211 | 50 | *380-415 | 190-208 | 220-240 | --- | 220-240 | 12W-Reconnectable |
| | 60 | *440- 480 | *220 -240 | 254 -277 | 380-415 | 240** | |
| 17 | 50 | 440-500 | 220-250 | --- | 380-415 | --- | 12W Reconnectable |
| | 60 | 550 - 600 | --- | --- | 460 - 480 | --- | |
| 19 | 50 | 415 460 | 210 - 230 | 240 - 266 | 360 -400 | 240 - 266 | 12W Reconnectable |
| | 60 | --- | --- | --- | 430480 | --- | |

**NOTES: 1. * To operate at 346 Volts 50 Hz, 416 Volts 60 Hz in Series Star or 208 Volts 60 Hz in Parallel Star de-rate machine output to 0.93.**
****· To operate at 240 Volts 60 Hz in Parallel Zig-Zag de-rate machine output to 0.9.**

**2. For windings 211 and 17 when connected Series Zig-Zag Star the machine output must be de-rated to 0.87.**

### MACHINE DESIGNATION

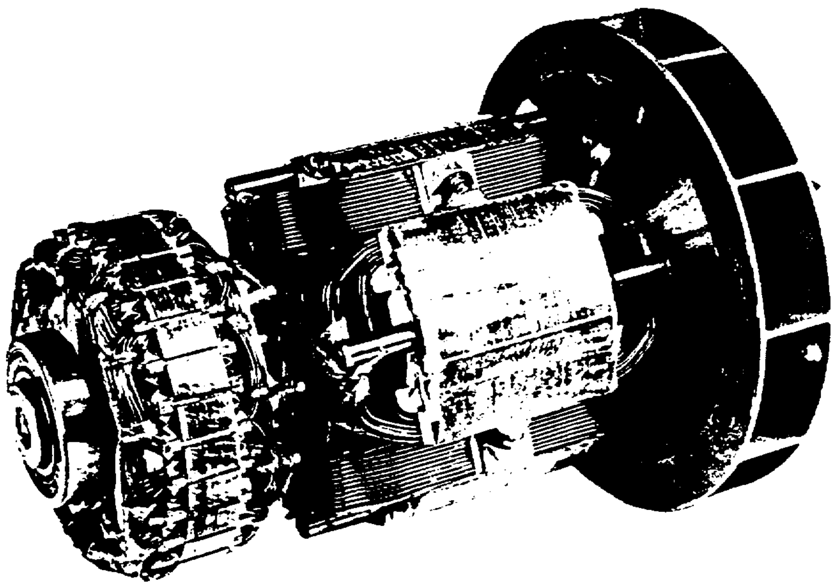
To facilitate identification, a simple coded system is used comprising letters and numbers. For example an industrial machine with a designation SC1440 would be identified as follows: The first letter ('S') indicates the series of machines and the second letter ('C') the range. The first number (1) indicates the frame, the second number (4) the excitation system and the third number (4) the number of poles. The letter ('D') after the numbers indicates the core length. For marine machines, the designation is prefixed by the letter 'M' (e.g.MSC144D).

### CONSTRUCTION

The machines are ventilated, screen protected and drip proof to BS4999 Part 20 and can be in either single or two bearing form. All machines are based around a cast or fabricated frame and cast iron endbrackets with a large sheet metal terminal box mounted at the non-drive end.

The stator/rotor core is produced from low loss electrical grade sheet steel laminations, which are jig built and welded under a fixed pressure to give an extremely rigid core to withstand vibration and load impulses The completed wound components are all insulated and impregnated to Class H limits.

A high grade precision machined shaft carries the rotor assembly which comprises the generator rotating field system, incorporating a fully interconnected damper winding, the exciter rotor/rotating rectifier system and cooling fan. The rotor is mechanically wedged and supported on the end winding to allow an overspeed of up to 2250 rev/min. On completion the whole rotor assembly, is dynamically balanced to within precision limits to ensure vibration-free running. The photograph below shows the complete assembly.



**Typical 4 Pole Rotor**

The rotor is supported by liberally rated, sealed for life ball bearings.,

Depending on output and frame size the exciter can be mounted internally or externally to the N.D.E. bearing.

The A.V.R. is mounted from the front panel (D.E.) of the terminal box.

Removable access covers are provided at the D.E. and N.D.E. of the machine. Both side panels and top panel are removable on the terminal box to provide easy access to the output terminals and other ancillary equipment.

## SECTION TWO

## INSTALLATION

### HEALTH AND SAFETY NOTE

**Important**

**British Government Health and Safety at Work Act, 1974**

In view of the above Act it is necessary to draw your attention to the following.

On adaptors/flanges fitted between the a.c. generator and engine the openings must be guarded. Where integral guards are not provided an external protection cover must be fitted.

All a.c. generators are designed with screen protected and drip proof enclosures and as such are not suitable for mounting outdoors unless adequately protected by the use of canopies.

### VENTILATION

When installed in a room without special ventilation arrangements it must be ensured that the ambient temperature of the normal operating conditions does not exceed the maximum value for which the machines are designed. (Normally a maximum of 40ºC). Heat dissipation and cooling air requirements are available on request.

### INITIAL CHECKS

If it is necessary to store the machine for long periods, the storage accommodation should be clean, dry and well ventilated. We would recommend the use of anti-condensation heaters to ensure that winding insulation is kept in a good condition where machines are stationary for long periods, i.e. standby plant. Before installation of an a.c. generator which has been kept in storage the insulation resistance of the windings should be checked using a megger or similar instrument. It is essential that the automatic voltage regulator (A.V.R.) is completely isolated before testing, otherwise damage to the electronic components may be sustained. If radio interference suppression capacitors have been fitted in the terminal box these should also be disconnected. If the tests show that the insulation resistance is below 0.5 of a megohm, the machine should be dried out and the test made again. With a completely dry machine the resistance value should be at least 2 megohms. The machine windings can be dried out by applying warm air from a fan heater or similar apparatus into the machine openings. Alternatively, the main stator windings may be short circuited, and the generating set run with the exciter stator supplied from a d.c. source. A 12 volt 0.5 amo d.c. supply should be connected to the exciter stator leads, marked X and XX

Normally no longer than half an hour will be required for drying out windings in this manner. After this period of time the insulation level should be checked and the drying out Procedure repeated if necessary.

### VOLTAGE ADJUSTMENT

As the machines are offered for a broad operating voltage range it may be necessary to adjust the factory set voltage to meet individual requirements and this should be carried out as follows.-

1. Remove A.V.R. box lid (SC type) or terminal box lid (PC type).
2. Adjust VOLTAGE RANGE control to required voltage.
3. Adjust STABILITY CONTROL **(only if necessary)** until stable operation is obtained 'ON and 'OFF' load. (Turning control clockwise increases A.V.R. 'gain').

If a hand trimmer has been supplied for remote voltage control, fine adjustment to the nominal voltage level set by the RANGE control can be made. (See page 31 for details).

### UNDER FREQUENCY PROTECTION ADJUSTMENT

This is set for 50 Hz or 60 Hz operation by means of a "JUMPER" lead on the A.V.R.

## EARTHING ARRANGEMENT

On all star connected machines a substantial neutral terminal is provided for connection to the distribution network. This is not connected to the frame of the machine. The a.c. generator frame should, however, be solidly earthed to the generating set bedplate and connected to the common system earth. On generating sets used for mains failure standby special earthing arrangements may be necessary and the local area Electricity Authority or Company should be consulted.

## DIRECTION OF ROTATION

All machines are fitted with a radial bladed fan and are suitable for running in either direction of rotation. The standard machine is supplied to give a phase sequence U.V.W. with the machine running clockwise looking at the drive end unless otherwise specified at the time of ordering. If machine rotation is reversed after the machine has been dispatched apply to factory for appropriate instructions and wiring diagrams.

## MAIN TERMINAL ARRANGEMENT

The main output terminals have been designed to accept cables rated in accordance with normal standard specifications for single or multicore cables, and are based on the use of crimped-type cable terminations.

**Frame PC1** - The terminal arrangement consists of 4, M6 dia. stud terminals
**SC1** - The terminal arrangement consists of 4, M6 dia. stud terminals
**SC2** - The terminal arrangement consists of 4, M10 dia. stud terminals
**SC3** - The terminal arrangement consists of 4, M12 dia. stud terminals

In all cases the 4 output terminals are marked U.V.W. and N.

## A.C. GENERATOR TO ENGINE ASSEMBLY

### Torsional Vibration

Torsional vibrations occur in all engine driven shaft systems and may be of a magnitude to cause damage at certain critical speeds. It is therefore necessary to consider the torsional vibration effect on the a.c. generator shaft and couplings. It is the responsibility of the generator set manufacturer to ensure comparability, and for this purpose drawings showing the shaft dimensions, coupling details and rotor inertias are available for customers to forward to the engine supplier.

### Two Bearing Machines

It is beyond the scope of this publication to give guidance on ways and means of a.c. generator installation in great depth due to the many different designs of generating sets and engine configurations. However, it is recommended that the engine/a.c. generator is mounted on a substantial steel bedplate with machined cads to ensure accurate engine/a.c. generator alignment. Where machine faces cannot be accurately achieved, it is necessary to fit shims under the engine/a.c. generator feet to ensure alignment and avoid vibration.

If flexible mountings are used under the bedplate and their position is far removed from the corresponding engine/ a.c. generator feet, a rigid bedplate becomes essential otherwise distortion during running will disturb the alignment or possibly create vibration.

### Couplings

A good quality flexible coupling should be fitted and alignment carefully checked, preferably in accordance with the coupling manufacturers' recommendation, to avoid excessive shaft and bearing stresses. In addition a flexible coupling will ensure that in the majority of cases torsional vibration problems will not arise.

Normally machines of this size are flexibly coupled. However, if belt drives are required full details of the drive, belt size and pulley dimensions should be forwarded to ensure bearing loadings and shaft stresses are not excessive.

**Single Bearing Machines**

Alignment of single bearing a.c. generators is critical. If necessary, shims should be fitted under the feet to counteract any irregularities in the mounting surfaces.

If there is any doubt about the alignment, the covers at the none-drive end should be removed and the air gap checked with long feeler gauges to ensure uniformity around the periphery of the rotor.

**Assembly to Engines**

The sequence of assembly to the engines should generally be as follows:-

1. Check on engine distance from the flywheel/coupling mating face to engine flywheel housing face. This should be within ± 0.5 mm of nominal dimension. This is necessary to ensure that the a.c. generator bearing does not thrust against the bearing caps.

2. Check that the bolts securing the flexible plates to the shaft hub are tight and locked into position. Torque tightening is as follows:-

   PC1 Bolt size M10. Torque tighten to 5.7 kgf-m (56N-m) (41lbf-ft)
   SC1 Bolt size M12. Torque tighten to 10 kgf-m (98N-m) (721bf-ft)
   SC2/3 Bolt size M16. Torque tighten to 25 kgf-m (244N-m) (1801bf-ft)

3. Remove drive end a.c. generator covers for access to coupling and adaptor bolts.

4. Check that coupling discs are central with adaptor spigot. This can be adjusted by the tapered wooden wedges supplied between the fan and adaptor for transit reasons; Alternatively the rotor can be suspended by means of a rope sling through the adaptor opening.

5. Offer the a.c. generator to engine and engage both flexible plates and housing spigots at the same time, finally pulling home by using the housing and coupling bolts.

6. Tighten coupling to flywheel bolts.

7. Remove wooden wedges and replace covers.

8. Run the machine up to speed and check for excessive vibration.

**CAUTION NOTE: When dismantling a.c. generator from the engine, care should be taken to ensure that the rotor is positioned with a pole at the bottom center line. This is to avoid any damage to the bearing or exciter by limiting the rotor movement to that of the air-gap.**

## SECTION THREE

## OPERATION OF THE MACHINE

### OPERATION

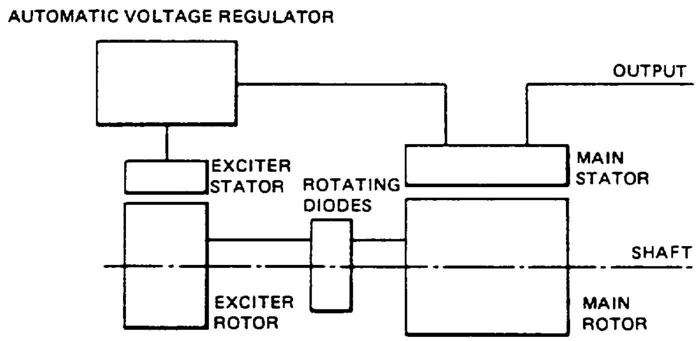



*Fig. 1. Block Diagram of Excitation System*

The block diagram above indicates the main electrical components and basic interconnections.

The control system is based on the main stator winding providing excitation power via the automatic voltage regulator (A.V.R.) to the main exciter. Residual magnetism of the machine is utilized via a circuit within the A.V.R. to provide a positive voltage build up. A reference signal is fed into the A.V.R. from the main stator through a high source impedance which is rectified and smoothed to maintain the voltage regulation to within fine limits. The main exciter output is fed into the main rotor windings via a rotating 3 phase bridge rectifier unit incorporating a surge suppressor to protect the diodes against voltage transients during heavy load surges, i.e. short circuits or out of phase paralleling.

A frequency sensitive circuit is incorporated into the A.V.R. which functions only when the shaft speed falls below approximately 90% of the rated speed. The voltage then reduces proportionally to any further reduction in speed, thus assisting the prime mover to recover after the application of high starting torque motor loads or high kilowatt load changes. This also provides low speed protection to the main rotor by ensuring the excitation does not exceed the safe operating level at all speeds.

### PERFORMANCE

#### Voltage regulation

Voltage regulation is maintained within the limits of **±2%** from no load to full load including cold to hot variations at any power factor between 0.8 lagging and unity and inclusive of a speed variation of 41/2%. If Current Sensing Kit supplied (for improved regulation of **±1%** ) see Section Six accessories.

#### Waveform Distortion, TH F and TI F Factors

The total distortion of the voltage waveform with open circuit between phases or between phases and neutral is in the order of **2%.** On a 3 phase balanced harmonic-free load the total distortion is in the order of **3.5%.** Machines are designed to have a THF better than **2%** and a TIF better than **50**.
A 2/3 pitch factor is standard on all stator windings to eliminate 3rd, 9th, 15th ..................harmonic voltages on the line-neutral waveform.

#### Response

Rapid response to transient load changes is a significant feature, upon application of full load at a power factor of 0.8 lagging, the output voltage recovers to within 3% of the steady state value in **0.25** seconds. The machines comply with the transient conditions laid down by BS 4999 Part 40 voltage grades VR2 11 to VR2.23 as standard Check with factory for compliance with grades VR2.31 to VR2.23.

## Motor Starting

An overload capacity equivalent to **250%** full load impedance at zero p.f. can be sustained for 10 seconds.

### Short Circuit

A current forcing unit must be fitted at the time of manufacture to provide a sustained short circuit current for discrimination of protective devices. Following the initial short circuit current envelope determined by the machine reactances/time constants, the standard machine does not support a sustained short circuit current.

### Voltage Build Up

The exciter design is such that voltage build-up is achieved from residual levels only.

### Standby Ratings

These are in accordance with NEMA MG 1 - 22.84.

### Parallel Operation (SC Machines Only)

The standard machine is fitted with a fully interconnected damper winding and the standard phases sequence is U-V-W when rotating clockwise viewed from the drive end. When paralleling Stamford a.c. generators the neutrals can be connected. When paralleling dissimilar machines it is recommended that the neutrals are not connected as differences in waveform may result in harmonic currents. For types of parallel operation refer to Section - Six Accessories.

### AUTOMATIC VOLTAGE REGULATOR TYPES

**PC (Series 6)** The A.V.R. on this frame designation is two phase sensed and controls the voltage within close limits under all load conditions providing high performance and the flexibility needed for most generator applications. The external wiring has been kept simple and comprises 3 push-on-type connections. By keeping the wiring simple no optional electrical accessories are available.

**SC (Series 4)** Two types of A.V.R. can be fitted on this frame designation depending upon the application and performance required:-

Type 1. The standard A.V.R. is two phase sensed and controls the voltage within close limits under all load conditions, providing high performance and flexibility needed for most generator applications. The design is such that a wide range of electrical accessories can be added to enhance the Specification.

Type 2. This comprises a special A.V.R. and three phase sensing unit for special applications and derives its sensing voltage from all 3 phases of the machine. All generators when an unbalanced load is applied, will result in differences between phase to phase and phase to neutral voltages depending upon the degree of unbalanced load. It is normally accepted that if unbalanced loading can be limited to within 30% the impact on the machine regulation will be marginal on both two phase and three phase sensed A.V.R.'s. If, for any reason, unbalanced loading occurs above this level the overall regulation will exceed the normal specified limits. On a two phase sensed A.V.R., the phase directly linked with the A.V.R. sensing, will be maintained to close regulating limits but the other phase will float outside the normal regulation limits. By incorporating a three phase sensed A.V.R. overall regulation will not improve but the overall balance around a set point will improve. For example, if the overall voltage regulation is 5% on a two phase sensed A.V.R. the regulation could be all one way either +5% or -5% on one of the phases and close to 0% on the other phases. On the three phase sensed A.V.R. although the overall regulation would still be 5% this would tend to float around the nominal setting to give a regulation of +2% between all phases.

A second advantage of three phase sensing is that it provides a more stable reference when operating on thyrsitor or rectifier loads which, due to the high harmonic content in the current waveform distort the generator waveform. The recommendation is that where high thyrsitor or rectifier loads are used, the best results will be obtained with a three phase sensed A.V.R.

**NOTE: A range of electrical accessories is available for both two phase and three phase sensed A.V.R.'s see Section 6 for details.**

### MARINE MACHINES (SC TYPE ONLY)

In order to meet the requirements of marine classifying societies certain modifications to the standard machine are required. From the electrical performance point of view the standard machine is suitable for marine use providing a current forcing unit is fitted to give short circuit maintenance for discrimination of protective devices. From the mechanical point of view it is necessary to incorporate a shaft manufactured from approved material and to add drip-proofing features to cater for the inclination of the machine in the form of louvered covers on the air outlets The requirements of most main classifying societies can be met in this way.

## SECTION FOUR

## SERVICE AND MAINTENANCE

### MAINTENANCE

Routine servicing of the a.c. generator is confined to an insulation resistance check on the windings if the machine has not been run for a considerable length of time.

#### Insulation Test

Prior to testing the insulation to earth of the various windings, it is advisable that the A.V.R. is isolated from the windings by disconnecting the push-on terminals. The machine can then be "Meggered" without risk of damaging the control circuits.

### FAULT FINDING PROCEDURE

Fault finding can be simplified considerably, by dividing the machine into two test sections:

A. THE WINDINGS AND THE MAIN RECTIFIER ASSEMBLY

B. THE ELECTRONIC CONTROL SYSTEM AND ITS WIRING

### SECTION A THE WINDINGS AND THE MAIN RECTIFIER ASSEMBLY

#### Separately Exciting the Machine

The a.c. generator is separately excited to give an indication of the condition of the windings and main rectifier assembly. For the frame sizes covered in this manual a 12 volt d.c. battery supply is sufficient to obtain the full output voltage within + or - 10%, **at no load, with the speed correct at nominal.**

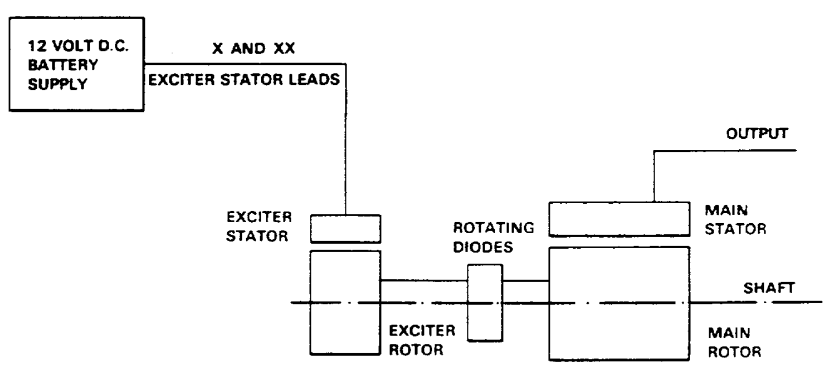



*Fig. 2. Method of Separately Exciting the Machine*

The d.c. supply is connected to the exciter stator leads marked X and XX , which should be removed from the A.V.R. terminals X and XX respectively. It is also advisable to remove the rest of the push-on terminals from the A,V. R. prior to this test.

With the battery connected to the stator leads, the machine is now run up to full speed (it Is essential that the speed is correct for this test), and with a multimeter or voltmeter the following tests are made on the output from" the main stator terminals.

#### Voltage is Balanced and within 10% of the Nominal

This indicates that the exciter windings, main windings and main rectifier diodes are In good working order. an: it is therefore not necessary to carry out the following tests up to and including "Main Excitation Windings". Fault; finding should continue with test "A.V.R. Sensing Supply from the Main Stator".

**Voltage Balance between Phases**

The voltages between the three phases, and each phase to neutral, should be balanced, and if an unbalance is shown on any phase of more than 1%, this indicates that a fault exists in the main stator windings. This test should be carried out with all of the customer's external connections removed to eliminate the possibility of external shorts between the machine and the main isolator. Further tests can be made on the resistance values of the stator windings (see Winding Resistance Chart, at the end of this section).

**Voltage Balanced but Reading Low when Separately Excited**

This indicates that a fault exists in either the main rotating rectifier assembly, or one of the excitation windings i.e. the main rotor and/or the exciter stator and rotor. **First check that the d.c. separate excitation supply is not lower than 12 volts, and that the speed is correct**

**Rectifier Diodes**

The diodes on the main rectifier assembly can be checked with a multimeter. The flexible leads connected to each diode should be disconnected at the terminal end, and the forward and reverse resistance checked. A healthy diode will indicate a very high resistance (infinity) in the reverse direction, and a low resistance in the forward direction. A faulty diode will give a full deflection reading in both directions with the test meter on the 10,000 ohms scale, or an infinity reading in both directions.

**Replacement of Faulty Diodes (See Fig. 11).**

The rectifier assembly is split into two plates, the positive and negative, and the main rotor is connected across these plates. Each plate carries 3 diodes, the negative plate carrying negative based diodes, and the positive plate carries positive based diodes. Care must be taken to ensure that the correct polarity diodes are fitted to each respective plate. When fitting the diodes to the plates they must be tight enough to ensure a good mechanical and electrical contact, but should not be overtightened. The recommended torque tightening is 2.03 - 4.74 Nm.

**Surge Suppressor**

This is a protection device which prevents high transient voltages from damaging the main rectifier diodes. All machines are fitted with a single surge suppressor connected across the +ve & -ve rectifier plates. The resistance of this device varies considerably, depending upon the meter used to check it. As a general guide, the forward resistance should be in excess of 500 ohms. The reverse resistance should be considerably higher i.e. above 10 k ohms. A faulty surge suppressor will be either open circuit or short circuit in both directions.

**Main Excitation Windings**

If after establishing and correcting any fault on the rectifier assembly the output is still low when separately excited, then the main rotor, exciter stator and exciter rotor winding resistances should be checked (see Resistance Charts), as the fault must be in one of these windings. The exciter stator resistance is measured across leads X and XX . The exciter rotor and main rotor resistances, can be obtained from the connections to the main rectifier assembly The exciter rotor is connected to six studs which also carry the diode lead terminals. The main rotor winding is connected across the two rectifier plates. The respective leads must be disconnected before taking the readings.

**A.V.R. Supply Leads from Main Stator**

The final test which can be made in the separately excited condition is to ensure that the supply from the main stator to the A.V.R. is correct. The voltages at the A.V.R. leads are derived from the main stator winding and the levels can be determined by checking the connections and referring to the wiring diagram.

**SECTION B THE ELECTRONIC CONTROL SYSTEM**

**A.V.R.**

Should the previous tests prove successful, any faults can now be assumed to be within the voltage control system and its respective wiring. This system can be affected by bad connections, therefore, the wiring between the auxiliary terminals and the A.V.R. push-on terminals should be carefully examined for broken, loose or corroded connections. The sensing circuit leads have been covered in a previous section.

**Accessories**

Forming an integral part of the electronic circuitry there may be fitted one or more electrical accessory. These items must also be checked for loose, broken or corroded connections, and their resistance values checked. See Section 6 - Accessories.

## DISMANTLING THE MACHINE

Metric Threads are used throughout.

**NOTE: On SINGLE BEARING MACHINES before removal from the prime mover, if possible, position the rotor such that a full pole face is at the bottom of the main stator core.**

### Removal of the A.V.R. (SC1 - 3)

1. Remove the 4 screws retaining A.V.R. lid.
2. Disconnect all cables to A.V.R.
3. Remove 4 pillars retaining A.V.R.

### Removal of A.V.R. (PC1)

1. Remove terminal box lid.
2. Disconnect all cables to A.V.R.
3. Remove 4 screws retaining A.V.R.

### Removal of Main Rotor Assembly

1. Remove all access covers and terminal box lid.
2. Disconnect exciter leads X + & XX - at the inline spade connectors inside the terminal box.
3. Two Bearing Machines only:- remove screws securing the D.E. endbracket.

3a. Two Bearing Machines only:- position rotor with a full pole face at the bottom and tap endbracket out of its spigot.
3b. Lower rotor on to stator core.
3c. Withdraw D.E. endbracket from bearing.

4. Single Bearing Machines only:- remove screws securing adaptor and tap adaptor out of its spigot.
5. Internal Exciter Machines:- remove N.D.E. bearing cap securing screws and bearing cover.

5a. Remove N.D.E. endbracket securing screws, using 2 of these screws, push endbracket out of its spigot by using the 2 threaded holes in the endbracket flange.
5b. Withdraw N.D.E. endbracket complete with exciter stator.

6. External Exciter Machines'- with external cover removed disconnect main rotor leads from rectifier

6a. Remove socket head capscrew securing exciter rotor stub shaft.
6b. Withdraw exciter rotor/rectifier/stub shaft assembly
6c. Remove N.D.E. bearing cap securing screws.
6d. Remove N.D.E. endbracket securing screws, using 2 of these screws, push endbracket out of its spigot through the 2 threaded holes in the endbracket.
6e. Withdraw N.D.E. endbracket complete with exciter stator.

7. Slide rotor out of stator bore towards the D.E. and withdraw rotor.

**NOTE: For removal of rotor of the SC2/3 alternator it maybe necessary to use rope slings as follows.**

1. To withdraw the rotor from the stator, it must be lifted by means of rope slings at both ends, and inched out towards the drive end, until half of the main rotor core is protruding out of the stator. At this point it Is safe to release the weight from the rope slings.
2. Tightly bind a rope sling around this portion of the rotor core, and take the weight on this sling.
3. With both ends of the rotor held, manually slide the rotor out of the stator bore. Care should be taken during this operation to prevent damage to the windings and rectifier assembly by manually guiding the non-drive end of the rotor assembly as it is withdrawn.

**WARNING: The rope sling may not be at the centre of gravity of the rotor, and guidance at the ends of the rotor is essential.**
**As the rotor is fully withdrawn from the stator core, THE FULL WEIGHT OF THE ROTOR MUST BE SUPPORTED BY THE CRANE. If the core is allowed to drop more than 6 mm at this point, it will make contact with the stator windings, and may damage them.**

**Re-Assembly**

Reverse process of the above.

**WINDING RESISTANCE CHART**

| Frame Size | Exciter Stator W | Exciter Rotor W /Ph-Ph | Stator Winding 211 W /Ph | Stator Winding 17 W /Ph | Stator Winding -19 W /Ph | Rotor W |
|---|---|---|---|---|---|---|
| 1A | | | 1.62 | 2.16 | 2.01 | 0.81 |
| 1B | 27 | 0.242 | 1.13 | 1.67 | 1.40 | 0.88 |
| 1C | | | 0.79 | 1.06 | 0.95 | 0.96 |
| 1D | | | 0.66 | 0.87 | 0.69 | 1.03 |
| 1E | 28 | 0.252 | 0.41 | 0.58 | 0.44 | 1.18 |
| 1F | | | 0.27 | 0.42 | 0.33 | 1.36 |
| 1G | 31 | 0.274 | 0.21 | 0.31 | 0.25 | 1.53 |
| 2A | | | 0.21 | 0.30 | 0.24 | 0.58 |
| 2B | 27 | 0.064 | 0.15 | 0.21 | 0.19 | 0.65 |
| 2C | | | 0.125 | 0.19 | 0.15 | 0.69 |
| 2D | 31 | 0.070 | 0.08 | 0.12 | 0.10 | 0.82 |
| 2E | | | 0.06 | 0.083 | 0.077 | 0.93 |
| 3A | | | | | | |
| 3B | 37 | 0.082 | 0.041 | 0.059 | 0.045 | 1.34 |
| 3C | | | 0.028 | 0.043 | 0.033 | 1.55 |
| 3D | | | 0.022 | 0.031 | 0.029 | 1.71 |
| | | | 0.019 | 0.027 | 0.023 | 1.88 |

**NOTES:**
1. **All figures are approximate.**
2. **Resistance figures are at 200C.**
3. **The figures given are for Series Star Connections on main stator.**
4. **For details of voltage ranges available from above Windings - see page 1.**

## SECTION FIVE

## RECOMMENDED SPARES/SECTIONAL ARRANGEMENTS/PARTS LISTS

### RECOMMENDED SPARES

The following list comprises of replaceable items which can be held by the machine owner for Service and Maintenance requirements.

| Description | Quantity per Machine |
|---|---|
| Bearing Drive End (2 Bearing Machines Only) | 1 |
| Bearing Non Drive End | 1 |
| Diode (Forward) | 3 |
| Diode (Reverse) | 3 |
| Automatic Voltage Regulator (A.V.R.) | 1 (See Note) |
| Surge Suppressor | 1 |

**NOTE Machines fitted with 3 phase sensing equipment require a special A.V.R.**

When ordering spare parts, the following information must be quoted.

1. Machine serial Number and type (the serial number can be obtained from the machine nameplate or the drive end of the main shaft).

2. Description of part and plate reference number.

3. Quantity required.

Orders and inquiries for spare parts should be addressed to:

Newage Engineers Limited
Spares Department
P.O. Box 17, Barnack Road
Stamford
Lincolnshire, PE9 2NB, England

Telephone: 0780-62552 Telex 32268 Cables Newage Stamford or any of our subsidiary companies listed on the back page

A full technical advice and on-site service facility is available from our service department at the above address.

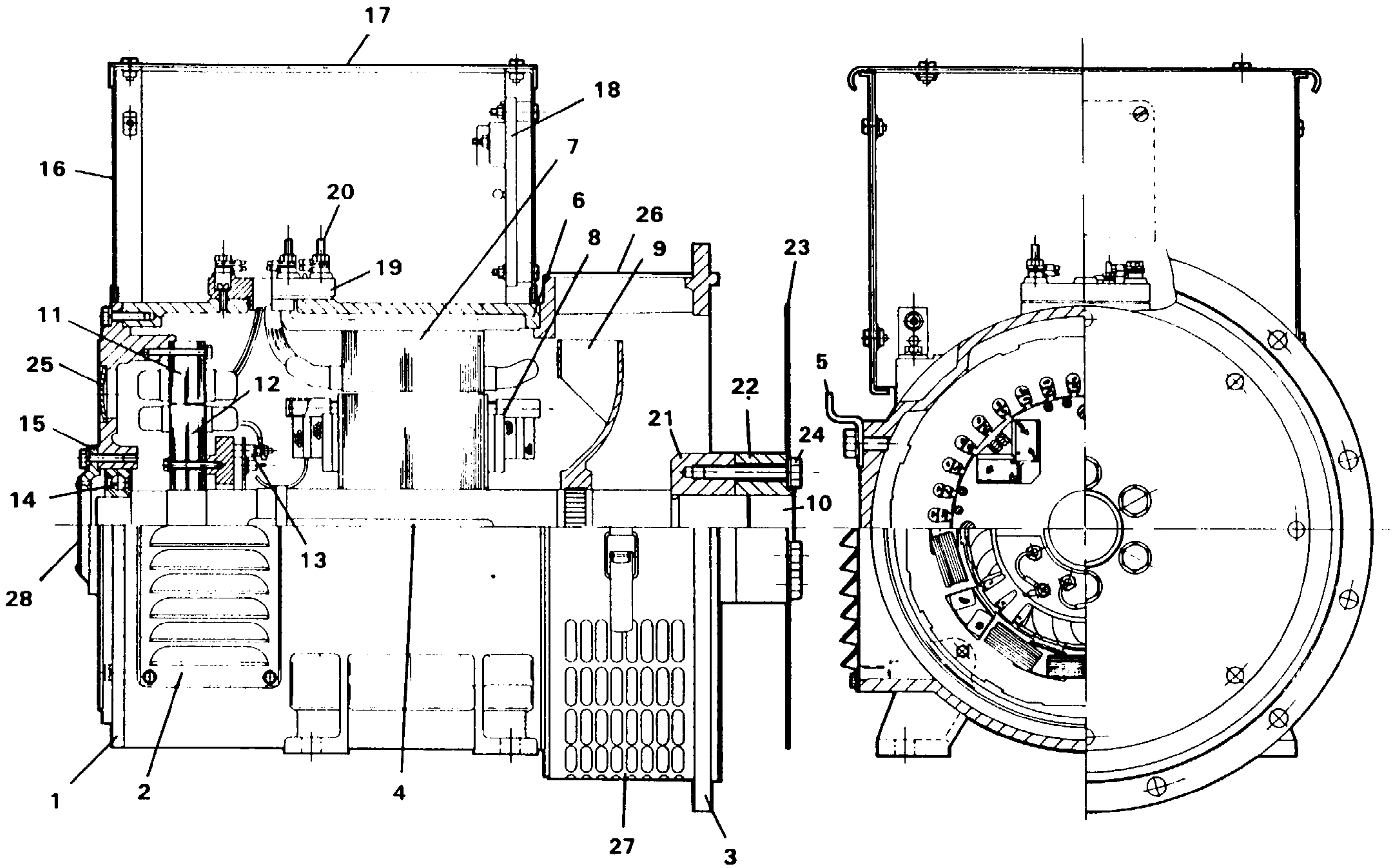



FIG. 3. PC1 SINGLE BEARING MACHINE (INBOARD - EXCITER)

## PARTS LIST

## PC1 SINGLE BEARING MACHINE (INBOARD EXCITER)

| Plate Ref | Description | Plate Ref | Description |
|---|---|---|---|
| 1 | N.D.E. Endbracket | 24 | Coupling screw |
| 2 | N.D.E. Louvered cover | 25 | Expansion plug |
| 3 | D.E. endbracket/adaptor | 26 | Upper D.E. Cover |
| 4 | Main rotor key | 27 | Lower D.E. Cover |
| 5 | Lifting lug | 28 | N.D.E. bearing cover |
| 6 | Main frame | | |
| 7 | Wound main stator assembly | | |
| 8 | Wound main rotor assembly | | |
| 9 | Fan | | |
| 10 | Shaft | | |
| 11 | Wound exciter stator assembly | | |
| 12 | Wound exciter rotor assembly | | |
| 13 | Main rectifier assembly | | |
| 14 | N.D.E. sealed bearing | | |
| 15 | N.D.E. Outer bearing cap | | |
| 16 | Terminal box 4 panels D. E., N.D E, sides | | |
| 17 | Terminal box lid | | |
| 18 | Automatic voltage regulator | | |
| 19 | Main terminal panel 4 panels 0 E., N D.E., sides | | |
| 20 | Main terminal panel stud and nut | | |
| 21 | Coupling hub | | |
| 22 | Coupling spacer | | |
| 23 | Coupling disc | | |

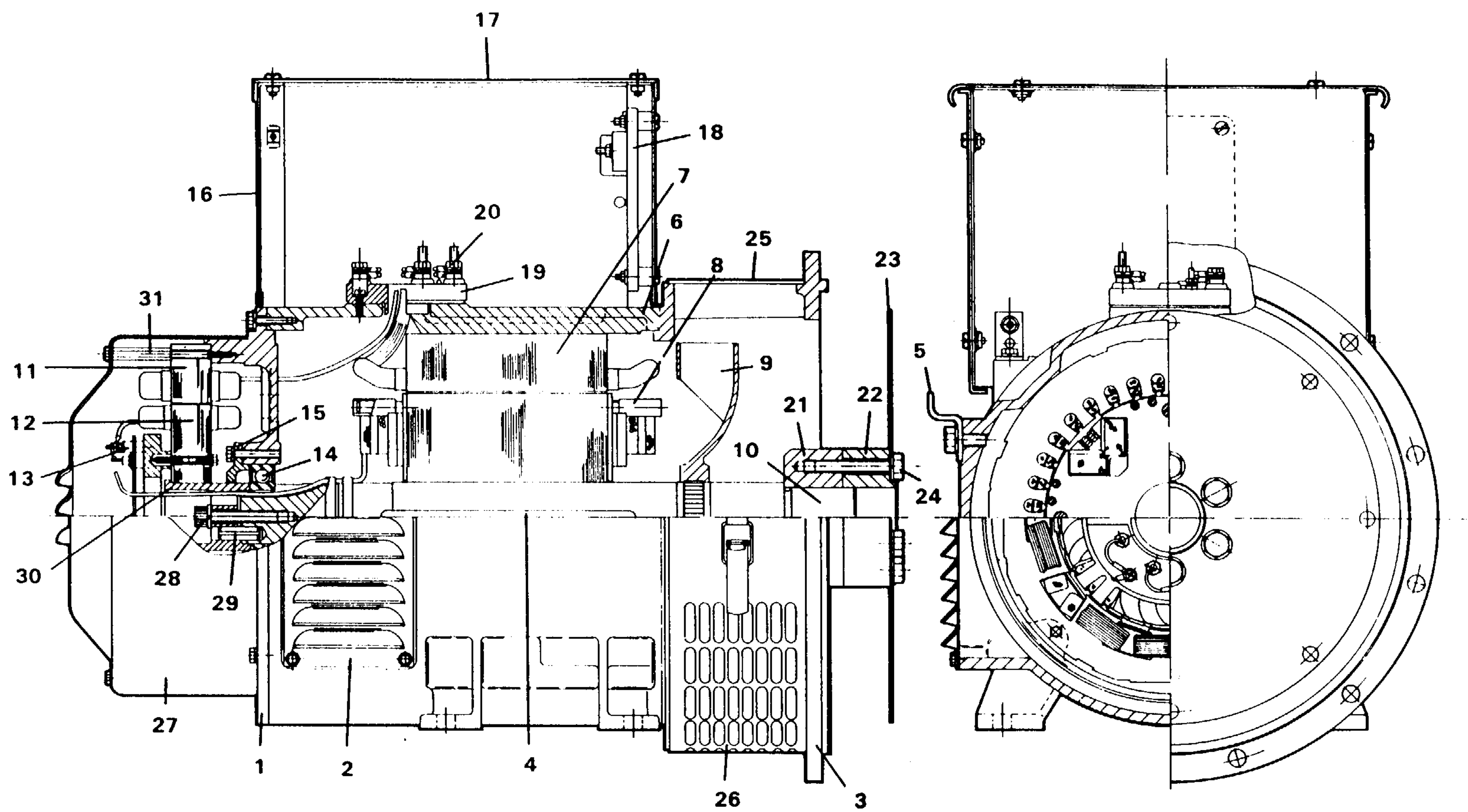



*FIG. 4. PC1 SINGLE BEARING MACHINE (OUTBOARD EXCITER)*

**PARTS LIST**

**PC1 SINGLE BEARING MACHINE (OUTBOARD EXCITER)**

| Plate Ref | Description | Plate Ref | Description |
|---|---|---|---|
| 1 | N.D.E. Endbracket | 24 | Coupling screw |
| 2 | N D.E. Louvered cover | 25 | Upper D.E. cover |
| 3 | D.E. Endbracket/adaptor | 26 | Lower D.E. cover |
| 4 | Main rotor key | 27 | N.D.E. cover |
| 5 | Lifting lug | 28 | Socket head capscrew |
| 6 | Main frame | 29 | Selok pin |
| 7 | Wound main stator assembly | 30 | Exciter stub shaft |
| 8 | Wound main rotor assembly | 31 | Exciter studs |
| 9 | Fan | | |
| 10 | Shaft | | |
| 11 | Wound exciter stator assembly | | |
| 12 | Wound exciter rotor assembly | | |
| 13 | Main rectifier assembly | | |
| 14 | N.D.E. sealed bearing | | |
| 15 | N.D.E. Outer bearing cap | | |
| 16 | Terminal box | | |
| 17 | Terminal box lid | | |
| 18 | Automatic voltage regulator | | |
| 19 | Main terminal panel | | |
| 20 | Main terminal panel stud and nut | | |
| 21 | Coupling hub | | |
| 22 | Coupling spacer | | |
| 23 | Coupling disc | | |

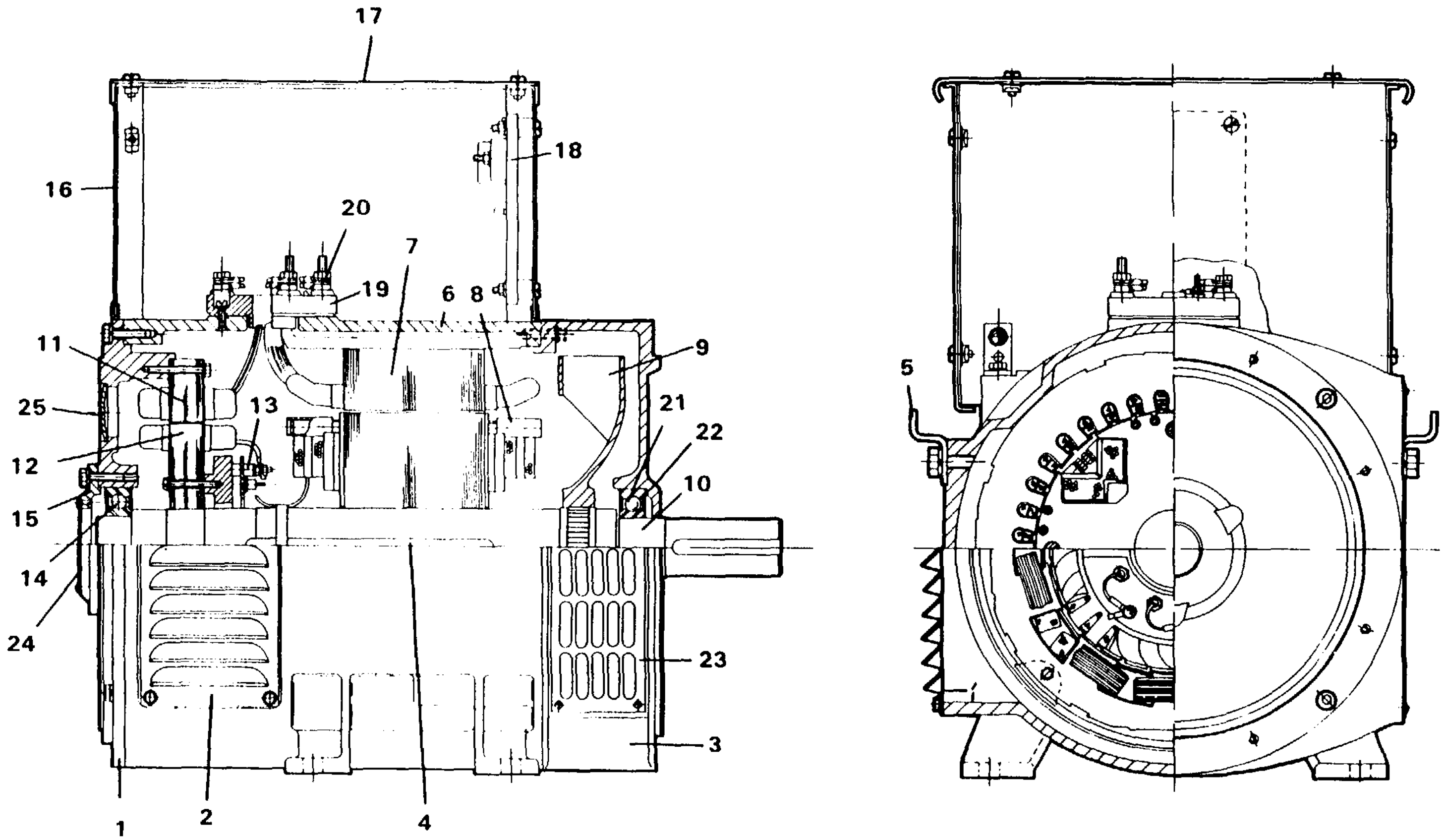



*FIG. 5. PC1 TWO BEARING MACHINE (INBOARD EXCITER)*

## PARTS LIST

## PC1 TWO BEARING MACHINE (INBOARD EXCITER)

| Plate Ref | Description | Plate Ref | Description |
|---|---|---|---|
| 1 | N.D.E. Endbracket | 24 | N.D.E. bearing cover |
| 2 | N.D.E. Louvered cover | 25 | Expansion plug |
| 3 | D.E. Endbracket/adaptor | | |
| 4 | Main rotor key | | |
| 5 | Lifting lug | | |
| 6 | Main frame | | |
| 7 | Wound main stator assembly | | |
| 8 | Wound main rotor assembly | | |
| 9 | Fan | | |
| 10 | Shaft | | |
| 11 | Wound exciter stator assembly | | |
| 12 | Wound exciter rotor assembly | | |
| 13 | Main rectifier assembly | | |
| 14 | N.D.E. sealed bearing | | |
| 15 | N.D.E. Outer bearing cap | | |
| 16 | Terminal box 4 panels D.E. N.D.E., sides | | |
| 17 | Terminal box lid | | |
| 18 | Automatic voltage regulator | | |
| 19 | Main terminal panel | | |
| 20 | Main terminal panel hexagonal nuts | | |
| 21 | D.E. sealed bearing | | |
| 22 | Waved Washer D.E | | |
| 23 | Screen D.E. | | |

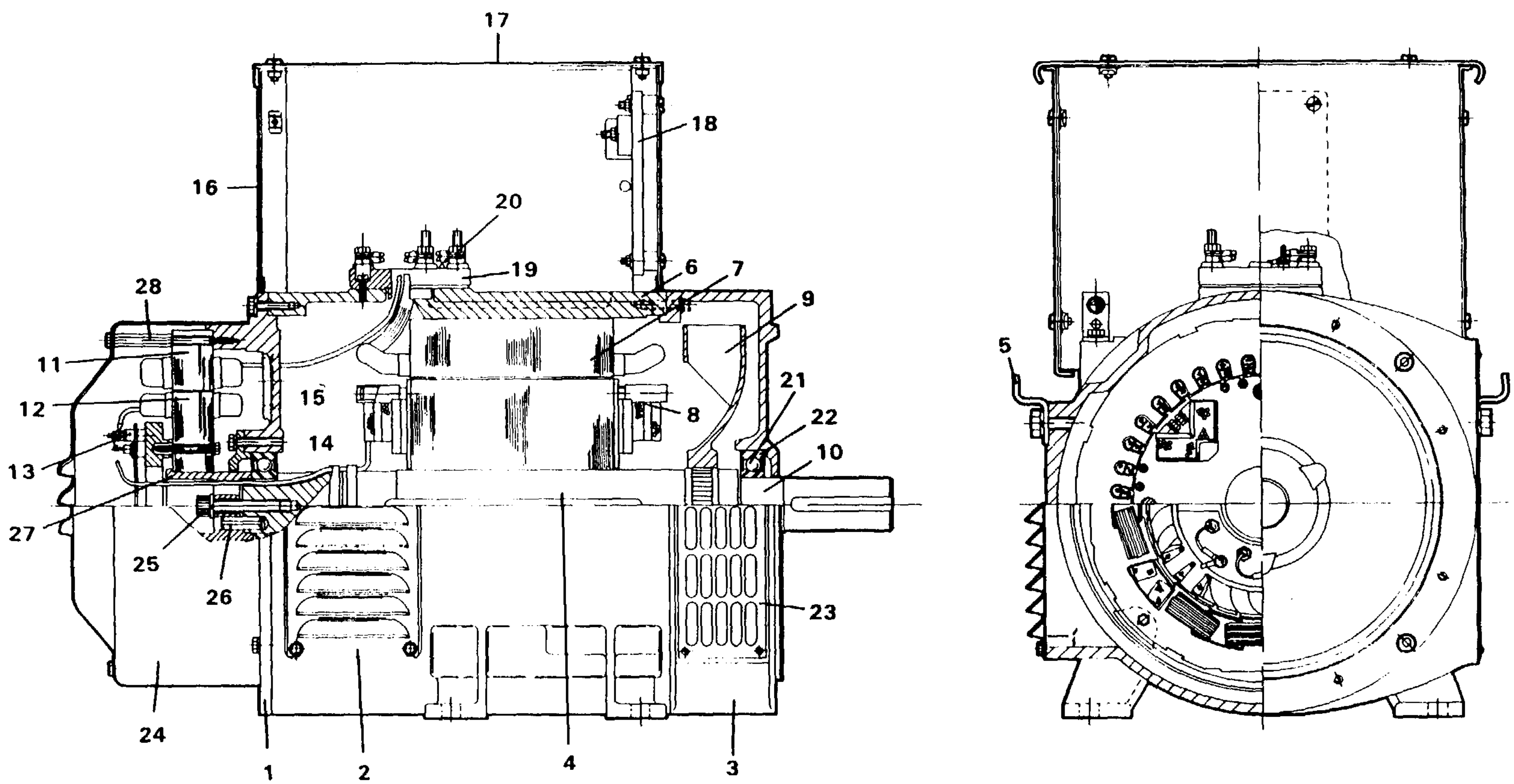



*FIG. 6. PC1 TWO BEARING MACHINE (OUTBOARD EXCITER)*

## PARTS LIST

### PC1 TWO BEARING MACHINE (OUTBOARD EXCITER)

| Plate Ref | Description | Plate Ref | Description |
|---|---|---|---|
| 1 | N.D.E.  Endbracket | 24 | N.D.E.  Cover |
| 2 | N.D.E.  Louvered cover | 25 | Socket head capscrew |
| 3 | D.E.  Endbracket | 26 | Selok pin |
| 4 | Main rotor key | 27 | Exciter stub shaft |
| 5 | Lifting lug | 28 | Exciter studs |
| 6 | Main frame | | |
| 7 | Wound main stator assembly | | |
| 8 | Wound main rotor assembly | | |
| 9 | Fan | | |
| 10 | Shaft | | |
| 11 | Wound exciter stator assembly | | |
| 12 | Wound exciter rotor assembly | | |
| 13 | Main rectifier assembly | | |
| 14 | N.D.E.  sealed bearing | | |
| 15 | N.D.E.  Outer bearing cap | | |
| 16 | Terminal box 4 panels D.E., N.D E, sides | | |
| 17 | Terminal box lid | | |
| 18 | Automatic voltage regulator | | |
| 19 | Main terminal panel | | |
| 20 | Main terminal panel stud and nut | | |
| 21 | D.E, sealed bearing | | |
| 22 | Waved washer D.E. | | |
| 23 | Screen DE. | | |

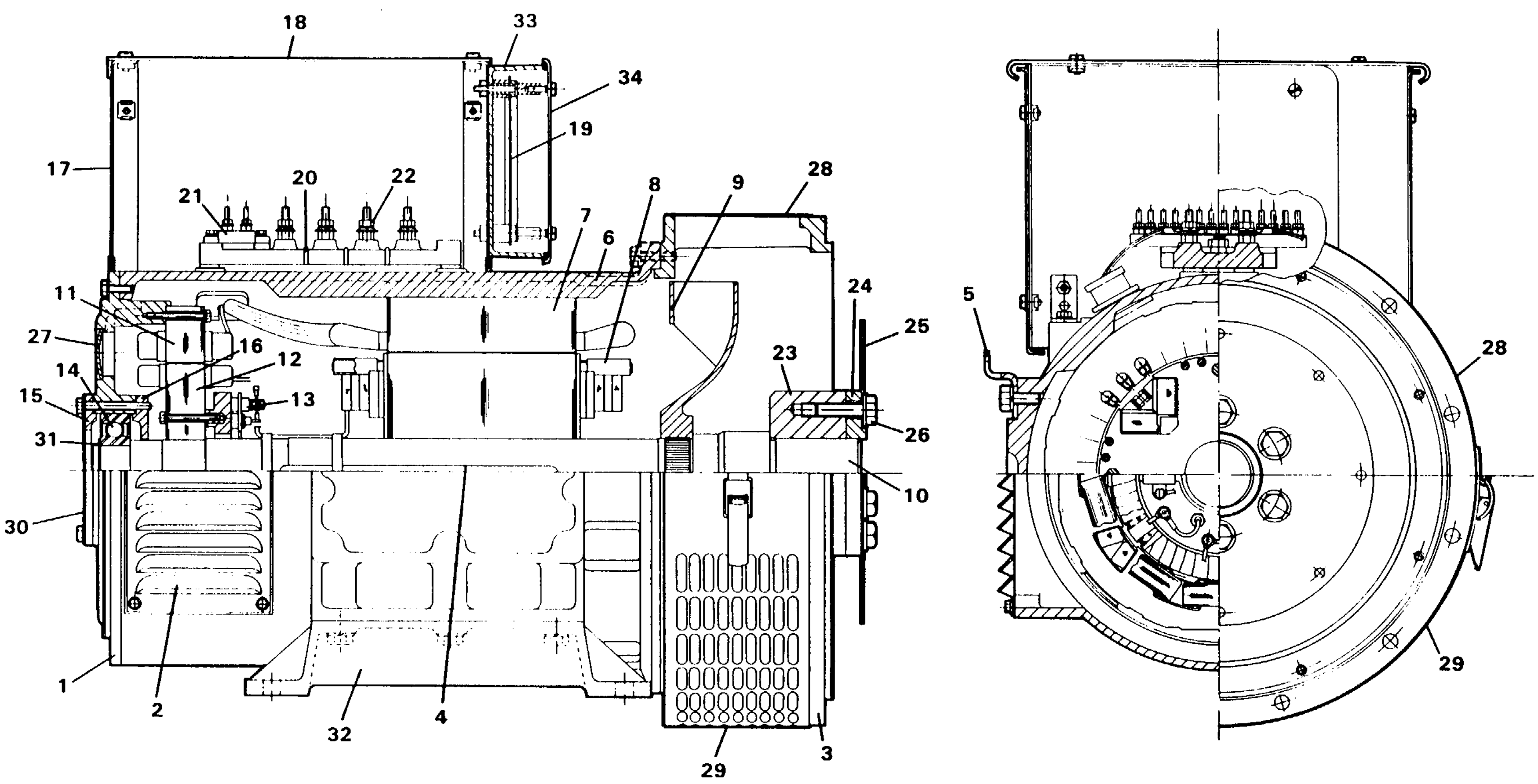



*FIG. 7. SC1 - 2 SINGLE BEARING MACHINE (INBOARD EXCITER)*

## PARTS LIST

### SC1 - 2 SINGLE BEARING MACHINE (INBOARD EXCITER)

| Plate Ref | Description | Plate Ref | Description |
|---|---|---|---|
| 1 | N.D.E. Endbracket | 26 | Coupling screw |
| 2 | N.D.E. Louvered cover | 27 | Expansion plug |
| 3 | D.E. endbracket/adaptor | 28 | Upper D.E. Cover |
| 4 | Main rotor key | 29 | Lower D.E. Cover |
| 5 | Lifting lug | 30 | N.D.E. bearing cover |
| 6 | Main frame | 31 | Circlip |
| 7 | Wound main stator assembly | 32 | Feet |
| 8 | Wound main rotor assembly | 33 | A.V.R. Box |
| 9 | Fan | 34 | A.V.R. Box Lid |
| 10 | Shaft | | |
| 11 | Wound exciter stator assembly | | |
| 12 | Wound exciter rotor assembly | | |
| 13 | Main rectifier assembly | | |
| 14 | N.D.E. sealed bearing | | |
| 15 | N.D.E. Outer bearing cap | | |
| 16 | N.D.E. Inner bearing cap | | |
| 17 | Terminal box | | |
| 18 | Terminal box lid | | |
| 19 | Automatic voltage regulator | | |
| 20 | Main terminal panel 4 panels D.E., N.D.E., sides | | |
| 21 | Auxiliary terminal panel | | |
| 22 | Main terminal panel stud and nut | | |
| 23 | Coupling hub | | |
| 24 | Coupling spacer | | |
| 25 | Coupling disc | | |

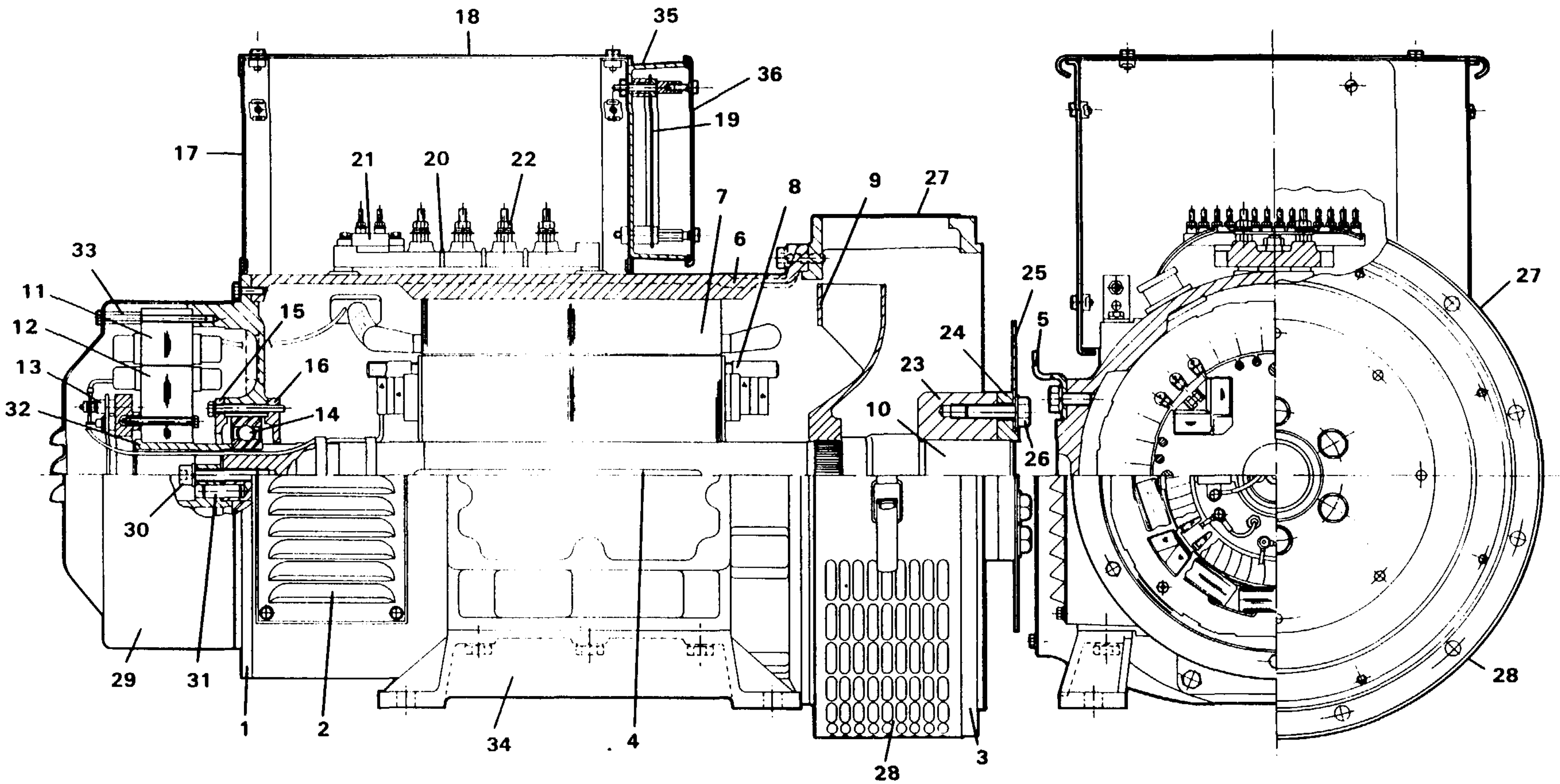



*FIG. 8. SC1 - 2 SINGLE BEARING MACHINE (OUTBOARD EXCITER)*

## PARTS LIST

## SC1 - 2 SINGLE BEARING MACHINE (OUTBOARD EXCITER)

| Plate Ref | Description | Plate Ref | Description |
|---|---|---|---|
| 1 | N.D.E. Endbracket | 26 | Coupling screw |
| 2 | N.D.E. Louvered cover | 27 | Upper D.E. cover |
| 3 | D.E. Endbracket/adaptor | 28 | Lower D.E. cover |
| 4 | Main rotor key | 29 | N.D.E. cover |
| 5 | Lifting lug | 30 | Socket head capscrew |
| 6 | Main frame | 31 | Selok pin |
| 7 | Wound main stator assembly | 32 | Exciter stub shaft |
| 8 | Wound main rotor assembly | 33 | Exciter studs |
| 9 | Fan | 34 | Feet |
| 10 | Shaft | 35 | A.V.R. Box |
| 11 | Wound exciter stator assembly | 36 | A.V.R. Box Lid |
| 12 | Wound exciter rotor assembly | | |
| 13 | Main rectifier assembly | | |
| 14 | N.D.E, sealed bearing | | |
| 15 | N.D E. Outer bearing cap | | |
| 16 | N.D.E. Inner bearing cap | | |
| 17 | Terminal box 4 panels D.E., N.D.E, sides | | |
| 18 | Terminal box lid | | |
| 19 | Automatic voltage regulator | | |
| 20 | Main terminal panel | | |
| 21 | Auxiliary terminal panel | | |
| 22 | Main terminal panel stud and nut | | |
| 23 | Coupling hub | | |
| 24 | Coupling spacer | | |
| 25 | Coupling disc | | |

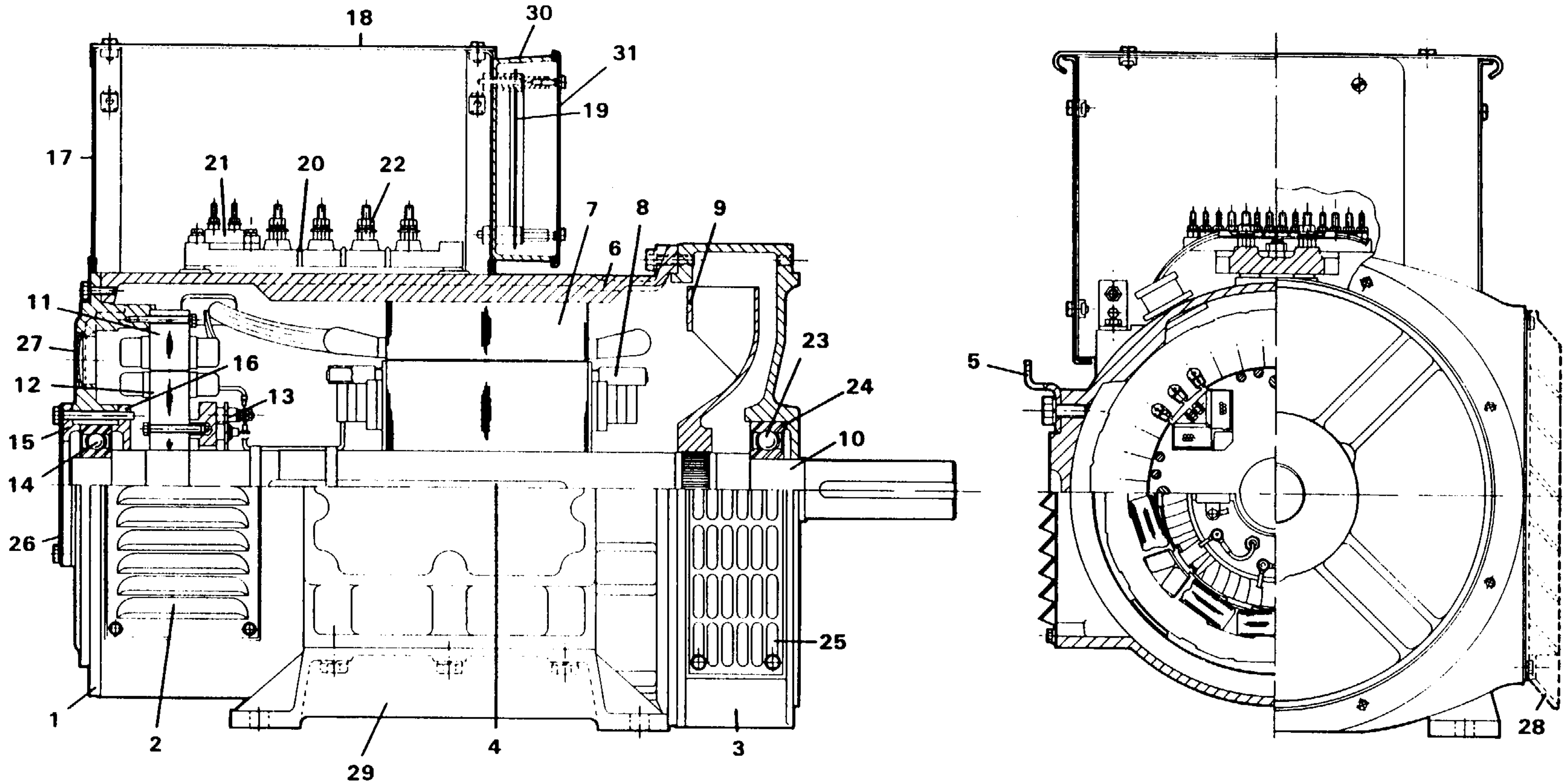



*FIG. 9. SC1 - 2 TWO BEARING MACHINE (INBOARD EXCITER)*

## PARTS LIST

## SC1- 2 TWO BEARING MACHINE (INBOARD EXCITER)

| Plate Ref | Description | Plate Ref | Description |
|---|---|---|---|
| 1 | N.D.E. Endbracket | 26 | N.D.E. bearing cover |
| 2 | N.D.E. Louvered cover | 27 | Expansion plug |
| 3 | D.E. Endbracket/adaptor | 28 | D.E. louvers (when fitted) |
| 4 | Main rotor key | 29 | Feet |
| 5 | Lifting lug | 30 | A.V.R. Box |
| 6 | Main frame | 31 | A.V.R. Box Lid |
| 7 | Wound main stator assembly | | |
| 8 | Wound main rotor assembly | | |
| 9 | Fan | | |
| 10 | Shaft | | |
| 11 | Wound exciter stator assembly | | |
| 12 | Wound exciter rotor assembly | | |
| 13 | Main rectifier assembly | | |
| 14 | N.D.E. sealed bearing | | |
| 15 | N.D.E. Outer bearing cap | | |
| 16 | N.D.E. Inner bearing cap | | |
| 17 | Terminal box 4 panels. D.E.. N.D.E., sides | | |
| 18 | Terminal box lid | | |
| 19 | Automatic voltage regulator | | |
| 20 | Main terminal panel | | |
| 21 | Auxiliary terminal panel | | |
| 22 | Main terminal panel hexagonal nuts | | |
| 23 | D.E. sealed bearing | | |
| 24 | Waved Washer D.E. | | |
| 25 | Screen D.E. | | |

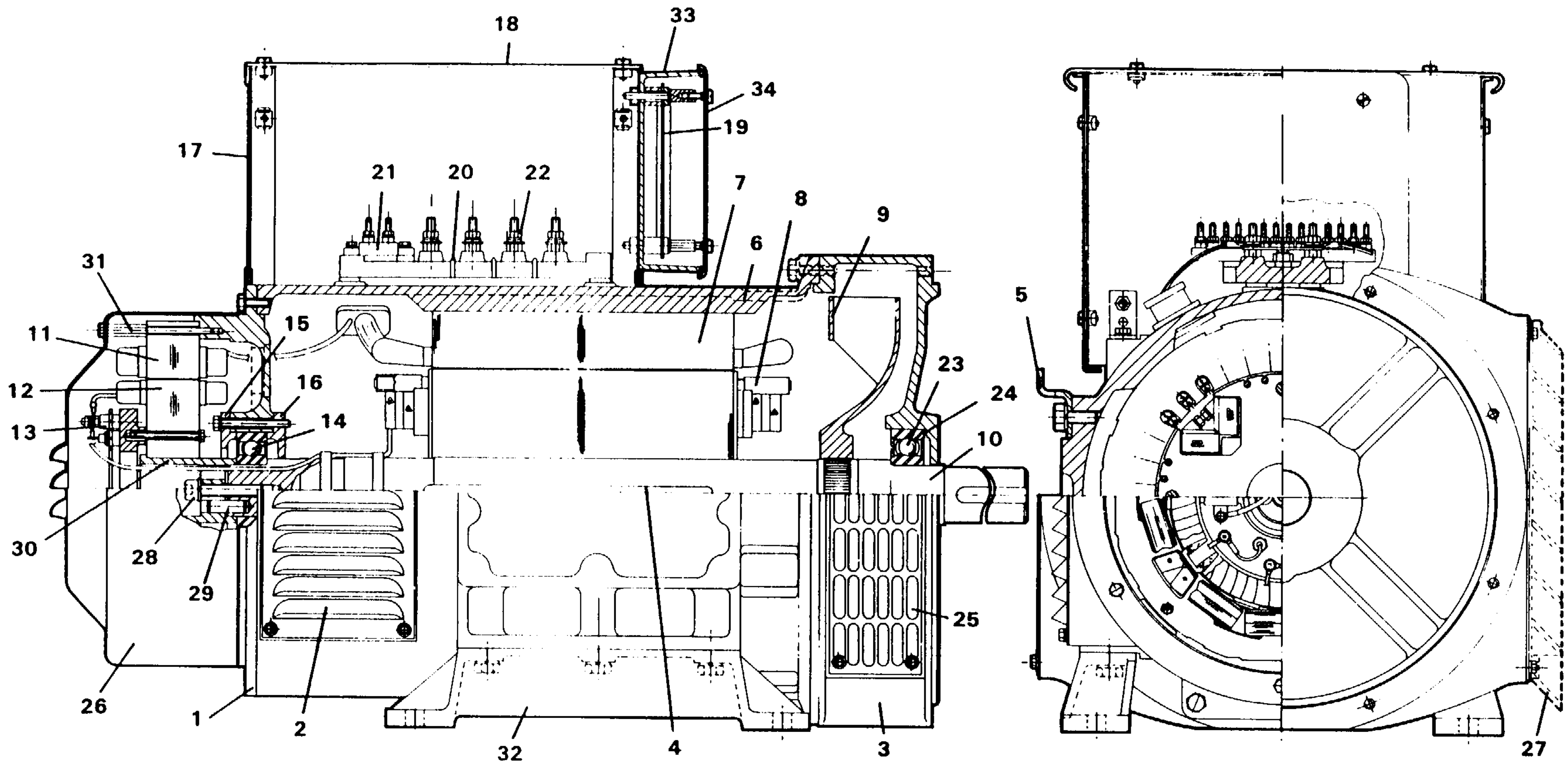



*FIG. 10. SC1 - 2 TWO BEARING MACHINE (OUTBOARD EXCITER)*

PARTS LIST

SC1 - 2 TWO BEARING MACHINE (OUTBOARD EXCITER)

| Plate Ref | Description | Plate Ref | Description |
|---|---|---|---|
| 1 | N.D.E. Endbracket | 26 | N.D.E. Cover |
| 2 | N.D.E. Louvred cover | 27 | D.E. louvres (when fitted) |
| 3 | D.E. Endbracket | 28 | Socket head capscrew |
| 4 | Main rotor key | 29 | Selok pin |
| 5 | Lifting lug | 30 | Exciter stub shaft |
| 6 | Main frame | 31 | Exciter studs |
| 7 | Wound main stator assembly | 32 | Feet |
| 8 | Wound main rotor assembly | 33 | A.V.R. box |
| 9 | Fan | 34 | A.V.R. box lid |
| 10 | Shaft | | |
| 11 | Wound exciter stator assembly | | |
| 12 | Wound exciter rotor assembly | | |
| 13 | Main rectifier assembly | | |
| 14 | N.D.E. sealed bearing | | |
| 15 | N.D.E. Outer bearing cap | | |
| 16 | N.D.E. Inner bearing cap | | |
| 17 | Terminal box 4 panels D.E., N.D.E , sides | | |
| 18 | Terminal box lid | | |
| 19 | Automatic voltage regulator | | |
| 20 | Main terminal panel | | |
| 21 | Auxiliary terminal panel | | |
| 22 | Main terminal panel stud and nut | | |
| 23 | D.E. sealed bearing | | |
| 24 | Waved washer D.E. | | |
| 25 | Screen D.E. | | |

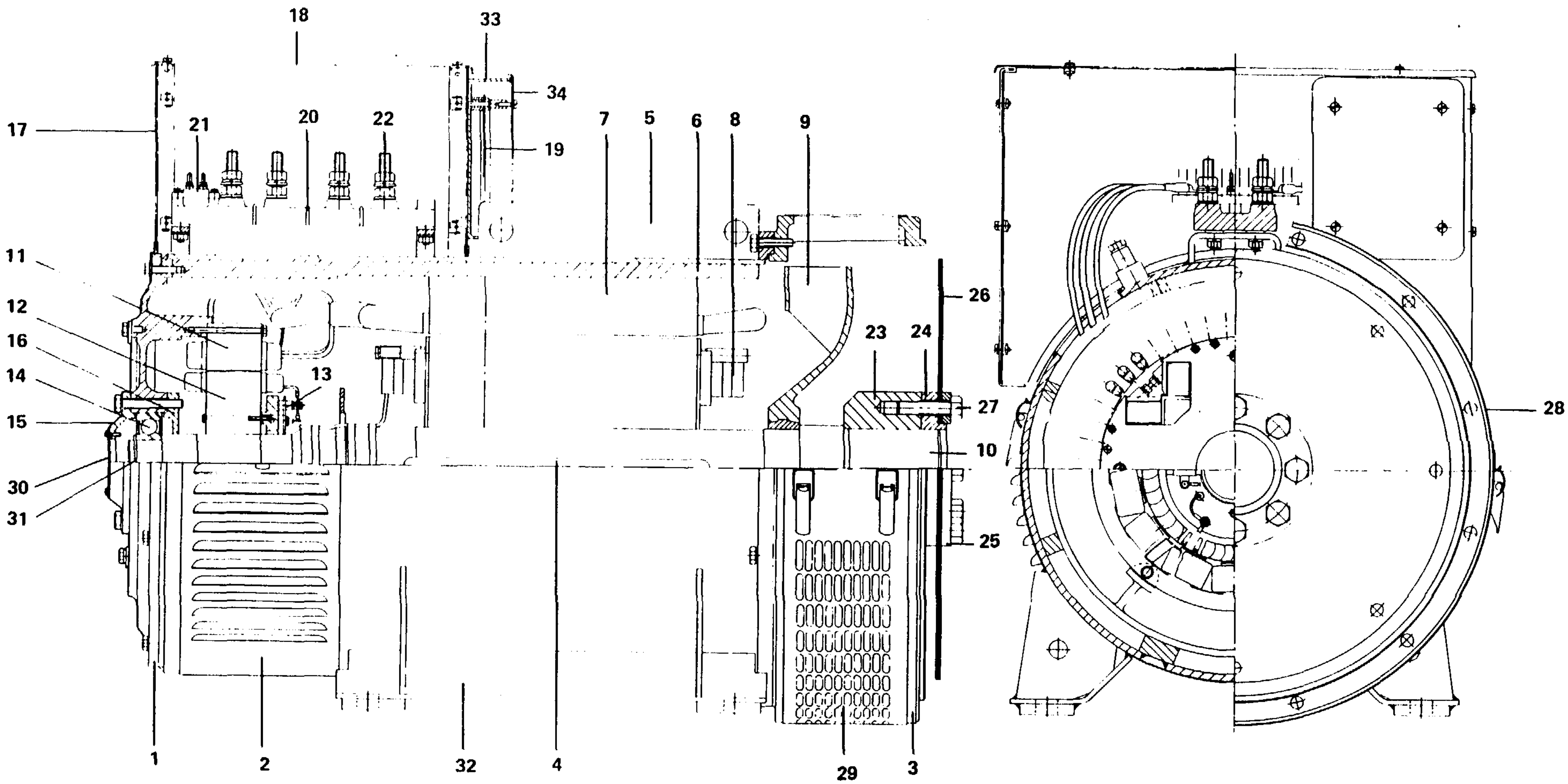



*FIG. 11 SC3 SINGLE BEARING MACHINE (INBOARD EXCITER)*

## PARTS LIST

## SC3 SINGLE BEARING MACHINE (INBOARD EXCITER)

| Plate Ref | Description | Plate Ref | Description |
|---|---|---|---|
| 1 | N.D.E. Endbracket | 26 | Coupling disc. |
| 2 | N.D.E. Louvred cover | 27 | Coupling Screw |
| 3 | D.E. endbracket/adaptor | 28 | Upper D.E. Cover |
| 4 | Main rotor key | 29 | Lower D.E. Cover |
| 5 | Lifting plate | 30 | N.D.E. bearing cover |
| 6 | Main frame | 31 | Circlip |
| 7 | Wound main stator assembly | 32 | Feet |
| 8 | Wound main rotor assembly | 33 | A.V.R. Box |
| 9 | Fan | 34 | A.V.R. Box Lid |
| 10 | Shaft | | |
| 11 | Wound exciter stator assembly | | |
| 12 | Wound exciter rotor assembly | | |
| 13 | Main rectifier assembly | | |
| 14 | N.D.E. sealed bearing | | |
| 15 | N.D.E. Outer bearing cap | | |
| 16 | N.D.E. Inner bearing cap | | |
| 17 | Terminal box | | |
| 18 | Terminal box lid | | |
| 19 | Automatic voltage regulator | | |
| 20 | Main terminal panel | | |
| 21 | Auxiliary terminal panel | | |
| 22 | Main terminal panel stud and nut | | |
| 23 | Coupling hub | | |
| 24 | Coupling spacer | | |
| 25 | Coupling Pressure Plate | | |

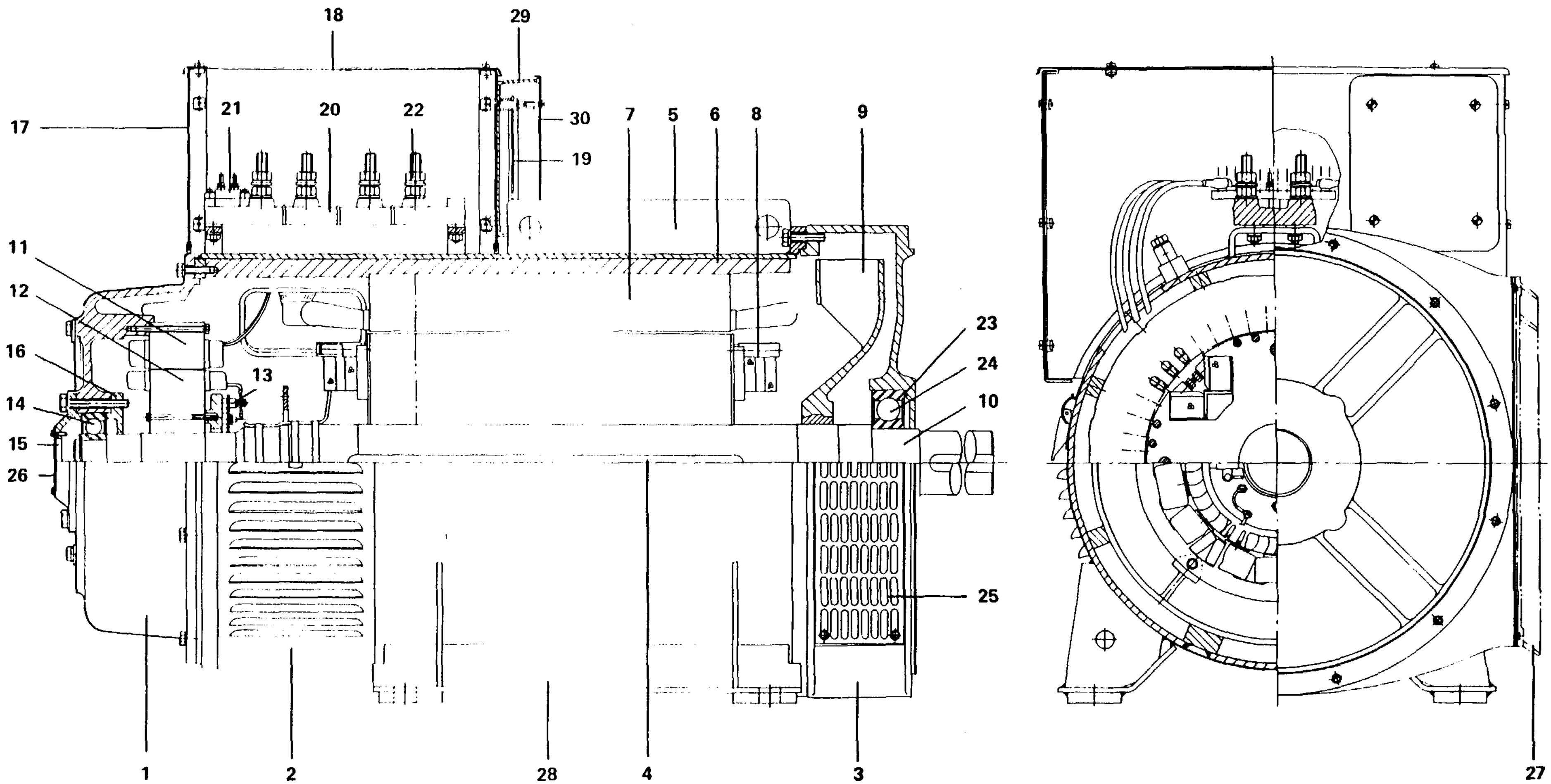
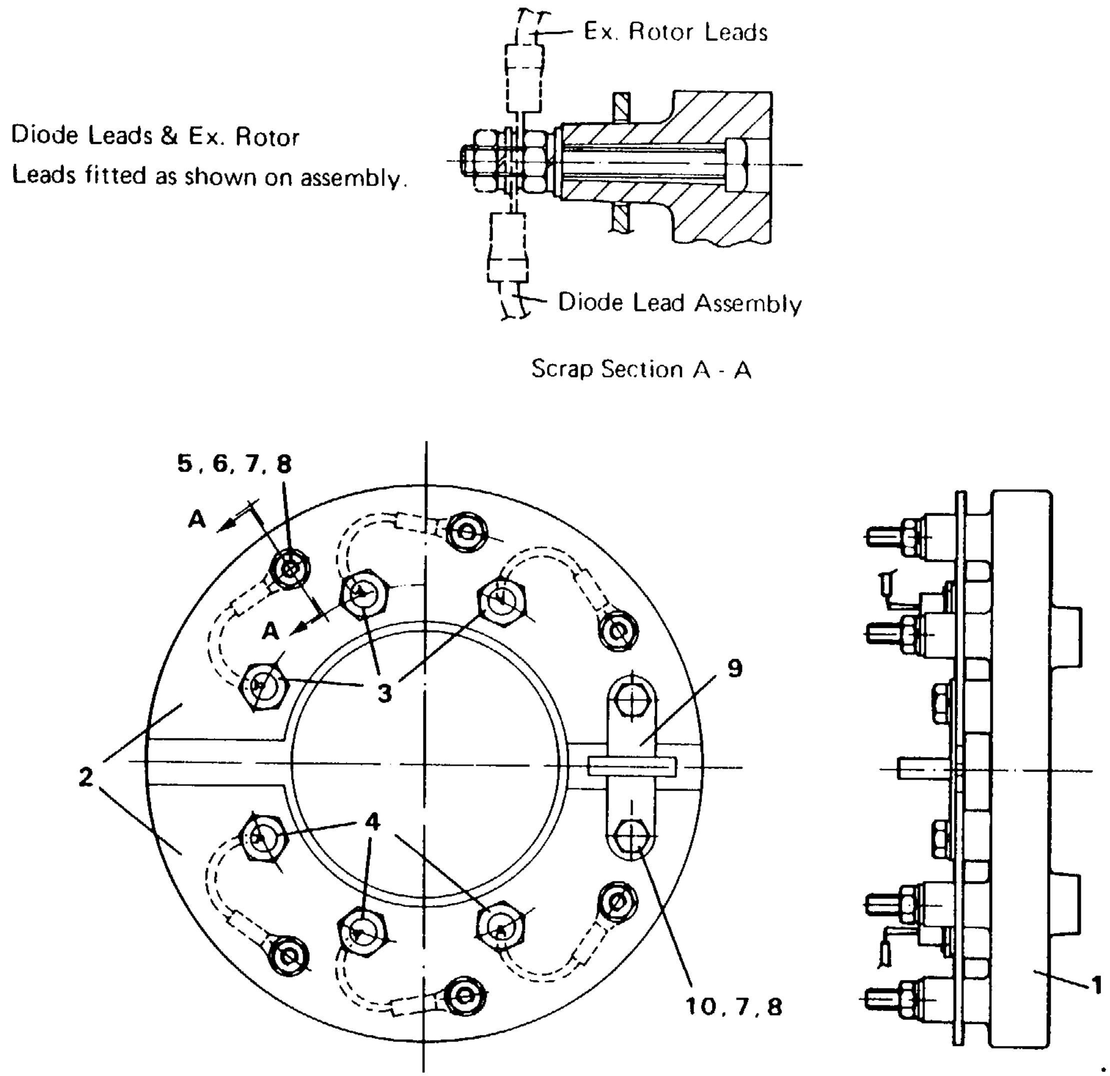



FIG. 12 SC3 TWO BEARING MACHINE (OUTBOARD EXCITER)

## PARTS LIST

## SC3 TWO BEARING MACHINE (OUTBOARD - EXCITER)

| Plate Ref | Description | Plate Ref | Description |
|---|---|---|---|
| 1 | N.D.E. Endbracket | 26 | N.D.E. Cover |
| 2 | N.D.E. Louvred cover | 27 | D.E. louvres (when fitted) |
| 3 | D.E. Endbracket | 28 | Feet |
| 4 | Main rotor key | 29 | A.V.R. box |
| 5 | Lifting plate | 30 | A.V.R. box lid |
| 6 | Main frame | | |
| 7 | Wound main stator assembly | | |
| 8 | Wound main rotor assembly | | |
| 9 | Fan | | |
| 10 | Shaft | | |
| 11 | Wound exciter stator assembly | | |
| 12 | Wound exciter rotor assembly | | |
| 13 | Main rectifier assembly | | |
| 14 | N.D.E. sealed bearing | | |
| 15 | N.D.E. Outer bearing cap | | |
| 16 | N.D.E. Inner bearing cap | | |
| 17 | Terminal box | | |
| 18 | Terminal box lid | | |
| 19 | Automatic voltage regulator | | |
| 20 | Main terminal panel | | |
| 21 | Auxiliary terminal panel | | |
| 22 | Main terminal panel stud and nut | | |
| 23 | Waved washer D E. | | |
| 24 | D.E. sealed bearing | | |
| 25 | Screen D. E. | | |




| Plate Ref. | Description | Qty |
|---|---|---|
| 1 | Hub | 1 |
| 2 | Fin | 2 |
| 3 | Diode (fwd) | 3 |
| 4 | Diode (rev) | 3 |
| 5 | Hx. Screw | 6 |
| 6 | Hx. Nut | 6 |
| 7 | Pl. Washer | 8 |
| 8 | SC. L/Washer | 8 |
| 9 | Varistor | 1 |
| 10 | Hx. Screw | 2 |

**NOTES:**
**Fitting of Diodes.**

1. Underside of diodes to be smeared with Midland Silicone 'heat sink' compound type MS2623. This compound **must not** be applied to the diode threads.
2. Diodes to be tightened to a torque load of 2.03 - 2.37 N - m.
3. A rectifier assembly must comprise diodes from one manufacturer only.

*Fig. 13 Rotating Rectifier Assembly*

**ACCESSORIES (all in terminal box except hand trimmer)**

**HAND TRIMMERS FOR REMOTE CONTROL (SC MACHINES ONLY)**

A remote hand trimmer can be provided to give fine adjustment to the output voltage of approx. 6%. The hand trimmer works in conjunction with the range control fitted to the A.V.R. to give the voltage range specified in Section One. **Resistance value** - 4.7 k ohms.

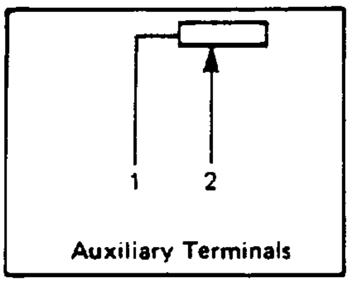



*Fig. 14 Wiring details*

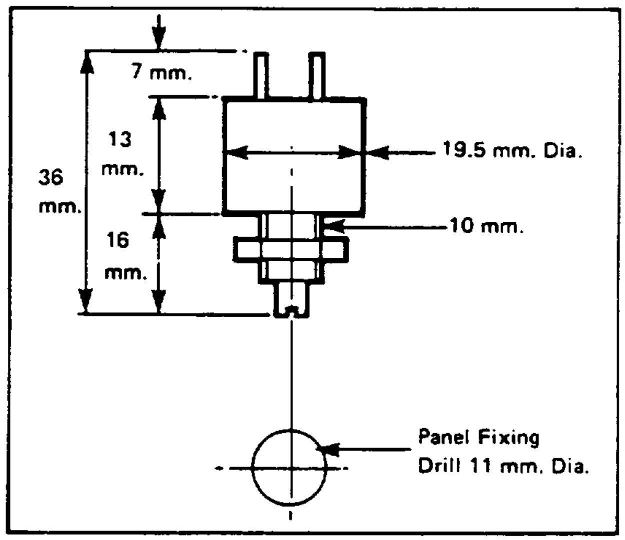



*Fig. 15 Fitting details*

**PARALLEL OPERATION (SC MACHINES ONLY)**

There are two important rules to bear in mind when paralleling two or more generators.

1. It is the engine that controls the kW load sharing.

2. It is the generator A.V.R. that controls the kVAr load sharing.

If the engine governors are not electrically interconnected and generator excitation systems are not electrically interconnected, then the larger the engine speed droop when kW load is applied and the larger the generator voltage droop with circulating current, the more flexible and stable the system becomes to obtain load sharing when the generators are in parallel. If closer control of both engine speed and generator voltage is required, then some form of cross connection is required between the governor systems and generator excitation systems.

The standard machine is fitted with a fully interconnected damper winding and the standard phase sequence is UVW when rotating clockwise viewed from the drive end. When paralleling Stamford a.c. generators, the neutrals can be connected but when paralleling dissimilar machines it is recommended that the neutrals are not connected as differences in waveform may result in harmonic currents.

Two paralleling systems can be supplied for the Stamford 'C' range a.c. generators.

Quadrature Droop - For both similar and dissimilar control systems provided, a droop circuit is fitted to all machines.

**Quadrature Droop Kit**

This is the most widely used and simple of paralleling systems and comprises a current transformer (C.T.) and burden resistor (see Fig. 16), or a current transformer (C.T.) and burden choke (see Fig. 17).

NOTES: 1. Depending on machine type, one or more main stator cables are connected to each output terminal, insert droop C.T. in one cable only. See Fig. 17 for C.T. position and wiring diagram.

2. Connect to auxiliary terminals 2 - 8 (after removing link) on two phase sensed machines and 4 - 7 (after removing link) on three phase sensed machines.

**Operation**

As stated earlier paralleling systems fitted to the generator can only ensure that the excitation system maintains the output voltage to the correct level to give satisfactory kVAr load sharing and minimize circulating currents to acceptable levels. As far as kW load sharing is concerned, this is entirely due to the engine throttle/governor setting.

For both two phase and three phase sensed machines the operation is the same in that any circulating current between machines produces a voltage across the burden-resistor or choke which directly adds or subtracts from the sensing voltage fed into the A.V.R. This makes the excitation system sensitive to circulating currents and ensures correct sharing of the kVAr load. The larger the droop voltage is set, the more flexible becomes the excitation system to reduce circulating currents and ensure kVAr load sharing. In most cases a 5% droop on the output voltage at full load, zero p.f. lag. is satisfactory, this setting impacts to worsen the voltage regulation by approx. 1% at full load, unity p.f. and approx. 3% at full load, 0.8 p.f. When a unity power factor load (kW) is applied the voltage produced across the burden resistor/choke adds vectorally at right angles to the sensing voltage and has a minimal effect. When the machines are run individually, the droop circuit can be switched out by short circuiting auxiliary terminals 2 to 8 on the two phase sensed A.V.R. and 4 to 7 on the three phase sensed A.V.R. to obtain the close regulating characteristics of the machine.

Setting up the droop circuit can be difficult as in most cases only unity p.f. load is available. A simple way of setting up the droop circuit under these conditions is to measure the voltage across the resistor/choke when load is applied, this should be in line with the graph Fig. 18 to obtain approx. 5% droop at full load zero p.f. lag.

The other important factor is to ensure that the voltage produced across the burden resistor/choke adds with the A.V.R. sensing voltage in the correct direction. If for any reason this is reversed, a rising characteristic will result which will give an unstable condition for parallel operation and will produce high circulating currents. This can be checked quite simply by applying a unity p.f. load on each machine separately and measuring the voltage across auxiliary terminals 6 to 2 and 6 to 8 on the two phase sensed A.V.R. and across auxiliary terminals 6 to 7 and 6 to 4 on the three phase sensed A.V.R. If the circuit is functioning correctly, the voltage across 6 to 2 should be less than the voltage across 6 to 8 and the voltage across 6 to 7 should be less than the voltage across 6 to 4.

| A.V.R. | Stator Connection | | Paralleling | | | |
|---|---|---|---|---|---|---|
| | | | Quadrature Droop | | Astatic | |
| Type | (Standard phase rotation) | | Fig. | C.T. Position | Fig. | C.T. Position |
| Two | 4 Wire & 6 Wire Star | | 16 | W2 | | Not available |
| Phase | 12 Wire | Series Star | 16 | W2 | | |
| | | Series Delta | 16 | W2 | | |
| | | Parallel Star | 16 | W2 | | |
| Sensed | | Series Zig-Zag Star | 17 | W2 | | |
| Three | 4 Wire & 6 Wire Star | | 17 | V2 | | Not available |
| Phase | 12 Wire | Series Star | 17 | V2 | | |
| | | Series Delta | 16* | W2 | | |
| | | Parallel Star | 17 | V2 | | |
| Sensed | | Series Zig-Zag Star | 16* | V2 | | |

*Fig. 19 Droop C.T. Positions*

NOTES:

1. *For these stator connections the C.T. secondary leads S1 and S2 must be reversed for correct machine operation.

2. Standard phase rotation is U.V.W. when a.c. generator is rotating clockwise viewed at the drive end. For phase rotation U.V.W. when rotating anti-clockwise refer to factory for details.

**General Notes on Paralleling**

**Main Metering Requirements**

For successful synchronization and load sharing between two or more a.c. generators, the following meters and equipment are essential:

**Voltmeter**

This can be one voltmeter per machine, or one which is switchable to either. The latter is more accurate for initial voltage setting to ensure identical voltages. Another voltmeter may be fitted to the main bus-bars for monitoring the machine on load.

**Ammeter**

At least one ammeter per machine is required, preferably with phase to phase switching.

**Wattmeter**

At least one wattmeter per machine is essential to observe the load sharing of the prime movers, i.e. engines.

**Frequency Meter**

As with the voltmeter, this can be one per machine or preferably one which is switchable to either, and another registering the bus-bar frequency.

## Synchronizing Equipment

This can be in the form of a synchronizing meter or a system of lamps connected across the a.c. generators to be paralleled. The synchronizing meter gives a direct indication when the machines are in synchronism. The lamps are connected across like phases, i.e. U-U. V-V, W-W, such that the machines are in phase when the lights are dimmed. It is important to rate the lamps to at least twice the machine voltage and in most instances it would be necessary to connect two or three in series.

## Protection Devices

In addition to essential protection devices, i.e. overload circuit breaker, fuses, etc. it is recommended that the breakers have a shunt release coil working in conjunction with a reverse power relay trip. This ensures that, should one of the sets malfunction for any reason, i.e. engine shutdown, voltage drop, etc. the power transferred from the other set, which is now trying to 'motor' the failed plant, will then de-energize the contact breaker and disconnect the sets.

## Setting Up Procedure for Parallel Operation

The droop equipment should be tested and set correctly and the machines can be set for synchronization as follows:

1. The speed of each set must be adjusted to the nominal frequency of the system, i.e. 50 Hz or 60 Hz.

2. The voltage of each machine can now be set identically on the hand voltage trimmers or A.V.R. range control.

3. The machine should only be paralleled when the difference in frequency between the two sets is small enough to enable the breaker to be closed when the in-phase condition is observed. This is achieved by adjusting the speed of the incoming set to match the set on the bus-bars and the easiest method of speed adjustment is with a governor motor control and a Raise/Lower speed control button.

   **Care must be taken to ensure that the machines are exactly in phase before paralleling is attempted, as the forces set up by out of phase paralleling can create severe mechanical and electrical stresses in the sets.**

4. As load is applied any discrepancy between the kW meters can be eliminated by slight adjustment of the speed on one of the machines.

5. With the kW meters sharing load correctly, any discrepancy between the ammeters can be eliminated with slight adjustment of the voltage on one of the machines.

**NOTE**: Current discrepancies are due to circulating currents which flow between the sets when there is a difference in excitation levels between the a.c. generators. High circulating currents may be due to a reversal in one of the droop transformers or incorrect adjustment of the droop setting on the burden resistor or choke. In general, when paralleling identical machines, the amount of droop should be approximately equal on all sets.

## CURRENT SENSING - IMPROVED VOLTAGE REGULATION KIT (SC MACHINES ONLY)

The standard machine is voltage sensed and if required current sensing can be added to make the machine more flexible to improve the voltage regulation where semi-conductor or thyristor loads are used which distort the voltage waveform of the machine. This unit can also be used to impact on the sensing circuit of the A.V.R. to overcome voltage drops where long cables between the generator and load are used. The unit consists of a current transformer C.T. and burden resistor. See Fig. 20.

The components are identical to those used for the quadrature droop kit for Parallel Operation, the only difference is that the circuit is arranged to be more sensitive between unity to 0.8 p.f. (lag) loads.

**NOTES:**

1. Depending on machine type, one or more main stator cables are connected to each output terminal, insert improved regulation C.T. on one cable only. See Fig. 21 for C.T. position and wiring diagrams.

2. Connect to auxiliary terminals 2 - 8 (after removing link) on two phase sensed machines and 4 - 7 (after removing link) on three phase sensed machines.

| A.V.R. Type | Stator Connection (Standard phase rotation) | | Improved Voltage Regulation | |
|---|---|---|---|---|
| | | | Fig. | C.T. Position |
| Two Phase | 4 Wire & 6 Wire Star | | 20 | V2 |
| | 12 Wire | Series Star | 20 | V2 |
| Sensed | | Series Delta | 20 | V2 |
| | | Parallel Star | 20 | V2 |
| | | Series Zig-Zag Star | 20* | W2 |
| Three Phase | 4 Wire & 6 Wire Star | | 20* | V2 |
| | 12 Wire | Series Star | 20* | V2 |
| Sensed | | Series Delta | 20* | V2 |
| | | Parallel Star | 20* | V2 |
| | | Series Zig-Zag Star | 20* | U2 |

*Fig. 21 Improved Regulation C.T. Positions*

**NOTES:**

1. *For these stator connections the C.T. secondary leads S1 and S2 must be reversed for correct machine operation.

2. Standard phase rotation is U.V.W. when a.c. generator is rotating clockwise viewed at the drive end. For phase rotation U.V.W. when rotating anti-clockwise refer to factory for details.

**Resistance Values**

Burden Resistor - 1000 ohms

C.T. Secondary - 16 ohms

**R.F.I./E.M.I. - SUPPRESSOR KIT**

In case where R.F.I./E.M.I. levels to BS800 are required an additional suppressor kit is recommended. The connections are shown below:-

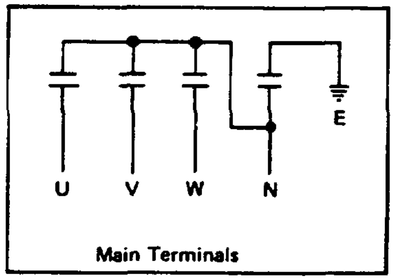



*Fig. 22*

**ANTI-CONDENSATION HEATERS**

It is recommended that anti-condensation heaters are fitted on standby applications, marine applications or where the machine is standing idle for long periods of time. The most effective anti-condensation heaters are taped directly to the overhang windings of the stator and as such must be fitted during the winding stage. See Fig. 23. On this basis heaters **must** be specified at time of ordering.

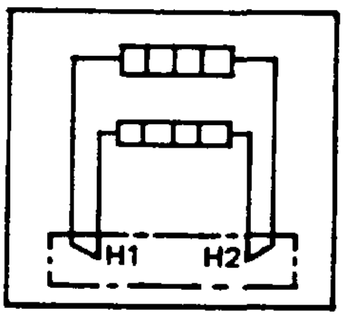



*Fig. 23*

**NOTE:** For reasons of safety, all heater leads are terminated in a separate box located on the outside of the main terminal box.

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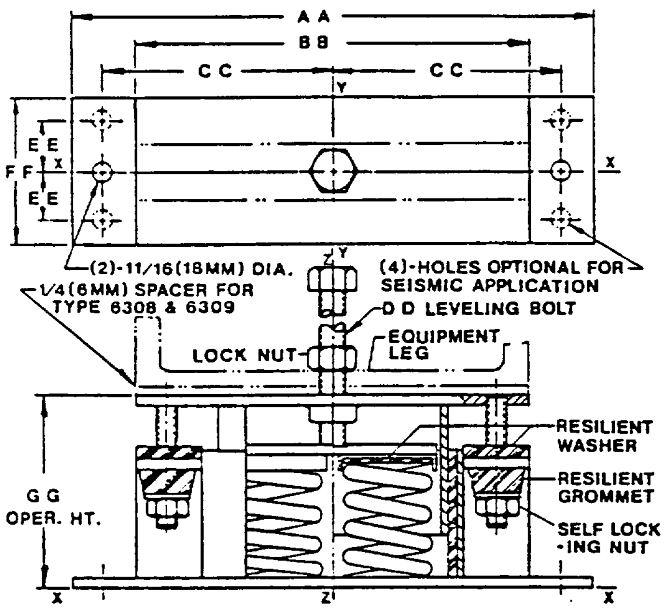
## DIMENSIONS - LOAD RATING




| SIZE | COLOR | TYPE & MAX. LOAD LBS. 631 6308 | TYPE & MAX. LOAD LBS. 632 6309 | DEFLECTION INS. |
|---|---|---|---|---|
| A | GRAY | 150 | 300 | 1.5 |
| B | TAN | 260 | 520 | 1.3 |
| C | YEL. | 435 | 870 | 1.3 |
| D | GREEN | 550 | 1100 | 1.1 |
| E | RED | 780 | 1560 | 1.0 |
| F | SILVER | 1070 | 2140 | 1.0 |
| G | BROWN | 1400 | 2800 | 1.0 |
| H | BLACK | 1800 | 3600 | 0.9 |
| K | BL'K & YEL. | 2500 | 5000 | 0.9 |

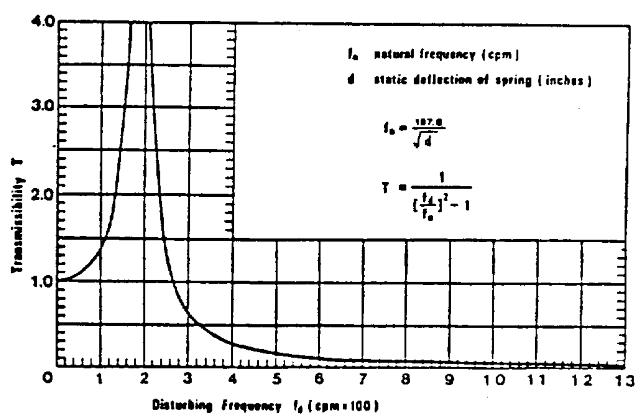
Note: Type 6308 & 6309 contain a 1-1/4"x1/4" thick spacer on the top plate for the off-set loading application.

| TYPE & SIZE | DIMENSION - INS.(MM) | | | | | | |
|---|---|---|---|---|---|---|---|
| | AA | BB | CC | DD | EE | FF | GG |
| 631 6308 A-K | 12 (305) | 8 (203) | 5 (127) | 5/8-11 | 1-1/4 (32) | 4-1/2 (114) | 6 (152)<br>6-1/4 (159) |
| 632 6309 A-H | 16 (406) | 12 (305) | 7 (178) | 5/8-11 | 1-1/4 (32) | 4-1/2 (114) | 6-1/4 (159)<br>6-1/2 (165) |
| 632 6309 K | 16 (406) | 12 (305) | 7 (178) | 3/4-10 | 1-1/4 (32) | 4-1/2 (114) | 6-3/8 (162)<br>6-5/8 (168) |

| TYPE & SIZE | LOAD RATING FOR SEISMIC RESTRAINT | | | | | | |
|---|---|---|---|---|---|---|---|
| | HOUSING | | | LEVELING BOLT | | | |
| | | | | STANDARD | | OPTIONAL | |
| | X-X | Y-Y | Z-Z | X-X & Y-Y | Z-Z | X-X & Y-Y | Z-Z |
| 631 6308 A-K | 13700 | 7850 | 8200 | 4600 | 8200 | 6900 | 11000 |
| 632 6309 A-H | 33400 | 10000 | 8200 | 4600 | 8200 | 6900 | 11000 |
| 632 6309 K | 33400 | 10000 | 8200 | 6830 | 14200 | 9940 | 19200 |

Note:

1. Series "630" spring isolator are suitable for seismic zone #1, #2, #3 and #4 applications in most conditions.
2. Seismic protection calculation available.




TRANSMISSIBILITY vs FREQUENCY

**INSTALLATION & OPERATION**

**INSTRUCTIONS**

**FOR MODELS**

| | | | |
|---|---|---|---|
| | **12V** | **5A** | **LA - or -** |
| **MBC8 -** | **- or - -** | **- or - -** | **FL - or -** |
| | **24V** | **10A** | **NC** |

**REGULATED - TWO RATE**

**BATTERY CHARGER**

**MASTER CONTROL SYSTEMS, Inc.**
**910 NORTH SHORE DRIVE, LAKE BLUFF, ILLINOIS 60044, U.S.A.**
**TELEPHONE: AREA CODE 312/295-1010 TELEX: 25-4636**

## INSTALLATION INSTRUCTIONS FOR MODEL MBC8 & MBC9 BATTERY CHARGERS

The Charger cabinet must be mounted in a vertical position, preferably on a wall in close proximity to the battery. The areas above and below the Charger must be clear for at least 12 inches to allow free air flow for cooling. The Charger cabinet must not be located in areas subject to falling or spraying water.

The cabinet should not be subject to shock or vibration. If it is necessary to mount the unit on an engine skid, select a point subject to the least amount of shock or vibration and install suitable vibration dampers.

The four mounting ears have 5/16 inch holes (or slots) to accept $^{1}/_{4}$ inch bolts. The horizontal spacing is 10 inches (centers) and the vertical (center) spacing is 13¼ inches. The unit weight is less than 60 pounds.

For wiring, use wire having insulation which is unaffected by the environment of the installation. For engine starting battery installations, use flexible stranded copper wire having insulation which is unaffected by oil or engine heat.

The bushing supplied with the Charger are in 7/8 inch diameter holes for $^{1}/_{2}$ inch nominal conduit fittings. Discard bushing(s) when conduit(s) is used.

### TABLE 1 - LOWER CHASSIS TERMINAL STRIP WIRING

| TERMINAL | MINIMUM WIRE SIZE | | DESIGNATION |
|---|---|---|---|
| GND | As Required | | Chassis Ground-Connect to ground wire of a three prong line cord when used. Connect to ground wire in a conduit wired installation when a wired ground is required. (The chassis is not insulated from the cabinet). |
| | Nameplate Input Amperes | AWG | |
| AC-H | 1 thru 8 amps<br>9 thru 12 amps<br>13 thru 20 amps<br>21 thru 30 amps | T14<br>#12<br>#10<br>#8 | A.C. Power Input Terminal (High Side, Fused Side)- Connect to high side of A.C. supply which has branch circuit protection capable of supplying the nameplate listed current requirement. |
| AC-N | Same as 'AC-H' | | A.C. Power Return Terminal Low Side - Connect to Low or Neutral Side of A.C. supply. |
| +B | -- Table 2 -- | | Positive Charge Current Output-Connect to battery positive terminal. |
| -B | -- Table 2 - | | Charge Current Return Terminal-Connect to battery negative terminal. |

**NOTE:** Neither battery output terminal is grounded in the Charger. Therefore, the unit may be used in positive ground, negative ground, or ungrounded installations.

## INSTALLATION INSTRUCTIONS FOR MODEL MBC8 & MBC9 BATTERY CHARGERS
(Continued)

### TABLE 1 - LOWER CHASSIS TERMINAL STRIP WIRING (Cont'd)

| TERMINAL | MINIMUM WIRE SIZE (COPPER) | DESIGNATION |
|---|---|---|
| DK1, DK2 | -- #24 AWG -- | Crank Disconnect Relay Input Terminals-Connect to a source of DC voltage equivalent to the Charger nominal DC voltage rating, when battery is supplying high current loads such as engine cranking or switch gear operation to prevent overloading the Charger. Coil resistance-800 ohms on 12 volt Chargers and 3,200 ohms on 24 volt units. |

### TABLE 2

### BATTERY MINIMUM WIRE SIZES (COPPER WIRE)

| CHARGER | | WITHOUT REMOTE SENSE | | WITH REMOTE SENSE | |
|---|---|---|---|---|---|
| Rated D.C. Current | Max Wire Run Length | Min Wire Size | Total Loop Drop | Min Wire Size | Total Loop Drop |
| | 10 FT | 16 AWG | 0.2V | 16 AWG | 0.2V |
| 2 $^{1}/_{2}$ AMP | 25 FT | 16 AWG | 0.5V | 16 AWG | 0.5V |
| | 50 FT | 14 AWG | 0.6V | 16 AWG | 1.0V |
| | 10 FT | 16 AWG | 0.4V | 16 AWG | 0.4V |
| 5 AMP | 25 FT | 14 AWG | 0.6V | 14 AWG | 0.6V |
| | 50 FT | 12 AWG | 0.8V | 14 AWG | 1.2V |
| | 10 FT | 12 AWG | 0.3V | 12 AWG | 0.3V |
| 10 AMP | 25 FT | 12 AWG | 0.8V | 12 AWG | 0.8V |
| | 50 FT | 8 AWG | 0.6V | 10 AWG | 1.0V |
| | 10 FT | 10 AWG | 0.4V | 10 AWG | 0.4V |
| 20 AMP | 25 FT | 8 AWG | 0.6V | 10 AWG | 1.0V |
| | 50 FT | 6 AWG | 0.8V | 8 AWG | 1.2V |

**Note that while the wire size shown for the AC wiring is based on wire current carrying capacity ('ampacity'), the wire sizes shown for the battery wiring are based on wiring resistance. In addition, splices or junctions in the wiring path must be low in resistance.**

Runs may be two of the next smaller even wire size, e.g. two #12 AWG wires may be used in place of a #10 AWG wire, etc. Aluminum wire NOT recommended.

# OPERATING PROCEDURES FOR MODEL MBC8 BATTERY CHARGER

GENERAL - The Model MBC8 Battery Chargers are constant voltage, two rate (Float-Equalize) manually switched, regulated (line compensated) battery chargers.

OUTPUT CAPACITY - These Chargers are capable of supplying up to 100% of their DC rated output current without allowing the battery to be depleted. Loads across the battery which are less than the Charger's rated current will be supplied by the Charger with the remaining Charger output being available to charge the battery, if required. For loads greater than the rated output, the Charger will supply at least its rated output (if the crank disconnect terminals--DK1 and DK2--are not energized) with the battery supplying the remainder.

LINE REGULATION - The Charger is regulated (line compensated) and requires no tap settings. The line voltage regulation (output change) is 1% maximum for a 10% line voltage change. The Charger will operate with line changes of up to ± 15% of nominal with reduced current rating on low line voltages.

WATER CONSUMPTION - In the "float" mode water consumption will be low. If left in the "equalize" mode the Charger will produce considerable gassing and subsequently high water consumption once the battery is fully charged. THE CHARGER SHOULD NOT BE LEFT IN THE "EQUALIZE" MODE FOR EXTENDED PERIODS OR BATTERY DAMAGE CAN OCCUR. The battery water level should be checked once a month until a water consumption pattern is established. The water level should be checked at least every three months due to climatic changes. Longest battery life will be obtained when distilled water is used to fill batteries.

FLOAT MODE - This is the NORMAL operating mode of the Charger, in this mode the Charger will maintain the battery charge level, supply external loads up to the Charger output current rating and will bring the battery up to a charged condition after a discharge. Water consumption will be low in this mode. With no external loads the final or maintaining current into a fully charged battery will I be less than 0.5 amperes.

EQUALIZE MODE - For batteries within the recommended range of capacity (ampere hour capacity of 5 to 20 times the Charger output current rating) the Charger will have sufficiently high output voltage and current to equalize a battery to eliminate charge level differences between individual cells. The equalize mode can also be used to charge the battery more rapidly. Most applications do not require equalizing the battery more often than once a month.

On engine starting applications the battery charging generator or alternator will equalize the battery if the engine is run long enough for the battery to be fully charged first.

**NOTE:** THE CHARGER SHOULD NOT BE LEFT IN THE "EQUALIZE" MODE FOR MORE THAN 24 HOURS OR EXCESSIVE WATER CONSUMPTION AND BATTERY HEATING WILL OCCUR.

CRANK DISCONNECT In applications requiring battery output currents which exceed the Charger output rating, such as engine cranking, a crank disconnect signal must be supplied to the Charger. This signal should be a DC voltage of the same nominal value as the Charger DC rated voltage. The signal may be either polarity and is supplied to terminals DK1 and DK2. The current required by the disconnect relay is less than 20mA on 12 volt units and 10mA on 24 volt units. Wiring these terminals to the starter contactor or starter motor terminals would provide the required signal on engine starting applications.

BATTERY CONDITION - A fully charged battery will be indicated by a low Charger output current and, for lead acid batteries, a full charge specific gravity hydrometer reading in all cells. A battery which has approached end of life will have a reduced ampere hour capacity (something less than the battery's rated capacity). An adequate check of a battery for capacity in an engine starting application is to monitor the battery voltage while it is cranking the engine during an expected worst case starting attempt. If the battery was fully charged its cranking voltage should be more than 75% of nominal voltage (9 volts minimum on a 12 volt lead acid battery). Batteries which have sufficient capacity but which are not fully charged may not pass this test. Similarly, worst case voltage drop can be established for other high current load application to determine the battery condition assuming that the battery is fully charged.

TO PUT THE CHARGER INTO OPERATION - Connect per installation instructions and apply A.C. power. CAUTION: Always disconnect, turn off, or remove A.C. power from the Charger before attempting to service the Charger or before connecting or disconnecting Charger or battery leads. Similarly, do not connect or disconnect battery leads with any loads connected.

NORMAL OPERATION - When power is first applied the Charger will normally supply at least rated current as indicated on the Charger ammeter. As the battery charge builds up the charge current will reduce finally to a level required to maintain the battery charge and supply any additional loads. The charge current should reduce to lower values within 30 hours or less for properly sized Chargers.

When a drain is put on the battery or A .C. power is interrupted the Charger will again produce higher output currents until the battery voltage builds up to a charged condition.

When connected to a fully discharged battery the charge current will be higher than rated current for part of the charge cycle. As above, a deep discharged battery can cause Charger shutdown (if its terminal voltage is less than +5.0 volts) for up to several hours before high charge currents to occur as above. Note that for a deep discharged battery to eventually allow Charger turn on, there must be no other loads on the Charger (or battery).

CHARGER MAINTENANCE - There are no field adjustments to be made on these Chargers. The only adjustable device is the float voltage adjustment on the regulator P.C. board which is factory set using precision equipment.

LOW VOLTAGE SHUTDOWN - These Chargers are normally supplied with low voltage shutdown which causes the Charger to reduce its output current any time the battery output terminal voltage drops below +5.0 volts. The Charger will shut off completely if the output terminal voltage drops below +2.5 volts. This provides reverse polarity and short circuit protection. In addition, in the absence of capacitive loads, the Charger will shutdown on "missing battery" or open leads, if the Charger output terminals (+B & -B) have 3.0K ohms or less of load resistance connected.

# THEORY OF OPERATION MODEL MBC8 BATTERY CHARGER

GENERAL - Refer to drawing 10003 for schematic representation. Note that while the transformer winding configuration changes with Charger voltage and current ratings, the typical winding configuration is representative of the Charger operation. This discussion will assume the unit is a 24 volt model.

A.C. PATH - The A.C. power is applied to the power transformer primary through fuse Fl. Note that the primary taps shown are factory wiring options to accommodate different battery types. The 'GND' terminal is tied directly to the chassis which is in electrical contact with the cabinet. The primary and secondary circuits are electrically isolated from each other and from chassis or cabinet ground. The transformer, then, isolates the A.C. power and transforms the voltage to the level required by the battery.

The regulator board has its own regulated power supply which is supplied via the 'AC' pins and terminals 15 and 16. The wiring options shown on drawing 10003 are to provide approximately 12 V AC to the regulator board. The return line for this supply is the 'RET' pin which connects to the transformer center tap via terminal '-B'. The local regulated supply on the board supplies the reference element providing the double regulated reference voltage for low line regulation error.

D.C. PATH - The main power rectifiers are port of the SCR assembly Q10. Rectification is full wave center tap with the center tap leads extending to the -B1 terminal (battery negative). The rectifier output goes directly to the anode of the SCR which is also part of the SCR assembly (Q10). Battery charge current will flow, then, when the SCR (Silicon Controlled Rectifier) is turned on and vice versa. The resistor and capacitor of Q10 SCR assembly form a "snubber" network to prevent false turn on of the SCR with line surges or transients. When the SCR is turned on via the '+PT' output from the regulator P.C. (Printed Circuit) board via terminal 14 of TS2 (blue) charge current will flow through the SCR to terminal 13 (green), terminal 23 (F2), Fuse F2, Ammeter (A) terminal 24 and to battery positive from the '+B' terminal. The SCR turn on signal is a pulse supplied from a pulse transformer on the regulator board. The return lead from this transformer is '-PT' which is connected to the cathode of the SCR via terminal 13. The shutdown sense line (SD) is also connected to terminal 13.

VOLTAGE SENSING - The regulator board is the controlling element of the whole Charger. The SCR assembly is a "Slave" to the regulator. The regulator senses the battery terminal voltage via terminal 24 (+V), the "Float" switch (SW-1), or resistor R30, and 25 (+RS) and terminal 26 (-V). The regulator will turn on the SCR sooner in each half line cycle when the sensed battery voltage is below the internal regulated reference voltage. Turning on the SCR sooner in each half cycle will allow more charge current to flow. When the battery voltage increases (with charge level) above the fixed reference voltage, the regulator will turn on the SCR later in each half cycle causing reduced charges currents. With the "Float-Equalize" switch in the "Equalize" position resistor R30 is in series with the regulator voltage sensing circuit, which reduces the battery terminal voltage seen by the regulator voltage comparing circuit. This causes the Charger output voltage to increase to equalize the battery. With the "Float-Equalize" switch in the "Float" position resistor R30 is shorted out causing the regulator voltage comparitor to see a true battery terminal voltage reducing the Charger output voltage to the "Float" level.

The battery voltage sensing network is high in impedance (approximately 100K ohm) and will not cause battery discharge on power outage.

THEORY OF OPERATION MODEL MBC8 BATTERY CHARGER
(continued)

CRANK DISCONNECT - The crank disconnect relay is supplied by the 'DK' terminals. This reed relay shunts the SCR pulse transformer input when operated which prevents SCR turn on.

SHUTDOWN - The shutdown sense line (SD) is connected to the internal SCR trigger drive signal on the regulator board through a diode. The 'SD' line does not input current and will not discharge the battery on power outage. Thus with a shorted output, the load will "Steal" the SCR trigger drive signal (via terminal +B), preventing SCR turn on, to shutdown the Charger.

## REPLACEMENT PARTS LIST

## MODEL MBC8 BATTERY CHARGER

| | PART NUMBER | | | | |
|---|---|---|---|---|---|
| CHARGER MODEL NUMBER | CHARGER | REGULATOR (PC) | CIRCUIT BREAKER | D.C. FUSE (F2) 3 AG (SIZE) | RESISTOR R30 |
| MBC8-12V-5A-LA | B600780 | B504000 | B300804 (1.5A) | B201566 (15A) | B101491 (6.2K) |
| MBC8-12V-10A-LA | B600781 | B504000 | B300793 (3.0A) | B201569 (30A) | B101491 (6.2K) |
| MBC8-24V-5A-LA | B600790 | B504001 | B300793 (3.0A) | B201566 (15A) | B101491 (6.2K) |
| MBC8-24V-10A-LA | B600791 | B504001 | B300796 (6.0A) | B201569 (30A) | B101491 (6.2K) |
| MBC8-12V-5A-FL | B600782 | B504002 | B300804 (1.5A) | B201566 (15A) | B101490 (5.6K) |
| MBC8-12V-10A-FL | B600783 | B504002 | B300793 (3.0A) | B201569 (30A) | B101490 (5.6K) |
| MBC8-24V-5A-FL | B600792 | B504003 | B300793 (3.0A) | B201566 (15A) | B101490 (5.6K) |
| MBC8-24V-10A-FL | B600793 | B504003 | B300796 (6.0A) | B201569 (30A) | B101490 (5.6K) |
| MBC8-12V-5A-NC | B600784 | B504004 | B300804 (1.5A) | B201566 (15A) | B101490 (5.6K) |
| MBC8-12V-10A-NC | B600785 | B504004 | B300793 (3.0A) | B201569 (30A) | B101490 (5.6K) |
| MBC8-24V-5A-NC | B600794 | B504005 | B300793 (3.0A) | B201566 (15A) | B101490 (5.6K) |
| MBC8-24V-10A-NC | B600795 | B504005 | B300796 (6.0A) | B201569 (30A) | B101490 (5.6K) |
| MBC8-24V-5A-NC19 | B600796 | B504001 | B300793 (3A) | B201566(15A) | B 101496 (10K) |

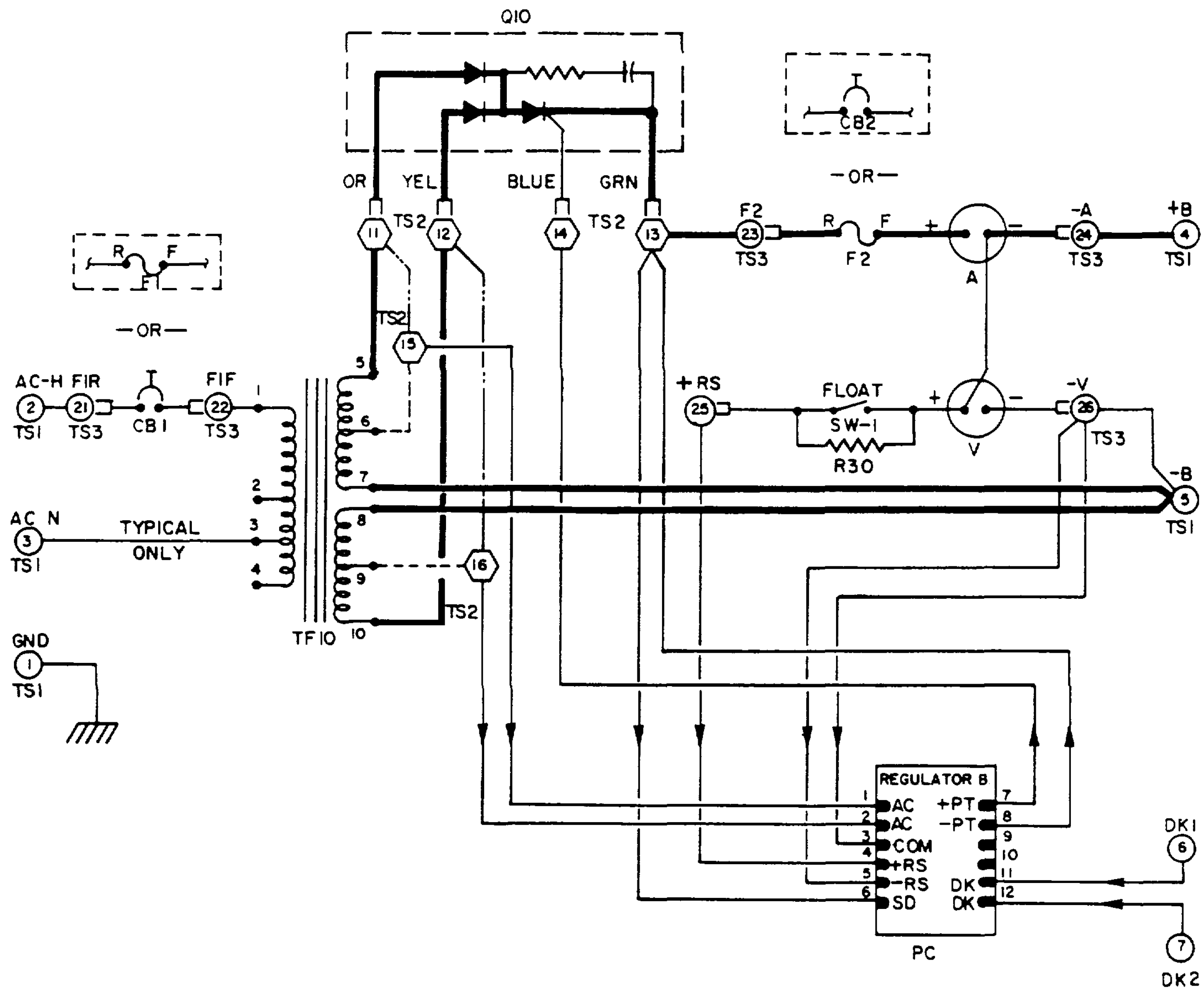
### COMMON PARTS (ALL MODEL MBC8 BATTERY CHARGERS)

| DESCRIPTION | SYMBOL | PART NUMBER |
|---|---|---|
| SCR Assembly | 0Q10 | B600032 |
| 0-30V Voltmeter | V | 780289 |
| 0-15A Ammeter | A | 780290 |
| 3AG Fuse Holder | F2 | A400013 |
| SPST Switch | "Float" | 730243 |

Note: When ordering Replacement Parts, be sure to specify MODEL NUMBER and SERIAL NUMBER of Charger in which they are to be used.

MASTER CONTROL SYSTEMS, INC.
910 North Shore Drive
Lake Bluff, Illinois 60044 USA
Phone: (312) 295-1010 Telex: 25-4636

| ISSUE | REVISIONS |
| --- | --- |
| 5 | REDRAWN 1-23-79 |




NOTES:

SPADED WIRING IS CABINET WIRING (RL-084)

CHASSIS WIRING (12V, 5A-RL-071; 12V, 10A-RL-096; 24V, 5A-RL-072; 24V, 10A-RL-097)

→ DIRECTION OF SIGNAL, POWER OR INFORMATION FLOW. (NOT NECESSARILY CURRENT DIRECTION)

— CHARGE CURRENT PATH

⬡ CHARGER TERMINALS TS2

-·-·- 12V. WIRING

- - - 24V. WIRING

TRANSFORMER WIRING SHOWN TYPICAL

SW-1 SHOWN IN "EQUALIZE" POSITION

◯ CHARGER TERMINALS TS1 & TS3

REF:
B600780
B600790

WIRING DIAGRAM
MBC8 CHARGER
(2 TS)

MASTER CONTROL SYSTEMS INC.
LAKE BLUFF ILLINOIS U.S.A.

| USED ON | ISS | SCALE — |
| --- | --- | --- |
| DRN | DES | |
| APP | DATE 1-23-79 | |
| DWG 10003 | ISS 5 | SHEET 1 OF 1 |

| ISSUE | REVISIONS |
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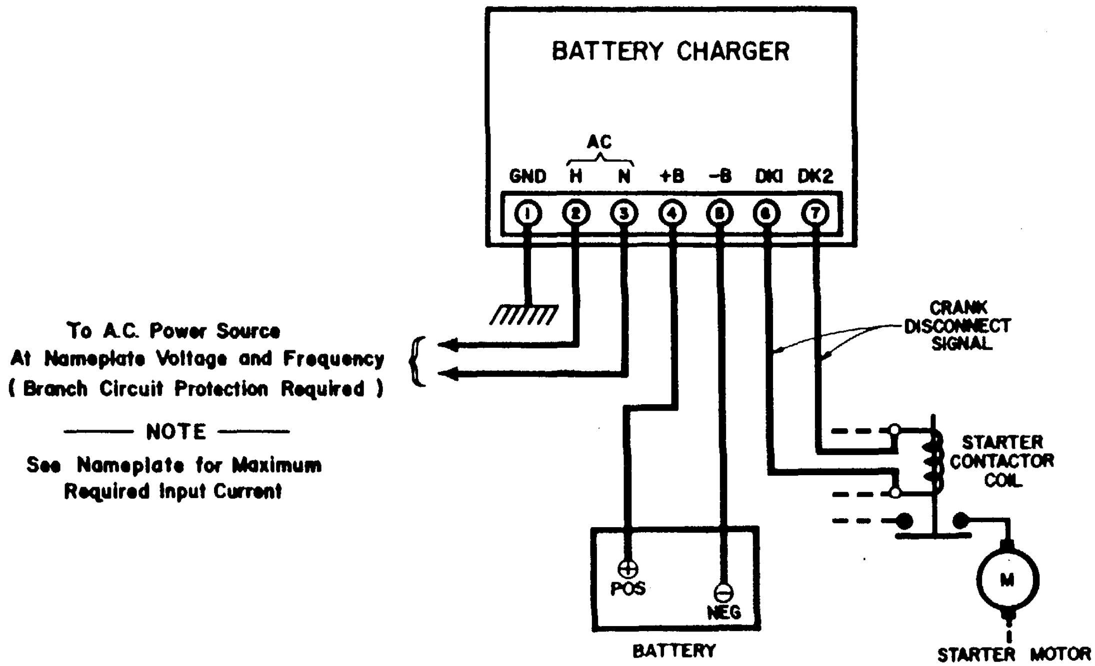
| 3 | GENERALIZED A.C. INPUT NOTE. [illegible] |




EXTERNAL WIRING OF
MBC8 & 9
BATTERY CHARGER

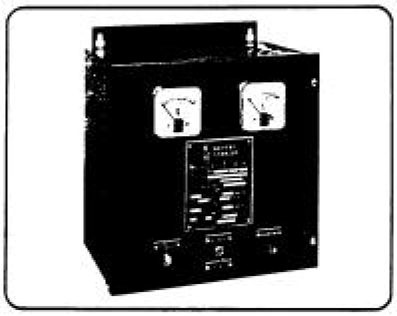
MASTER CONTROL SYSTEMS INC.
7344 N MONTICELLO AVE SKOKIE, ILL

| | | | |
|---|---|---|---|
| USED ON | | SCALE | |
| DRN | | | |
| APP | | DATE 8-10-74 | |
| DWG | ISS 3 | SHEET 1 OF 1 | |

*MASTER CONTROL SYSTEMS, INC.*

**REGULATED TWO RATE**
FLOAT EQUALIZE
**BATTERY CHARGER**

**This Charger has been specifically designed for recharging and maintaining engine starting batteries. It will carry continuous or intermittent loads up to 100%/o of the charging rate.**



**These Chargers Provide:**

- **Automatic Float operation -output is regulated to meet battery demand.**
- **A.C. Line Voltage Compensation.**
- **D.C. Voltage Regulation.**
- **Two Rate, Float-equalize toggle switch.**
- **Built-in Crank disconnect relay.**
- **Complete Solid State Control.**
- **Output Voltmeter and Ammeter.**

**CHARGER PERFORMANCE SPECIFICATIONS**

FOR MBC8 MODELS, 12 and 24 Volt Nominal Voltage, and 5 and 10 Ampere Rated Current.

INPUT LINE REQUIREMENTS: Nominal 117V. A.C. at 60 Hertz, Range of input voltage: 105-125V. A.C.

RECOMMENDED BATTERY CAPACITY: 5.0 to 23.0 Times rated current.

The following specifications apply at 117-125V. A.C. input at 25°C in either mode.

OUTPUT CURRENT: Unit will deliver at least rated current into a fully discharged battery.

OUTPUT VOLTAGE LIMITS: Nominal Value (Factory Set).

| BATTERY TYPE: | LA (1.275 S.G.) | FL (1.220 S.G.) | NC (High Rate) |
|---|---|---|---|
| EQUALIZE: | 2.42 V/Cell | 2.29 V/Cell | 1.55 V/Cell |
| FLOAT: | 2.25 V/Cell | 2.17 V/Cell | 1.40 V/Cell |

MODE SWITCHING: Front - Panel Toggle Switch.

VOLTAGE REGULATION - LOAD: ± 1.0%o Maximum - No Load to Full Load (Float Mode).

VOLTAGE REGULATION - LINE: ± 1.0% Maximum for 10% Line Change.

OPEN CIRCUIT LEAKAGE: 50mA Maximum.

OUTPUT DRAIN (A.C. INPUT OFF): 10mA Maximum.

OUTPUT TERMINAL VOLTAGE FOR CHARGER SHUTDOWN (WITH SHUTDOWN OPTION): + 4.0 Volts Maximum.

Although designed especially for use with engine starting batteries, the MBC8 is a true, two rate float charger and can be used on other applications not requiring the precision output regulation of the Master Controls Model MBC7 or the automatic high recharge capability of the MBC6.

This charger will carry external loads up to 100% of its rating. In order to prevent extremely high external loads (such as engine cranking) from overloading the charger, a built-in crank disconnect relay is provided. Under no load conditions, when the battery is fully charged, and with the charger in the float mode, only enough current will be supplied to replace the power lost through the internal leakage of the battery. This keeps gassing and water consumption to an absolute minimum.

When batteries are charged by the float method, the battery has a tendency to develop differences (inequalities) in the charge level among the individual cells. This condition can be corrected by applying an "equalizing" charge at periodic intervals. This is accomplished by raising the charger output voltage by several tenths of a volt per cell for a specified time. A manual toggle switch is provided for this purpose.

All charge controls are factory preset so as to provide proper operation on the particular type of battery.

**LOW AND HIGH VOLTAGE ALARMS**

Master Control's low voltage alarm Option (LCA) provides a set of SPDT dry contacts rated for 10 amps @ 115 V. A.C. The alarm set point is factory-adjusted to a voltage set point which represents an open circuit battery that is 25°% to 50% discharged. Factory-adjusted for the particular battery type involved, it requires no field adjustments. In order to prevent false actuation of the alarm during high battery load conditions, a built-in time delay of approximately 15 seconds is provided.

High voltage alarm Option (HCA) is also available. It will detect abnormally high charge rates due to charger failure. The alarm set point is factory-adjusted to a voltage slightly higher than the charger's normal output.

**Construction Features:**

- A.C. circuit breaker and D.C. Fuse is provided
- All semiconductors are silicon and hermetically sealed
- Modular construction (Plug-in printed circuit regulator board)
- Float and equalize voltage levels are factory preset for the specific battery type
- No transformer tap settings are required
- Output is completely isolated from A.C. power

**Ordering Information:**

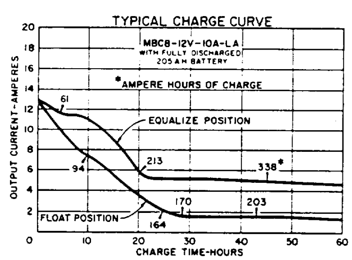
- State Master Control's Model number
- A.C. input voltage frequency and phase
- Number and type of battery cells
- Specific gravity of lead acid battery
- Ampere Hour Capacity of Battery
- Continuous D.C. load
- Allowable Recharging Time from full discharge (when applicable)

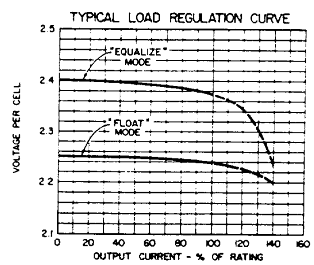
## MODEL DESIGNATION

| CHARGER | | | | | BATTERY | |
|---|---|---|---|---|---|---|
| Model Number | Nominal Output D.C. Volts | Rated Output D.C. Amp. | Max. A.C. Amps. Input at 120 VAC | Approx. Weight Lbs. (KG) | No. of LA or FL Cells | Recommended Capacity Range (A.H.) |
| MBC8-12-5(*) | 12 | 5 | 1.5 | 22 (10) | 6 | 25-115 |
| MBC8-12-10(*) | 12 | 10 | 3 | 26 (12) | 6 | 50-230 |
| MBC8-12-20(*) | 12 | 20 | 6 | 34 (15) | 6 | 100-460 |
| MBC8-24-5(*) | 24 | 5 | 3 | 25 (11) | 12 | 25-115 |
| MBC8-24-10(*) | 24 | 10 | 6 | 34 (15) | 12 | 50-230 |
| MBC8-24-20(*) | 24 | 20 | 12 | 37 (17) | 12 | 100-460 |
| MBC8-30-5(*) | 30 | 5 | 4 | 29 (13) | 15 | 25-115 |
| MBC8-30-10(*) | 30 | 10 | 8 | 36 (16) | 15 | 50-230 |
| MBC8-32-5(*) | 32 | 5 | 4 | 29 (13) | 16 | 25-115 |
| MBC8-32-10(*) | 32 | 10 | 8 | 36 (16) | 16 | 50-230 |

(') Add Suffix (LA) to model number when charger is for use with automotive lead acid batteries having 1.265-1.285 sp. gr.
(') Add Suffix (FL) to model number when charger is for use with float service lead acid batteries having 1.200-1.200 sp. gr.
(') Add Suffix (NC) to model number when charger is for Nickel Cadmium Batteries.

**NOTE:** Battery manufacturers recommend that the equalizing current be not less than C/20 with C representing the ampere hour capacity of the battery. As an example, a 200 ampere hour battery would require a charger having a rated current of 10 amperes.
The charger output recommendations outlined in the above table should be followed to assure proper system operation and reasonable operating life of the charger and batteries.




## SAMPLE SPECIFICATIONS

The battery charger shall be a Master Control Model MBC8 or approved equal. The charger shall have an output rating of at least 1/20 of the rated ampere hour capacity of the battery to which it is applied and be capable of carrying continuous loads up to 100% of its rated output. The charger shall have two ranges (equalize and float). Voltage settings for both ranges shall be factory preset for the specific battery type and shall not be field adjustable. It shall maintain its rated output voltage within ± 1% with A.C. input variation of ± 10%. Output voltage regulation between no load and full load shall be within ± 1%.

Specifications subject to change without notice.


**MASTER CONTROL SYSTEMS, Inc.**
**910 NORTH SHORE DRIVE, LAKE BLUFF, ILLINOIS 60044, U.S.A.**
**TELEPHONE: AREA CODE 312/295-1010 TELEX: 25-4636**

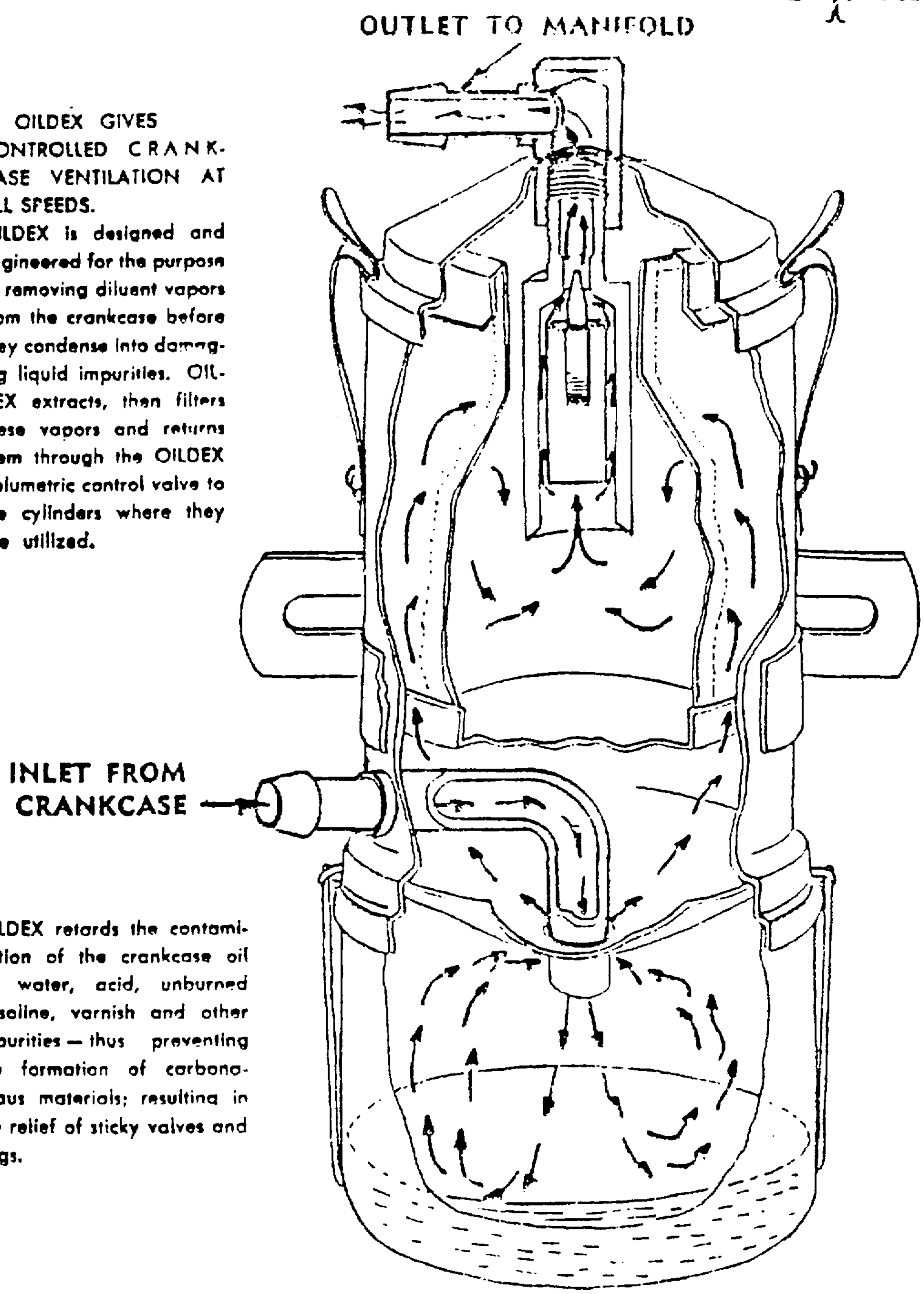
**MASTER CONTROL SYSTEMS, Inc.**

# OILDEX® - How it Operates...

● OILDEX GIVES CONTROLLED CRANK-CASE VENTILATION AT ALL SPEEDS.

OILDEX is designed and engineered for the purpose of removing diluent vapors from the crankcase before they condense into damaging liquid impurities. OILDEX extracts, then filters these vapors and returns them through the OILDEX Volumetric control valve to the cylinders where they are utilized.

OILDEX retards the contamination of the crankcase oil by water, acid, unburned gasoline, varnish and other impurities — thus preventing the formation of carbonaceous materials; resulting in the relief of sticky valves and rings.




The "escalator," or up-and-down action of valve insures accurate, controlled crankcase ventilation, at both idle and high speed.

NOTE: Spring loaded valve not shown

Vapor Filtering Element removes carbonaceous materials, allowing the metering valve to operate freely. Keeps harmful varnish and other materials from clogging intake manifold and interrupting air ratio of carburetor to engine.

Baffle plate acts as a secondary retention to vapors from the crankcase, resulting in increased element life.

Retention chambers for unburned vapors and varnish which are drawn from crankcase while in vapor form.

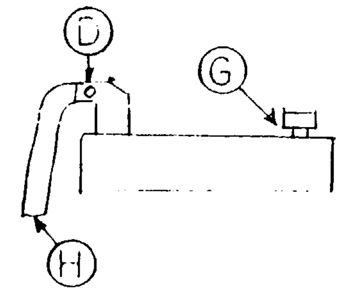
Detects porus blocks or blown gaskets by extracting excessive water.

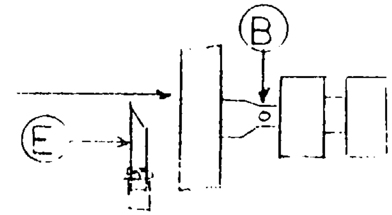
OILDEX/corporation

OILDEX* ORIGINATORS OF FILTERED AND CONTROLLED CRANK CASE VENTILATION

INSTALLATION INSTRUCTIONS - READ CAREFULLY

1. Remove valve cover and drill a 23/32" hole in valve cover at G. Tap with 1/2" pipe tap and install Oildex oil bath air filter. Remove cover and fill to oil level hole with engine oil. Replace cover. Reinstall valve cover on engine.
2. Remove road draft tube and drill a 37/64" hole in side of vent cap at D. Tap with 3/8" pipe tap and install Oildex hose fitting. Replace road draft tube and close end at H with solid cork furnished.
3. Install Oildex mounting bracket in any convenient location as close as possible to point D.
4. Place Oildex band bracket around Oildex unit and assemble to mounting bracket with Oildex side inlet hose fitting C pointing towards D.
5. Remove air cleaner and drill a 23/32" hole in turbocharger inlet housing at B. Tap with 1/2" pipe tap and screw Oildex venturi tube into hole. When tight be sure cut-off portion is pointing towards the turbo inlet per sketch E. Replace air filter.

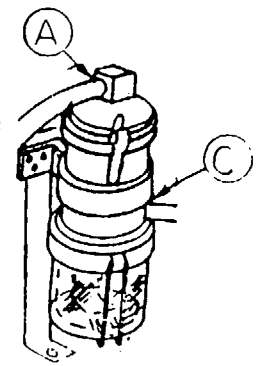



6. Connect Oildex side inlet hose fitting C to D with Oildex hose.
7. Connect Oildex top outlet hose fitting A to B with Oildex hose.

NOTE: On some engines it may be necessary to fabricate and install an adaptor between the air cleaner and turbocharger inlet in order to install the venturi tubes, due to lack of clearance at point B.

When using an external oil level gauge or automatic oil level regulator they must be vented back to the crankcase or valve cover.




**INSTALLATION NOTES:**

1. INSTALL OILDEX UNIT IN VERTICAL POSITION ALLOWING FOR HOOD CLEARANCE AND JAR AND ELEMENT INSPECTION AND REMOVAL.
2. MOUNT OILDEX UNIT AS CLOSE AS PRACTICAL TO INTAKE MANIFOLD USING A MINIMUM AMOUNT OF OILDEX HOSE WITHOUT SHARP BENDS.
3. START ENGINE AND RUN UNTIL NORMAL TEMPERATURE IS REACHED. ADJUST CARBURETOR IDLE AIR SCREW FOR SMOOTH IDLE. ALSO ADJUST CARBURETOR THROTTLE SCREW FOR DESIRED RPM.
4. MECHANICAL TAPPETS SHOULD BE CHECKED FOR PROPER CLEARANCE AFTER A FEW DAYS OF OPERATION WITH THE OILDEX SYSTEM.
5. CHECK FOR HOOD CLEARANCE WHEN INSTALLING OIL BATH AIR FILTER.

**OILDEX corporation**
Long Beach, California

PART NAME - OILDEX* FILTERED AND CONTROLLED CRANKCASE VENTILATION SYSTEM for 3304 Caterpillar Turbocharged Diesel Engine and 3306

| MAT'L: | TOLERANCE UNLESS SPECIFIED | | DATE |
|---|---|---|---|
| | DECIMAL: | DRN: Y | |
| | FRACTIONAL: | CHECKED: | |
| | ANGULAR: | SCALE: | |

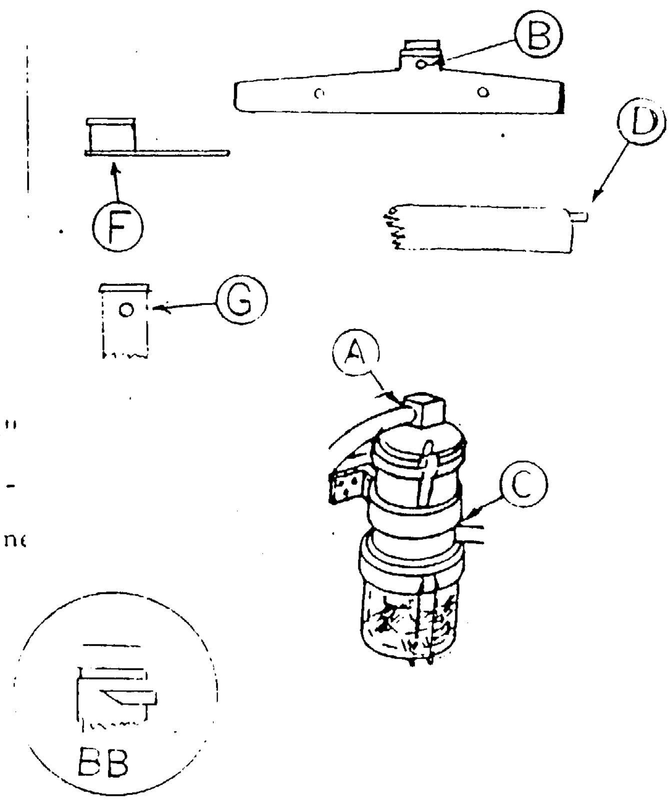
DWG. NO. XCAD-12T .D

OILDEX® ORIGINATORS OF FILTERED AND CONTROLLED CRANK CASE VENTILATION

INSTALLATION INSTRUCTIONS - READ CAREFULLY

1. Locate Oildex unit in any convenient location as close as possible to intake manifold and in a vertical position.
2. Install Oildex mounting bracket in location selected.
3. Place band bracket around Oildex unit and assemble to the mounting bracket.
4. Remove intake manifold or place intake full of rags so that you can drill one 23/32" hole at B. Tap to 1/2" pipe thread and screw venturi tube into hole. Be sure the cut-off portion of the venturi tube is pointing downward as in sketch BB. Replace manifold or remove rags and all cuttings with a magnet.
5. Remove existing ventilation hose from road draft tube in valve cover at D and discard.
6. Connect Oildex top outlet hose fitting A to intake manifold hose fitting B with Oildex hose.
7. Connect Oildex side inlet hose fitting C to D with Oildex hose.
8. Drill one 37/64" hole in oil fill pipe a G and tap 3/8" pipe thread and install hose fitting in G.
9. Install Oildex oil bath air filter and screw hose fitting into bottom at F. Connect F to G with Oidex hose. Remove cover from oil bath and fill oil bath with engine oil to oil level hole and replace cover.

All hoses should be as short as possible and without sharp bends or droops.




INSTALLATION NOTES:

1. INSTALL OILDEX UNIT IN VERTICAL POSITION ALLOWING FOR HOOD CLEARANCE AND JAR AND ELEMENT INSPECTION AND REMOVAL.
2. MOUNT OILDEX UNIT AS CLOSE AS PRACTICAL TO INTAKE MANIFOLD USING A MINIMUM AMOUNT OF OILDEX HOSE WITHOUT SHARP BENDS.
3. START ENGINE AND RUN UNTIL NORMAL TEMPERATURE IS REACHED. ADJUST CARBURETOR IDLE AIR SCREW FOR SMOOTH IDLE. ALSO ADJUST CARBURETOR THROTTLE SCREW FOR DESIRED RPM.
4. MECHANICAL TAPPETS SHOULD BE CHECKED FOR PROPER CLEARANCE AFTER A FEW DAYS OF OPERATION WITH THE OILDEX SYSTEM.
5. CHECK FOR HOOD CLEARANCE WHEN INSTALLING OIL BATH AIR FILTER.

| MAT'L: | TOLERANCE UNLESS SPECIFIED | | |
|---|---|---|---|
| | DECIMAL: | DRN: Y | DATE |
| | FRACTIONAL: | CHECKED: | |
| | ANGULAR: | SCALE: | |

**OILDEX corporation**
Long Beach, California

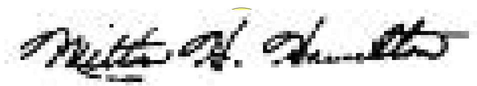
PART NAME- OILDEX® FILTERED AND CONTROLLED CRANKCASE VENTILATION SYSTEM for Perkins Diesel 4.108, 4.154, 4.203, 4.236, 4.248, 6.354.

DWG. NO. XPERK-1

**By Order of the Secretary of the Army:**

GORDON R. SULLIVAN
*General, United States Army*
*Chief of Staff*

Official:



MILTON H. HAMILTON
*Administrative Assistant to the*
*Secretary of the Army*
02761

DISTRIBUTION;
To be distributed in accordance with DA Form 12-25E, qty rqr block no. 3643, requirements for TM 55-1930-209-14&P-9-4.

**☆U.S. GOVERNMENT PRINTING OFFICE: 1992:756-316**

RECOMMENDED CHANGES TO EQUIPMENT TECHNICAL PUBLICATIONS


SOMETHING WRONG WITH THIS PUBLICATION?

FROM (PRINT YOUR UNIT'S COMPLETE ADDRESS)
PFC JOHN DOE
COA, 3d ENGINEER BN
FT. LEONARDWOOD, MO 63108

DATE SENT

| PUBLICATION NUMBER | PUBLICATION DATE | PUBLICATION TITLE |
|---|---|---|
| TM 55-1930-209-14&P-9-4 | 15 October 1992 | Water Purification Barges, Electric Power System |

BE EXACT PIN-POINT WHERE IT IS

| PAGE NO | PARA-GRAPH | FIGURE NO | TABLE NO | IN THIS SPACE TELL WHAT IS WRONG AND WHAT SHOULD BE DONE ABOUT IT: |
|---|---|---|---|---|
| 6 | 2-1 a | | | In line 6 of paragraph 2-1a the manual states the engine has 6 Cylinders. The engine on my set only has 4 Cylinders. Change the manual to show 4 Cylinders. |
| 81 | | 4-3 | | Callout 16 on figure 4-3 is pointing at a bolt. In key to figure 4-3, item 16 is called a shim - Please correct one or the other. |
| 125 | line 20 | | | I ordered a gasket, item 19 on figure B-16 by NSN 2910-00-762-3001. I got a gasket but it doesn't fit. Supply says I got what I ordered, so the NSN is wrong. Please give me a good NSN |

| PRINTED NAME, GRADE OR TITLE AND TELEPHONE NUMBER | SIGN HERE |
|---|---|
| JOHN DOE, PFC (268) 317-7111 | John Doe<br>JOHN DOE |

DA FORM 1 JUL 79 2028-2 PREVIOUS EDITIONS ARE OBSOLETE.

DRSTS-M Overprint 1, 1 Nov 80

P.S.--IF YOUR OUTFIT WANTS TO KNOW ABOUT YOUR RECOMMENDATION MAKE A CARBON COPY OF THIS AND GIVE IT TO YOUR HEADQUARTERS

TEAR ALONG PERFORATED LINE

TEAR ALONG PERFORATED LINE

FILL IN YOUR UNIT'S ADDRESS

FOLD BACK

DEPARTMENT OF THE ARMY

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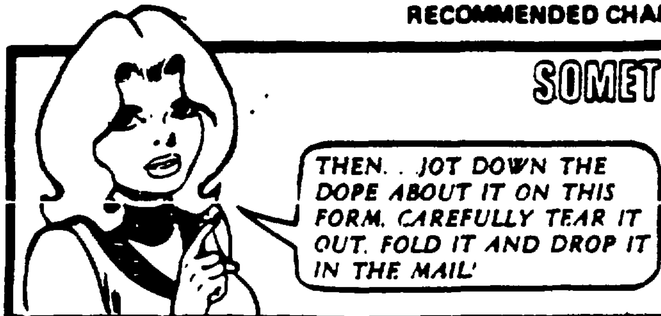
OFFICIAL BUSINESS

COMMANDER
U.S. ARMY TROOP SUPPORT COMMAND
ATTN: AMSTR-MMTS
4300 GOODFELLOW BOULEVARD
ST. LOUIS, MO 63120-1798

RECOMMENDED CHANGES TO EQUIPMENT TECHNICAL PUBLICATIONS




**SOMETHING WRONG** WITH THIS PUBLICATION?

FROM: (PRINT YOUR UNIT'S COMPLETE ADDRESS)

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| PAGE NO | PARA-GRAPH | FIGURE NO | TABLE NO | |
| | | | | |

| PRINTED NAME, GRADE OR TITLE AND TELEPHONE NUMBER | SIGN HERE |
|---|---|
| | |

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REVERSE OF DA FORM 2028-2 Reverse of DRSTS-M Overprint 2,
1 Nov 80

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# The Metric System and Equivalents

### *Linear Measure*

1 centimeter = 10 millimeters = .39 inch
1 decimeter= 10 centimeters = 3.94 inches
1 meter = 10 decimeters = 39.37 inches
1 dekameter = 10 Meters = 32.8 feet
1 hectometer = 10 dekameters = 328.08 feet
1 kilometer = 10 hectometers = 3,280.8 feet

### *Weights*

1 centigram = 10 milligrams = .15 grain
1 decigram = 10 centigrams = 1.54 grains
1 gram = 10 decigram = 0.35 ounce
1 dekagram = 10 Grams = .35 ounce
1 hectogram = 10 dekagrams = 3.52 ounces
1 kilogram = 10 hectograms = 2.2 pounds
1 quintal = 100 kilograms = 220.46 pounds
1 metric ton = 10 quintals = 1.1 short tons

### *Liquid Measure*

1 centiliter = 10 milliliters = .34 fluid ounce
1 deciliter = 10 centiliters = 3.38 fluid ounces
1 liter = 10 deciliters = 33.81 fluid ounces
1 dekaliter = 10 liters = 2.64 gallons
1 hectoliter = 10 dekaliters = 27.42 gallons
1 kiloliter = 10 hectoliters = 264.18 gallons

### *Square Measure*

1 sq. centimeter = 100 sq millimeters = .155 sq. inch
1 sq. decimeter= 100 sq centimeters = 125.5 sq. inches
1 sq. meter (centare) = 100 sq decimeters = 10.76 sq. feet
1 sq. dekameter (are) = 1,076.4 sq. feet
1 sq. hectometer (hectare) = 100 sq. dekameters = 2.47 acres
1 sq. kilometer = 100 sq. hectometers = .386 sq. mile

### *Cubic Measure*

1 cu. centimeter = 1000 cu. millimeters = .06 cu. inch
1 cu. decimeter = 1000 cu. decimeters = 61.02 cu. inches
1 cu. meter = 1000 cu. decimeters = 35.31 cu. feet

## Approximate Conversion Factors

| To change | To | Multiply by | To change | To | Multiply by |
|---|---|---|---|---|---|
| inches | centimeters | 2.540 | ounce-inches | newton-meters | .007062 |
| feet | meters | .305 | centimeters | inches | .394 |
| yards | meters | .914 | meters | feet | 3.280 |
| miles | kilometers | 1.609 | meters | yards | 1.094 |
| square inches | square centimeters | 6.451 | kilometers | miles | .621 |
| square feet | square meters | .093 | square centimeters | square inches | .155 |
| square yards | square meters | .836 | square meters | square feet | 10.764 |
| square miles | square kilometers | 2.590 | square meters | square yards | 1.196 |
| acres | square hectometers | .405 | square kilometers | square miles | .386 |
| cubic feet | cubic meters | .028 | square hectometers | acres | 2.471 |
| cubic yards | cubic meters | .765 | cubic meters | cubic feet | 35.315 |
| fluid ounces | milliliters | 29.573 | cubic meters | cubic yards | 1.308 |
| pints | liters | .473 | milliliters | fluid ounces | .034 |
| quarts | liters | .946 | liters | pints | 2.113 |
| gallons | liters | 3.785 | liters | quarts | 1.057 |
| ounces | grams | 28.349 | liters | gallons | .264 |
| pounds | kilograms | .454 | grams | ounces | .035 |
| short tons | metric tons | .907 | kilograms | pounds | 2.205 |
| pound-feet | newton-meters | 1.356 | metric tons | short tons | 1.102 |
| pounds-inches | newton-meters | .11296 | | | |

## Temperature (Exact)

| | | | | |
|---|---|---|---|---|
| °F | Fahrenheit Temperature | 5/9 (after subtracting 32) | Celsius Temperature | °C |

PIN: 072804-000