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TM 9-5000-29

DEPARTMENT OF THE ARMY TECHNICAL MANUAL

NIKE I SYSTEMS

MISSILE ELECTRICAL CHECKOUT EQUIPMENT (U)

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TM 9-5000-29, NIKE I SYSTEMS, Missile Electrical Checkout Equipment (U), is published for the use of all concerned.

The special texts in the TM 9-5000-series are training supplements to those in the TM 9-5001-series which are the basic Army directives for the operation and maintenance of the NIKE I Guided Missile System. In the event of conflict, technical manuals in the basic TM 9-5001-series will govern.

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By Order of *Wilber M. Brucker*, Secretary of the Army:

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44-201R, Hq & Hq Btry, AAA Brig, Continental (5)
44-445R, AAA Msl Bn, NIKE, Continental (17)

NG: None.
USAR: None.
For explanation of abbreviations used, see SR 320-50-1.

CONTENTS

CHAPTER 1

INTRODUCTION

1. PURPOSE AND SCOPE

a. The material presented in this text is intended to acquaint the student with the various items of equipment utilized in the electrical checkout of the Nike I missile. The units of equipment are discussed in sufficient detail to provide the student with a comprehensive view of the purpose and function of each unit.

b. This text was prepared for use in courses dealing with electrical materiel maintenance of the Nike I missile. It is intended to be a comprehensive discussion of the subject matter presented. Chapter 2 gives an over-all description and summary of all items of checkout equipment. The following chapters discuss each major item of checkout equipment in greater detail. For information concerning equipment hookup data, consult TM 9-5000-5.

2. REFERENCE

All references made in this special text are to schematics, figures, or other material in TM 9-5000-33.

CHAPTER 2

ELECTRICAL CHECKOUT EQUIPMENT

Section I. GENERAL

3. FUNCTION OF ELECTRICAL CHECKOUT EQUIPMENT

a. The effectiveness of the Nike I system depends upon its ability to guide a missile to a target and destroy it. It is necessary to have positive insurance that the missile will carry out this mission.

b. This insurance can be obtained only by the use of specially designed checkout equipment and an effective checkout procedure. The Nike I missile is only as effective as the checkout equipment and the checkout procedure used.

c. The Nike I checkout equipment is designed to provide a means of quickly, efficiently, and completely testing the assembled missile. The equipment must be rugged, compact, and portable. It must operate with little or no difficulty under most climatic conditions.

4. CHECKOUT AREAS

a. Assembly area.

(1) In the assembly area, the missile is uncrated and sent to the assembly area test station for a complete checkout. If all missile components are operating properly, the missile is joined to a booster, fueled, armed, and sent to the launching area.

(2) If a minor defect is discovered, repair may be performed in the assembly area. If a serious defect is discovered, the missile is rejected and sent to an ordnance unit for repair or replacement of defective components.

(3) The following items of checkout equipment are used in the assembly area:

(a) Stagnation pressure pump.

(b) Missile dolly.

(c) Guidance section blower.

(d) Guidance section dolly.

(e) Hydraulic test stand.

(f) TS-737/U nickel-cadmium battery tester.

(g) Battery charger.

(h) Booster igniter tester, model 8160961.

(i) Potentiometer centering bridge, model 8014428.

(j) Electrical test set.

(k) R-F test set.

b. Launching area.

(1) The ready missiles from the assembly area are received at the launching area and placed upon loading and storage racks.

(2) Periodic tests are performed in the launching area to insure that the missile remains in proper operating order throughout its storage period.

(3) The following items of checkout equipment are used in the launching area:

(a) Launching area portable test equipment (fig II-11):

R-F test set.
Electrical test set.
TS-737/U nickel-cadmium battery tester.
Cable supporting boom.
Portable test equipment case.

(b) Launcher regulated power supply and launcher operating panel (replace the test power control unit) (fig II-43).

(c) Launcher-missile testing hydraulic power package (replaces the hydraulic test stand).

Section II. NIKE I CHECKOUT EQUIPMENT

5. MISCELLANEOUS CHECKOUT EQUIPMENT

a. Stagnation pressure pump (fig II-1). The stagnation pressure pump is used to test the pressure transmitter in the missile. The pressure transmitter controls the amplitude of fin voltages at different altitudes, so that a given command from the computer will cause a corresponding response from the missile at any altitude. The stagnation pressure pump performs its test by applying either a pressure or a vacuum to the pressure transmitter, which feels the changes in pressure as changes in altitude, and responds accordingly. The stagnation pressure pump is manually operated. It incorporates a pressure gage and control valve. It is housed in an aluminum alloy case.

b. Missile dolly (fig II-3). The missile dolly supports the missile during test. Its construction allows the missile to be moved in various directions. The dolly is constructed of welded steel, has an over-all length of approximately 10 feet, is supported by four 10-inch wheels, and weighs about 315 pounds.

c. Guidance-section blower (fig II-2). The guidance-section blower ventilates and cools the guidance unit during test. The blower consists of a 115-volt, 1-phase, 400-cycle motor, a fan, and a duct to deflect the airstream into the guidance-section casting.

d. Guidance-section dolly (fig II-4). The guidance-section dolly supports the missile guidance unit if the missile must be disassembled. The dolly is designed to allow the guidance section to be rotated around its longitudinal axis. The dolly is constructed of welded steel, is approximately 48 inches in height, and weighs 200 pounds.

e. Hydraulic test stand (fig II-5). The hydraulic test stand provides hydraulic power to the missile under test and fills the missile accumulator with hydraulic fluid. The top of the hydraulic test stand may be used as a support for the electrical test equipment. Two aluminum booms approximately 7 feet high are attached to the rear corners of the test stand. These support the hydraulic and electrical connections from the test equipment to the missile under test. The hydraulic test stand must be supplied with 208/416-volt, 3-phase, 60-cycle power.

f. TS-737/U nickel-cadmium battery tester (fig II-9). The TS-737/U nickel-cadmium battery tester is used to measure the voltages of the individual cells or the total voltage of the missile battery. Two sensitivity ranges are provided, 1.0 to 1.7 volts and 25.2 to 33.6 volts.

g. Battery charger (fig II-8). The battery charger is provided in the assembly area to maintain the missile batteries in a constant state of readiness.

h. Booster igniter tester, model 8160961 (fig II-7). The booster igniter tester is used for testing the igniter, booster, and launcher components of the firing circuit. It consists of a voltohmmeter, associated controls, and three test harnesses for the performance of its tests. Information concerning required values on each test is printed on the inside of the cover.

i. Potentiometer centering bridge, model 8014428 (fig II-6). The potentiometer centering bridge is used to position the fins at the electrical zero point on the fin potentiometers during missile assembly. The bridge is housed in a 7 1/2-inch by 5 1/2-inch by 2 1/2-inch aluminum case, and is made up of a null meter, associated controls, and a connector lead.

6. ELECTRICAL TEST SET (fig II-12)

The electrical test set is used in conjunction with the r-f test set in the performance of missile checkout. It is made up of the missile electrical test equipment case, the electrical test cabinet which houses the test control unit and the test power control unit; and associated equipment.

a. Electrical test equipment case (fig II-10). The electrical test equipment case is used as a shipping and handling container for the other components of the electrical test set. The case is constructed of sheet metal, and may be used as a base for the electrical test cabinet during checkout.

b. Electrical test cabinet (fig II-12). The electrical test cabinet houses the test control unit and the test power control unit. It is a self-contained sheet-metal, waterproof case with a sloping front panel. The cabinet is 26 inches high and weighs 150 pounds with the test control unit and test power control unit in place.

(1) Test power control unit. The test power control unit provides a regulated power source for the missile under test and has control of all circuits passing through the missile ground power cable. The test power control unit is housed in the lower compartment of the electrical test cabinet.

(2) Test control unit. The test control unit is a multipurpose voltmeter which is connected to various test points within the missile by switching circuits. It is housed in the top compartment of the electrical test cabinet.

c. Associated equipment. The associated equipment of the electrical test set consists of the stagnation pressure pump and all cables necessary for missile checkout with the exception of the switching attenuator cable and flexible waveguide. The cables are the missile test cable, guidance section test cable, guidance section blower cable, ground power cable, power cable, battery-simulator cable, and burst-indication cable.

7. R-F TEST SET, GS-15722 (fig II-13)

a. The r-f test set is used to test the operation of the r-f components in the missile guidance unit. The tests are accomplished by sending to the missile commands that closely approximate those of the missile-tracking radar, and noting the response of the missile to these commands.

b. The r-f test set operates from 120-volt, 1-phase, 400-cycle power.

c. The r-f test set consists of the GS-15723 cabinet assembly, the GS-16888 waveguide assembly (antenna coupler), the 8015526 waveguide assembly (flexible waveguide), and the 8015648 wiring assembly (switching attenuator cable).

(1) The r-f test set cabinet assembly is the heart of the r-f test set. It contains all components necessary for the generation of coded r-f signals, and is used as a control unit for all tests performed with the entire r-f test set. The cabinet assembly is made of magnesium and has a sloping front panel. It is divided into two compartments; an upper drawer and a lower drawer, into which two equipment drawers are inserted. A blower, which provides ventilation, is located on the lower back portion of the cabinet. With both drawers in place, the cabinet assembly weighs approximately 250 pounds.

(2) The flexible waveguide couples the r-f energy from the r-f test set cabinet assembly to the antenna coupler and from the antenna coupler back to the r-f test set cabinet assembly. The flexible waveguide is 17 feet long, and has a flexible rubber covering for protection.

(3) The antenna coupler directs the r-f energy from the flexible waveguide into the missile antennas and from the antennas back to the flexible waveguide. The antenna coupler has three connectors; two are fastened to the two receiving antennas (2 and 4), and one is fastened to the transmitting antenna (1). The connectors are inclosed in shells of Bakelite-bonded iron to eliminate leakage at the point of connection. The second transmitting antenna (3), is terminated by a dummy antenna connector, which blocks all unnecessary radiation. Each antenna connector is mounted on the antenna coupler by circular rubber mounts, which

permit flexibility in attaching the connector to the missile antennas. The dummy connector is not attached to the antenna coupler.

(4) The switching attenuator cable is used to transfer the voltages necessary to energize certain switch attenuators within the antenna coupler. These attenuators control the flow of r-f energy into the two receiving antennas.

CHAPTER 3

HYDRAULIC TEST STAND

8. PURPOSE AND SPECIFICATIONS

The hydraulic test stand (fig II-29) provides hydraulic power for assembly area missile checkout. It is equipped with a vane-type pump which is capable of delivering a maximum flow of 2 gallons per minute at a pressure of 2,000 pounds per square inch. The hydraulic oil reservoir has a capacity of 55 gallons. This amount of oil is sufficient for servicing 48 missiles. The reservoir serves as a base for the pump, motor, accumulator, various valves, and hydraulic lines. The entire unit is enclosed within a 4-wheel stand which is equipped with a foot brake. Its dimensions are 59 inches x 32 inches x 31 inches. It weighs approximately 1,500 pounds.

9. CONTROLS AND INSTRUMENTS (fig II-29)

a. START, STOP, and RESET pushbuttons. Three pushbutton motor control switches labled START, STOP, and RESET are located on the upper left front of the hydraulic test stand. The motor is started by pressing the START button. If the circuit breaker is tripped, the motor may be energized by pressing the RESET button, then the START button. The motor is shut off by pressing the STOP button.

b. BYPASS VALVE control handle. The BYPASS VALVE control handle is located in the recess in the upper right front panel of the hydraulic test stand. It controls the manual bypass valve, which governs the amount of hydraulic pressure applied to the output hose and the missile. Turning the BYPASS VALVE control handle clockwise increases the pressure. Turning the BYPASS VALVE control handle counterclockwise decreases the pressure.

c. Truck lock. The hydraulic test stand truck lock is mounted on the front of the hydraulic test stand near the right front caster. It is operated by means of a foot pedal, and serves to hold the hydraulic test stand in one position during test or storage.

d. ACCUMULATOR AIR pressure gage. The ACCUMULATOR AIR pressure gage is located behind the center compartment access door on the front panel of the hydraulic test stand. It indicates the air pressure present in the hydraulic test stand accumulator. Its pressure range is from 0 to 3,000 psi.

e. Hydraulic FLUID LEVEL gage. The hydraulic FLUID LEVEL gage is located behind the center compartment access door on the front panel of the hydraulic test stand below the ACCUMULATOR AIR pressure gage. It is a direct reading gage which indicates the level of the hydraulic fluid within the reservoir.

f. Hydraulic fluid PRESSURE GAGE. The hydraulic fluid PRESSURE GAGE is located in the recess in the upper right of the hydraulic test stand front panel. The PRESSURE GAGE indicates the pressure at which oil is supplied to the missile. It has a range of from 0 to 3,000 psi, and is referred to when adjusting the fluid pressure by means of the manual BYPASS VALVE control handle.

10. ENERGIZATION (fig II-30)

a. When the 3-phase, 60-cycle, 220-volt electric motor is energized, hydraulic fluid stored in the reservoir is drawn through a suction line and into the pump.

b. The pump is a two-stage,vane-type apparatus which forces the hydraulic fluid into a pressure line and through the system relief valve, which is set to operate at 2,250 to 2,350 psi. The valve functions only if the unloading valve is incapable of handling excessive pressure or becomes inoperative.

c. The unloading valve operates at 1,750 to 1,950 psi. Pressures above these two values are ported by the two valves into the reservoir through a return line.

11. OPERATION

a. After being regulated by the unloading valve, the hydraulic fluid is sent through a tee joint. One side of the tee is connected to a manually operated bypass valve by means of which the pressure may be reduced to any desired degree. The opposite end of the tee is connected to another tee joint.

b. From one side of the second tee, pressurized fluid flows through the pressure line filters to the pressure hose connected to the missile by means of the quick disconnect plug.

c. The line from the other side of the second tee is connected to the accumulator and a solenoid valve. The pressurized air in the accumulator damps the pulsations caused by the action of the pump and thus maintains an unfluctuating pressure. The solenoid valve is closed during the operation of the pump. When the STOP pushbutton is depressed, the solenoid valve opens, allowing the pressurized oil to flow back to the reservoir by means of the return line.

d. Fluid and air from the missile accumulator are returned to the test stand reservoir by means of the quick disconnect plug, the exhaust hose, and the return line. The air is then released from the reservoir by the action of the reservoir air vent check valve. A small orifice in the check valve poppet permits air to return to the reservoir as needed to prevent the formation of a partial vacuum as oil is pumped from the reservoir.

CHAPTER 4

ELECTRICAL TEST SET

Section I. TEST POWER CONTROL UNIT

12. FUNCTIONAL DESCRIPTION (fig II-31)

Five -28-volt outputs from the test power control unit (TPCU) are used by the missile guidance section. These outputs:

a. Simulate power from the missile battery. This voltage is coupled to the missile by the battery simulator cable, and applied to the guidance section power supply in exactly the same manner as the output of the missile battery (internal operation).

b. Apply -28 volts directly to the heaters and gyro motors in the guidance section. The guidance section vibrator power supply is bypassed (external operation).

c. Apply -28 volts directly to the guidance section power supply, after a 38 (±3)-second time delay. This time delay allows enough time for the guidance section filaments to warm up and the gyro motors to attain rated speed before plate voltages are applied (external operation).

d. Supply power to energize the cage and uncage relays in the guidance section after the 38-second time delay has elapsed (internal operation).

e. Drive the roll-position gyro preset motor. The same output is coupled to a voltage divider network from which the voltages for the four terminals of the roll position gyro potentiometer are tapped. These voltages permit identification of the terminals when the gyro is preset.

13. OPERATION (fig II-42)

The guidance section cannot be switched from external to internal power until the 38-second time delay has elapsed. This is prevented by a relay, which opens the power circuit connections, grounds the transfer relay holding circuit, and deenergizes the heaters relay in the TPCU. When the guidance section is switched to internal power, the heater relay is energized, breaking the external power connections to the heaters, gyro motors, and vibrator. Valve simulator resistors are employed in the TPCU to simulate loading of the hydraulic fin valve solenoids when the guidance section is checked separately. A fin signal resistor is similarly used to simulate loading of the fin and aileron potentiometers. All missile control voltages are coupled to the guidance section through receptacle J1 or to the ground power receptacle on the assembled missile. An internal connection (J3) between the TPCU and test control unit provides cage and uncage indications from the missile. The TPCU and r-f test set are connected by the r-f test cable, which relays the fail-safe and command-burst signals from the guidance section to the r-f test set. Receptacle J4 on the TPCU is provided for the performance of instrumentation tests.

14. OPERATIONAL SEQUENCE

a. When the AC POWER switch is placed in the ON position, the TPCU is connected to the 120-volt, 400-cycle primary power source. The POWER ON indicator lamp will be lighted, and the cabinet blower will be activated. The 28-volt regulated power supply is controlled separately by the HEATERS EXTERNAL switch so that the power supply may be deactivated during brief periods of inactivity without affecting the operation of the blower.

b. Placing the HEATERS EXTERNAL switch in the ON position lights the HEATERS EXTERNAL indicator lamp and connects the regulated power supply to the primary power source. The output of the regulated power supply is then relayed to the guidance section heaters and gyros and applied directly to the time-delay relay, which energizes the 38-second timer. During the time delay, power cannot be applied to the missile vibrator power supply. With the HEATERS AND GYROS switch in the OFF position, the MISSILE CURRENT meter will read approximately 50 percent, the value of the current drawn by the heaters and gyro motors in the guidance section. If the timer has run down and the VIBRATOR EXTERNAL switch is placed in the ON position, the VIBRATOR EXTERNAL indicator lamp will be lighted, and the MISSILE CURRENT meter reading will increase to 100 percent. The increased reading is a result of applying plate voltage and increasing the load. The reading of the MISSILE VOLTAGE meter reading will continue to be 100 percent.

c. The transfer relay in the guidance section determines whether the missile will be on internal or external power. This relay is paralleled by the heaters relay in the test control unit. The transfer relay may be energized, putting the missile on internal power in two ways.

(1) The POWER SUPPLY switch on the test power control unit, when switched to the INT position, applies a ground to the transfer relay, causing it to energize. This action causes the HEATERS EXTERNAL,and VIBRATOR EXTERNAL lights to be extinguished and the MISSILE INTERNAL light to be lighted. The switch may be released to its neutral position, and the transfer relay will be held in the energized position by a holding circuit

through the relay contacts. Switching the POWER SUPPLY switch to the EXT position applies a ground to this holding circuit, causing the transfer relay to deenergize. The energizing circuit for the transfer relay goes through the energized control battery relay in the TPCU. This relay is not energized until the 38-second timer has run down; therefore, the missile may not be put on internal power until after a warming period for the guidance section heaters.

(2) The inertia switch, activated by placing the inertia weight to the rear, applies -28 volts to the transfer relay. Ground is applied through the positive battery terminal. The inertia weight may be positioned forward immediately, and the transfer relay will be held in the energized position. The relay holding circuit may then be broken either by switching the POWER SUPPLY switch on the TPCU to EXTERNAL or by turning the missile off. If the inertia weight is left in the rearward position and the missile is deenergized, the transfer relay will be shorted to ground through the deenergized control battery relay when power is reapplied to the missile.

d. Positioning the GYRO CAGE-UNCAGE switch to the CAGE position energizes the cage relay in the missile. The uncage relay is energized, and the cage relay deenergized by placing the GYRO CAGE-UNCAGE switch in the UNCAGE position. The gyro is protected by wiring the uncage relay through the time-delay relay, which prevents the gyro from being uncaged before the gyro motor attains its rated speed.

15. TPCU REGULATED POWER SUPPLY (fig II-44)

a. General. The -28-volt d-c power supply in the test power control unit provides the d-c power required to operate the missile guidance unit and the relay circuitry in the test equipment. The input to the power supply is 120-volt 400-cycle single phase a-c power; outputs are -28 volts d-c. Because of the high current rating of the power supply (9 amperes), VR tubes are insufficient. Therefore, a type of circuit known as a ferro-resonant voltage regulator is utilized. This type of regulator will correct for changes in load, input, frequency, and temperature.

b. Line voltage stabilization. The line voltage stabilizer circuit is composed of transformers T1 and T2, resistors R1 through R3, and capacitors C1 and C2. Transformers T1 and T2 are autotransformers. T2 is designed to operate near saturation, so that a given change in line voltage will drive it into saturation. The output of T1 is much smaller than that of T2. T1 is wound in opposition to T2 but is not a saturable transformer. With an increase in input voltage, the winding of T1 will present a larger amount of inductive reactance. The output of

T1 and the voltage dropped across it will increase because of an increase in current flow. A similar reaction will take place across T2. Regulation results from the corresponding change between the two windings. Since T1 is wound in opposition to T2, the output of T1 will be of a polarity opposite to that of the output of T2. It may be seen that if the outputs of T1 and T2 change a proportionate amount in opposite polarities that regulation will occur, and the total output voltage of the power supply will remain the same. The output of T2 is larger than that of T1. With an increase in input, the output of T2 would normally change a larger amount than would the output of T1. In this case, the output of the power supply would change. However, T2 is designed in a manner which will cause a change in input voltage to result in a corresponding change in the operating point of T2 on the saturation curve. The resulting change in current flow will produce a change in output voltage which is directly proportional to the change in the output of T1. C1, C2, and R1 through R3 form a phase-shifting network which insures that the two outputs will remain in the same phase relationship to each other.

c. Line frequency compensation. Line frequency compensation is accomplished by the upper coils of REG 1, resistors R4 through R7, and capacitors C3 and C4. These components form a series resonant circuit. The circuit is designed so that the point of resonance is at a frequency above 400 cycles. If the input frequency remains at 400 cycles, the impedance presented by the circuit will be constant, and the output will remain the same. In an untuned circuit, a rise in frequency will cause an increase in inductive reactance. Voltage drops in the circuit will then increase, causing a decrease in the output voltage of the resonant circuit. An increase in input frequency will cause the circuit impedance to decrease and the current flow to increase. An increase in current flow through output transformer T3 will restore the output voltage to normal. If a decrease in input frequency is felt, impedance will increase, and current flow will decrease. A decrease in current flow will again restore the output voltage to normal.

d. Load compensation. Load changes are compensated for by a saturable reactor consisting of the lower portion of REG 1, and resistors R11 through R14. The circuit is designed so that the currents through the two coils are equal and opposite. With the correct load, they will not affect the operation of the circuit. With an increased load, the terminal voltage of the regulator will decrease. Since the left-hand coil is connected across the load, the current through the coil will increase as the load increases. The current between the two coils will then be unbalanced, and a flux field will be established between the two. The coils of the frequency compensator and the coils of the load compensator are wound on the same core. The flux field set up in the lower coils will thus aid the field established between the two coils of the resonant circuit, effectively lowering the resistance of the resonant circuit. A greater current flow will occur across T3, and the output will increase. If the load decreases, the current in the left-hand coil will decrease, creating an unbalance between the two coils and setting up a magnetic field. This field will oppose that created by the coils of the resonant circuit. The resistance of the resonant circuit will rise, and the current flow through T3 will decrease, resulting in a decreased output. Due to age and wearing of components, the output of the power supply may change to such a degree that automatic regulation is not sufficient. This defect may be corrected by connecting into the circuit more of the resistors (R12 through R25) connected in series with the coils of the saturable reactor. Resistors R11 through R14 serve as a coarse adjustment; R15 through R25 serve as a vernier adjustment.

e. Temperature compensation. Temperature changes are compensated for by a saturable reactor made up of the lower right-hand winding of REG 1, resistors R15 through R25, R8 through R10, thermistor TH1, and RV2. It is known that the value of some electronic components will increase with an increase in temperature. This will produce additional voltage drops and will decrease the output voltage of the power supply. RV2 is connected across C3. The impedance presented by the capacitor will cause a current flow through RV2, R15 through R25, one section of REG 1, R8 through R10, TH1, and back to the bridge network. This causes a magnetic field to develop around the right-hand coil of REG 1. At the correct operating point of the circuit, this magnetic field will be equal and opposite to the field set up by the other coil. If the temperature increases, resistance will increase, and the output voltage will be decreased. TH1 is a negative coefficient thermistor. Such a thermistor will develop a decrease in resistance in response to an increase in temperature. The resistance of TH1 will therefore decrease at this time, resulting in an increase in current flow through the lower right-hand coil of REG 1 and unbalancing the two coils. This produces a flux which aids that of the two top coils, lowering the resistance of the resonant circuit and increasing the current flow, to bring the output back to normal. If the temperature decreases, the resistance of TH1 will increase, decreasing the current flow through REG 1 and unbalancing the two coils. The flux field thus produced increases the resistance of the resonant circuit. Less current flows through output transformer T3, and the output is raised to normal.

Section II. TEST CONTROL UNIT

16. GENERAL

The test control unit (TCU) (fig II-31) is a voltage-measuring device used in checking the operating voltages of the guidance section. Three separate circuits are employed in the TCU. These circuits measure the outputs of the missile vibrator power supply, missile servo system voltages, 250-cycle buzz voltages, and the differential voltage drop across the solenoid valves.

17. CONTROL FUNCTIONS

a. Missile vibrator power supply (fig II-32). The d-c outputs of the vibrator power supply are read on the VOLTAGE meter. The various voltages to be measured are selected by the VOLTAGE SELECTOR pushbuttons, which switch the desired voltages into the VOLTAGE meter circuit. In table I, the controls and their functions are listed.

Table I. Functions of the VOLTAGE SELECTOR controls.

CONTROL	FUNCTION
230	Pressing the 230 VOLTAGE SELECTOR pushbutton connects the VOLTAGE meter across the 230-volt output of the vibrator power supply and ground.
300	Pressing the 300 VOLTAGE SELECTOR pushbutton connects the VOLTAGE meter across the 300-volt output of the vibrator power supply and ground.
STRG PLATE	Pressing the STRG PLATE VOLTAGE SELECTOR pushbutton connects the VOLTAGE meter across the +200-volt and -100-volt outputs of the vibrator power supply.
150	Pressing the 150 VOLTAGE SELECTOR push-button connects the VOLTAGE meter across the 150-volt output of the vibrator power supply and ground.
CONT SIG	Pressing the CONT SIG VOLTAGE SELECTOR pushbutton connects the VOLTAGE meter across the +18-volt and -18-volt outputs of the vibrator power supply.

Table I. Functions of the VOLTAGE SELECTOR controls (cont).

FIN VOLT (fig II-38, 39)	Pressing the FIN VOLT VOLTAGE SELECTOR pushbutton connects the VOLTAGE meter across the fin pots and reads the voltage as determined by the pressure transmitter. The meter reading is dependent upon atmospheric pressure, and should be between 25 percent and 50 percent at altitudes between 0 and 5,000 feet above sea level.
STRG PLATE BAL (fig II-33)	The +200-volt and -100-volt outputs of the vibrator power supply form a floating 300-volt signal, which is used to supply plate and bias voltages to the control amplifiers. A bridge-type circuit, using the SERVO meter as a null indicator, is used to check the balance of the +200-volt and -100-volt outputs of the vibrator power supply. The measurement is made by depressing the STRG PLATE BAL pushbutton located at the left of the ROLL SERVO TEST SELECTOR pushbuttons. A reading within the 20 percent tolerance zone should be obtained.
CONT SIG BAL (fig II-33)	A bridge-type circuit is used to check the balance of the +18-volt and -18-volt control signal voltage outputs of the vibrator power supply. The SERVO meter is connected across the bridge by depressing the CONT SIG BAL pushbutton, located in the row of ROLL SERVO TEST SELECTOR pushbuttons.

b. Servo system operating potentials (fig II-35). The servo system operating potentials are measured by the SERVO meter. The outputs of the missile servo system are switched into the SERVO meter circuit by the SERVO TEST SELECTOR pushbuttons, which are divided into three groups of five each. The groups correspond to the two command channels used in the Nike I guidance system, pitch and yaw, and also to the roll circuits in the missile. In table II the controls and their functions are listed.

Table II. Functions of the SERVO TEST SELECTOR controls.

CONTROL	FUNCTION
YAW +5G (fig II-34)	Cancels a +5g yaw command from the r-f test set by feeding an opposing signal into the yaw steering amplifier.
YAW -5G (fig II-34)	Cancels a -5g yaw command from the r-f test set by feeding an opposing signal into the yaw steering amplifier.
YAW ACC	Connects the SERVO meter across the yaw accelerometer potentiometer wiper arm and ground.
YAW RATE	Connects the SERVO meter across the yaw rate gyro potentiometer wiper arm and ground.
YAW FIN	Connects the SERVO meter across the yaw fin potentiometer wiper arm and ground.
PITCH +5G (fig II-34)	Cancels a +5g pitch command from the r-f test set by feeding an opposing signal into the pitch steering amplifier.
PITCH -5G (fig II-34)	Cancels a -5g pitch command from the r-f test set by feeding an opposing signal into the pitch steering amplifier.
PITCH ACC	Connects the SERVO meter across the pitch accelerometer potentiometer wiper arm and ground.
PITCH RATE	Connects the SERVO meter across the pitch rate gyro potentiometer wiper arm and ground.
PITCH FIN	Connects the SERVO meter across the pitch fin potentiometer wiper arm and ground.

Table II. Functions of the SERVO TEST SELECTOR controls (cont).

ROLL POS	Connects the SERVO meter across the roll-rate gyro potentiometer wiper arm and ground.
ROLL FIN	Connects the SERVO meter across the roll fin potentiometer wiper arm and ground.

c. Control. Buzz voltage is connected to the VALVE meter by placing the VALVE VOLTAGE switch in the BUZZ position. The DC position of the VALVE VOLTAGE switch connects the VALVE meter to the missile servo system. In table III the controls and their functions are listed.

Table III. Functions of the VALVE VOLTAGE control.

CONTROL	FUNCTION
BUZZ	By placing the VALVE VOLTAGE switch (figs II-36) and II-37) in the BUZZ position, a rectifier is switched into the VALVE meter circuit, enabling the a-c voltage across the transfer valve which has been connected by the SERVO TEST SELECTOR pushbutton to be measured.
DC	Connects the VALVE meter across the solenoid valve of the channel that is selected by depressing the FINS pushbutton.

d. Gyro preset operation. Checking the roll-position gyro preset operation requires the use of both the ROLL POSITION toggle switch and the GYRO PRESET switch. The GYRO PRESET switch is spring-loaded to the center position. By the combination and use of these two switches, the roll-position gyro is preset to the control point. The control point is obtained so that in later checks using the ROLL POS pushbutton the proper readings on the meters used will be obtained. In table IV, the control and functions of the ROLL POSITION and GYRO PRESET toggle switches are listed.

Table IV. Functions of the ROLL POSITION and GYRO PRESET controls.

CONTROL	FUNCTION
ROLL POSITION PRESET	With the ROLL POSITION toggle switch (fig II-40) in the PRESET position, the preset relay is deenergized, which applies ground potential to terminal 1 of the roll-position gyro potentiometer, -12 volts to terminal 2, -6 volts to terminal 3, and -18 volts to terminal 4, when the GYRO PRESET switch is in the CW position. If the GYRO PRESET switch is in the CCW position, -18 volts is applied to terminal 2, and -12 volts is applied to terminal 4.
ROLL POSITION FLIGHT	With the ROLL POSITION toggle switch in the FLIGHT position, the preset relay is energized, which applies +18 volts to terminal 4 and -18 volts to terminal 2. Terminals 1 and 3 are at control signal ground.
GYRO PRESET CW	With the GYRO PRESET switch in the CW position, the output of the roll-position gyro potentiometer, taken from the TPCU power supply, is fed into the gyro preset motor, causing the gyro preset motor to turn in a clockwise direction and causing the SERVO meter needle to count 1, 2, 3, and 4 in that order and to repeat the count as long as the GYRO PRESET switch is held in the CW position. This action is accomplished only if the ROLL POSITION switch is in the PRESET position. If the ROLL POSITION switch is in the FLIGHT position, there will be a smooth transition of the meter needle over a full-scale range of deflection. The position of the GYRO PRESET switch will not change these effects.

Table IV. Functions of the ROLL POSITION and GYRO PRESET controls (cont).

GYRO PRESET CCW	With the GYRO PRESET switch in the CCW position, the gyro preset motor is caused to turn in a counterclockwise direction, but the count is the same as that in the CW position. The count is the same because the potentials at terminals 2 and 4 change when the GYRO PRESET switch is placed in the CCW position.

CHAPTER 5

MISSILE R-F TEST SET (GS-15722)

Section I. GENERAL

18. PURPOSE

The r-f test set enables the maintenance and operating personnel to perform an operational check on the missile guidance unit and the completed missile in both the assembly and launching areas. To check the missile's response to proper commands, the r-f test set simulates the operation of the missile-tracking radar by sending commands to the missile in the form of r-f pulse pairs. Simulation of the missile-tracking radar requires that accurately spaced bursts of r-f energy be transmitted to the missile. These bursts of r-f energy must have a duration of about 0.25 microsecond and a frequency-modulated prf which varies within the same limits as that of the missile-tracking radar. In addition, these bursts of r-f energy must be generated in pairs spaced from 2 to 29 microseconds. The spacing of the pulse pairs is necessary because for tactical purposes the missile will respond only to pulse pairs with a specific spacing. The spacing of the pulse pairs in microseconds is referred to as the missile code, and is not the same for all missiles. In addition to simulating the missile-tracking radar, the r-f test set has facilities for self-calibration, to insure that the commands and code signals generated are accurate enough to obtain correct responses from the missile under test. The r-f test set also provides a means of monitoring the response to commands sent to the missile.

19. CAPABILITIES AND LIMITATIONS

The r-f test set is designed to test only the over-all operational condition of the Nike I missile. It is not intended for locating specific difficulties within one particular unit. If the missile will not respond to a correctly coded signal, the r-f test set will give an indication to that effect but will not locate the trouble. For detailed troubleshooting, more specialized test equipment must be used. (For missile adjustment procedures, refer to TM 9-5000-5.)

20. PHYSICAL DESCRIPTION

a. General. The r-f test set (fig II-13) is used to test the XSAM-A-7 missile, the GS-15660 guidance section, and the GS-15638 test responder for response to radio-frequency signals generated within the test set. The r-f test set consists of five major units: the cabinet assembly, antenna coupler, antenna coupler trunk, flexible waveguide, and the switching attenuator cable.

b. GS-15723 cabinet assembly. The cabinet assembly is the major unit of the test set and is shown in figure II-46. It comprises the cabinet itself, the GS-15724 upper drawer assembly, and the GS-15725 lower drawer assembly.

(1) The cabinet assembly is made of metal and has a gray lacquer finish. It is weatherproof when the drawers are inserted and tightened in place. The front is sloping and has two large openings for the two drawer assemblies. At the bottom front corners, two insert pins hold the cabinet assembly in place and prevent it from bouncing when used in a mobile testing unit. On each side is a carrying handle. On the rear of the cabinet assembly are the blower intake louver, rectangular openings for the rear panels of each drawer, the drawer release bolts, and a tie-down ring. The tie-down ring is used with a strap to keep the cabinet assembly from tipping over because of excessive shift in weight when the drawers are pulled out. The bottom of the cabinet has four mounting feet which engage indents on the equipment case or a test stand when the test set is mounted on them.

(2) Inside the cabinet, two sets of drawer slides support the drawers and allow them to slide in and out. The drawers are secured to the slides by snap slide fasteners. Inside the cabinet are also the blower and the intake filter. The intake filter is mounted on the rear of the cabinet, and the blower is mounted on the filter housing. The blower is a 400-cycle, 120-volt, split-phase motor with a propeller-type fan. The intake filter is an oiled wire-mesh type.

(3) The lower drawer assembly (fig II-54) is made up of seven subassemblies, which are supported and interconnected by the GS-15735 common equipment. The common equipment is made up of a framework, a rear panel, and a cable harness. The framework supports the subassemblies and is supported by the drawer slides. The cable harness terminates in plugs and jacks and interconnects the subassemblies. The front of the framework supports four of the subassemblies. These slide into four openings in the face of the framework to form the lower drawer front panel. The panel is weatherproofed by a sponge rubber gasket around the outer edges and around each of the subassembly openings. These gaskets also help to seal the cabinet to insure proper air circulation from the blower. The rear panel is spring-mounted on the back of the framework and presses into the lower back cabinet opening. A gasket seals the opening when the drawer is tightened in place. In addition to the gasket, the rear panel contains an exhaust filter and louver, the power plug, and the ORD 6 TEST plug.

(4) The common equipment GS-15735 and seven subassemblies comprise the lower drawer:

(a) GS-15736, command modulator.

(b) GS-15737, microsecond oscillator.

(c) GS-15738, pitch oscillator.

(d) GS-15739, yaw oscillator.

(e) GS-15740, burst oscillator.

(f) GS-15741, power supply.

(g) GS-15742, reference oscillator.

(5) The first four named are the front panel subassemblies; the remaining three are internal. The front panel subassemblies are fastened to the framework by captive Phillips-type screws, and the internal subassemblies are connected to the cabling harness of the common equipment by plug and jack combinations, which must be disconnected before a subassembly is removed. When removed, all subassemblies can be readily serviced, since they are designed to make all components easily accessible. The power supply, when removed, requires further adjustment; a subchassis, called the mounting bracket, must be released and pivoted for complete accessibility. Any electron tube in the test set can be replaced without removing any subassembly.

(6) The upper drawer assembly (fig II-53) has the same basic construction as the lower drawer.

(7) The upper drawer subassemblies, including the common equipment, GS-15726, are:

(a) GS-15727, pulser.

(b) GS-15728, oscilloscope.

(c) GS-15729, burst timer.

(d) GS-15730, r-f power meter circuit.

(e) GS-15731, pulse selector.

(f) GS-15732, response indicator.

(g) GS-15733, r-f signal generator.

(h) GS-15734, waveguide assembly.

(8) The pulser, oscilloscope, burst timer, and r-f power meter circuit are front panel subassemblies; the pulse selector, response indicator, r-f signal generator, and waveguide assembly are internally mounted. As in the lower drawer, the tubes are arranged for easy replacement with the exception of the reflex oscillator tube (klystron). The common equipment, as in the lower drawer, consists of a framework, a rear panel, and a cable harness. In addition, the upper drawer common equipment contains a 6.3-volt filament transformer. The rear panel contains connecting plugs, designated BURST INDICATION and WAVEGUIDE ASSEMBLY, an exhaust filter, and a quick-disconnect coupling. The BURST INDICATION plug connects to a cable that leads to the electrical test set. This cable is part of the electrical test set and not the r-f test set. The WAVEGUIDE ASSEMBLY plug connects to the relay cable. The exhaust filter is part of the blower system. The quick-connect coupling is a rotary-type clamp for connecting two waveguide sections.

c. GS-16888 antenna coupler.

(1) The antenna coupler is used to direct r-f energy into and out of the missile. As shown in figure II-13, the antenna coupler consists of microwave components housed in three projecting antenna couplings, an antenna terminator, a carrying handle, and legs. When in use, this unit is mounted on the missile so that the open ends of the antenna couplings engage the missile antennas. Two of the couplings engage the number 2 and number 4 receiving antennas, and one engages the number 1 transmitting antenna. The antenna terminator, which is a separate unit supplied with the antenna coupler and stored in a compartment within it, is connected to the number 3 transmitting antenna. When not in use, the antenna coupler is stored in the antenna coupler storage trunk.

(2) Each antenna coupling consists of an antenna connector, a spring clamp, sections of waveguide, and a phase-shifting vane. The antenna connector is constructed of a powdered-iron material called polyiron, which surrounds the end of the waveguide section and is held together by a binder, such as Bakelite. The polyiron surrounds the waveguide, so that when a connection is made to the missile antenna, the polyiron electrically seals the joint to prevent escape or entry of r-f energy. To avoid unnecessary wear and possible damage to the polyiron, it is inclosed in a rubber covering and held by a steel holder. Each antenna connector is equipped with a clamp, which engages pinholes in the missile antennas. The antenna connector with its associated waveguide connects to the microwave components in the antenna coupler housing

through a solid and a flexible waveguide section. The flexible waveguide section allows the end of the antenna coupling to move. This facilitates connection to the missile antennas. Although all three antenna couplings are flexibly mounted, the two receiving antenna couplings have greater flexibility, and require a bellows and clamp arrangement where the waveguide passes into the housing. The clamp holds the receiving antenna couplings before the couplings engage the missile antennas. The output of each antenna coupling is electrically matched to its respective missile antenna by the phase-shifting vane. These vanes are mounted within the waveguide section of each coupling. They insure that the output or input signals are properly polarized.

(3) The electrical portions of the antenna coupler are located within the housing. They are made up of microwave components, which include two switch attenuators, a hybrid junction, a directional coupler, and sections of waveguide. Transmission through the antenna coupler is controlled entirely from the cabinet assembly. The number 3 transmitting antenna on the missile is terminated with the antenna terminator. This is a coupling physically separated from the antenna coupler, and it contains an absorbing impedance. This antenna terminator prevents radiation from the number 3 transmitting antenna, which is not used in the test procedure. When not in use, the antenna terminator is stored in a compartment within the antenna coupler housing.

d. GS-205659 antenna coupler storage trunk. The antenna coupler storage trunk is used for shipping or storing the antenna coupler. It is made of riveted plywood and vulcanized fiber.

e. 8015526 flexible waveguide. The flexible waveguide connects the cabinet assembly to the antenna coupler and carries the r-f signals between the two units. The flexible waveguide (fig II-13) is an assembly consisting of the flexible waveguide itself, a 90° elbow connector at one end, and a straight waveguide connector at the other. The flexible waveguide portion is a 17-foot length of rubber-covered tubing. The tubing is metal, rectangularly shaped, and made flexible by a helical strip construction. The rubber covering is resistant to heat and cold.

(1) The 90° elbow coupling is 7 inches in length. One end of the elbow is connected to the end of the flexible waveguide by flanges held together by screws. The other end connects to the waveguide output on the cabinet assembly by means of the quick-disconnect coupling. This end of the elbow is sealed with a polystyrene plug, which is relatively transparent to microwaves but prevents foreign matter from entering the waveguide. The 90° bend is required to direct the flexible waveguide upward; because in use the flexible waveguide is supported above the test set by means of a boom which is part of the electrical test set.

(2) The straight waveguide connection is 2 inches long and also contains a polystyrene plug seal. The free end connects the flexible waveguide to the antenna coupler by means of a quick-disconnect coupling.

f. 8015648 switch attenuator cable. This is a 17-foot, 3-conductor cable with connecting plugs at each end. This cable (fig II-13) carries the 28-volt d-c power which is necessary to operate the two switch attenuators in the antenna coupler.

21. USES OF THE TEST SET

The missile r-f test set must be used in performing the following tests.

a. Receiver sensitivity. This is a test of the missile receiver's ability to receive signals of the lowest amplitude that might be expected at maximum missile range.

b. Beacon transmitter power and frequency. This test determines the power transmitted by the missile beacon unit and whether or not the frequency is within the limits assigned.

c. Nonresponse to adjacent codes. This test is made to insure that the missile will respond only to the assigned code.

d. Pattern modulator operation. This test is made to determine if the pattern modulator motor is operating correctly.

e. Response time measurement. This test determines the delay within the missile between the time the radar signal is received by the receiver and a beacon response signal is transmitted.

f. Response to steering commands. This is a test to determine that the missile will receive and respond with proper fin movements to steering commands.

g. Burst time measurement. A measurement of the time required for the command burst circuit to detonate the warheads after receipt of the burst command signal.

h. Fail-safe time measurement. A measurement of the time required for the fail-safe circuit to detonate the warheads in case of command signal loss.

22. FUNCTIONAL COMPONENTS OF THE R-F TEST SET

Performance of the above tests requires equipment to generate the required r-f signals, couple these signals to the missile, and then measure or permit observation of the missile response to these signals.

a. Pulses for triggering the r-f signal generator in the r-f test set are generated by one of two methods, depending on the type of test being performed. For code interval checks, the triggering signal is furnished by a 33- to 500-kc oscillator through the pulse selector and pulser. For command operation, the signal is generated by the free-running multivibrator, which is frequency-modulated by the pitch, yaw, and burst oscillators. The output from the command circuits is pulse coded by the pulser, the coded output coupled to the r-f signal generator.

b. To insure that the signals generated by the test set are in accordance with the requirements of the missile, these signals can be checked and adjusted within the test set. The adjustments are made by front panel and internal controls, the check is made by comparing the signal in question to a known standard. An oscilloscope and three crystal-controlled oscillators are provided for checking the frequency of the command oscillators, the 33- to 500-kc oscillator, and the frequency-modulator multivibrator. A peak voltage meter is included to check the output voltages of the command oscillators and the amount of modulation of the frequency-modulated multivibrator. An r-f power meter and a frequency meter of the coaxial resonator type are used to check the power and frequency of the test set signal generator output and the output of the beacon unit in the missile. Additional meters, calibrated attenuators, and stabilized voltages are provided to check and adjust the outputs of the various other circuits with the missile r-f test set.

c. To select the proper signal and couple it to the missile, several switches and relays are provided. These relays interconnect the various circuits of the test set. The interconnections are made not only between the wire-connected circuits, but also between those circuits connected by r-f components.

d. A 17-foot flexible waveguide, an interconnecting cable, and an antenna coupler are used to send signals into the missile. The r-f signals are sent from the test set cabinet through the flexible waveguide into the antenna coupler. From the antenna coupler, the signals are sent through the receiving antennas and into the missile beacon. The waveguide and antenna coupler provide a closed r-f path to the missile, thus preventing r-f energy from escaping and eliminating interference from external sources. The interconnecting cable supplies power to energize the switch attenuators in the antenna coupler. These switch attenuators completely cut off the r-f energy from or to the missile or direct the energy into either of the receiving antennas of the missile. The antenna coupler and flexible waveguide also return signals to the r-f test set from one of the two transmitting antennas (antenna 1).

e. To check the response of the missile to commands sent from the r-f test set, the test set provides means of measuring the r-f power, frequency, and response time of the pulses transmitted by the missile. Power and frequency are measured by the r-f power and frequency meters described in b above. The response time is measured by determining the time lapse between two pulses. One pulse is the radar pulse sent to the missile; the other is the pulse transmitted from the missile.

f. A counting-tube circuit is provided for the measurement of burst and fail-safe times. This circuit counts in 0.5-millisecond increments and measures from the start of the burst command to the instant a burst pulse is generated within the missile. Observation of the missile response to steering orders is made by observing meters on the TCU and observing the movements of the missile fins in response to changing orders transmitted by the test set. Observation of fail-safe time requires the removal of the r-f signals transmitted to the missile. After the commands are removed, the time between the removal of commands and the receipt of the fail-safe signal is clocked or counted. The fail-safe signals will cause the counting tubes to stop counting.

Section II. FUNCTIONS

23. MICROSECOND AND REFERENCE OSCILLATORS (fig II-47)

The missile r-f test set consists of many individually functioning circuits. To present a comprehensive introduction to its operation, a simplified over-all block diagram is discussed in the following paragraphs.

a. The microsecond oscillator is a 33- to 500-kc oscillator. It is a Wein bridge oscillator and generates a sinusoidal output. The oscillator operates in conjunction with the pulse selector to generate accurately timed pulses. The timing of these pulses is determined by the frequency of the oscillator. This frequency may be varied by the adjustment of dials calibrated in microseconds. These are known as the TIME-MICROSECONDS dials.

b. The reference oscillator contains three crystal-controlled oscillators and a modulator or mixing oscillator. The reference oscillator produces output frequencies of 1 mc, 26 kc, 30 kc, 6 kc, 2 kc, and 24 kc. All these frequencies are used in the calibration of the test set, with the exception of the 2-kc output, which controls the action of the counting tubes in the burst timer.

24. PULSE SELECTOR

The pulse selector converts the sinusoidal output of the microsecond oscillator into trains of either pulse pairs or a train of continuous pulses. These pulses

The r-f power meter circuit is used to measure the power and frequency of the r-f signals transmitted by the r-f test set and the missile.

For calibration, the burst calibration frequency and the calibration-reference frequency are applied to the oscilloscope. The resulting Lissajous pattern is balanced until the burst frequency is exactly proportional to the calibration frequency.

27. COMMAND MODULATOR

a. The command modulator receives pitch, yaw, and burst signals from the command oscillators and sends out corresponding frequency-modulated pulses. It is composed of a relay switching circuit, and an isolation amplifier, a frequency-modulated multivibrator, a peak voltmeter (CAL meter), and a calibration switch (COMMAND CAL switch).

b. When checking missile response to command signals, the outputs of the command oscillators pass through the relay-switching circuit. When a burst command is sent, the switching circuit removes the pitch and yaw command signals and applies the burst command.

c. From the relay circuit, the signals are sent through the isolation amplifier where they are amplified and used to modulate the frequency-modulated multivibrator. The frequency-modulated multivibrator sends frequency-modulated pulses to the pulser. Commands sent to the missile are proportional to the amount of frequency modulation of the frequency-modulated multivibrator output.

d. The CAL meter and COMMAND CAL switch are used for calibration purposes. Calibration consists of adjusting the frequency of the frequency-modulated multivibrator and the output voltages of the yaw, pitch, and burst oscillators.

28. R-F SIGNAL GENERATOR

The r-f signal generator generates the r-f pulses that command the missile. Its input is furnished by the pulser. It consists of a reflex oscillator and a d-c restoring circuit. The reflex oscillator is a 2K25 klystron, which generates r-f frequencies in the range between 8,500 and 9,600 megacycles. The d-c restoring circuit automatically clamps the reflex oscillator repeller voltage so that each pulse will force the klystron to operate in the most efficient mode. When the restoring circuit is not pulsed, the repeller voltage automatically adjusts so that the klystron will be in continuous-wave operation.

29. R-F POWER METER CIRCUIT

The r-f power meter circuit is used to measure the power and frequency of the r-f signals transmitted by the r-f test set and the missile.

actuate the pulser. The pulse pairs are used for coding and response-time measurements. The continuous pulse train is used in setting the output power of the r-f signal generator. A secondary function of the pulse selector is to convert the 2-kc output of the reference oscillator into pulses which are sent to the burst timer.

25. PULSER

The pulser receives its input from either the pulse selector or the command modulator. The pulse selector input to the pulser consists of continuous pulses, which are used in calibrating the output power of the r-f signal generator; pulse pairs of equal amplitude for determining the code spacing of the missile; and pulse pairs with the second pulse starting from a negative reference, used in conjunction with the previous pulse pair for measuring missile response time. The command modulator input to the pulser is used in making command checks of the missile guidance system.

26. COMMAND OSCILLATORS

There are three command oscillators. Except for the difference in component values necessary for the production of different output frequencies, the three are identical. Each has a sinusoidal output, which is used to frequency modulate the command modulator.

a. Pitch oscillator. The pitch oscillator generates a frequency which may be adjusted to 400, 500, or 600 cycles per second, or may be adjusted in the range between 460 and 540 cycles per second. The 400-, 500-, and 600-cycle-per-second frequencies are used to check the response of the missile to pitch steering orders of -5g, 0g, and +5g. The missile is checked by applying these commands and noting fin response. The range of variable frequencies between 460 and 540 cycles per second corresponds to a command in the pitch channel variable between -2g and +2g. This variable command is used in observing the smoothness with which the missile fins deflect in response to a changing pitch command.

b. Yaw oscillator. The yaw oscillator generates fixed frequencies of 120, 150, and 180 cycles per second and a frequency which may be varied between the limits of 138 and 162 cycles per second. The fixed frequencies correspond to yaw commands of -5g, 0g, and +5g respectively.

c. Burst oscillator. The burst oscillator generates fixed frequencies of 880 and 857.14 cycles per second. The frequency of 880 cps is the actual burst frequency. For calibration purposes, however, a frequency must be used which is a divisor of the 6,000-cps reference frequency from the reference oscillator. The 857.14-cps frequency is one-seventh of this reference signal.

35. OSCILLOSCOPE

The oscilloscope is used to calibrate the frequency output of the microsecond oscillator, the operating limits of the frequency-modulated multivibrator, and the output frequencies of the yaw, pitch, and burst oscillators. The frequencies are calibrated by applying them to the horizontal plates of the scope at the same time that calibration frequencies from the reference oscillator are applied to the vertical plates. The resulting Lissajous pattern gives an indication of the relationship between the calibration frequency and the frequency to be calibrated. The frequency to be calibrated is then adjusted until the Lissajous pattern becomes stationary. This indicates that the frequency to be calibrated is proportional to the calibration frequency. The position of the COMMAND CAL switch determines which frequencies are applied to the oscilloscope.

36. POWER SUPPLY AND OVER-ALL OPERATION OF THE R-F TEST SET

a. The power supply provides necessary power to all circuits within the r-f test set.

b. The over-all operation of the GS-15722 r-f test set can best be explained by explaining what tests and adjustments are performed and the functions of the various circuit components in each position of the TEST SELECTOR switch. The TEST SELECTOR switch is the most important control on the r-f test set. It operates in conjunction with other switches and controls to interconnect the various circuits in the proper manner for each step in the test procedure. Table V lists the TEST SELECTOR switch positions, the designation of each, and the test performed in each position.

30. WAVEGUIDE ASSEMBLY

The waveguide assembly is an r-f transmission circuit consisting of waveguide sections, three switch attenuators, a directional coupler, and three hybrid junctions. The waveguide sections perform the same basic function that wires do in electrically connected circuits. The switch attenuators act as switches, controlling the flow of energy through the waveguides. The directional coupler can attenuate the signal by a specified amount. The hybrid junction is a device which splits the input signal equally into two parts, each of which is coupled to one of the receiving antennas.

31. ANTENNA COUPLER

The antenna coupler is used to connect the r-f test set to the missile antennas. The antenna coupler contains three antenna couplings, a hybrid junction, two switch attenuators, a directional coupler, and a number of sections of waveguides. The antenna couplings connect the antenna couplers to the missile antennas. The hybrid junctions divide the r-f energy equally between the two receiving antennas. The switch attenuators permit cutting off the r-f energy to both receiving antennas, or switching the energy from one to the other. The directional coupler is used primarily to attenuate the output of the beacon transmitter.

32. TEST SELECTOR SWITCH

The TEST SELECTOR switch is used to interconnect the various circuits required for each test.

33. RESPONSE INDICATOR

The response indicator is used to indicate missile response to commands or to measure the time difference between pulses sent into or received from the missile. The latter function is required when measuring response time, and the response indicator receives pulses from the crystal detectors in the waveguide circuit and from the pulser. It indicates when two of these pulses arrive in coincidence at a gate tube in the circuit, and the response indicator is then said to be operating as a coincidence indicator.

34. BURST TIMER

The burst timer is the counting circuit used to measure burst time. This circuit receives a train of pulses from the pulse selector. The train is started by the relay circuit in the command modulator and is stopped by a burst signal from the missile. The burst timer indicates time in milliseconds. The indication is read by observing the position of glow discharges in a pair of cold-cathode counting tubes.

b. Reference oscillator.

c. Pulse selector.

d. Pulser.

e. R-F signal generator.

f. R-F power meter circuit.

g. Command modulator.

h. Yaw oscillator.

i. Pitch oscillator.

j. Burst oscillator.

k. Oscilloscope.

l. Power supply.

38. CALIBRATION OF POWER SUPPLY

The +300-volt output of the power supply is used as B+ or plate voltage in the r-f test set. The -250-volt output is used to provide biasing potentials.

a. With the TEST SELECTOR switch in position 1, the +300-volt output of the power supply is connected to the bottom of the RF POWER meter. With the PWR METER CAL switch in the ADJ V position, ground is applied to the top of the RF POWER meter through the PWR METER CAL switch. The meter will then read the +300-volt power supply output. If the voltage is not correct, it must be adjusted by positioning the CAL V knob, which controls the +300-volt output of the power supply.

b. The -250-volt potential is connected across the RESPONSE OR VOLTAGE meter through the -250v toggle switch. When the -250v toggle switch is closed, the -250-volt output of the power supply may be read on the RESPONSE OR VOLTAGE meter. The meter needle should be deflected to the point marked ADJ V. If the reading obtained is incorrect, the power supply must be adjusted by positioning the ADJ -250v screwdriver adjustment.

39. CALIBRATION OF COMMAND CIRCUITS

The command circuits generate the modulated command pulse necessary to send accurate commands to the missile. Calibration of these circuits is necessarv to

Table V. Functions of the TEST SELECTOR switch.

POSITION	POSITION DESIGNATION	TESTS PERFORMED
1	RF TEST SIG	Calibration of the r-f test set.
2	REC SENS	Measurement of receiver sensitivity.
3	TRANS TEST	Measurement of power and frequency of missile transmitter. Check of nonresponse to adjacent codes. Check of pattern modulator operation.
4	RESP TIME A	Measurement of r-f test set delta (delay) time.
5	RESP TIME B	Measurement of missile response time.
6	COMM SIG	Test of missile response to steering orders. Observation of missile fin operation. Measurement of burst and fail-safe time.

Section III. TEST SELECTOR SWITCH POSITION 1

37. CALIBRATION CHECKS

In TEST SELECTOR switch (fig II-49) position 1 (RF TEST SIG), the r-f test set is calibrated to certain fixed references, which insure that the output power and frequency of the r-f signal generator will be within the necessary limits to maintain optimum operational characteristics, that the frequencies of the command oscillators are correct, and that the +300-volt and -250-volt outputs of the r-f test set power supply are within tolerance. The components of the r-f test set utilized in switch position 1 are:

a. Microsecond oscillator.

b. With the COMMAND CAL switch in position 2, the 1600~position, the output of the frequency-modulated multivibrator is connected to the horizontal plates of the oscilloscope through the COMMAND CAL switch. At the same time, a 24-kc signal from the reference oscillator is connected to the vertical plates of the oscilloscope through the COMMAND CAL switch. A stationary Lissajous pattern of 15:1 will result if the frequency of the frequency-modulated multivibrator is correct. If the Lissajous pattern is not stationary, the 1600~ screwdriver adjustment must be positioned to obtain a stationary Lissajous figure or one as nearly so as possible. The 1600~screwdriver adjustment controls the amount of voltage picked from a voltage divider, thereby determining the amount of voltage supplied to cause modulation of the frequency-modulated multivibrator.

c. With the COMMAND CAL switch in position 3, the 2400~position, the frequency of the frequency-modulated multivibrator is calibrated. The output of the multivibrator is coupled to the horizontal plates of the oscilloscope through the COMMAND CAL switch, and 24-kc output from the reference oscillator is coupled to the vertical plates of the oscilloscope through the COMMAND CAL switch. A Lissajous pattern of 10:1 will result. If the pattern is not stationary or very nearly so, the 2400~screwdriver adjustment must be positioned accordingly. The 2400~screwdriver adjustment changes the linearity of a capacitor discharge curve in the frequency-modulated multivibrator. This results in a corresponding change in output frequency.

d. With the COMMAND CAL switch in position 4, the CAL meter is balanced. The CAL meter is a peak voltmeter measuring differences between potentials instead of the absolute values of the potentials. It is later used in balancing the outputs of the command oscillators. The CAL meter is balanced by applying an equal voltage to both sides of a bridge network and varying the current flow through each leg of the bridge. This may be done by positioning the BAL screwdriver adjustment until the needle of the CAL meter reads at the zero (midscale) position.

e. With the COMMAND CAL switch in position 5, the amplitude of the output of the yaw oscillator is adjusted. The output of the yaw oscillator is coupled to the grid of the isolation amplifier through the COMMAND CAL switch. From the isolation amplifier, the yaw signal is coupled to one side of the CAL meter bridge through the COMMAND CAL switch. The other side of the CAL meter is permanently connected to a reference voltage supplied by a voltage divider network. The CAL meter compares the amplitude of the yaw signal with that of the reference voltage. The two voltages are balanced by positioning the YAW screwdriver adjustment until the CAL meter reads at the zero (midscale) position. At the same time, the yaw signal is coupled from the isolation amplifier to the horizontal plates of the oscilloscope through the COMMAND CAL switch, and a frequency of 6 kc is applied to the vertical plates through the COMMAND CAL switch insure that the commands generated will be of the proper frequency to cause the missile to respond. The calibration is performed by comparing their outputs to known reference values. The values used as reference signals are generated by the reference oscillator, which produces stable output frequencies. The outputs of the command circuits are compared to the outputs of the reference oscillator by observing the screen of the r-f test set oscilloscope. An indication in the form of a Lissajous figure on the oscilloscope is caused by applying the reference frequencies to the vertical plates, and the frequencies to be calibrated to the horizontal plates of the oscilloscope. The resulting Lissajous pattern is used to determine the relationship between the reference frequencies and frequencies of the command circuits. The outputs of the command circuits are adjusted by screwdriver adjustments associated with the positions of the COMMAND CAL switch, which selects the various command circuits to be calibrated. These positions are: 2000~, 1600~, 2400~, BAL, PITCH, YAW, BURST, TIME, and MEAS. The code at which a missile operates is determined by the distance between the pulses in a pulse pair. The distance between these pulse pairs contains the command information generated by the r-f test set. This distance is primarily determined by the frequency-modulated multivibrator in the command modulator. The frequency-modulated multivibrator oscillates at some value between the limits of 1,600 cps and 2,400 cps. This value is determined by the voltage with which the circuit is modulated. Applying a greater voltage will cause the multivibrator to oscillate at a higher frequency. Applying a voltage of lesser amplitude will cause the multivibrator to oscillate at a lower frequency. Applying a sinusoidal voltage to the multivibrator will therefore cause the frequency of oscillation to change in direct proportion to the changing voltage applied. The frequency-modulated multivibrator is modulated by three fixed d-c voltages for purposes of calibration, one for each of the first three positions of the COMMAND CAL switch. When modulated by one of these d-c voltages, the frequency-modulated multivibrator may be adjusted to the frequency corresponding to the modulation voltage applied, and the frequency limits between which the multivibrator will oscillate are calibrated.

a. With the COMMAND CAL switch in position 1, the 2000~ position, the output of the multivibrator is connected to the horizontal plates of the oscilloscope through the COMMAND CAL switch. At the same time, a 24-kc signal from the reference oscillator is connected to the vertical plates of the oscilloscope through the COMMAND CAL switch. A 12:1 ratio Lissajous pattern will result if the 2000~ operation of the frequency-modulated multivibrator is correct. If it is not correct, the 2000~ screwdriver adjustment must be positioned until a stationary or as nearly stationary as possible Lissajous pattern is observed. The 2000~ screwdriver adjustment varies the R-C time constant of the frequency-modulated multivibrator, which changes the frequency of the multivibrator oscillations.

h. With the COMMAND CAL switch in position 8, the frequency of the microsecond oscillator is calibrated. The code of the missile is determined by the time between the two pulses of the pulse pair. This time is controlled by the microsecond oscillator, which has a frequency range from 33 to 500 kc and thus provides a code range of from 2 to 30 microseconds. The frequency is controlled by the TIME-MICROSECONDS dials, which switch various values of capacitance into the oscillator bridge. The microsecond oscillator frequency must be adjusted so that it will be exactly the same as that indicated by the position of the TIME-MICROSECONDS dials. This is necessary to insure that the frequency set up by the TIME-MICROSECONDS dials will be the same as the frequency desired. In COMMAND CAL switch position 8, the TIME-MICROSECONDS dials are set to the nearest full microsecond of the code of the missile to be tested. For example, with a missile with a 4-microsecond code, the TIME-MICROSECONDS dials will be set to a value of 4 microseconds. This will cause the microsecond oscillator to oscillate at a frequency of 250 kc. This 250-kc signal is coupled from the microsecond through the COMMAND CAL switch and applied to the vertical plates of the oscilloscope. A Lissajous pattern of 4:1 will result if the frequency of the microsecond oscillator is correct. If this frequency is found to be incorrect, the TIME screwdriver adjustment must be positioned to cause the Lissajous pattern to become as nearly stationary as possible. The TIME screwdriver adjustment varies the amount of resistance in the frequency selective bridge in the microsecond oscillator, thus changing its frequency.

i. With the COMMAND CAL switch in position 9, the MEAS position, either the combined output of the yaw and pitch oscillators or the signal from the burst oscillator may be applied to the frequency-modulated multivibrator, resulting in a frequency-modulated output which is sent to the pulser. The command circuits are now calibrated.

40. CALIBRATION OF R-F COMPONENTS

After the command circuits have been adjusted, the various circuits that generaté and measure the r-f signal are calibrated. These consist of the r-f signal generator, frequency meter, and the r-f power meter circuit. The output of the r-f signal generator is fed to the r-f power meter circuit and the frequency meter for calibration purposes. The RF POWER meter must be calibrated before it is used in measuring the power output of the r-f signal generator.

a. Calibration of RF POWER meter. Calibration of the RF POWER meter is accomplished by means of the PWR METER CAL switch, the CAL ∞ knob, and the CAL 0 knob. By placing the PWR METER CAL switch in the ADJ ∞ position and adjusting the CAL ∞ knob, the RF POWER meter is adjusted for a maximum dip toward ∞. This establishes an accurate zero reference for the following calibration procedures. It must be understood that although the RF POWER meter from the reference oscillator. A Lissajous pattern of 40:1 will result. If the pattern is not stationary or very nearly so, the frequency of the yaw oscillator must be adjusted by positioning an internal screwdriver adjustment until the pattern on the oscilloscope becomes as nearly stationary as possible. The internal yaw frequency adjustment varies the amount of resistance within a frequency-sensitive bridge, thus changing the frequency of the oscillator. The YAW screwdriver adjustment controls the amplitude of the output of the yaw oscillator by varying the potentiometer located on the output of the oscillator.

f. With the COMMAND CAL switch in position 6, the amplitude of the pitch oscillator output is calibrated. The output of the pitch oscillator is applied to the grid of the isolation amplifier through the COMMAND CAL switch. From the isolation amplifier, the pitch signal is coupled to one side of the CAL meter bridge through the COMMAND CAL switch. The function of the CAL meter bridge is identical to that described in e above. The pitch signal is also applied from the isolation amplifier to the horizontal plates of the oscilloscope through the COMMAND CAL switch, and the 6-kc signal from the reference oscillator is applied to the vertical plates of the oscilloscope through the COMMAND CAL switch. A Lissajous pattern of 12:1 will result. If the pattern is incorrect, the frequency of the pitch oscillator may be adjusted by positioning the internal pitch frequency adjustment, the function of which is identical to that described for the yaw oscillator.

g. With the COMMAND CAL switch in position 7, the output amplitude of the burst oscillator is calibrated. The output of the burst oscillator is applied to the grid of the isolation amplifier through the COMMAND CAL switch. From the isolation amplifier, the burst signal is coupled to one side of the CAL meter bridge through the COMMAND CAL switch. The operations of the CAL meter bridge and the BURST screwdriver adjustment are identical to the operations discussed for the pitch and yaw oscillators. From the isolation amplifier, the burst signal is also applied to the horizontal plates of the oscilloscope through the COMMAND CAL switch, and the 6-kc reference signal from the reference oscillator is applied to the vertical plates of the oscilloscope through the COMMAND CAL switch. The burst frequency of 880 cps is not an even divisor of 6 kc. Therefore, using the normal burst frequency would not produce the desired Lissajous pattern. To overcome this difficulty, the burst oscillator is designed to oscillate at either the normal frequency of 880 cps or a special calibration frequency of 857.14 cps. This is accomplished by connecting a resistor in parallel with the bottom half of the burst oscillator bridge. With the resistor connected, the output frequency will be held at 880 cps. In position 7 of the COMMAND CAL switch, the resistor is switched out of the circuit, holding the output frequency at 857.14 cps. This is the burst calibration frequency applied to the horizontal plates of the oscilloscope. Since 857.14 cps is a divisor of 6 kc, a 7:1 ratio Lissajous pattern is obtainable on the oscilloscope. If the frequency is incorrect, the burst frequency internal screwdriver adjustment may be made as described in e above.

e. Final output power calibration. The r-f signal generator final output power must be adjusted to a known value, so that tests on the missile will be accurate. To calibrate the power output of the r-f signal generator, the TIME-MICROSECONDS dials are set to 0400. This value was selected as average output power for calibration purposes. To insure that no other pulse frequency will be used, the final stage of the pulser is biased to cutoff unless the TIME-MICROSECONDS X1 dial is set to 4 when the TEST SELECTOR switch is in position 1. The ATTEN DB control is set to zero. The r-f signal generator will produce a 4-microsecond train of r-f pulses. The RF POWER meter circuit was calibrated with a voltage equal to the output desired from the r-f signal generator. The actual power output of the r-f signal generator is now adjusted by the OUTPUT knob, which controls a variable attenuator in the waveguide assembly and regulates the amount of r-f energy that may be applied to the missile. The OUTPUT knob is adjusted until the r-f output of the klystron equals the amount previously established in the calibration of the power meter. This r-f power output is indicated by a reading of zero on the RF POWER meter.

Section IV. TEST SELECTOR SWITCH POSITION 2

41. MEASUREMENT OF RECEIVER SENSITIVITY

In TEST SELECTOR switch position 2 (fig II-49), the sensitivity of the two missile receiving antennas are checked. For the measurement of receiver sensitivity, the TIME-MICROSECONDS dials in the microsecond oscillator are sent to the assigned code of the missile under test. The output of the microsecond oscillator will then be a sine wave with a period equal to that of the code. This output is squared and differentiated by the pulse selector, now operating as a self-controlled recycling gate. In this condition, the pulse selector will pass only 2 pulses per 500 microseconds. These pulses will be in the form of a pulse pair. The time between the pulses in each pair is equal to the code set on the TIME-MICROSECONDS dials. The pulse pairs are amplified and shaped by the pulser and sent to the r-f signal generator, which produces a burst of r-f energy for each input pulse. These coded r-f pulses are sent through the waveguide assembly into missile antenna 2 or 4, depending upon the position of the ANT 2-4 switch. The components of the r-f test set used in TEST SELECTOR switch position 2 are:

a. Microsecond oscillator.

b. Pulse selector.

c. Pulser.

will give a reading close to ∞ when the bridges are properly balanced, the actual voltage applied to the RF POWER meter is equal to zero. The RF POWER meter reads in decibels of attenuation. Therefore, a reading of ∞ is equal to infinite attenuation of the voltage across the bridges. If the attenuation of this voltage is infinite, the voltage must therefore be equal to zero. In the ADJ 0 position of the PWR METER CAL switch, ground is applied to the RF POWER meter through the PWR METER CAL switch. In this position, the gain of the power meter amplifier is adjusted until a reading of zero is obtained on the RF POWER meter. The power meter amplifier is adjusted to obtain a reference by which the output power of the r-f signal generator may be later calibrated. The adjustment is made by applying a voltage with a power content equal to the power output desired from the r-f signal generator and adjusting the power meter amplifier until the RF POWER meter reads at the zero position. Therefore, a reading of zero on the RF POWER meter is equal to the desired output power of the r-f signal generator.

b. Calibration of the r-f signal generator. Calibration of the r-f signal generator is accomplished by first placing the PWR METER CAL switch in the MEAS position. This removes all calibrating voltages from the r-f power meter circuit, and switch attenuator AT3 in the waveguide assembly is deenergized, allowing r-f power from the klystron to flow to the thermistor mount. The r-f thermistor detects the energy, causing an unbalance in the power meter circuit, resulting in an indication on the RF POWER meter.

c. Maximum power calibration. The r-f signal generator is operated continuous wave (c-w) and adjusted for maximum output power. This is accomplished by setting the TIME-MICROSECONDS dials to 0000, which removes the pulses from the pulser. The REPELLER knob, a trimming adjustment for the r-f signal generator klystron, is positioned until the RF POWER meter reads as high as possible, indicating that the c-w output of the klystron is at its maximum. When adjusting the REPELLER knob, the ATTEN DB knob is used to keep the RF POWER meter reading on scale.

d. Frequency calibration. The r-f signal generator frequency is measured by rotating the MEAS FREQ control until the RF POWER meter dips sharply toward ∞ , indicating that the coaxial resonator in the waveguide is absorbing maximum power. A reading is taken from the calibrated FREQ dial, and compared with the MEAS FREQ table. The frequency of the signal generator is then calculated by interpolating between two of the values on the MEAS FREQ table. The MEAS FREQ control varies the length of the coaxial resonator inner conductor, which will resonate at a value proportional to 15 quarter-wavelengths of the r-f output. The resonator must be detuned after use, so that power from the klystron may be transmitted to the missile guidance unit and not absorbed in the waveguide. If the frequency is incorrect, it may be adjusted by positioning the FREQ knob, which varies the spacing between the resonator grids in the klystron, thus controlling its output frequency.

b. Pulse selector.

c. Pulser.

d. R-F signal generator.

e. R-F power meter circuit.

f. Response indicator.

g. Antenna coupler.

44. MEASUREMENT OF MISSILE TRANSMITTER POWER AND FREQUENCY

a. Measurement of missile transmitter power is necessary to insure that the missile beacon output power is of sufficient amplitude to allow accurate tracking at maximum missile range. All signals from the r-f test set reach the missile through either antenna 2 or 4, depending upon the position of the ANT 2-4 switch. The transmitter power is measured by using the RF POWER DB switch, which changes the gain of an amplifier in the r-f power meter circuit, thereby effectively attenuating the r-f signal from the missile. The RF POWER meter indicates the amount of power transmitted by the missile. The RF POWER DB switch is set in the position which will cause the RF POWER meter to read between zero and 1, if possible. If this reading is not possible, the RF POWER DB switch is set to 14. In any case, the sum of the reading of the RF POWER meter and the RF POWER DB switch setting must be 15 db or less, indicating that the signal from the missile beacon is not attenuated more than 15 db at maximum range.

b. Measurement of missile transmitter frequency is necessary to ascertain whether the missile beacon output frequency is within tolerance. This measurement is accomplished by using the frequency meter and the RF POWER meter. The FREQ knob is adjusted until a sharp dip is noted upon the RF POWER meter. Thé operation of the frequency meter is the same as in TEST SELECTOR switch position 1. The cavity resonator now absorbs power from the missile beacon output. As before, the FREQ knob is adjusted for a sharp dip on the RF POWER meter. When the dip occurs, a reading is taken from the FREQ dial, and the frequency is determined by interpolating this figure in reference to the MEAS FREQ table on the face of the r-f test set. After the frequency has been measured, the frequency meter must be detuned so that it will not draw power from the waveguide.

45. CHECK OF NONRESPONSE TO ADJACENT CODES

This check is necessary to insure that the missile will not respond to code signals from nearby unassociated radars. Any signal affecting the missile must

d. R-F signal generator.

e. Response indicator.

f. Antenna coupler (r-f test saddle).

42. ANT 2-4 SWITCH

a. Antenna 2. In the antenna 2 position of the ANT 2-4 switch, ground is applied to relay K2, which energizes the switch attenuator in the waveguide assembly. This attenuator blocks the waveguide, forcing all signals to reach the missile through antenna 2 (switch attenuator K1 is deenergized). When the missile receives the signal, the missile beacon responds, sending out a burst of r-f energy for each pair of input pulses. This r-f pulse is transmitted back to the r-f test set where it is detected by CR1 and applied to the response indicator circuit and RESPONSE OR VOLTAGE meter. The RESPONSE knob, which controls the amount of power applied to the response indicator, may be used to keep the reading of the RESPONSE OR VOLTAGE meter on scale. When a response is noted on the response or voltage meter, the ATTEN DB knob, which controls a calibrated attenuator in the waveguide (and thus the amount of power transmitted to the missile), is rotated in a counterclockwise direction until the missile response becomes erratic or falls off entirely. When missile response drops off, the reading on the ATTEN DB dial should be 5 or greater. This indicates that the missile will receive and respond to commands of the low amplitude that is encountered at maximum missile range. The ATTEN DB knob effectively increases the distance of the missile from the signal source. Missile response to a signal with an attenuation of 5 db or higher is a positive indication that the missile will respond to MTR commands at maximum range.

b. Antenna 4. In the antenna 4 position of the ANT 2-4 switch, ground is removed from K2 and applied to K1. All energy is now transmitted to the missile through antenna 4 rather than antenna 2. Operation and procedure from this point on is identical with that in a above.

Section V. TEST SELECTOR SWITCH POSITION 3

43. TESTS PERFORMED

In TEST SELECTOR switch position 3 (fig II-50), four tests are performed: measurement of missile transmitter power; measurement of missile transmitter frequency; check of nonresponse to adjacent codes; and check of operation of the pattern modulator. The components of the r-f test set used in TEST SELECTOR switch position 3 are:

a. Microsecond oscillator.

first. It should be remembered, however, that the delta time of the r-f test set must be known to accurately determine missile response time. The components of the r-f test set used in TEST SELECTOR switch positions 4 and 5 are:

(1) Microsecond oscillator.

(2) Pulse selector.

(3) Pulser.

(4) R-F signal generator.

(5) R-F power meter circuit.

(6) Response indicator.

(7) Antenna coupler.

b. Measurement of missile response time (fig II-91). To measure response time, the TEST SELECTOR switch is placed in position 4, RESP TIME A. The TIME-MICROSECONDS dials are adjusted to a value equal to the code of the missile under test + delta time + 0.1 microsecond. The 0.1-microsecond interval is the amount of time which will cause the missile to be triggered by the leading edge of the radar pulse. The output of the microsecond oscillator will then be a sine wave with a period equal to the value established by the TIME-MICROSECONDS dials. The signal is coupled to the pulse selector through the TEST SELECTOR switch. The pulse selector, operating as a self-controlled recycling gate, squares and differentiates the sine wave into pulses, and passes one pulse pair every 500 microseconds. For simplicity of explanation, the pulse pair passed every 500 microseconds will be referred to as pulse A and pulse B, with pulse A corresponding to the code pulse and pulse B corresponding to the radar pulse. This train of pulse pairs is divided into two identical outputs, pulse selector outputs 1 and 2 (PS1 and PS2), both of which are coupled to the pulser. The pulser performs two separate functions; one upon pulse selector output 1 and another upon pulse selector output 2. PS1 is amplified and coupled directly to the response indicator through the TEST SELECTOR switch. This outfit consists of the above-mentioned A pulse and B pulse. PS2 is treated somewhat differently. The pulser removes pulse B from PS2 and substitutes a corresponding pulse C. Pulse C is then known as the radar pulse, and may be controlled by the ADJ CODE knob. PS2 is coupled from the pulser to the r-f signal generator and from the r-f signal generator to the response indicator. Switch attenuator AT3 is deenergized. In addition, ground is applied to both sides of the ANT 2-4 switch through the TEST SELECTOR switch, causing switch attenuators AT1 and AT2 to become energized, blocking the waveguide path to the receiving antennas on the missile. Because of the inherent delta necessarily come from its own missile-tracking radar. The allowable tolerance of a missile code is ±0.75 microsecond. Therefore, a missile with a code of 4 microseconds should not respond to signals above 4.75 microseconds or below 3.25 microseconds. The test is performed by varying the TIME-MICROSECONDS dials in 0.75-microsecond increments around the missile code from 2.5 to 10 microseconds. For example, if the missile under consideration has a code of 4 microseconds, the TIME-MICROSECONDS dials will be set at 4.75, 5.50, 6.25, 7.00, 7.75, 8.50, 9.25, 10.00, 3.25, and 2.50. No response should be noted on the RESPONSE OR VOLTAGE meter for any setting other than 4.00 microseconds. The test is carried into various steps to insure that the missile will not respond to any multiple or harmonic of the assigned code.

46. CHECK OF PATTERN MODULATOR OPERATION

The pattern modulator controls the phase relationship of the signals transmitted by the missile from antennas 1 and 3. If the pattern modulator is not operating, there is danger of the signals from the two antennas canceling each other, resulting in no signal output to the missile-tracking radar. The pattern modulator is tested by connecting a headset-handset to the MON telephone jack and depressing the MON toggle switch, which removes the output of the response indicator from the RESPONSE OR VOLTAGE meter and applies it to the headset-handset. If the pattern modulator is operating, the 2-kc output of the reference oscillator frequency modulated by a 50-cps signal from the pattern modulator may be heard through the phone. If the pattern modulator is inoperative, the 2-kc tone may still be heard, but the 50-cps modulation will not be present.

Section VI. TEST SELECTOR SWITCH POSITIONS 4 AND 5

47. MISSILE RESPONSE

a. General. TEST SELECTOR switch positions 4 and 5 (fig II-51) are used in the measurement of missile response time. Response time is the delay time of the missile beacon, or the time lapse between the reception of a pair of pulses from the missile-tracking radar and the transmission of a return pulse for the purpose of tracking. Any delay time in the missile beacon will affect missile position data. Compensation for missile response time is made in the missile-tracking radar. Response time must be checked to insure that the delay of the missile beacon is within required limits. There are two steps in the measurement of response time: the measurement of the delay time of the r-f test set (delta time), and the measurement of actual missile response time itself. For convenience in explanation, the measurement of response time will be discussed day the r-f test set is operated should be adequate. Measurement of delta time begins in TEST SELECTOR switch position 3, TRANS TEST. The CAL ∞ control is adjusted until the RF POWER meter reads 2.0. This step adjusts the RF POWER meter so that all readings necessary in the measurement of delta time may be read on the midscale portion of the RF POWER meter, since the midscale portion is more sensitive and easily read. The TIME-MICROSECONDS dials are next set to the code of the missile under test + 0.1 microsecond, and then decreased until the missile begins to trigger on the leading edge of the radar pulse, as indicated by a rise of 0.1 db on the RF POWER meter. The TEST SELECTOR switch is next placed in position 5, RESP TIME B, and the ADJ CODE knob is turned fully clockwise. PS2 is then adjusted by rotating the ADJ CODE knob counterclockwise until the missile triggers on the leading edge of the radar pulse. Pulses A, B, and C of PS1 and PS2 are now spaced equally. The TEST SELECTOR switch is then placed in position 4, RESP TIME A, and switch attenuators AT1 and AT2 are energized, blocking the waveguide paths to the missile. PS2 is now coupled through the r-f signal generator to the response indicator, while PS1 is coupled directly to the response indicator through the TEST SELECTOR switch. Delta time is now impressed upon PS2. Pulse B of PS1 and pulse C of PS2 will now be out of coincidence, with pulse C of PS2 occurring later than pulse B of PS1. PS1 is adjusted by increasing the reading of the TIME-MICROSECONDS dials until maximum coincidence is registered on the RESPONSE OR VOLTAGE meter. The distance between the leading edge of pulse C of PS2 and the leading edge of pulse B of PS1 is equal to the delta time of the r-f test set.

Section VII. TEST SELECTOR SWITCH POSITION 6

49. MEASUREMENTS AND COMMAND SIGNAL RESPONSE

a. General. In TEST SELECTOR switch position 6 (fig II-52), the burst and fail-safe time are measured, and the missile is checked for response to command signals. The components of the r-f test set utilized in TEST SELECTOR switch position 6 are:

(1) Yaw oscillator.

(2) Pitch oscillator.

(3) Burst oscillator.

(4) Command modulator.

(5) Pulser.

time of the r-f circuits in the r-f test set, PS2 (pulse A and pulse C) will reach the response indicator shortly after PS1 (pulse A and pulse B). Pulse A of the AC pulse pair (PS2) will be out of coincidence with the corresponding pulse A of the AB pulse pair (PS1) by an amount equal to the delta time of the r-f test set. A similar relationship exists between pulses C and B. The code interval of the missile must be set in the AC (PS2) pulse pair, using the ADJ CODE knob. To do this, the ADJ CODE knob is turned counterclockwise, moving pulse C closer to pulse A until a coincidence indication occurs on the RESPONSE OR VOLTAGE meter. This insures that the leading edge of the radar pulse rather than the trailing edge will trigger the missile. The reading on the RESPONSE OR VOLTAGE meter is an indication that pulses B and C are in coincidence. Since pulses A and C reached the response indicator later than pulses A and B by a time equal to the delta time, pulse A of the AC pulse pair occurs delta time later than pulse A of the AB pulse pair. Pulse C was adjusted to coincidence with pulse B. Therefore, since the AB pulse pair is set at code + delta + 0.1 microsecond, the distance between pulses A and C is now equal to the code of the missile + 0.1 microsecond. The TEST SELECTOR switch is next placed in position 5, RESP TIME B. Ground is removed from the ANT 2-4 switch, opening a waveguide path to the missile, and AT3 is energized, removing the alternate r-f path to the r-f power meter circuit. Pulse selector output 2 is now allowed to trigger the missile, and return pulses will be coupled from the missile to the response indicator through CR1. The missile is triggered by pulse C of PS2. The return pulse (D) from the missile to the r-f test set occurs sometime later than pulse C. This time lapse is the response time of the missile. In the previous step, pulse B of pulse selector output 1 and pulse C of pulse selector output 2 were set in time coincidence. Since pulses A and B of PS1 are still coupled directly from the pulser to the response indicator, a new coincidence may be set between pulse B of PS1 and the return pulse (D) from the missile. This is done by increasing the setting of the TIME-MICROSECONDS dials until maximum indication occurs on the RESPONSE OR VOLTAGE meter. With the new setting of the TIME-MICROSECONDS dials, the distance between pulses A and B of PS1 is equal to the code of the missile + delta + 0.1 microsecond + response time. The measured response time of the missile may now be found by subtracting the distance between pulses A and B of pulse selector output 1 (code + delta + 0.1 microsecond) from the distance between pulses A and B as described in paragraph 48 (code + delta + 0.1 microsecond + response time). The actual response time of the missile is equal to the measured response time -0.04 microsecond, the value of the inherent delay of the waveguide assembly.

48. MEASUREMENT OF R-F TEST SET (DELTA) DELAY TIME (fig II-91)

Delta time of the r-f test set is the inherent time delay in the r-f test set itself. It must be measured for accurate response time measurement. Procedures differ as to the frequency of delta time measurement. One measurement each pulses and coupled to the burst timer. The burst timer transforms the train of negative pulses into two square waves of opposite polarity and uses them to trigger the burst counting tubes. The tubes will continue to count until a burst indication is received from the missile. The burst indication is coupled from the missile to the test power control unit by means of the ground power cable, and from the test power control unit to the r-f test set through the r-f test cable. When the burst indication reaches the pulse selector, it closes the gate, causing the counting tubes to cease counting. The burst timer may then be read from the calibrated dials encircling the counting tubes. The burst time should be 64 ± 5 milliseconds.

50. MEASUREMENT OF FAIL-SAFE TIME

The procedure for the measurement of fail-safe time is somewhat different from that used in the measurement of burst time. The function of the circuit is however very nearly identical. Instead of applying the burst command upon the removal of the P and Y commands by the START switch, no burst command is applied, and the fail-safe circuit in the missile is allowed to give the burst order. The COMMAND CAL switch is placed in the TIME position. Pulse pairs will still be coupled to the missile, but a path from the output of the command modulator through the COMMAND CAL switch to burst relay K2 is established. The START switch is then pressed, and the operator begins counting in 1-second increments. Pressing the START switch causes the counting tubes to operate as in the measurement of burst time. The r-f test set operation differs from burst time measurement in that the output of the command modulator is now grounded through the contacts of K2. There is now no output to the missile. With no signal to the missile, the fail-safe circuit begins to operate. Within 2 to 7 seconds, the fail-safe circuit sends a pulse to the arming device. This pulse is coupled through the TPCU to the r-f test set, having the same effect as the burst signal in burst time measurement. That is, the pulse closes the gate in the pulse selector and causes the counting tubes to stop counting. The time lapse (as counted by the operator) between the pressing of the START switch and the reception of the burst indication (indicated by stop of count by counting tubes) is equal to the fail-safe time of the missile.

51. TEST OF MISSILE RESPONSE TO COMMAND SIGNALS

To check the missile for response to steering orders, P and Y signals from the P and Y oscillators are sent into the command modulator and modulate the frequency-modulated multivibrator. The output of the frequency-modulated multivibrator is a frequency-modulated train of single pulses. This output is coupled from the command modulator to the pulser through the TEST SELECTOR switch. In the pulser, the frequency-modulated single pulse output of the command modulator is amplified and reshaped as before; but in addition, a second pulse is added to the single pulse for coding purposes. The output of the pulser is therefore

(6) R-F signal generator.

(7) Reference oscillator.

(8) Pulse selector.

(9) Burst timer.

(10) Response indicator.

(11) R-F power meter circuit.

(12) Antenna coupler.

b. Measurement of burst time. The measurement of burst time consists of sending a burst signal into the missile in place of the steering orders and measuring the time in milliseconds required for the missile to receive the burst command and return the burst signal to the r-f test set. The first step in the measurement of burst time is to depress the RESET switch, which applies a -60-volt input to the burst timer, causing the glow indications in the cold-cathode burst counting tubes to be positioned on the normalizing cathodes, the point from which the counting tubes begin to count. Relays K1 and K2 are also deenergized. Releasing the RESET switch removes the -60-volt potential from the burst timer and applies it to the pulse selector, insuring that the gate is closed. Relays K1 and K2 cannot energize at this time because of the short applied from the upper contacts of K2 through the START switch. Depressing the START switch removes the short. Relays K1 and K2 will now energize. Relay K1 will remove P and Y commands from the command modulator and apply the burst command. Relay K2 removes the ground from an amplifier in the r-f power meter circuit, disabling the RF POWER meter to prevent an erroneous indication of missile response during measurement of burst time. When the START switch is released, the short circuit, which had previously prevented K1 and K2 from energizing is still held open by the energized contacts of K2 rather than by the START switch itself. The burst command is applied to the frequency-modulated multivibrator in the command modulator. The frequency-modulated multivibrator converts the sine wave into a frequency-modulated square wave, which is coupled to the pulser through the TEST SELECTOR switch. The pulser receives the differentiated square wave output of the command modulator and transforms it into a train of coded pulse pairs, which trigger the r-f signal generator. A train of r-f pulse pairs is transmitted to the missile from the r-f signal generator through the waveguide assembly. At the same time, depressing the START switch opens the gate in the pulse selector, which operates as an externally controlled recycling gate. The sine wave output of the reference oscillator flows into the pulse selector, where it is changed into a train of negative

CHAPTER 6

R-F TEST SET CIRCUIT ANALYSIS

Section I. MICROSECOND OSCILLATOR

52. GENERAL

a. The purpose of the microsecond oscillator is to generate a sine wave with stable frequency characteristics. This sine wave is used by the pulse selector in forming accurately timed pulses which are used to trigger the missile in tests of receiver sensitivity, missile transmitter power and frequency, and missile response time.

b. The microsecond oscillator is of the Wien bridge type. The Wien bridge oscillator is used because of its excellent frequency and amplitude stability. These high stability characteristics are accomplished by means of positive and negative feedback loops. The negative feedback loop provides amplitude regulation; the positive feedback loop provides frequency regulation.

c. An oscillator is formed by adding a positive feedback loop to a one-stage amplifier. If a positive feedback loop is present and a positive signal is applied to the control grid of the tube, the negative signal produced at the plate is coupled to the cathode. Since this coupling effectively makes the cathode more negative, the value of the signal removed from cathode to grid is effectively larger, resulting in a stronger input signal at the grid. This build-up process will continue, resulting in continued oscillations.

d. In a two-stage amplifier, a positive feedback loop may be connected similarly. Since, in a two-stage amplifier, the output phase is the same as the input phase, the positive feedback loop must be connected to the grid of the input tube rather than the cathode, since an in-phase signal applied to the cathode would tend to effectively decrease the signal at the grid. The additional gain of the two-stage amplifier will insure continuous oscillation.

e. Negative feedback in a two-stage amplifier may be obtained by the addition of a connection from the plate of the output tube to the cathode of the input tube. After this step, if a positive signal is applied to the input grid, the output of the oscillator will be observed to be positive also. This positive signal, when coupled back to the cathode of the input tube results in a lower grid-to-cathode signal, thus decreasing the input to the oscillator. In this manner, the amplitude of the oscillator output is controlled.

a train of pulse pairs carrying the command information. This output triggers the r-f signal generator. The r-f signal generator converts these pulses into a train of r-f pulse pairs carrying the command information. From the r-f signal generator, the command signal is passed through the waveguide assembly and antenna coupler into the missile. In the missile, the frequency-modulated pulses are decoded and converted into d-c voltages, corresponding to the P and Y commands. These d-c voltages are measured and indicated by d-c meters located in the electrical test set. Indication of missile response is indicated in TEST SELECTOR switch position 6 upon the RF POWER and RESPONSE OR VOLTAGE meters. Various commands are selected by using the PITCH COMMAND and YAW COMMAND switches and the associated FINS knobs. Each COMMAND switch is capable of selecting commands of -5g, 0g, and +5g. An additional position of each switch switches the FINS knob in or out of the circuit. In the FINS position of each switch, the associated FINS knob may be used to control the fins in a smooth command change from -2g to +2g. The COMMAND switches control the resistance in the bridge circuits of the command oscillators and thereby control the output frequency of each oscillator.

in a horizontal row across the chassis front panel. Although not associated with the operation of the microsecond oscillator, the AC POWER ON OFF switch, fuses, the POWER ON indicator lamp, RESPONSE MON switch, -250V switch, ADJ-250V screwdriver adjustment, TIME screwdriver adjustment, and MON telephone jack are mounted in a horizontal row along the bottom edge of the chassis. Jack J7 provides connections to the command modulator and pulser circuits.

54. BLOCK DIAGRAM (fig II-70)

a. General. The microsecond oscillator consists of an oscillator circuit comprising electron tubes V1, V2, and V3, and the bridge circuit. Also incorporated in the microsecond oscillator is a cathode follower composed of V4A and V4B.

b. Operation of the microsecond oscillator. As has been previously explained, the microsecond oscillator is of the Wien bridge type. A positive feedback loop provides frequency stability, and a negative feedback loop provides amplitude stability. In the microsecond oscillator, oscillations are established by means of a positive feedback loop connected through the left-hand arms of the bridge circuit to the grid of V1. The values of capacitance in the left half of the bridge are varied by means of the TIME-MICROSECONDS dials. This adjustment determines the frequency at which the microsecond oscillator will oscillate. The frequency may be varied between 33 kc and 500 kc, or periods of from 2 to 30 microseconds. The TIME screwdriver is used for the calibration of the frequency of the microsecond oscillator in TEST SELECTOR switch position 1, and COMMAND CAL switch position 8. The 1-mc output of the reference oscillator is used as a standard frequency for the adjustment of the microsecond oscillator. Negative feedback is applied to the cathode of V1 by the right-hand arms of the bridge circuit. The controlling element in the negative feedback circuit is thermistor RT1. As the output of the oscillator increases, more power will be applied to the feedback circuits. This increased power when applied to RT1 will cause the resistance of RT1 to decrease, thus increasing the flow of current through the right-hand arm of the bridge circuit. This increases the amount of feedback voltage applied to the cathode of V1, thus decreasing the gain of V1. A regulating action upon the output of the oscillator results. Tubes V1 and V2 are used as amplifier stages in the oscillator. Tube V3 is a cathode follower, providing an output stage of low impedance characteristics. This is necessary because feedback voltage is taken off the cathode of V3. Tubes V4A and V4B serve as isolation amplifiers. Two outputs are taken from V4. One output is coupled through the TEST SELECTOR switch to the pulse selector. The other output, used for calibration purposes, is coupled to the horizontal plates of the oscilloscope through the COMMAND CAL switch.

f. Since oscillation occurs only when the positive feedback is exactly in phase with the input signal, a circuit which produces a phase lag or lead at any other frequency than the desired one can be used to control the output frequency of the oscillator. The frequency sensitive circuit or bridge is composed of resistive and capacitive elements. At frequencies lower than the desired one, the relatively high impedance of the capacitive elements in the bridge will prevent much current flow through the resistive elements of the bridge, resulting in a small feedback voltage. At frequencies higher than the desired one, the lowered impedance of the capacitive elements will short-out most of the signal normally developed across the resistive elements, and the feedback voltage will again be slight. Since oscillation depends upon the amplitude of the feedback voltages, oscillation will occur only when the feedback is high. Oscillation,however, is also dependent upon the phase of the feedback signal. Since the R-C circuit is designed in such a manner as to produce zero phase shift at the proper frequency, it is at this frequency that oscillation must occur. Hence the frequency stability of the Wien bridge oscillator.

g. Amplitude regulation in the Wien bridge oscillator is accomplished by means of a modification of the previously discussed circuit. The amount of feedback voltage is determined by means of a voltage divider composed of a resistor and a thermistor. If the output of the oscillator increases, more power will be fed back to the input through the voltage divider. This power applied to the thermistor will cause its resistance to decrease, creating a greater current flow in the circuit and thus causing an increase in the amount of negative feedback voltage. This, in turn, decreases the gain of the oscillator to its required operating point. In addition, the resistance of the resistive component in the voltage divider is now much greater than that of the thermistor.

h. Since the upper arms of the bridge circuit will be affected by the output impedance of the second stage, it is desirable to maintain the impedance of this stage at as low a point as possible. This is done by a third stage which functions as a cathode follower and serves as an impedance-matching device for the bridge circuit.

53. LOCATION AND PHYSICAL CHARACTERISTICS (figs II-46, II-54, and II-55)

The microsecond oscillator is located in the r-f test set lower drawer assembly. It is mounted in the lower left of the lower drawer assembly front panel. The microsecond oscillator chassis measures 10 x 13 x 6 inches and weighs approximately 5 pounds. The TIME-MICROSECONDS dials are mounted

C_a = total capacitance connected between the lower end of R2 and control grid of V1

C_b = total capacitance connected in parallel with R_b

R_a = resistance in ohms of R2

R_b = effective resistance of the network R3 through R5

and where $C_a = C_b$

and $R_a = R_b$.

If f is in cycles per second and t = time in seconds for one cycle, then

$$t = \frac{1}{f} = 2\pi RC .$$

Therefore, if R is constant, the time, t, varies directly with the amount of capacitance present in the bridge circuit. In the microsecond oscillator, the time in seconds for one cycle is the important factor. The amount of capacitance present in the bridge circuit is controlled by means of three switches and a variable capacitor, C51. The switches connect various values of capacitance into the bridge circuit to change the frequency of oscillation. It may be seen that if a pair of capacitors, when connected into the bridge circuit, causes the oscillator to generate a frequency of 500 kc,(a period of 2μsec), and a second pair connected similarly generates the same frequency, when these two pairs are connected into the bridge circuit simultaneously, the frequency generated will be equal to 250 kc (a period of 4μsec) because

$$f = \frac{1}{2\pi RC}$$

(the frequency varies inversely with the amount of capacitance). Also, if a pair of capacitors capable of generating a frequency of 100 kc (a period of 10μsec) is added to this combination, the resulting period will be 2 + 2 + 10 = 14 microseconds (71.428 kc). By extending this principle, any desired frequency of oscillation may be accomplished. Switches S1 through S3 produce a time sequence of from 2 to 29.9 microseconds in 0.1-microsecond steps. Capacitor C51 acts as a vernier adjustment and produces a linear change in time over each 0.1-microsecond step.

d. Operation of switching circuits.

(1) Switch S1. Switch S1 is the TIME-MICROSECONDS X10 switch. It is capable of producing changes in the period of the microsecond oscillator

55. DETAILED CIRCUIT OPERATION (fig II-71)

a. General. The microsecond oscillator is of the Wien bridge type and is composed primarily of a bridge circuit, an amplifier, and a cathode follower. The bridge circuit contains thermistor RT1, resistors R8 and R7 and R2 and R5; capacitors C52 and C53, and switches S1, S2, and S3 with their associated capacitors. The amplifier contains electron tubes V1, V2,and V3 and associated resistors, capacitors, and inductors. The cathode follower is made up of both sections of V4 and associated resistors and capacitors.

b. Operation of amplifier circuit. In the microsecond oscillator, oscillations are generated by electron flow through the amplifier to the bridge, and through the bridge back to the amplifier input. The first and second stages of the amplifier are coupled by an R-C network. The network is conventional, with the exception that resistor R14 is connected to the control grid of V2 for the purpose of suppressing possible high-frequency oscillations. The direct coupling between the second and third stages includes inductor L1, the purpose of which is to introduce shunt peaking. The direct coupling between the two stages simplifies the problem of stabilizing the oscillator by eliminating the conventional coupling capacitor with its inherent phase shift at low frequencies. L1, in conjunction with C58 and R18, stabilize the phase shift through the third stage at frequencies of about 500 kc. The output of the third stage of the amplifier is connected as a cathode follower. The lower output impedance of the cathode follower minimizes phase shift between the amplifier and the bridge network. The heater circuits of V1, V2, and V3 are positively biased to minimize cathode heater leakage and possible 400-cycle modulation of the oscillator output. The grid biasing circuits for V1 and V2 are resistors R49, R50, and R51 in the power supply circuit. The biasing voltage for V3 is obtained from R21 in the yaw oscillator circuit.

c. Operation of bridge circuit. In the bridge network, the two left-hand arms determine the frequency, and the two right-hand arms control the amplitude of the oscillations. In order to understand the operation of the bridge, note that frequency of the oscillator is determined by the formula

$$f = \frac{1}{2\pi RC}$$

because

$$f = \frac{1}{2\pi\sqrt{C_a C_b R_a R_b}}$$

where f = frequency in cycles per second

Table VII. TIME-MICROSECONDS X1 switch (cont).

Switch Position	Time in Microseconds	Capacitors (top half of circuit)	Capacitors (bottom half of circuit)
3	3	C8, C19, C16	C21, C22, C20, C18, C17, C15
4	4	C8, C16, C13	C21, C22, C17, C15, C14, C12
5	5	C8, C13, C10	C21, C22, C14, C12, C11, C9
6	6	C8, C10, C32	C21, C22, C11, C9, C33, C34
7	7	C8, C32, C29	C21, C22, C33, C34, C31, C30
8	8	C8, C29, C26	C21, C22, C31, C30, C27, C28
9	9	C8, C26, C23	C21, C22, C27, C28, C24, C25

C31, and C34 are trimmer capacitors which perform the same function as C5 and C7 discussed in (1). If S3, the X0.1 switch, is in any other than the zero position, more capacitors are connected through the X1 switch. This produces various periods from 0 to 29.9 microseconds.

(3) Switch S3. Switch S3 is the TIME-MICROSECONDS X0.1 switch. When used separately, S3 is capable of producing periods of from 0 to 0.9 microsecond. When used in conjunction with S1 and S2, periods of from 0 to 29.9 microseconds may be produced. Table VIII indicates the capacitors switched in and out of the bridge circuit by the action of S3. C48, C40, C43, and C45 are trimmer capacitors which function identically with C5 and C7 discussed in (1).

in steps of 10 microseconds from 0 to 20 microseconds. Table VI indicates the capacitors switched in and out of the circuit by the action of S1. Capacitor C7 is a trimming capacitor connected in parallel with C6. It is used to adjust the parallel combination of C6 and C7 so that the value of capacitance they provide is the correct amount to cause the oscillator to oscillate at a period of 10 microseconds. Capacitor C5 functions similarly but is used to produce a period of 20 microseconds rather than 10. It may be seen from observation of the schematic that when the X1 switch (S2) is in any position other than the zero position, more capacitors are connected into the bridge circuit through the X10 switch as well as the X1 switch. This interaction of the two switches provides unit period values of from 0 to 29 microseconds.

Table VI. TIME-MICROSECONDS X10 switch.

Switch Position	Time in Microseconds	Capacitors (top half of circuit)	Capacitors (bottom half of circuit)
0	0	---------	---------
1	10	C2	C6, C7
2	20	C1	C4, C5

(2) Switch S2. Switch S2 is the TIME-MICROSECONDS X1 switch and is capable of producing unit period values of from 0 to 9 microseconds if used alone, and capable of producing unit period values of from 0 to 29 microseconds when used in conjunction with switch S1 as described in (1). Table VII indicates the capacitors switched in and out of the circuit by the action of S2. C11, C14, C17, C20, C25, C28,

Table VII. TIME-MICROSECONDS X1 switch.

Switch Position	Time in Microseconds	Capacitors (top half of circuit)	Capacitors (bottom half of circuit)
0	0	---------	---------
1	1	C8	C21, C22
2	2	C8, C19	C21, C22, C20, C18

Section II. REFERENCE OSCILLATOR

56. GENERAL

The reference oscillator circuit provides signals with accurate frequency characteristics. These signals are used as standards for adjusting the frequencies of the yaw, pitch, burst, and microsecond oscillators and the limits between which the frequency-modulated multivibrator in the command modulator may be modulated. The reference oscillator also generates the 2-kc frequency used in the measurement of burst time by the burst timer circuit.

57. LOCATION AND PHYSICAL CHARACTERISTICS

The reference oscillator circuit chassis (fig II-56) is located in the r-f test set lower drawer assembly. It is secured to the lower drawer assembly by means of Airloc fasteners. The reference oscillator is not a front panel assembly and is mounted in a vertical position within the lower drawer assembly (fig II-54). Plug P15 provides connections to the command modulator and the pulser. Jacks J16, J17, and J18 are used to connect crystals Y2 and Y3 into the 26-kc/30-kc oscillator circuit through the COMMAND CAL switch.

58. BLOCK DIAGRAM OF THE REFERENCE OSCILLATOR (fig II-72)

a. General. The reference oscillator is composed of three crystal-controlled oscillators and a modulator. The crystal oscillators generate sinusoidal outputs with frequencies of 1 mc, 24 kc, 26 kc, and 30 kc. In addition, the modulator produces two additional outputs with frequencies of 2 kc and 6 kc. The 2-kc output is obtained by combining the output of the 24-kc oscillator with the 26-kc output of the 26-kc/30-kc oscillator. The 6-kc output is obtained by combining the output of the 24-kc oscillator and the 30-kc output of the 26-kc/30-kc oscillator.

b. Operation of the reference oscillator circuit. The 24-kc oscillator and the 26-kc/30-kc oscillator are identical in circuit configuration. Both consist of a crystal and two oscillator tubes. The 24-kc oscillator produces two outputs, both of which are taken from tube V1A. One output is coupled to the modulator circuit, the other coupled to the vertical plates of the oscilloscope in the 1600~, 2400~, and 2000~ positions of the COMMAND CAL switch. This signal is used when calibrating the three frequencies in the command circuits which determine the limits between which the frequency-modulated multivibrator may be modulated. The other output of the 24-kc oscillator is present at the input of the modulator at all times.

Table VIII. TIME-MICROSECONDS X0.1 switch.

Switch Position	Time in Microseconds	Capacitors (top half of circuit)	Capacitors (bottom half of circuit)
0	0.0	---------	---------
1	0.1	C39	---------
2	0.2	C39	C46, C47
3	0.3	C38	C46, C47
4	0.4	C38	C44, C45
5	0.5	C37	C44, C45
6	0.6	C37	C42, C43
7	0.7	C36	C42, C43
8	0.8	C36	C40, C41
9	0.9	C35	C40, C41

(4) X0.01 control. The TIME-MICROSECONDS X0.01 control is capacitor C51. C51 is an ordinary variable capacitor and acts as a vernier adjustment between the limits of 0 and 0.10 microsecond.

(5) Range of periods. The interaction of the four TIME-MICROSECONDS switches provides a range of periods in the output of the microsecond oscillator between the limits of 0.00 and 30.00 microseconds.

e. Operation of V4. Tube V4 is a duotriode connected as two cathode followers. The operation of both is conventional. The output of V4A is coupled to the oscilloscope for calibration purposes. The output of V4B is coupled to the pulser, where it is used in the generation of accurately timed pulses which are used to trigger the missile beacon.

components. The operation of the 1-mc oscillator is conventional. The grid and plate of the oscillator tube are connected through a series circuit comprising capacitors C28, C29, C30, and crystal Y4. This network is designed to produce a 180° phase shift at a frequency of 1 mc, and will therefore cause the oscillator to operate at the frequency. A series resonant circuit is formed by crystal Y4 and capacitor C29. This circuit is designed to resonate at a frequency of 1 mc. In a series resonant circuit, phase shift is equal to zero at the resonant frequency. The amount of phase shift in the entire circuit is thus equal to 180°. If the operating frequency increases, the amount of phase shift will decrease, and the feedback voltage applied to the grid of V4 will be slightly out of phase with the signal already present on the grid. This operation decreases the amount of regeneration, and decreases the frequency of oscillation. If the frequency of operation increases, the reverse will occur.

(1) Capacitor C29, the 1-mc FREQ adjustment varies the resonant frequency of the resonant circuit and thus is used to change the operating frequency of the 1-mc oscillator. Capacitor C29 has a very small effect upon the circuit, and the change it may produce is only approximately one hundred parts per million.

(2) Electron tube V5A is connected as a conventional cathode follower, which serves to prevent changes in output load from affecting the output frequency of the oscillator.

c. Operation of 24-kc oscillator. The 24-kc oscillator is composed of oscillator tube sections V1A and V1B, crystal Y1, and associated circuit components. In the 24-kc oscillator, the positive feedback loop, composed of crystal Y1, resistors R10 and R9, and capacitors C6, C7, C5, and C2, is connected in parallel with tube sections V1A and V1B. Since crystal Y1 shifts the phase of the feedback signal 180° and since a two-stage amplifier is utilized, the feedback voltage applied to the grid of V1A would be 180° out of phase with the signal initially present on the grid of V1A were it not for the combination of C2, C5, C6, and C7, which causes an additional phase shift of 180°. This additional phase shift causes the feedback signal to be in phase with the signal on the grid of V1A at the operating frequency of 24 kc. Resistor R10 acts as a voltage divider which keeps high amplitude oscillations from shattering crystal Y1. Frequency in the 24-kc oscillator is controlled in the same manner as in the 1-mc oscillator, with crystal Y1 and capacitor C5 forming the resonant circuit. C5 also serves as a vernier frequency adjustment. The two outputs of the 24-kc oscillator are taken from the cathode circuit of V1A, preventing any changes in load from affecting the output frequency of the oscillator.

d. Operation of 26-kc/30-kc oscillator. The 26-kc/30-kc oscillator is composed of oscillator tube sections V3A and V3B, crystals Y2 and Y3, and

(1) In the YAW, PITCH, and BURST positions of the COMMAND CAL switch, crystal Y2 is connected into the 26-kc/30-kc oscillator circuit. This crystal causes the 26-kc/30-kc oscillator to oscillate at a frequency of 30 kc. The 30-kc output is coupled to the modulator, which then combines the 30-kc signal from the 26-kc/30-kc oscillator with the 24-kc output of the 24-kc oscillator, producing an output frequency of 6 kc. The 6-kc signal is applied to the vertical plates of the oscilloscope, where it is used to check the accuracy of the command oscillator output frequencies.

(2) Crystal Y3 is connected into the 26-kc/30-kc oscillator circuit in the TIME and MEAS positions of the COMMAND CAL switch, causing the 26-kc/30-kc oscillator to oscillate at a frequency of 26 kc. This output is coupled to the modulator circuit, which combines the 24-kc and 26-kc frequencies, producing an output frequency of 2 kc, which is coupled to the pulse selector and burst timer in the COMM SIG position of the TEST SELECTOR switch.

(3) The 1-mc oscillator consists of an oscillator stage, a crystal, and an isolation amplifier. The output of the 1-mc oscillator is coupled to the vertical plates of the oscilloscope through the TIME position of the COMMAND CAL switch, where it is used in calibration of the output frequency of the microsecond oscillator.

(4) Potentiometers R17 (the 2-kc OUT adjustment), R18 (the 6-kc OUT adjustment), and R37 (the 1-mc OUT adjustment) are used for adjusting the output amplitude of the crystal oscillator circuits.

(5) Capacitors C5 (the 24-kc FREQ adjustment), C29 (the 1-mc FREQ adjustment), C22 (the 6-kc FREQ adjustment) and C23 (the 2-kc FREQ adjustment) are used to adjust the outputs of the crystal oscillators to the precise values required for purposes of calibration and burst time measurement.

59. DETAILED CIRCUIT OPERATION (fig II-73)

a. General. The reference oscillator circuit is composed of three crystal oscillators and a modulator. The crystal oscillators produce output frequencies of 24 kc, 1 mc, 26 kc, and 30 kc. One oscillator circuit provides both the 26-kc and 30-kc outputs. The 26-kc and 30-kc outputs are not utilized as such but are used in conjunction with the output of the 24-kc oscillator to produce output frequencies of 2 kc and 6 kc.

b. Operation of 1-mc oscillator. The 1-mc oscillator consists primarily of oscillator tube V4, crystal Y4, buffer amplifier V5A, and associated circuit

b. The pulse selector consists of a pulse-forming section, a gate section and a gate-actuating section. The pulse-forming section shapes the sine wave input into pulses. The gate section, depending upon the operation of the gate-actuating section, will pass a continuous train of pulses or pairs of pulses as required.

c. The pulse selector is designed to perform three conditions of operation. The position of the TEST SELECTOR switch will determine under which of the following three conditions the pulse selector will operate.

(1) During TEST SELECTOR switch position 1 the gate is continuously open. The sine wave input from the microsecond oscillator is converted into pulses in the pulse-forming section. The pulses pass through the gate, are amplified, and fed as a continuous train of positive pulses to the pulser for use in calibrating the r-f signal generator.

(2) During TEST SELECTOR switch positions 2, 3, 4, and 5 the pulse selector operates as a self-controlled recycling gate. The input from the microsecond oscillator is converted into pulses, but the gate will now pass a pair of pulses every 500 microseconds. This is due to the gate actuating section where a synchronized free-running multivibrator causes the gate to open every 500 microseconds and a counting circuit closes the gate after two pulses have passed. The positive pulse pairs are amplified and fed to the GS-15727 pulser for use in the test indicated by the position of the TEST SELECTOR switch.

(3) During the TEST SELECTOR switch position 6 the pulse selector operates as an externally controlled gate. The gate is opened by the action of the START switch and burst relay and is closed by the burst signal from the missile. In this case the pulse-forming section shapes the sine wave input from the reference oscillator into pulses. The gate passes a continuous train of negative pulses to the burst timer. These pulses operate the burst counting tubes during the interval between operation of the START switch and receipt of the burst signal from the missile

61. LOCATION AND PHYSICAL DESCRIPTION

The pulse selector is located in the top right rear of the upper drawer of the missile r-f test set (fig II-53). The pulse selector (fig II-57) measures approximately 9.5 x 7.5 x 4 inches and weighs approximately 2.5 pounds. It contains 7 electron tubes, 5 of which are dual purpose. The 5 dual purpose tubes are triodes. Two pentodes are used, one as an amplifier and the other, a special coincidence type, as a gate tube. In addition to the electron tubes and associated circuit components, one pulse transformer is used. There are no switches or relays physically located in the pulse selector.

associated circuit components. The operation of the 26-kc/30-kc oscillator is identical with that of the 24-kc oscillator with the exception that either one of the two output frequencies (26 kc or 30 kc) may be selected by means of the COMMAND CAL switch. In the YAW, PITCH, and BURST positions of the COMMAND CAL switch, crystal Y2 is connected into the circuit, causing it to oscillate at a frequency of 30 kc. In the TIME and MEAS positions of the COMMAND CAL switch, crystal Y3 is connected into the circuit, causing it to oscillate at a frequency of 26 kc. Both outputs of the 26-kc/30-kc oscillator are coupled from the cathode of V3A to the control grid of modulator tube V2.

e. Operation of modulator circuit. The modulator circuit is composed of gate tube V2 and a filter network made up of inductors L1 and L2 and capacitors C12 through C18. The gate tube V2 is identical to those tubes used for gating in the pulse selector and response indicator. The tube is designed so that the control grid and suppressor grid have nearly equal control over the conduction of the tube. The output of the 24-kc oscillator is applied to the suppressor grid, and one of the outputs of the 26-kc/30-kc oscillator is applied to the control grid. V2 heterodynes these signals. An output of 2 kc or 6 kc will appear at the plate of V2, depending upon the output of the 26-kc/30-kc oscillator. If the output frequency of the 26-kc/30-kc oscillator is 26 kc, the output of V2 will be the difference in frequency produced by the heterodyning of 24 kc and 26 kc. This value is equal to 2 kc. If the output frequency of the 26-kc/30-kc oscillator is 30 kc, the output of V2 will be 6 kc. The 2-kc output is generated in the TIME and MEAS positions of the COMMAND CAL switch but is used only by the burst timer when the TEST SELECTOR switch is in the COMM SIG position. The 6-kc signal is generated and used for purposes of calibration in the PITCH, YAW, and BURST positions of the COMMAND CAL switch. The filter network is a low-pass filter with a cutoff characteristic in the neighborhood of 8 kc. Its function is to filter out high-frequency products which result from the heterodyning process of the modulator circuit.

Section III. PULSE SELECTOR

60. INTRODUCTION

a. The GS-15731 pulse selector is primarily a gating circuit. It converts the sine wave output of the microsecond oscillator into pulses and passes these pulses as a continuous train or as pulse pairs to activate the GS-15727 pulser. In TEST SELECTOR switch position 6, the pulse selector converts the sine wave output of the reference oscillator into a train of timing pulses to activate the burst counting tubes in the GS-15729 burst timer.

from the repetition rate and count multivibrators, thus insuring that they will have no effect on the gating action. It also removes B+ from the B-section of the pedestal multivibrator. With this path to B+ open, a -60-volt potential is applied to the grid of V6A. Pedestal multivibrator tube V6A remains cut off, which insures that the gate is open. A continuous train of pulses at a frequency determined by the time dials of the microsecond oscillator pass to the pulser.

d. In TEST SELECTOR switch positions marked REC SENS, TRANS TEST, RESP A and RESP B, the pulse selector operates as a self-controlled recycling gate. The gate-actuating section allows the gate to pass a pair of pulses every 500 microseconds. All three multivibrators are supplied with B+, and the first series of pulses will cause the A-sections of the multivibrators to conduct. The gate will then be closed. The repetition rate multivibrator has a normal period of 500 microseconds. The negative sync pulses from transformer T1 are at a much higher frequency determined by the setting of the microsecond oscillator. The pulse arriving at approximately the normal period of the multivibrator will cause the A-section to go into cutoff. Tube V5B will conduct, coupling a negative pulse to V6A of the pedestal multivibrator. Tube V6A will go into cutoff, thereby opening the gate. The next positive pulse arriving at the gate tube V3 will cause it to conduct. The resultant negative pulse is coupled to the final amplifier and becomes the first pulse of the pulse pair supplied to the pulser. This negative pulse from the gate tube is also coupled through cathode follower V4B to the grids of the count multivibrator. The A-section of the multivibrator will cut off, and the B-section will conduct. The positive pulse from V7A is unable to affect the condition of the pedestal multivibrator. Since the pedestal multivibrator is a bistable type, V6A will remain cut off and the gate will pass another pulse. This negative pulse will be coupled to the final amplifier to become the second pulse of the output pulse pair. It is also coupled to the count multivibrator through V4B where it will drive the now conducting V7B into cutoff. The A-section will conduct, coupling a negative pulse to the grid of V6B of the pedestal multivibrator. Tube V6B will cut off, regeneration will occur, and V6A will conduct. When V6A conducts, the gate will close. Thus two pulses have passed the gate, and the gate-actuating section has returned to its previous state with the A-sections of the multivibrators conducting. The gating action will not be repeated until approximately 500 microseconds later when a negative pulse from T1 will again be able to trigger the repetition rate multivibrator.

e. In TEST SELECTOR switch position COMM SIG the pulse selector operates as an externally controlled gate. The pulse selector controls the pulses which activate the burst timer during the measurement of burst time and

62. BLOCK DIAGRAM DISCUSSION (fig II-74)

a. The pulse selector derives its input from either the microsecond oscillator or the reference oscillator, depending upon the position of the TEST SELECTOR switch (TSS). In either case, the input sine wave is fed to the grid of pentode V1, which along with its associated components form the wave squarer. Wave squaring is accomplished by clipping the positive and negative extremes of the sine wave. The resultant square wave is fed to the pulser section of the pulse selector which consists of V2A, V2B, transformer T1 and associated components. Triode V2A in conjunction with T1 amplifies the input signal. Transformer T1 acts as a peaking transformer, coupling a peaked or differentiated waveform to the two secondary windings. From the lower secondary winding through a crystal diode, sharp negative peaks are applied to tube V5A. These pulses are used to synchronize the repetition rate multivibrator. Differentiated pulses from the upper secondary winding of T1 are applied to the grid of V2B, a cathode follower. Tube V2B is operated at cutoff, therefore only the sharp positive peaks of the waveform will cause conduction. When V2B conducts, a resistor-capacitor network will discharge through V2B forming a sharp positive pulse which is coupled to the control grid (CG) of the gate tube V3. Provided the gate is open, negative pulses will be fed to tube V4A where they will be amplified, and positive pulses will be sent to the pulser. In TSS 6, the output to the burst counting tubes is taken directly from the gate tube as negative pulses, bypassing the final amplifier. The gate tube V3 is a specially designed pentode whose suppressor grid acts as another control grid. The normal control grid (CG) receives the signal pulse, while the second control grid (SG) receives biasing voltages only. The second control grid (SG) is connected to the plate circuit of pedestal multivibrator tube V6A in the gate actuating section. The circuit is designed so that the normal rise in plate voltage that occurs when V6A is cut off will open the gate by causing the bias on the SG of the gate tube V3 to rise above cutoff. Conversely, the drop in plate voltage when V6A conducts will close the gate by lowering the bias on the gate tube to cutoff value.

b. The gate-actuating circuit is composed of three multivibrators and their associated circuitry. The repetition rate multivibrator, V5A and B, a synchronized, free-running type, triggers the pedestal multivibrator to open the gate. The pedestal multivibrator, V6A and B, a bistable multivibrator,directly controls the gate. The count multivibrator, V7A and B, also a bistable multivibrator, triggers the pedestal multivibrator to close the gate. Operation of the gate-actuating section differs somewhat for each of the three pulse selector conditions of operation.

c. In the RF TEST SIG position of the TEST SELECTOR switch, the pulse selector operates as an open gate. The TEST SELECTOR switch removes B+

b. Compensation. The amplifier, pentode VI, with its coupling capacitor C1, and grid resistor R1 provide some compensation to improve the shape of the low-frequency, 2-kc, squared waves. The frequency compensating network provides compensation for both the long rise time of the 2-kc signal and the attenuation of the high frequencies. This compensation can best be illustrated by considering the effect of the wave squarer on two input signals, one of comparatively high frequency from the microsecond oscillator, and one of low frequency, the 2-kc signal from the reference oscillator as described in paragraphs c and d.

c. High frequency input. Amplifier VI has its cathode grounded or is biased to zero under no-signal conditions. As the input sine wave goes positive, grid current will flow. The time constant of C1 and R1 is sufficiently long as compared to the period of the signals from the microsecond oscillator so that grid leak bias will be present at these frequencies. As a result VI will be biased at slightly less than the peak amplitude of the input signal. A typical operating point would be with a 6-volt peak-to-peak input signal biasing the grid to -2.9 volts. With VI operating in this manner, the output signal will be sinusoidal with the negative peak clipped slightly due to saturation and grid limiting which occur as the positive peak of the input signal causes grid current to flow. Since the gain of V1 is approximately 10 if a 6-volt input signal is assumed, the output of V1 will be slightly less than 60 volts peak to peak. At the higher frequencies of the microsecond oscillator, stray capacitance becomes important. To counteract the effect of stray capacitance, the frequency-compensating network composed of C3 and R6 of the upper arm in parallel with C4 and R7 of the lower arm is designed to present a lower impedance to the higher frequency signals. At the higher frequencies, the reactance of C3 will become comparatively small, and the reactance of C4 will be negligible. The effective impedance to the signal will be the resistance of R7 in parallel with the series combination of R6 and the small reactance of C3. This impedance will be about 5,000 ohms. At lower frequencies, the reactance of C3 increases; therefore, the total impedance of the network increases. This network favors the high frequencies and thus compensates for the high-frequency signal losses. The signal from the compensating network is developed across the crystal diode clipper circuit composed of CR1 and CR2 with their associated components. On the positive half-cycle of the signal, CR2 will conduct, charging capacitor C5B negative to positive from ground. As the signal goes negative, C5B will begin to discharge through resistor R9. The R-C time constant of C5B and R9 is long enough to provide a positive bias at pin 2 of CR2 when the next positive half-cycle occurs. Crystal CR2 will conduct and short the signal only when the positive voltage across it is sufficient to overcome the bias. Therefore, the crystal will clip the positive half-cycle of the signal so as to provide a squared top wave at the grid of V2A. Crystal diode CR1 will have a similar effect on the negative half-cycle of the signal so as to square the negative portion of the signal. Since the fail-safe time. The repetition rate and count multivibrators are disabled by removing B+ through the contacts of the TEST SELECTOR switch. Both sections of the pedestal multivibrator are supplied with B+ and operate in conjunction with external circuitry to control the gate in the following manner. Operation of the RESET switch momentarily removes -60 volts from the pedestal multivibrator which insures that V6A will conduct. Since the pedestal multivibrator is a bistable type the A-section will continue to conduct. When the START switch is operated, it will provide a discharge path for capacitor C23. This capacitor has previously been charged through a resistive network from a +300-volt source. The discharge of C23 will cause a negative pulse to be applied to the grid of tube V6A. Tube V6A will cut off, and the gate will open. With the gate open, 2-kc timing pulses derived from the reference oscillator will be passed. The negative pulses from the gate tube are fed through the TEST SELECTOR switch to the burst timer. With application of these pulses the counting tubes will begin counting and continue to do so until the pulse selector gate is closed by the burst signal from the missile. This signal is a negative pulse which is fed to the grid of V6B of the pedestal multivibrator and is sufficient to cut off V6B and cause V6A to conduct. The gate will close, and the counting action will cease.

63. DETAILED CIRCUIT OPERATION (fig II-75)

a. <u>Wave squarer</u>. The variable frequency output of the microsecond oscillator or the 2-kc output of the reference oscillator is fed to pin 4 of plug P9 through section S1C of the TEST SELECTOR switch. From P9 the sine wave signal is coupled to the wave squarer section of the pulse selector. The wave squarer is composed primarily of amplifier tube V1, frequency compensating network C3, R6, C4 and R7, and the crystal diode limiters CR1 and CR2. The complexity of the wave squarer is due largely to the wide frequency band in which it must operate. Its function is to amplify and clip the sine wave input so as to deliver to the pulser section a squared wave of short rise time and reasonably constant amplitude throughout the frequency range. To accomplish this, compensation must be provided for two problems which arise.

(1) Although a high-frequency sine wave may be clipped at approximately 40 percent of its amplitude and result in a squared wave with a reasonably short rise time, a low-frequency sine wave clipped in a similar manner will result in a squared wave of long rise time.

(2) At the higher operating frequencies of the pulse selector, stray wiring capacitance tends to attenuate the signal.

positive pulse is required at the grid of V6B. To aid in obtaining this pulse, a saturable core transformer is used. The voltage across the primary of T1 will lead the current through it as in any inductor. That is, for a sudden rise in voltage, the current will first rise sharply, then more slowly, until there is no further change in voltage. As the square wave at the grid of V2A goes positive, the current through T1 will increase. The operating point of the stage is selected so that the primary of T1 will saturate at a point where the current is still rising sharply. Although the current through the primary may continue to rise with the positive portion of the square wave on the grid of V2A, the flux buildup will cease sharply at core saturation. Since the secondary voltage follows the primary flux, the secondary voltage will rise sharply, then drop as flux buildup ceases. There will be no change in flux until the input square wave goes negative. At this point, the current flow in the primary of T1 will decrease well below core saturation. The flux lines will collapse, and a negative secondary voltage will result. The current through the primary will continue to decrease to a point controlled by the negative peak of the input square wave. At this point there will be no change in flux, and the secondary voltage will go to zero. There will be no further change in voltage until the input square wave goes in a positive direction.

f. Tube V2B. Transformer T1 has two secondary windings. One of these windings supplies the signal to the grid of V2B while the other supplies the signal to synchronize the repetition rate multivibrator as will be explained later. The upper winding of transformer T1 is connected to the grid of triode V2B. Grid leak bias sufficient to cut off cathode follower V2B is supplied by the action of capacitor C8 and resistor R10. As the signal goes positive, grid current will flow through the upper winding of T1 and charge C8 negative to positive toward ground. Capacitor C8 must then discharge through R10. The time constant of this network is sufficient to keep V2B cut off between positive pulses. Only the positive peak of the signal will be sufficient to overcome the grid leak bias and cause V2B to conduct. During tube cutoff, capacitor C9 will charge from ground through plate load R11 to the B+ value. As the positive peak of the signal causes V2B to conduct, capacitor C9 will discharge through the cathode resistor R12 and the tube. A sharp positive pulse, due to the rapid discharge, will be developed across R12. This pulse is coupled through C10 to the control grid of gate tube V3.

g. Gate. The gate tube V3 is a special type of pentode with the equivalent of two control grids. The suppressor grid is wound so that it will have approximately the same control over plate current as the normal control grid. Pentode V3 will be cut off with approximately -8 volts on the normal control grid or with approximately -12 volts on what is normally the suppressor grid.

corresponding components of the positive and negative clippers are of the same value and the signal is approximately symmetrical, the square wave will be symmetrical. The clippers are designed to give a square wave amplitude approximately 40 percent as large as the impressed signal.

d. Low frequency input. In TEST SELECTOR switch position 6, the 2-kc sine wave from the reference oscillator is fed to the pulse selector. Since tube V1 is biased to zero, grid current will flow as the input signal goes positive. No grid leak bias will be present at this time because the time constant of C1 and R1 is not long enough as compared to the period of the 2-kc signal. With V1 operating at zero bias, a greater amplitude signal can be applied to the grid without producing a larger output. With no charge on C1 to overcome as the input goes positive, grid current will flow immediately. This will produce grid limiting and plate current saturation. Therefore, on the positive portion of the input the gain of V1 will be small. If an input signal of sufficient amplitude is used, the negative portion of that signal will drive V1 into cutoff. With the circuit designed to operate in this manner, the amplitude of the 2-kc input signal is adjusted to be somewhat larger than the input from the microsecond oscillator. This will produce a comparable amplitude output at the plate of V1 for both the microsecond and reference oscillator inputs. The shape of the waveforms from the two sources will differ considerably. While the signal caused by the microsecond oscillator is nearly a sine wave, the 2-kc signal at the plate of V1 will resemble a square wave. The positive peaks will be flattened due to cutoff limiting, and the negative portion will be squared as a result of grid and saturation limiting. The 2-kc signal at the plate of V1 will be composed of that portion of the sine wave which is rapidly changing about its center reference. The square wave produced by clipping this signal at approximately 40 percent of its amplitude will have a much shorter rise time than would be available if a true 2-kc sine wave were clipped in a similar manner. Since the leading edge of the signal at the plate of V1 appears as a higher frequency, the frequency-compensating network of C3, R6, C4, and R7 will further sharpen the rise time. The wave squarer therefore presents a squared wave of reasonably constant amplutude and short rise time to the grid of V2A.

e. Pulser. The pulser portion of the pulse selector is composed of two triodes, V2A and V2B, transformer T1, and associated components. The square wave output of the wave squarer is fed to the grid of triode amplifier V2A. Resistor R9 and bypass capacitor C6 provide cathode bias, and the primary of transformer T1 is the plate load for V2A. The transformer is connected so that the voltage taken from the secondary is in phase with the signal developed in the primary. The design of the pulser is such that a sharp

The count multivibrator V7A and B, a bistable type, triggers the pedestal multivibrator to close the gate. Operation of the gate tube, opened or closed, depends directly on the operation of tube V6A of the pedestal multivibrator. Grid 3, normally the suppressor of the gate tube, is connected to the plate circuit of V6A. The design of the circuit is such that conduction of V6A will lower the bias of grid 3 of V3 to cutoff value, thus closing the gate. Conversely, when V6A is cut off, the bias on grid 3 of the gate tube will rise above cutoff and open the gate. The bias control circuit is actually a voltage divider. There exists a complex voltage divider from -250 volts through R53, R54, and R55 to ground and from the junction of R53 and R54 through R38, R35, and R32 to +300 volts, the B+ for V6A. The condition of V6A and V6B will affect the voltage drops along the voltage divider. Grid 3 of the gate tube, as well as the grid of V6B, is connected to the junction of R35 and R38. The voltage at this point therefore becomes the bias for grid 3 of V3. If V6A conducts, its internal resistance and subsequent current flow will drop its plate voltage to a value considerably below B+. This value becomes the positive end of the voltage divider. The voltage drops through the circuit are such that the bias voltage will be approximately -20 volts, which is sufficient to cut off V3 and close the gate. When V6A is cut off, the plate voltage rises toward B+. It will not reach the B+ value because there are auxiliary paths for current flow through R32. As the plate voltage for V6A rises, the potential at the junction of R38 and R35 will tend to go positive. As this point starts to go positive, V6B will conduct, and grid current will flow. Grid current will keep the voltage at the junction of R38 and R35, and hence the bias for the gate tube V3, at a slight positive potential. The gate will be open. The gate action will be determined by the position of the TEST SELECTOR switch. Operation of the gate-actuating section differs somewhat for the various TEST SELECTOR switch positions.

j. Open gate. In the RF TEST SIG position of the TEST SELECTOR switch, the gate is continuously open. This position of the TEST SELECTOR switch (TSS) removes B+ from both sections of the repetition rate and count multivibrators and the B-section of the pedestal multivibrator. The voltage at the junction of R53 and R54, due to the action of the voltage divider, will be approximately -60 volts. This voltage is applied through the normally closed contacts of the RESET switch (burst timer) to the grid of V6A. Since the plate circuit of V6B is open in this TSS position, there is no path for current flow, and the grid of V6A will be at -60 volts. Tube V6A will be cut off and the gate, V3, will be open.

k. Recycling gate. In the REC SENS, TRANS TEST, RESP A and RESP B positions of the TEST SELECTOR switch, the pulse selector operates as a self-controlled recycling gate. At this time the pulse selector will form and pass pairs of pulses every 500 microseconds. The gate-actuating circuit controls the gate to accomplish this. All three multivibrators are supplied with B+ through the TSS. The first series of pulses through the pulse selector will cause the A-sections of the multivibrators to conduct, and the gate will be closed.

Thus, either grid may be biased so as to take control from the other. The normal control grid is connected through grid resistor R14 to the junction of R54 and R55. This point is held at approximately -8.5 volts due to the voltage divider action of R54 and R55. Therefore, the normal control grid will keep V3 cut off during no-signal operation. If grid 3, normally the suppressor grid, is not biased to cutoff, the normal control grid will have control over the tube. Positive pulses from the cathode of V2B will override the fixed bias and cause V3 to conduct. The resulting negative output pulses from V3 are coupled to three different points. The signal is coupled to the grid of cathode follower V4B to be used in triggering the count multivibrator during certain gating functions. The output is also coupled to P10 where in TEST SELECTOR switch position 6 the negative pulses are used to activate the burst timer. Output amplifier tube V4A receives these pulses to provide an output to the pulser.

h. Output amplifier. The negative pulses, either a continuous pulse train or paired pulses depending upon the gate function, are coupled through an R-C coupling network composed of C14 and R18 to the grid of triode V4A. Cathode bias for V4A is provided by resistor R20 and bypass capacitor C15. Resistor R23 and inductor L1 act as plate load for the stage. Inductor L1 acts as a shunt peaking coil to aid the high-frequency component of the output pulses. Two outputs are taken from V4A. Output number 1 is coupled across C16 to pin 1 of P9 where it is fed to the amplifier stage of the pulser. This output is in the form of positive pulses, continuous or paired, with a negative overshoot due to the action of L1. Output number 2 from the pulse selector is coupled through C17 to pin 3 of P9. From P9, the output is fed to the TEST SELECTOR switch in the pulser, where in positions 4 and 5 pulse pairs are connected to the pulser circuitry. Output number 2 differs from number 1 in that the second pulse is riding a negative reference. The damping or negative reference for the second pulse is accomplished by an action of the count multivibrator. The negative pulse from the gate tube which causes the first pulse of the output pulse pairs is also coupled to the count multivibrator, causing the B-section to conduct. The negative square wave output of V7B will cause a negative pulse to be coupled through C18 and isolating resistor R24 to the output side of capacitor C17. The second pulse of output number 2 will ride on this negative reference. The value of C17 is chosen to isolate the negative output of V7B from the plate of V4A. Resistor R24 serves to isolate the output of V4A from the plate of V7B of the count multivibrator.

i. Gate-actuating circuit. The gate-actuating circuit is composed of three multivibrators. The repetition rate multivibrator V5A and B is a synchronized free-running type, used to trigger the pedestal multivibrator to open the gate. The pedestal multivibrator V6A and B, a bistable type, directly controls the gate.

will go to the output amplifier to become the second pulse of the pulse pair and to the cathode follower V4B. The negative output of V4B will cause CR6 to conduct, placing a negative pulse on the grid of the now conducting V7B. The count multivibrator will flip back to its previous state of operation with V7A going into conduction. The negative output of V7A will cause CR4 to conduct, placing a negative voltage on the grid of V6B of the pedestal multivibrator. Typical multivibrator action will result in V6A going into conduction. The bias on the gate tube V3 will drop to cutoff value, and the gate will be closed. The A-sections of the three multivibrators are once again conducting. The pulse selector will remain in this state until approximately 500 microseconds later, when a pulse from the lower winding of T1 will again be able to trigger the rep rate multivibrator to start the gate action. It can be seen that the pulse selector is now operating as a self-controlled recycling gate; the gate opens, passes a pair of pulses, closes, and recycles to open the gate. It should be noted that the period between the pulse pairs is controlled largely by the rep rate multivibrator, while the period between the pulses of a pulse pair (code spacing) is controlled by the period of the input from the microsecond oscillator.

n. Jitter voltage. The cathode of V5B receives a 400-cycle jitter voltage at approximately 3.2 volts. This is provided from the 6.3-volt filament supply through resistors R57 and R58. The sine wave voltage prevents sudden changes in the repetition (rep) rate multivibrator action. It was found that during response time measurement, the RESPONSE OR VOLTAGE meter made sudden jumps as the X0.01 TIME-MICROSECONDS dial was adjusted over its range. Since adjustment of the X0.01 dial is necessary in response time measurement and the erratic operation of the meter would make it difficult to check for maximum response indication, some compensation is necessary. As an example of erratic operation, if tube V5B fires on every 124th pulse from T1, then changes suddenly to firing on every 125th pulse from T1, the RESPONSE OR VOLTAGE meter reading decreases because the rep rate multivibrator ultimately determines how often the gate will open and pass pulses. If the rep rate multivibrator changes from the 124th pulse to the 125th pulse, the average energy content of the signal through the gate will drop, since the pulses will be further apart. The number of the pulse which fires the rep rate multivibrator is not usually important, since the response reading is a relative value, but a sudden change from one pulse to another will cause erratic operation. To prevent sudden changes in rep rate frequency, the 400-cycle signal at the cathode of V6B sinusoidally changes the operating point of the tube so that it fires smoothly over a range of pulses from the 120th to the 130th. The reading at the RESPONSE OR VOLTAGE meter then becomes a smooth average of many pulses. The negative pulse is readily passed by CR3 and applied to the grid of V6A of the pedestal multivibrator. Typical multivibrator action will take place and the pedestal multivibrator will flip to its other stable state with V6B conducting. With V6A cut off, the voltage on grid 3 of the gate tube will rise, and the gate will be open. Use of the negative portion of the differentiated wave at T1 to

l. Gate opens. The repetition rate multivibrator is a synchronized, free-running type with a normal period of 500 microseconds. This period may be adjusted by use of potentiometer R27 which will vary the discharge time for C21, thus changing the natural period of the multivibrator. The synchronizing pulses are taken from the lower winding of transformer T1. Only the negative portion of the differentiated waveform on T1 will be passed by crystal diode CR8. These pulses are coupled to the grid of V5A. Their amplitude is such that they cannot change the conducting (synchronizing) state of the multivibrator except at approximately its normal period. The operation of the repetition rate multivibrator, as in any multivibrator of this type, depends upon the discharge of a capacitor. In this case, with V5A conducting, the discharge of C20 provides cutoff bias for V5B. The capacitor discharge rises exponentially from a high negative value toward ground. The negative pulses from T1, at a frequency determined by the microsecond oscillator, are amplified by V5A. The positive pulses from the plate of V5A are coupled to the grid of V5B. The amplitude of these pulses will not be sufficient to overcome the bias caused by the discharge of C20 until that bias rises to near cutoff value. The multivibrator is therefore operating at approximately its normal rate, but is synchronized by a pulse from transformer T1. As V5B conducts, typical multivibrator action takes place and a negative-going signal is coupled to the grid of V6A. This pulse is coupled through C24 and developed across grid resistor R34.

m. Gate closes. The count multivibrator behaves as a bistable multivibrator. When V7A is conducting, two paths exist for current flow from ground to B+ for V7A. Heaviest current flow will take place through common cathode resistor R45, tube V7A, and plate load resistor R44. This flow will place the cathodes of both tubes at approximately +135 volts. The plate voltage for V7A will then be approximately +225 volts. Current flow through the higher resistance path of R50 and R46 will place the grid of V7B at about +112 volts. In effect, the grid of V7B will be 23 volts negative with respect to its cathode, and the tube will remain cut off. With V7B cut off, current can flow from ground through R47, R49, and R51 to the B+ for V7B. Voltage drops along this path make the grid of V7A positive with respect to the cathode. As this happens, grid current flows in the conducting tube, resulting in the grid being just slightly positive with respect to the cathode. Since the plate side of CR5 and CR6 is at the same or a lower potential than the cathode side, no conduction will occur during the no-signal condition. With the negative trigger from cathode follower V4B, CR5 will conduct, impressing a negative pulse on the grid of V7A, which will be amplified as a positive pulse at the plate of V7A and coupled to the grid of V7B. Regeneration will result, and the count multivibrator will switch to its other stable state with V7B conducting. Heavy conduction now exists through V7B, and the voltages will adjust to keep V7A cut off until application of another trigger. The positive pulse from V7A as it goes into cutoff will be unable to effect the conduction of V6B of the pedestal multivibrator. Since the pedestal multivibrator is a bistable type, V6A will remain cut off, and the gate will pass another pulse. The negative pulse from the gate tube closing the gate. The 2-kc train of pulses to the burst timer will cease, giving a visible indication on the counting tubes of the burst signal. Operation of the RESET switch at this time will have no effect on the operation of the pedestal multivibrator since V6A was placed into conduction by receipt of the burst signal. The RESET switch, as far as the pedestal multivibrator is concerned, simply insures that V6A will conduct and the gate will be closed (this action would be necessary if the START switch was operated with no missile to send a burst response). The gate will remain closed until the START switch is operated, discharging C23 to cut off V6A.

Section IV. PULSER

64. GENERAL

The GS-15727 pulser operates in conjunction with either the pulse selector or the command modulator to generate the pulses required to pulse the reflex oscillator in the r-f signal generator. The pulser has four conditions of operation depending upon the setting of the TEST SELECTOR switch. Each of the four conditions results in sending into the r-f signal generator accurately shaped 0.25-microsecond pulses. Under two of the conditions, input pulses are amplified, reshaped, and sent out to the r-f signal generator. Under the other two conditions, a new pulse is added to each input pulse to form paired pulses which, as before, are used to pulse the r-f signal generator. The new pulse is added by a delayed pulser which is a section of the pulser circuit. A secondary function performed by the pulser is to provide an amplifier, which, when not required for use within the pulser, is used to amplify pulses from the pulse selector. These pulses are sent into the gate of the response indicator and are used as a time reference in measuring the response time of the missile.

65. LOCATION AND PHYSICAL CHARACTERISTICS

The pulser chassis (fig II-58) is located in the upper drawer assembly of the missile r-f test set (figs II-46, II-53). It is a front panel subassembly with the RF POWER meter, TEST SELECTOR switch, ADJ CODE control, and CODE RANGE switch S2 on the front panel. The RF POWER meter has no functional relationship to the pulser circuit while the TEST SELECTOR switch (TSS) has decks A through D directly associated with it. The pulser chassis measures 10.5 x 5 x 11.5 inches and weighs approximately 9 pounds. It is secured to the upper drawer framework by captive (Phillips-type) screws. Inputs to the pulser from the pulse selector are brought in through J1 and J2. The squelch pulse and the time reference pulses are conducted to the response indicator from J2. The pulser output to the r-f signal generator is brought out via P13.

initiate the gate action insures that the gate will be fully open to accept the next positive pulses. The negative pulse from the gate tube will be coupled to the grid of output amplifier V4A and result in the first pulse of the output pulse pair. The negative pulse from the gate tube is also applied to the grid of cathode follower V4B. The negative output of the cathode follower will be impressed on crystal diodes CR5 and CR6 to trigger the count multivibrator.

o. Externally controlled gate. In the COMM SIG position of the TEST SELECTOR switch, the pulse selector operates as an externally controlled gate. In this position the pulse selector is not used to control the steering commands to the missile. The pulse selector is activated in conjunction with the burst circuitry for use in the measurement of burst and fail-safe time. The TEST SELECTOR switch in this position removes B+ from the rep rate and count multivibrators and switches the source of input from the microsecond oscillator to the 2-kc sine wave from the reference oscillator. Activating the RESET switch, located in the burst timer, momentarily removes the -60-volt potential from the voltage divider that supplies grid bias to V6A of the pedestal multivibrator. The grid potential will rise momentarily and cause V6A to conduct, closing the gate. Since the pedestal multivibrator is a bistable type, V6A will continue conducting when the RESET switch, normally closed, returns the -60 volts to the voltage divider. Capacitor C23 has been previously charged to a high potential through resistors R34, R36, and R30 to 300 volts. The amount of charge on C23 is determined by the voltage division between R29 and R30 and will be approximately 100 volts. When the START switch is activated, a ground is placed on pin 9 of plug P9, which will allow C23 to discharge through R36 and R34 to ground. The voltage developed across R34 causes CR3 to conduct, placing a negative voltage on the grid of V6A. Tube V6A will cut off, raising the bias on grid 3 of gate tube V3 out of cutoff. The output of the gate tube will be 2-kc negative pulses resulting from the 2-kc sine wave input from the reference oscillator. These negative pulses go to the output amplifier, plug P10, and cathode follower V4B. Only the output to P10 is used. This train of negative timing pulses is coupled to the burst timer to activate the burst counting tubes. The gate will remain open (V7A cut off) until the r-f test set receives the burst signal from the missile. This negative pulse from the missile is coupled to the r-f test set and to terminal 11 of plug P9. The negative pulse will be coupled through C22, CR7, and CR4 to the grid of V7B. Regeneration will take place and V7A will conduct, lowering the bias on the gate tube V3 and trailing edge of the rectangular output waveform is determined by the setting of the ADJ CODE capacitor C12 and the CODE RANGE switch S2 in the multivibrator. The trailing edge of the output waveform, when differentiated, produces the delayed pulse. The delayed pulse, after passing through a single stage isolating amplifier V4B, is used to trigger a pulse-shaping stage (V6, Z3) associated with this part of the circuit. The original pulse from the single pulser and the pulse from the delayed pulser are mixed in an R-C network to form paired pulses, with the required 2- to 29-microsecond spacing being determined by the setting of the ADJ CODE and CODE RANGE controls. The paired pulses are used to drive the final pulser. Also in TSS 4 and 5, pulse selector output 1 is amplified by pulse amplifier V2A and sent through the TEST SELECTOR switch to the response indicator for use as a time reference in the measurement of delta time and missile response time.

d. TSS position 6. Under the fourth condition of operation, the pulser circuit operates the same as for the third condition except for the input signal. In TSS position 6, the input is from the command modulator into the single pulser and is a train of frequency-modulated positive pulses. The period between each pulse varies from 416 to 625 microseconds, and the rate of this variance determines the command information. The output of the pulser circuit to the r-f signal generator consists of frequency-modulated pulse pairs in this condition of operation.

67. DETAILED CIRCUIT OPERATION (fig II-77)

a. Pulse amplifier V2A. The pulse amplifier stage operates as a conventional triode amplifier that is biased beyond cutoff. The train of positive input pulses from pulse selector output 1 has a slight negative overshoot. Biasing V2A beyond cutoff permits only the positive portions of the input signal to be amplified. The negative 17-volt cutoff bias is established by a voltage divider connected between the negative 250-volt supply and ground. This bias is applied to the grid through signal-developing resistor R9. During the period that V2A is conducting, additional bias is provided by cathode resistor R10. The supplementary bias from R10 increases the input signal amplitude range over which V2A may operate. Capacitor C5 prevents cathode degeneration. The output pulses from the stage are developed across the primary of T2. The secondary of T2 is connected so that the pulses across it are positive in polarity. In TSS positions 1, 2, and 3, these pulses are applied to the final pulser and in TSS positions 4 and 5 are sent to the response indicator circuit. In TSS position 6, the output of the pulse amplifier is not used although it is still receiving an input from the pulse selector circuit.

b. Single pulser V1. The single pulser consists of a transformer-coupled amplifier stage V1A and a pulser stage V1B. The input to V1A is output 2 of the pulse selector. This signal, which consists of positive pulse pairs with the

66. BLOCK DIAGRAM (fig II-76)

a. General. The pulser circuit may be divided into four functional sections whose interconnections depend upon the setting of the TEST SELECTOR switch. These sections with their associated tubes are:

(1) Pulse amplifier V2A.

(2) Single pulser V1.

(3) Delayed pulser V4, V5, and V6.

(4) Final pulser V3 and V2B.

b. TSS positions 1, 2, and 3. Under the first condition of operation, only the pulse amplifier and final pulser are used. In TSS 1, single pulses are received from the pulse selector at a uniform 250-kc rate. These pulses are from pulse selector output 1. They are roughly triangular in shape, are amplified in V2A, and are used to trigger the final pulser. The resultant pulses emerge from the final pulser as accurately shaped flat-topped pulses. The 250-kc pulsing rate is required so that power output from the reflex oscillator in the r-f signal generator will be sufficient to be measured by the RF POWER meter. In TSS 1, the bias on the final pulser V3B is controlled by the X1 switch of the microsecond oscillator. The final pulser is disabled in all TIME-MICROSECONDS dial settings except the 4-microsecond position where the negative 250-volt cutoff bias is removed. This insures that the r-f signal generator will always be pulsed at the same rate during the calibration procedure. In TSS 2 and 3, the circuit arrangement of the pulser is the same as before, but the pulse selector is changed so that only paired pulses are applied to V2A and the bias on V3B is no longer controlled by the setting of the TIME-MICROSECONDS controls in the microsecond oscillator. The paired pulses occur at 500-microsecond intervals and have a spacing from 2 to 29 microseconds within each pair depending upon the setting of the TIME-MICROSECONDS controls.

c. TSS positions 4 and 5. Under the third condition of operation, pulse selector output 2 is utilized by the pulser. Paired pulses from the pulse selector are sent into the single pulser V1. The single pulser passes the first pulse but rejects the second due to the fact that it is depressed in amplitude. The first pulse in passing through the single pulser is reformed into a relatively rectangular pulse. This pulse is sent into both the final pulser and the delayed pulser. The pulse which is sent into the delayed pulser triggers the monostable multivibrator V5 which produces a rectangular output waveform. The position in time of the voltage drop across R25 and R26 caused by its conduction. Tube V5B will remain cut off for a period determined by the R-C time constant of R24, R25, C12, and the CODE RANGE capacitors switched in by S2. The voltage on the grid of V5B rises exponentially toward +300 volts, and, when it reaches the cutoff potential for V5B, V5B again conducts. The positive voltage developed across R27 and R28 is applied to the cathode of V5A and cuts off its conduction. The multivibrator is again in its quiescent condition and will not recycle until V4A is triggered by another negative pulse. The delay multivibrator is plate-triggered with C11 keeping the grid of V5A at a-c ground potential. Bias for V5A is developed by a voltage divider consisting of R20, R21, and R22. Adjustment of potentiometer R21 determines the minimum voltage to which the plate of V5A will fall when it conducts. This, in turn, determines how far negative the grid of V5B is driven when it is cut off and how much C12 and the CODE RANGE capacitors must discharge before conduction of V5B can begin again. Potentiometer R21 thus controls the period of the output waveform and must be adjusted for optimum operation of the multivibrator in the 2- to 29-microsecond range of periods as determined by the ADJ CODE and CODE RANGE controls. There are four positions of the CODE RANGE switch which are designated A, B, C, and D. In position A, only the ADJ CODE capacitor C12 is in the circuit. In position B, C21 is connected in parallel with C12. In position C, C22 is connected in parallel with C12 and C21. Finally, in position D, C23 is connected in parallel with C12, C21, and C22. The ranges of delay periods established by the multivibrator for each position of the CODE RANGE switch are as follows:

(1) Position A: 2 to 9 microseconds.

(2) Position B: 8 to 17 microseconds.

(3) Position C: 16 to 24 microseconds.

(4) Position D: 23 to 30 microseconds.

Resistor R25 and capacitor C13 decouple V5B from the other circuits. The rectangular wave output from V5B is differentiated (peaked) by C14 and R29 and is applied to the grid of amplifier-clipper V4B. Tube V4B is operated at zero bias, since the grid resistor R29 is returned directly to the cathode. Excessive current flow through V4B is limited by R30 and R31. Capacitor C15 prevents cathode degeneration in the stage. The zero bias condition of V4B causes considerable grid limiting to occur with the result that only the negative peaks of the differentiated rectangular waves are amplified to any extent. These negative peaks, which are coincident in time with the variable trailing edge of second pulse of the pair depressed in amplitude, is applied to the grid of V1A in all TSS positions except position 6. In TSS position 6, the input consists of an FM train of positive pulses from the command modulator circuit. Cathode bias for V1A is developed across R3 and C1. The primary of T1 serves as the plate load impedance for developing the output of V1A. The secondary of T1 is connected so that positive pulses are applied to V1B. Pulse formation in pulser V1B is accomplished by the line-pulsing network Z1. Network Z1 is an artificial transmission line that is terminated in its characteristic impedance. The charge path for Z1 is up from ground through R19 in the delayed pulser to terminal C of Z1, and from terminal L of Z1 through R6 to the +300-volt supply. Tube V1B functions as an electronic switch to provide a discharge path for Z1 when V1B is triggered by a positive pulse. This stage is biased beyond cutoff by a negative 17-volt signal applied to its grid through R4 and the secondary of T1. Resistor R5 is a cathode load impedance for developing an output signal to the final pulser. Capacitor C2 prevents degeneration by enabling all the signal across the secondary of T1 to be applied between grid and cathode of V1B. Resistor R4 isolates the cathode signal on V1B from the a-c ground in the negative 17-volt bias source. The positive input pulses from V1A and T1 cause V1B to conduct, thereby providing a discharge path for Z1. The discharge path is from terminal C of Z1 through R19 to ground, and up from ground through R5 and V1B to terminal L of Z1. The flat-topped discharge pulse from Z1 through R19 and R5 causes a signal to be developed across these resistors. The positive signal across R5 is coupled through C3 and isolating resistor R7 to the final pulser. In addition to providing an input to the delayed pulser, the negative signal across R19 is used as the squelch pulse for the response indicator circuit. The squelch pulse is sent to the response indicator through CR3 and R40. Crystal CR3 removes positive overshoots from the pulse.

c. Delayed pulser V4, V5, and V6. The delayed pulser consists of isolation amplifier stage V4A, monostable (one-shot) multivibrator V5, amplifier-clipper V4B, amplifier V6A, and pulser V6B. Tube V4A operates as a grounded-grid amplifier biased beyond cutoff. Negative pulses developed across R19 are also applied to the cathode of V4A causing it to be driven out of cutoff. The grid of V4A will always be at a-c ground potential because it is connected to the negative 17-volt bias source. Resistor R23 is the plate load for both V4A and the A-section of the delay multivibrator. In its quiescent state, V5A of the delay multivibrator is cut off and V5B is conducting. The appearance of a negative pulse on the cathode of V4A will cause it to conduct, bringing the plates of V4A and V5A in a negative direction from their quiescent +300-volt potential. This negative potential is coupled to the grid of V5B through C12, and the capacitors switched in by CODE RANGE switch S2, thereby causing V5B to cut off. The plate voltage on V5B rises abruptly to +300 volts because there is no longer any

The negative pulses developed across R16 have a short rise time and a flat top of 0.25-microsecond duration. These pulses are applied to the primary of T4 through coupling capacitor C9. Bias for V3B in TSS position 1 is determined by the setting of the X1 TIME-MICROSECONDS switch on the microsecond oscillator. In the 4-microsecond position of switch X1, a negative voltage of approximately 25 volts is applied as bias to V3B by voltage divider R13 and R1 (located on X1 in the microsecond oscillator) connected between the negative 250-volt supply and ground. In all other positions of X1, the full negative 250-volt supply voltage is applied to the grid of V3B disabling the stage. In TSS positions 2, 3, 4, 5, and 6, the bias on V3B is established by voltage divider R13 and R1 (located on S1D in the pulser) connected between the negative 250-volt supply and ground. This bias has a value of about negative 44 volts. It is only in TSS position 1 that the X1 TIME-MICROSECONDS switch controls the bias. The secondary of T4 is connected so that positive pulses are applied across R17 and R18. Crystals CR1 and CR2 limit negative overshoots of the pulses. A pulse amplitude of about 30 volts is derived from the voltage divider combination of R17 and R18 and is used for pulsing the reflex oscillator in the r-f signal generator.

Section V. COMMAND OSCILLATORS

68. GENERAL

Three command oscillators are incorporated in the missile r-f test set. These oscillators generate signals of the frequencies required for checking operation of the missile command channels. The oscillators are on separate chassis and are designated as follows:

a. GS-15738 pitch oscillator.

b. GS-15739 yaw oscillator.

c. GS-15740 burst oscillator.

69. LOCATION AND PHYSICAL CHARACTERISTICS (fig II-54)

a. Pitch and yaw oscillators (figs II-60 and II-61). The pitch and yaw oscillators are located in the r-f test set lower drawer assembly. These oscillators are front panel subassemblies secured to the drawer framework by captive (Phillips-type) screws. The pitch oscillator chassis measures 9 x 4.5 x 6 inches and weighs approximately 3 pounds. Operating voltages and output signal connections are made through J10. The yaw oscillator chassis measures 10.5 x 4.5 x 6 inches and weighs about 3 pounds. Operating voltages and output signal connections for this unit are made through J11.

the multivibrator output, appear as positive peaks across plate load resistor R30 and are coupled through C16 to the grid of amplifier V6A. Tube V6A operates as a conventional transformer-coupled triode amplifier with cathode bias. The secondary of T5 is connected so that positive pulses are applied to pulser V6B. The operation of V6B is similar to that of the pulser V1B in the single pulser. Tube V6B is cut off by a negative 17-volt potential applied to its grid through R34 and the secondary of T5. Pulse-forming network Z3 is charged from the +300-volt supply through R36. Resistor R35 is a cathode load resistor. Capacitor C18 permits the full signal amplitude across the secondary of T5 to be applied between grid and cathode of V6B. Resistor R34 prevents the cathode signal from being grounded out in the negative 17-volt bias supply. A positive pulse applied to the grid of V6B causes it to conduct, providing a discharge path for Z3. The discharge path for Z3 is from terminal C of Z3 to ground, up from ground through R35 and V6B, and to terminal L of Z3. The flat-topped discharge pulses from Z3 are developed across R35 and are positive in polarity. These positive pulses are added to the undelayed pulses from the single pulser through R8 and C4 to form pulse pairs which are applied through the TEST SELECTOR switch to the final pulser. Adjustment of the ADJ CODE control and CODE RANGE switch determines the position in time of the delayed pulse with respect to the undelayed pulse from the single pulser because the undelayed pulses are used for triggering the delay multivibrator and therefore are coincident in time with the leading edge of the multivibrator output waveforms.

d. Final pulser V3 and V2B. The final pulser section of the pulser circuit consists of an amplifier V3A, pulser stage V3B, charging diode V2B, and coupling transformer T4. Positive pulses from either pulse amplifier V2A or from the single pulser and delayed pulser (depending upon TSS positions) are applied to the grid of V3A. Amplifier V3A is biased past cutoff by a negative 17-volt potential applied to the grid through R11. Additional bias is provided by R12 while V3A is conducting. Capacitor C6 prevents cathode degeneration. Negative overshoots of the input pulses will not be amplified by V3A because it is biased beyond cutoff. The positive input pulses cause V3A to conduct, and negative output pulses are developed across the primary of T3. The secondary of T3 is connected so that positive pulses are applied to the grid of pulser V3B. The operation of pulser stage V3B is very similar to that of pulser stages V1B and V6B. The charge path for Z2 is from ground through V2B to terminal C of Z2, from terminal L of Z2 through R14, R39, L1, and R15 to the +300-volt supply. The combination of low-resistance resistors and inductor L1, together with charging diode V2B, shortens the recovery time of the final pulser. Tube V3B is biased beyond cutoff. A positive pulse from the secondary of T3 causes V3B to conduct, providing a discharge path for Z2. Network Z2 discharges from terminal C through R16 to ground and up from ground through V3B to terminal L.

and the d-c grid return for V2. Capacitor C6 is used to suppress possible high-frequency parasitic oscillations by reducing the input amplitude to V2 at very high frequencies and slightly shifting the phase at these frequencies. The third stage is a cathode follower whose low output impedance stabilizes the oscillator frequency by minimizing phase shift between the amplifier and the bridge. Capacitors C7 and C8 in the amplifier output are sufficiently large to preserve the low output impedance. Two 1-microfarad capacitors are used instead of a single 2-microfarad capacitor because of space requirements. Output amplitude of the oscillator is controlled by potentiometer R1 in the command modulator circuit. This is the PITCH control which is used to set the oscillator output voltage as required in the calibrating procedure. Resistor R22 limits the range of this control. In the bridge section of the pitch oscillator, the amplitude of the oscillations is controlled by the two right-hand bridge arms and frequency by the two at the left. The two right-hand arms consist of thermistor RT1, capacitor C3, and resistor R15. Thermistor RT1 maintains amplitude stability by varying the amount of negative feedback to the cathode of V1A in accordance with oscillator output amplitude variations. Due to the negative coefficient of RT1, increases in output from V2 drive the bridge toward balance thus decreasing the input amplitude to V1A. This input decreases until the loss through the bridge is exactly balanced by the gain of the amplifier. This establishes a stable operating condition and a constant output. As the bridge approaches balance, the resistance of RT1 approaches twice the resistance of R15. Capacitor C3 across RT1 minimizes the possi bility of high-frequency parasitic oscillations. Such oscillations develop because of bridge unbalance caused by the cathode-to-heater capacity of V1A which has a shunting effect on R15 at high frequencies. This capacity is balanced out by C3. In the FINS position of switch S1, potentiometers R2A and R2B smoothly vary the frequency of the oscillator by changing the operating point of the frequency selective network which makes up the left-hand portions of the bridge. These potentiometers are designated FINS on the front panel. The PITCH COMMAND switch S1 sets the oscillator frequency at fixed values of 400, 500, and 600 cycles by switching resistors in and out of the upper and lower left-hand arms of the bridge.

71. YAW OSCILLATOR

The yaw oscillator circuit is identical to the pitch oscillator except for the values of the resistors used to control the frequency and the additional output-coupling capacitors C9 and C10. Additional coupling capacitors are necessary to maintain the low output impedance at the lower operating frequencies of the yaw oscillator. The block diagram of the yaw oscillator is identical to that of the pitch oscillator and is given in figure II-82. Figure II-83 is the schematic

b. Burst oscillator (fig II-62). The burst oscillator chassis is an internal subassembly located in the r-f test set lower drawer assembly. It is secured to the drawer framework by Airloc fasteners. Also located on the burst oscillator chassis is a 28-volt d-c supply for operation of the switch attenuators in the waveguide and antenna coupler. There is no functional relationship between the burst oscillator and this power supply. The burst oscillator chassis measures 11.5 x 6 x 4.5 inches and weighs approximately 5 pounds. Electrical connections to the burst oscillator and 28-volt supply are made through P12.

70. PITCH OSCILLATOR

a. General. The pitch oscillator generates a frequency which may be set to 400, 500, or 600 cycles or may be varied smoothly in the range from 460 to 540 cycles. The 400-, 500-, and 600-cycle frequencies are used to check the operation of the missile for pitch commands of -5g, 0g, and +5g respectively. The missile is checked by applying these commands and noting the deflection of a meter in the electrical test set. This meter measures a d-c output obtained from within the missile. The variable frequency corresponds to a pitch command which can be varied over the range from -2g to +2g. This is used in observing the smoothness of operation of the missile fins in responding to these commands.

b. Block diagram. As can be seen from figure II-80, the pitch oscillator is a Wien bridge oscillator and consists of an amplifier and a bridge circuit. The amplifier is a three-stage amplifier comprising tubes V1A, V1B, and V2 with associated resistors and capacitors. The bridge is a four-arm network. Thermistor RT1 and capacitor C3 comprise the first arm; resistor R15 the second; capacitor C1 and resistors associated with S1A the third; and C2 and resistors associated with S1B the fourth. The resistors connected into the third and fourth arms at any one time are determined by the setting of PITCH COMMAND switch S1, and their values determine the frequency.

c. Circuit operation (fig II-81). In the amplifier, the first and second stages are interconnected by a resistance-capacitance network. This type of coupling is conventional except that negative feedback is applied through R18 to the grid of the second stage from the cathode of the third stage. The negative feedback minimizes phase shift through the amplifier so that changes within the amplifier will not affect the oscillator frequency. The direct coupling between the plate of V1B and the control grid of V2 simplifies the problem of stabilizing the over-all oscillator frequency by eliminating the coupling capacitor and the phase shift it introduces. Resistor R20 is the plate load for V1B fine adjustment of the burst oscillator frequency. This is an internal adjustment and its setting is not a part of the r-f test set calibration procedure.

Section VI. COMMAND MODULATOR

73. INTRODUCTION

a. The GS-15736 command modulator provides intelligence to the signals sent to the missile during test. In the REC SENS, TRANS TEST, RESP A, and RESP B positions of the TEST SELECTOR switch, pulses at a fixed repetition rate are sent to the missile. In the COMM SIG position of the TEST SELECTOR switch, the missile r-f test set simulates the missile-tracking radar by adding intelligence to the signals in the form of a frequency-modulated pulse repetition rate. Steering orders and burst orders are given by this method. The command modulator provides means of frequency-modulating these signals.

b. As indicated in the block diagram, figure II-78, the command modulator consists of several smaller circuits interconnected by the COMMAND CAL switch. Input to the command modulator circuit is from the command oscillators through jack J2. Pitch and yaw signals are fed through a mixing circuit (not illustrated) to the COMMAND CAL switch. The mixing circuit, relay K1, the isolation amplifier, the frequency-modulated multivibrator, and the output amplifier are used for generating the frequency-modulated signals. During normal operation, the yaw, pitch, and burst oscillators generate audio-frequency sinusoidal signals. The pitch and yaw signals are added together in the mixing circuit. The relay may select either the combined pitch and yaw or the burst signals. These signals pass through the isolation amplifier and modulate the FM multivibrator. The FM multivibrator output is amplified and differentiated by the output amplifier and fed to the pulser.

c. The peak voltmeter, the voltage divider, and the COMMAND CAL switch are used for calibration purposes. The peak voltmeter is used in adjusting the output voltage of the command oscillators. Calibrating voltages for the FM multivibrator are obtained from the voltage divider. The nine-position rotary COMMAND CAL switch makes all connections for calibration and use of the command modulator.

74. LOCATION AND PHYSICAL CHARACTERISTICS

The command modulator (fig II-59) is located in the upper left corner of the missile r-f test set lower drawer assembly (fig II-54). It is a front panel of the yaw oscillator. The yaw oscillator generates a fixed frequency which may be set to 120, 150, and 180 cycles and a variable frequency from 138 to 162 cycles. These frequencies correspond to yaw commands of -5g, 0g, and +5g, respectively, for the fixed frequencies and from -2g to +2g for the variable frequencies. The variable frequencies produce a variable yaw command which can be used to observe the smoothness of operation of the yaw fins on the missile. Resistor R23 (which was not present in the pitch oscillator) applies a positive bias to the heater supply used for V2 in the yaw oscillator, V2 in the pitch oscillator, V2 in the burst oscillator, and V3 in the microsecond oscillator. This positive bias reduces the heater-cathode potential difference in the cathode follower stage of each of these oscillators.

72. BURST OSCILLATOR

a. General. The burst oscillator generates a frequency of 880 cycles to check the response of the missile to burst commands. However, when calibrating the r-f test set, it is necessary that the frequency of this oscillator be slightly different than 880 cycles because when the COMMAND CAL switch is set to the BURST position, a precise 6-kc signal from the reference oscillators is applied to the vertical plates of the oscilloscope. If the 880-cycle burst frequency were applied then to the oscilloscope horizontal plates, these two frequencies would not produce a clear, stationary Lissajous pattern because 880 is not a factor of 6,000. For calibrating purposes only, the frequency of the burst oscillator is set at 857.14 cycles, which is one-seventh of 6,000 cycles. With these two frequencies, a stationary pattern is obtained. When the COMMAND CAL switch is later set to the MEAS position, the burst oscillator frequency is automatically increased to 880 cycles.

b. Block diagram (fig II-84). Like the pitch and yaw oscillators, the burst oscillator consists of an amplifier and a bridge. The right-hand arms of the bridge determine the degree of bridge unbalance and therefore the output amplitude. The left-hand arms form a frequency selective network which controls the operating frequency. Resistor R1 determines whether the burst oscillator frequency is 857.14 or 880 cycles. In the MEAS position of the COMMAND CAL switch, R1 is connected in parallel with the lower left-hand arm of the bridge, and the oscillator operates at 880 cycles. In all other COMMAND CAL switch positions, R1 is out of the circuit, and the operating frequency is 857.14 cycles.

c. Circuit operation (fig II-85). The amplifier portion of the burst oscillator is identical to that of the yaw oscillator. The burst oscillator bridge is simpler than that in either the pitch or yaw oscillators because the burst oscillator has only two operating frequencies. Potentiometer R6 provides a of the multivibrator are returned through the upper secondary winding of T1 to a positive potential sufficient to cause the multivibrator to oscillate at 2,000 cps. The sine wave signal coupled to the secondary of T1 is therefore riding above and below the potential for 2,000 cps operation. Thus, the grids of the multivibrator are returned to a positive potential that is varying sinusoidally with the input signal. The peak-to-peak amplitude of the modulating sine wave will determine the limits of the operating frequency. That is, the multivibrator is adjusted to oscillate at 2,000 cps with its grids returned to a definite d-c potential. As this potential rises toward its peak value, the frequency of oscillation will increase and continue to do so until the modulating voltage reaches its peak. At this point the operating frequency will be 2,400 cps. The frequency will decrease as the modulating voltage drops toward its lowest value. At this point the multivibrator will oscillate at 1,600 cps. Thus the frequency range (1,600 cps to 2,400 cps) is determined by the peak-to-peak amplitude of the modulating voltage. The rate at which the multivibrator changes its frequency between these limits is dependent upon the frequency of the modulating voltage. The higher the modulating frequency the faster the multivibrator will change frequency within this range. The resulting output of the multivibrator is a frequency-modulated train of positive pulses. The intelligence in the orders to the missile is determined by the rate of change of pulse repetition rate between the limits of 1,600 cps and 2,400 cps. The frequency-modulated train of pulses is coupled to the grid of output amplifier tube V4B. Two outputs are taken from this cathode follower. One is taken from the cathode through an integrating circuit for use in calibration. The second output is taken from the plate of V4B through a differentiating circuit to the grid of cathode follower V4A. The frequency-modulated differentiated pulses from the cathode of V4A are fed through a coaxial cable to the GS-15727 pulser chassis.

b. Calibration. Calibration of the command modulator and associated circuits is carried out through the use of the peak voltmeter, the voltage divider, and the COMMAND CAL switch. The peak voltmeter indicates potential difference rather than absolute value. It is used in adjusting the output amplitude of the three command oscillators to a predetermined value. Primarily the circuit consists of a zero-center reading meter (CAL meter) and a bridge circuit. Triodes V6A and V6B act as variable resistances in the upper arms of the bridge while resistors (not shown) form the lower arms of the bridge. Diode V5A connects the (adjustable) centertap of the voltage divider to the grid of V6A, thus establishing a value of grid voltage for V6A and a certain value of current flow through that side of the bridge. Diode V5A and its associated components form a half-wave rectifier. The sine wave signal from the oscillator that is to be adjusted is fed to the plate of V5B, rectified, and subassembly weighing 8.5 pounds and measuring approximately 12.5 x 9 x 6 inches. There are six vacuum tubes; three duotriodes, two pentodes, and a duodiode. One transformer and three relays are used. Two of these relays are of the mercury-wetted type. There are two meters located in the front panel of the command modulator. One of these, the RESPONSE OR VOLTAGE meter, is not part of the command modulator circuitry. The CAL meter is part of the peak voltmeter circuitry. The COMMAND CAL switch, a nine-position, five-deck, rotary switch, is a front panel component. Also on the front panel are seven screwdriver-type adjustments used in conjunction with the COMMAND CAL switch positions. Connections from the command modulator to other test set circuits are made through two multicontact receptacles and three coaxial connectors.

75. BLOCK DIAGRAM DISCUSSION

a. Normal operation. Inputs to the command modulator are derived from one or more of the command oscillators. These are the yaw, pitch, and burst oscillators which generate audio-frequency sine wave signals for use in the command modulator. Normal operation of the command modulator takes place with the COMMAND CAL switch in the MEAS position. The block diagram, figure II-78, shows the input to the command modulator fed through J2 to a deck of the COMMAND CAL switch. In the MEAS position, both pitch and yaw signals are fed to the upper (normally closed) contacts of burst relay K1. Pitch and yaw signals are mixed through a resistive network (not illustrated here) and applied to the grid of triode amplifier V1A as a complex sine wave. During zero-g steering order operation, this complex sine wave will be a 500-cps sine wave impressed on a 150-cps sine wave. The burst signal, a simple sine wave, is connected directly to the lower (normally open) contacts of burst relay K1. The amplified output of V1A is coupled to the grid of V1B. The output of V1B is developed across the primary of transformer T1. A negative feedback path is provided from the output of V1B to the cathode of V1A. This feedback minimizes the effect of the fluctuating load presented by the multivibrator. The signal developed in the primary of T1 is coupled to the two secondary windings, one of which feeds the multivibrator. The multivibrator is a free-running type with positive grid return. It is designed to operate at frequencies between the limits of 1,600 cps and 2,400 cps. The operating frequency is determined by the grid return voltage which is used to modulate the multivibrator. Applying a greater positive voltage will cause the multivibrator to oscillate at a higher frequency. A lower voltage will cause oscillation at a lower frequency. Application of a sinusoidal voltage will therefore cause the multivibrator operating frequency to vary in accordance with the changing voltage. In the MEAS position of the COMMAND CAL switch, the grids be modulated by a symmetrical sine wave, it is necessary that the potential difference required to change from 2,000-cps to 2,400-cps operation be equal to the difference necessary to change from 2,000-cps to 1,600-cps operation. The required potential for 2,400-cps operation is supplied from the upper tap of the voltage divider, and the nonlinearity is corrected by adjustment of the discharge path of one side of the multivibrator. Interaction between the three multivibrator adjustments will take place, making it necessary to repeat the adjustment procedure for optimum results.

f. BAL position. In the BAL position of the COMMAND CAL switch (CCS 4), the CAL meter is calibrated before it is used in calibrating the command oscillators. As the block diagram indicates, the same d-c potential is applied to both sides of the peak voltmeter bridge. The front panel screwdriver adjustment is then turned until the CAL meter reads to the zero or center position. This adjustment is located between the lower arms of the bridge and is used to compensate for aging of components.

g. YAW position. In the YAW position of the COMMAND CAL switch (CCS 5), the output of the yaw oscillator is fed through the isolation amplifier and coupled to the secondary of transformer T1. In this COMMAND CAL switch position, the left side of the bridge remains connected to the d-c potential for 2,000-cps operation of the multivibrator while the right side (V6B) is connected to a lower potential. From the upper secondary winding of T1, the yaw signal is applied to V5B, where it is rectified and raises the voltage applied to V6B. The panel adjustment labeled YAW is turned to center the CAL meter needle. This adjusts the amplitude of the yaw oscillator output and hence the potential at V6B. This is the amplitude of voltage necessary to fully modulate the multivibrator. At the time the adjustment is being made, the same yaw signal is taken from the lower secondary winding of T1 and applied to the horizontal plates of the oscilloscope. Here it is compared to a reference voltage of 6 kc and yields a stationary Lissajous pattern indicating the yaw oscillator is operating at the proper frequency. If the pattern is not stationary, an internal adjustment of the yaw oscillator frequency is necessary.

h. PITCH and BURST positions. In the PITCH and BURST positions of the COMMAND CAL switch (CCS 6, 7),the output amplitudes of the pitch and burst oscillators are adjusted in the same manner as for the yaw oscillator. The connections are made as indicated by the block diagram. Their output frequency is observed on the oscilloscope, and their output amplitude is adjusted by use of the CAL meter.

i. TIME position. In the TIME position of the COMMAND CAL switch (CCS 8), no adjustment of the command modulator is made. The COMMAND appears as a d-c voltage on the grid of V6B. Thus V6B has a grid bias which may be adjusted as required to balance the current flow through the bridge. When the bridge is balanced the CAL meter reads at its center position and the particular oscillator output is properly adjusted. The voltage divider delivers the necessary voltages for calibration of the multivibrator and supplies the potential necessary for 2,000-cps operation of the multivibrator in addition to its use in balancing the peak voltmeter bridge and in adjustment of the command oscillators. The COMMAND CAL switch, as illustrated in the block diagram, provides the necessary connections within the command modulator during calibration of the command circuits. A general discussion of the calibration is given below.

c. COMMAND CAL switch position 1. In COMMAND CAL switch position 1, labeled 2,000~ the multivibrator is adjusted to operate at that frequency with a previously selected potential taken from the voltage divider. There is no modulation signal present at the multivibrator. The multivibrator output is taken as a sawtooth wave from cathode follower V4B and applied to the horizontal plates of the oscilloscope. A reference signal of 24 kc is applied to the vertical plates of the oscilloscope from the reference oscillator (see section II,ch 6). A screwdriver-type front panel adjustment is turned to cause a standing Lissajous pattern to appear on the oscilloscope face. This adjustment is labeled on the block diagram, and its use results in changing the R-C time constant in the multivibrator grid circuits to cause 2,000-cps operation, which is indicated when the required pattern appears on the oscilloscope.

d. COMMAND CAL switch position 2. In COMMAND CAL switch position 2, labeled 1,600~ another potential from the lower tap of the voltage divider replaces the 2,000-cps potential at the grids of the multivibrator. As in c, the sawtooth output is applied to the oscilloscope and compared with the 24-kc reference. Turning the 1,600-cps screwdriver adjustment will give a standing Lissajous pattern on the oscilloscope when the multivibrator operating frequency is 1,600 cps.

e. COMMAND CAL switch position 3. In COMMAND CAL switch position 3, 2,400~ the screwdriver adjustment is turned to give a standing Lissajous pattern indicating 2,400-cps operation. As shown in the block diagram, when the 1,600~ control is adjusted, the upper tap of the voltage divider also is moved. The voltage divider is set up so that the potential difference between the centertap and the upper tap will be equal to the potential difference between the centertap and the lower tap. Since the centertap causes 2,000-cps operation and the lower tap causes 1,600-cps operation, the upper tap should cause 2,400-cps operation. As in most multivibrators of this type, the frequency change may not be linear with respect to changes in modulating potential. Since the multivibrator is to impedance of V1B, insuring that load changes presented to the amplifier by the multivibrator and by the varying primary impedance of T1 with frequency will not affect the output amplitude appreciably.

c. Frequency-modulated multivibrator. Pentodes V2 and V3 with associated circuit components comprise a multivibrator which is frequency-modulated by the output of the isolation amplifier. The circuit is basically the same as that of an ordinary free-running multivibrator with positive grid return. In operation this positive grid potential is varied to produce frequency modulation. A variation of approximately ±57 volts from a midvoltage of about 230 volts changes the frequency of the multivibrator ±400 cycles from a midfrequency of 2,000 cycles. In the following discussion it will be assumed that the basic operation of the ordinary free-running multivibrator is already understood and that it is not necessary to show how the two tubes (V2 and V3) are intercoupled and alternately become conducting and nonconducting. If V3 is in the nonconducting condition, the right-hand sides of C6 and C7 rise to 300 volts because the series combination R20 and R22 is returned to the +300-volt supply. At the same time, through R11 and R12A, the left-hand plates of C6 and C7 rise toward +230 volts (supplied by the voltage divider R46 to R51) but are prevented from rising much above zero by the clamping action of the control grid of V2. Clamping action occurs because the d-c resistance of the diode composed of the grid and cathode of V4 is about 1,000 ohms as compared with 0.812 megohm for R11 and R12A in series. This results in almost all of the grid current voltage drop occurring across these resistors and the control grid being maintained only slightly above ground potential. When V3 changes from nonconducting to conducting, the right sides of C6 and C7 drop from +300 to +20 volts, and the left sides drop by the same amount, from 0 to -280 volts. As soon as the -280-volt drop is completed, the voltage on the left plates of C6 and C7 immediately starts to rise toward +230 volts because the series resistor combination R11 and R12A is terminated on one end by the -280 volts of capacitor C6 and C7 and the other by the +230-volt source. The rise continues until the left-hand plates of C6 and C7 reach the potential at which conduction will resume through V2. This potential will be about -10 volts.

d. Modulating multivibrator frequency. The rate of discharge of a capacitor is very rapid at first and then decreases exponentially as the capacitor becomes discharged. Since C6 and C7 are discharging toward a potential of +230 volts, they will be discharging rapidly when their left-hand plates reach a potential of approximately -10 volts. Thus the potential for the cut-on of conduction of V2 is passed very rapidly so that small variations in this cut-on potential have little effect upon the total time of discharge from a -280-volt to about a -10-volt potential. This is time for one-half cycle of the multivibrator. With the grids returned to

CAL switch connects the microsecond oscillator output to the oscilloscope (sec I, ch 6). This position of the COMMAND CAL switch connects the potential for 1,600-cps operation to the grid circuits of the multivibrator. Connection is also made from the output of V4A to the normally open contacts of relay K2. These connections are made within the command modulator for ease in measurement of fail-safe time (sec X, ch 6).

j. MEAS position. In the MEAS position of the COMMAND CAL switch (CCS 9), the necessary connections are made for normal operation of the command modulator as explained in a.

76. DETAILED CIRCUIT OPERATION (fig II-78)

a. Input and mixing circuit. The output of the three command oscillators is fed through J2 to the command modulator. Three potentiometers R39 BURST, R29 YAW, and R1 PITCH are physically located in the command modulator as front panel adjustments. Electrically these potentiometers govern the output amplitudes of their respective oscillators. The wiper arms of these potentiometers are connected to the command modulator circuitry through deck E of the COMMAND CAL switch. The pitch and yaw outputs are connected to this switch through resistors R2 and R3, respectively. During calibration, the output amplitude of each of the oscillators is adjusted to cause full modulation of the frequency-modulated multivibrator. In the MEAS position of the COMMAND CAL switch (CCS 9), the pitch and yaw outputs are combined by R2 and R3 to form a complex sine wave. Resistors R2 and R3 make up a summing network. The voltage from the junction of R2 and R3 which is applied to the grid of V1A will always be equal to one-half the algebraic sum of the instantaneous voltages at the wiper arms of R1 and R29. Thus, the amplitude of the signal on the grid of V1A will never exceed the maximum amplitude of either the pitch or yaw signals alone.

b. Isolation amplifier. The output from the command oscillators is fed through relay K1 and applied to the grid of triode V1A. Relay K1 functions in conjunction with the START and RESET switches to apply the outputs of the yaw and pitch oscillators or the burst oscillator to the command modulator in the measurement of missile burst time. The isolation amplifier provides a small amount of amplification, but is used principally to isolate the multivibrator from the command oscillators. The isolation amplifier is a conventional resistance-capacitance-coupled amplifier employing negative feedback. The output of V1B is developed across the primary of transformer T1. Negative voltage feedback is provided from the plate of V1B to the cathode of V1A. This feedback stabilizes the over-all amplifier gain with respect to changes in circuit components and reduces distortion and phase shift. Negative voltage feedback lowers the output and V3 each pass a large amount of current because of the positive grid return, and sometimes the multivibrator becomes locked. This large current causes relay K3 to operate momentarily and open contact 5-6. This contact opening causes current in the plate circuit of V2 to drop to 0. Relay K3 then releases and discharges capacitors C8 and C9 so as to start the circuit operating. Resistors R16 and R18 and capacitor C5 associated with relay K3 are for the purpose of slowing the operation of this relay so that capacitors C6 and C7 have time to discharge as the relay closes. When the multivibrator is in operation, the current through K3 is insufficient to cause it to operate. The output from the multivibrator is a symmetrical square wave and is fed into the grid of V4B in the output amplifier.

f. Output amplifier. The output amplifier supplies output signals to both the oscilloscope and the pulser. The output amplifier consists of an R-C coupled triode amplifier stage V4B and a cathode follower V4A. Slightly less than one-tenth of the multivibrator output signal amplitude is coupled by C10 to the grid of V4B from a voltage divider R20 and R22 in the plate circuit of V3 to prevent the multivibrator from overdriving V4B. Tube V4B is cathode-biased by R28 and R52. Since these resistors are unbypassed, there is a signal developed across them. This square-wave signal is integrated by R26 and C13 and is applied as a triangular-wave signal to the horizontal plates of the oscilloscope. This connection to the oscilloscope is made through the D-deck of the COMMAND CAL switch S1 in the 2,000~, 1,600~, and 2,400~ positions. The square-wave signal developed across plate-load resistor R25 is differentiated by C12 and R23 and is applied to the grid of cathode follower V4A. The train of alternately positive and negative output pulses is developed across cathode resistor R24 and sent through coupling capacitors C11 and C15 and a coaxial cable to the pulser chassis. The low output impedance of the cathode follower minimizes the attenuating and distorting effects of the relatively long coaxial cable.

g. Relay circuit. Relays K1 and K2 are high-speed relays having mercury-wetted contacts which close and open rapidly and without chatter. The mercury is sealed with the contacts inside a pressurized glass tube. These relays can be operated only in the upright position; otherwise the pool of mercury will close all the contacts. For a simplified circuit of the connections to relays K1 and K2, refer to figure II-52. A complete discussion of the operation of these relays may be found in paragraph 93b.

h. Voltage divider. The purpose of the voltage divider, composed of R46A, R47, R48, R49, R50, R46B, and R51, is to provide three d-c voltages to the multivibrator grid circuits and to establish a reference d-c voltage for use in

+230 volts, this time is 250 microseconds. Since the multivibrator is symmetrical, all that has been said for C6, C7, and V2 may be said for C8, C9, and V3. Thus the time for one cycle is 500 microseconds. This corresponds to a frequency of 2,000 cycles per second. If the positive grid return voltage is changed from +230 to +287 volts (an increase of 57 volts), the discharge time for C6 and C7 (or for C8 and C9) will decrease from 250 to 208 microseconds because of the more rapid discharge toward the higher potential of +287 volts. This will result in a corresponding multivibrator frequency change from 2,000 to 2,400 cycles. If the grid return voltage is returned to +230 volts and then lowered still further to +173 volts, the half-cycle times will change from 208 to 250 to 312 microseconds, corresponding to frequency changes from 2,400 to 2,000 to 1,600 cycles. Thus, by changing the positive grid return voltages, the rates of discharge of C6, C7, C8, and C9 can be varied, and the frequency of the multivibrator altered. When the multivibrator is frequency modulated by the yaw, pitch, or burst signals, the effect is basically the same as applying the d-c voltages, except that the voltage is changed rapidly. If the peak a-c voltage of the pitch and yaw combined signals is 57 volts and the burst signal voltage is the same, the multivibrator voltage change will be 230 ±57 volts. This voltage is changed by superimposing the output of the isolation amplifier from winding 3-4 of T1 on the 230-volt d-c voltage obtained from voltage divider R46 to R51. It should be noted that while the peak a-c voltage is 57 volts, the peak may not be applied for a sufficient time during frequency modulation to produce a frequency variation of 2,000 ±400 cycles. The actual equivalent change in frequency may be appreciably less than the limit of 1,600 to 2,400 cycles.

e. Calibrating the multivibrator. In calibrating the multivibrator, it is checked first with d-c potentials. The procedure consists of applying a nominal voltage of 230 volts and adjusting the frequency by changing the setting of a dual potentiometer R12A and R12B. This adjusts the R-C time constant in each grid circuit so that the free-running frequency of the multivibrator is 2,000 cycles. The grid-return voltage is then reduced by 57 volts, and R46 is adjusted so that the frequency will be almost exactly 1,600 cycles. The grid-return voltage is then increased by the same amount it was previously decreased, and the frequency should be 2,400 cycles. If the frequency is not 2,400 cycles, the multivibrator is not properly linearized. Resistor R15 is then adjusted to obtain the correct linearity. Resistors R15 and R14 and capacitor C4 slightly modify the discharge path of capacitors C8 and C9 in such a way as to make the frequency modulation linear. Adjusting resistor R15 also changes the base frequency of the multivibrator from the 2,000-cycle value, so that each time the linearity is adjusted it is also necessary to make compensating adjustments in the R12 and R46 controls. The function of relay K3 is to insure that the multivibrator starts immediately. When the power is first applied to the multivibrator, V2 full scale) is used as a galvanometer to indicate bridge balance. This meter is marked CAL on the front panel. Resistor R42 in series with the meter converts the microammeter to a zero-center, 5-volt meter. Diode V5A connects the grid of V6A to the wiper arm of R48 on the voltage divider. Resistor R40 is a grid leak for V6A. Diode V5B connects the grid of V6B to both a d-c and an a-c voltage on the corresponding COMMAND CAL switch position. Diode V5B, capacitor C14, and resistor R45 form a half-wave rectifier. When an a-c voltage is applied to the plate of diode V5B, capacitor C14 charges to the peak value of the applied wave. Thus the peak applied a-c voltage is converted to a d-c voltage at the grid of V6B. Resistor R45 is a grid leak resistor which ties the grid of V6B to a fixed d-c voltage. This prevents a large current flow through V6B when no voltage is applied to the plate of diode V5B. Such a current flow would unbalance the bridge to such an extent that the CAL meter would be driven off scale. Before the peak voltmeter is used it must be balanced. This is done in the BAL position of the COMMAND CAL switch (CCS 4) by use of the BAL control R43. In this switch position, the plates of V5A and V5B are tied together through the A-deck of the COMMAND CAL switch. This applies the potential at the wiper arm of R48 to the plates of both diodes. Potentiometer R43 is then adjusted to obtain a zero reading of the CAL meter which indicates the bridge is exactly balanced. This balancing eliminates errors due to tube aging or other changes in component values. In the YAW, PITCH, and BURST positions of the COMMAND CAL switch (CCS 5, 6, and 7), the peak values of the sinusoidal outputs from the yaw, pitch, and burst oscillators respectively are set to the required value. This is done by connecting the output from transformer T1 secondary winding 3-4 to the plate of V5B through the B-deck of the COMMAND CAL switch. In these switch positions, the action of rectifier V5B causes the voltage across C14 to be built up to the peak value of the sinusoidal yaw, pitch, or burst signals. The lower plate of C14 is connected to the d-c potential for 1,600-cps operation of the multivibrator. Thus the potential on the grid of V6B is the potential for 1,600-cps multivibrator operation plus the potential across C14. Since the grid of V6A is at the potential for 2,000-cps operation of the multivibrator, the grid of V6B must be at this same potential for the bridge to be in balance. The yaw, pitch, and burst oscillator output voltage controls are adjusted individually in the respective COMMAND CAL switch positions so that C14 is charged to the potential difference between 1,600-cps and 2,000-cps operation of the multivibrator. This insures that when the command oscillator outputs are applied to the multivibrator they will drive the multivibrator frequency between the limits of 1,600 and 2,400 cycles from the rest frequency of 2,000 cycles.

the peak voltmeter. The three d-c voltages are used in setting the multivibrator frequencies to 2,000, 1,600, and 2,400 cycles. These voltages are taken from the sliders of potentiometers R48, R46B, and R46A respectively. The switching of the multivibrator grid circuits and the peak voltmeter to these d-c voltage points is performed by the COMMAND CAL switch. The voltage at the wiper arm of R48 is about 230 volts and is variable by about ±0.5 volt. The wiper arm of this potentiometer is set to make this point the electrical midpoint between the d-c voltage at the sliders of R46A and R46B. In order to set this midpoint accurately, the following bridge arrangement is used. Adjustment of R48 is not a part of the r-f test set calibration procedure. The left-hand arms of the bridge consist of all the resistors of the voltage divider from the wiper arm of R46A to the wiper arm of R46B. The right-hand arms consist of the paired resistors R33 and R34. A meter is connected between the wiper arm of R48 and the junction of R33 and R34. The voltmeter used in this adjustment is not included in the r-f test set. The wiper arm of R48 is adjusted to obtain zero meter current. Resistors R46A and R46B are identical and form a dual potentiometer. The setting of R46A and R46B determines the voltage to which the multivibrator grid circuits are returned on the 1,600-cps and 2,400-cps positions of the COMMAND CAL switch. Potentiometers R46A and R46B are wired in such a manner that a clockwise rotation of the shaft results in increase of the voltage at the 1,600-cps tap and a decrease of the voltage at the 2,400-cps tap. At all times the potential difference between the wiper arm of R48 and the wiper arm of either R46A or R46B is the same. The dual potentiometers R46A and R46B can change the voltage at their wiper arms by about 12 volts. Resistors R35 to R38 connected to the C-deck of the COMMAND CAL switch are dummy loads which are used to maintain the voltage at the fixed points along the voltage divider constant for all positions of the switch. These resistors are necessary because the multivibrator grids draw current from the voltage divider. Since the multivibrator grids are returned to different points along the voltage divider in the various switch positions, a changing load is placed across the different points along the voltage divider. The dummy loads balance out the multivibrator loads, keeping the voltage along the voltage divider constant for all calibrating switch positions.

i. <u>Peak voltmeter</u>. The peak voltmeter is used to set the peak values of the sinusoidal outputs from the three command oscillators. The peak voltmeter indicates potential differences by comparing the unknown a-c voltage to a reference d-c voltage. The peak voltmeter consists primarily of a bridge circuit. The upper arms of the bridge contain tubes V6A and V6B which act as variable resistances. The lower arms consist of resistors R41 and R44 and potentiometer R43. Potentiometer R43 is the bridge balance control designated BAL on the front panel. The zero-center, d-c microammeter M1 (500 microamperes

RT1 determines the amount of feedback voltage by changing its resistance in proportion to the amount of heat generated by current flow through it. If current flow increases, the resistance of RT1 will decrease, and the amount of feedback voltage will increase. In operation of the circuit, RT1 maintains the output of the 85-kc oscillator at a constant amplitude when it is at the same value of resistance as the other three resistors in the r-f bridge circuit. The bridge is then said to be balanced. The comparison bridge is identical to the r-f bridge, and when the r-f bridge is balanced the comparison bridge will be balanced also. RT2 is also mounted in the waveguide assembly, but will not absorb microwave energy because of its physical position. The purpose of RT2 is to compensate for changes in ambient temperature occurring in the waveguide which might affect RT1. The comparison bridge provides an input for the amplifier-detector. If the comparison bridge is balanced, no output voltage is present at terminals 1 and 2 of T3. In order for an input for the amplifier-detector to appear at T3, the comparison bridge must be unbalanced. Since the r-f bridge is capable of maintaining the comparison bridge in a balanced condition, it is also possible for the r-f bridge to cause the comparison bridge to unbalance, thus causing an output to the amplifier-detector. The r-f bridge must be unbalanced, too. This unbalance is caused by changing the amount of current flow through RT1, and thus changing its resistance. The output of the 85-kc oscillator is coupled to both bridge circuits and has an equal effect upon both. Therefore, the amount of unbalance present in the comparison bridge is equal to the amount of unbalance caused by the change in resistance of RT1. The input to the amplifier-detector is then also proportional to the change in resistance of RT1. When the oscillator circuit has stabilized, it has no further effect upon the resistance of RT1 since the feedback voltage will not vary after this time. RT1 must therefore be unbalanced in another manner. RT1 is sensitive to the microwave energy present in the waveguide and will absorb part of it. This microwave energy causes the current flow through RT1 to increase, thus increasing its temperature and decreasing its resistance and resulting in an unbalance of the r-f bridge equal to the amount of energy present in the waveguide. This energy may be either the output of the r-f signal generator or the return signal from the missile, depending upon the position of the TEST SELECTOR switch. The presence of microwave energy in the wave-guide assembly causes the resistance of RT1 to change, which causes the r-f bridge to become unbalanced. This results in an unbalance in the comparison bridge, and an output to the amplifier detector. It may be seen that this output is proportional to the amount of microwave energy present in the waveguide. This output is in the form of an 85-kc sine wave, which is amplified by V2A, V2B, V3A, and V3B, and detected by V4. The output of V4 is coupled to the RF POWER meter.

c. Controls and adjustments. Functions of controls and adjustments will be covered in the detailed circuit analysis but are summarized as follows:

Section VII. R-F POWER METER CIRCUIT

77. GENERAL

The r-f power meter circuit is used to measure both the power generated by the r-f signal generator in the r-f test set, and the power output of the missile beacon. The r-f power meter circuit also contains a frequency-measuring component which is used for measuring the output frequency of the r-f signal generator and the missile beacon.

78. LOCATION AND PHYSICAL CHARACTERISTICS (fig II-46)

The r-f power meter circuit is located in the r-f test set upper drawer assembly. It is mounted in the lower right of the upper drawer assembly (fig II-53) front panel. The r-f power meter circuit chassis (fig II-65) measures 12 x 12 x 6 inches and weighs approximately 7 pounds. The CAL ∞, CAL 0, and CAL V controls are mounted in a horizontal row along the top of the chassis front panel. The RF POWER DB and PWR METER CAL switches are mounted side by side in the lower left portion of the chassis front panel. The MEAS FREQ control, indication dial, and interpolation chart are mounted in a group at the right of the chassis front panel. The RF POWER meter is mounted in the upper portion of the pulser chassis front panel, located at the right edge of the r-f test set upper drawer assembly. Jack J5 provides connections to the pulser, the switch attenuators in the waveguide assembly, power supply, and command modulator.

79. BLOCK DIAGRAM (fig II-89)

a. General. The r-f power meter circuit uses a temperature compensated circuit for the measurement of average power output of either the r-f signal generator or the missile. This output is determined by measuring the amount of microwave power present in the r-f test set waveguide assembly.

b. Operation of the r-f power meter circuit. The r-f power meter circuit is composed of an amplifier and a bridge circuit (r-f bridge) which make up an 85-kc oscillator, the comparison bridge, an amplifier detector, and the RF POWER meter. The output amplitude of the 85-kc oscillator is controlled by the r-f bridge circuit which contains a temperature sensitive element (thermistor RT1), which is physically mounted in the waveguide assembly so as to absorb a portion of any microwave energy present in the waveguide. The bridge circuit determines the amplitude of the oscillator output by means of varying amounts of feedback voltage. The amount of this feedback voltage is determined by RT1.

thermistor RT1. (Note that RT1 is physically mounted in the waveguide assembly.) The greater the amount of unbalance created in the r-f bridge, the greater the amount of signal fed back through T1 to amplifier stages V1A and V1B. The amplitude of the oscillations is directly determined by the amount of feedback voltage. The amount of feedback voltage is in turn controlled by the unbalance of the r-f bridge circuit. The amount of unbalance is determined by the resistance of thermistor RT1. RT1 is a negative coefficient thermistor. If the current through RT1 increases, its temperature will increase, and the resistance will decrease. When the circuit commences operation, RT1 is cold, and its resistance is therefore somewhat higher than that of the other resistors in the r-f bridge circuit. Because of this difference, there is a large amount of unbalance in the r-f bridge circuit before the output of the oscillator builds up, and a correspondingly large feedback voltage is applied to the amplifier. The amplifier amplifies this voltage and applies it again to the r-f bridge where it further heats RT1. As the thermistor heats, its resistance decreases resulting in less feedback and in turn less heating of the thermistor. This action continues until the exact amount of power necessary to balance the r-f bridge is developed at the output of the amplifier. The comparison bridge is identical to the r-f bridge. Therefore, when the r-f bridge is balanced, the lower bridge will be balanced also. Since the input to the amplifier-detector is obtained from the comparison and since the amplifier-detector provides signals to the RF POWER meter, the actual meter indication is directly proportional to the amount of unbalance present in the comparison bridge. Both RT1 and RT2 are physically located within the waveguide assembly. They are mounted in such a manner that RT1 will absorb power from the waveguide while RT2 will not. Thus, RT1 receives power from two sources, the oscillator and the waveguide, while thermistor RT2 receives power only from the oscillator. When r-f energy is present in the waveguide, it may be seen that less output from the oscillator is necessary to balance thermistor RT1 because RT1 is heated not only by the output of the oscillator, but also by the microwave power in the waveguide assembly. Since thermistor RT2 is receiving power only from the oscillator, the comparison bridge will be unbalanced by an amount proportional to the difference in power applied to the two thermistors. The more power present in the waveguide, the less will be the output of the oscillator and the greater the unbalance in the comparison bridge. Since the comparison bridge provides an input to the amplifier-detector when unbalanced, and since the comparison bridge is fed by the 85-kc oscillator, part of the 85-kc voltage furnished by the oscillator will be applied to the amplifier-detector and to the RF POWER meter if the comparison bridge is unbalanced. The amount of 85-kc voltage applied to the amplifier-detector is proportional to the amount of unbalance present in the comparison bridge. Certain compensation adjustments may be made in the r-f power meter circuit. Capacitors C1 and C2 in the input to the oscillator are used to tune transformer

(1) MEAS FREQ control. This control measures the frequency of the energy in the waveguide by means of a variable cavity which resonates when adjusted to a multiple wavelength of the frequency.

(2) CAL ∞ control. CAL ∞ controls the amount of 85-kc voltage applied to the two bridge circuits.

(3) CAL 0 control. CAL 0 adjusts the gain of the amplifier circuit.

(4) PWR METER CAL switch. This switch selects the inputs for the RF POWER meter.

(5) RF POWER DB switch. This switch adjusts the gain of the amplifier.

80. DETAILED CIRCUIT OPERATION (fig II-90)

a. General. The r-f power meter circuit is composed of two bridge circuits, the r-f bridge and comparison bridge, an amplifier, an amplifier detector, and the RF POWER meter M1. The two bridge circuits contain thermistors RT1 and RT2, which are the microwave power-measuring elements. The r-f bridge and the amplifier circuit form an 85-kc oscillator. The output of this oscillator is controlled by thermistor RT1, located in the r-f bridge, so that changes in the oscillator output are a measure of microwave power. The r-f power meter circuit performs the following functions:

(1) It gives an indication proportional to microwave power present in the waveguide assembly.

(2) It reduces to a small value variations in the power indication with ambient temperature changes.

(3) It compares the indicated microwave power to known d-c calibrating power.

b. Operation of oscillator and bridge circuits. The 85-kc oscillator is composed of the r-f bridge, the amplifier which contains electron tubes V1A and V1B, and associated circuit components. The comparison bridge is associated with the oscillator, but is essentially a load for the oscillator rather than an integral part. Each bridge circuit is composed of three resistors and a thermistor. Energy in the form of oscillations with a frequency of 85 kc is applied to both bridge circuits from the output of V1 through transformer T2. Feedback to sustain the oscillations is supplied by the r-f bridge circuit which contains through the cathode of the first stage to ground. The ground is picked up in the command modulator through contacts 5 and 3 of relay K2 in order to disable the detector circuit when K2 energizes. If the detector circuit is not disabled, the RF POWER meter will give a false indication of missile response after a burst or fail-safe signal is in effect. On the negative half-cycle of the input signal, the other half of V4 will conduct since the plate is held at ground potential by means of a connection made through the PWR METER CAL switch. This conduction will cause capacitor C32 to charge to a value equal to the sum of the charge remaining on C26 from the positive half-cycle and the voltage amplitude of the negative half-cycle. If the circuit were unloaded, the resultant voltage across C32 would be nearly double the peak voltage of the input signal. Meter M1 is a combination voltmeter and milliammeter. The meter contains an internal resistance in series with the meter movement which allows it to be used as a voltmeter when connections are made to its V and - terminals. This is the condition in the ADJ V position of the PWR METER CAL switch. In this switch position, the 300v output of the power supply is adjusted to its nominal value by means of potentiometer R52, the CAL V potentiometer. In all remaining positions of the PWR METER CAL switch, the connections are made at the + and - terminals, and the meter is used as a milliammeter. The 300v supply voltage still remains connected to the V terminal of the meter but has no effect because the + terminal is grounded and none of the 300v current flows through the meter.

d. Power indication. The CAL ∞ control is adjusted so that the oscillator power output to RT2 is sufficient to heat it to a resistance equal to that of R13. Under this condition, the comparison bridge is balanced so that 85-kc voltage appears at the amplifier-detector input and meter M1 indicates almost at the ∞ mark.

e. D-C power calibration. In order to check the measuring accuracy of the r-f power meter circuit, known amounts of d-c power are applied to RT1. D-C power is used because it may be measured and controlled easily. In calibration, all microwave power is removed from the r-f power meter circuit. The PWR METER CAL switch is set to the ADJ V position, and the 300-volt output of the power supply is measured by the RF POWER meter. The 300-volt supply voltage may be adjusted by potentiometer if necessary. The PWR METER CAL switch is then set to the ADJ ∞ position, and the balance made as explained in d. The PWR METER CAL switch is then set to the ADJ 0 position. In this position, the gain of the amplifier is adjusted by means of the CAL 0 control potentiometer R23 until the RF POWER meter deflects to the 0 position. R23 adjusts the gain of V2A by changing the amount of negative feedback in the cathode circuit. The calibration is made with the RF POWER DB switch out of the circuit

T1 to 85 kc. T1, C1, and C2 form a tank circuit. Changing the value of the capacitive elements will accordingly change the frequency of the tank circuit. The resultant peak in the response curve of the amplifier determines the frequency of the oscillator. Variable capacitors C8, C9, C10, and C11 in the bridge circuit are used to balance out stray capacitances in the transformers and wiring of the bridge circuit. Fixed capacitors C12 and C15 may be strapped into the circuit if necessary to achieve balance. Potentiometer R8, the PWR METER CAL ∞ control is used to calibrate the RF POWER meter in the ADJ ∞ position of the POWER METER CAL switch. This adjustment varies the amount of oscillator output power applied to the r-f and comparison bridge circuits. The potentiometer is adjusted so that the differential unbalance voltage between the two bridge circuits approaches zero. This adjustment, made in the calibration of the r-f test set compensates for the different amounts of power required to heat each thermistor. If the ambient temperature of RT1 and RT2 increases, the 85-kc oscillator power automatically decreases in order to maintain the resistance of RT1 at a constant value. This decrease in oscillator power also tends to maintain the value of the resistance of RT2. Similarly, a decrease in ambient temperature will be compensated for by an increase in oscillator power output. As a result, microwave power indications are relatively independent of changes in ambient temperature.

c. Operation of the amplifier-detector circuit. The amplifier-detector is composed of a four-stage amplifier (V2A, V2B, V3A, and V3B) and a detector (V4A and V4B). The amplifier is tuned to a frequency of 85 kc by means of capacitors C17 and C18 across the secondary winding of T3. The input to the amplifier is the 85-kc voltage developed across the output of the comparison bridge circuit. The gain of the amplifier may be adjusted by means of the RF POWER DB switch. This varies the gain of the amplifier by changing the resistance in the cathode circuits of V2B and V3B. Connections to the RF POWER DB switch are made through the TEST SELECTOR switch and the PWR METER CAL switch. The resistance in the cathode circuits of the tubes determines the amount of feedback voltage from the cathode of V3B to the cathode of V2B. The feedback voltage is proportional to the amount of current flow through the load consisting of V4 and the meter circuit. There is an additional current feedback because the cathode resistors are not bypassed, but this feedback is small in comparison to the other feedback. The larger the resistance in the cathode circuits, the greater the feedback voltage, and the less the gain of the amplifier. The amplifier gain is changed in order to increase or decrease the deflection of the RF POWER meter. The detector consists of the twin triode V4 with the plates and grids connected to form two diodes, capacitors C26 and C32, and meter M1. The plate of V4A (terminals 3 and 4) draws current on the positive half-cycle of the input signal. The current in this path is short-circuited test requirements on the frequency meter are intended to keep its frequency measuring error less than ±3 mc at 80° F and 50 percent relative humidity. At other temperatures a correction of +0.03 mc per degree Fahrenheit should be added to the indicated frequency. A change in relative humidity from 50 percent at 77° F to 90 percent at 95° F will require a frequency correction of approximately -1.0 mc.

Section VIII. R-F SIGNAL GENERATOR, WAVEGUIDE ASSEMBLY, AND ANTENNA COUPLER

81. GENERAL

In order to check out the Nike missile, it is necessary to send to the missile coded r-f pulses which closely approximate those transmitted by the missile-tracking radar during actual firing. In the r-f test set, these pulses are generated by the r-f signal generator circuit. These pulses are then coupled to the missile by means of the waveguide assembly and antenna coupler.

82. LOCATION AND PHYSICAL CHARACTERISTICS (figs II-53 and II-63)

The r-f signal generator circuit is located in the r-f test set upper drawer assembly. The r-f signal generator is not a front panel assembly, and is mounted in the rear center of the upper drawer assembly. It is fastened to the upper drawer assembly by means of Airloc fasteners. The r-f signal generator chassis also contains the waveguide assembly. The chassis measures 10 x 7.5 x 3.5 inches and weighs approximately 2 pounds. The OUTPUT, FREQ, and REPELLER controls are concerned with the operation of the r-f signal generator but are mounted on other components of the r-f test set upper drawer assembly. The OUTPUT and FREQ controls are mounted on the oscilloscope front panel; the REPELLER control is mounted on the burst timer front panel. Jack J13 provides connections to the pulser circuit. Jack J12 provides connections for filament and biasing voltages from the upper drawer assembly common equipment to the r-f signal generator chassis. The output of the r-f signal generator is coupled from the waveguide assembly through the flexible waveguide to the antenna coupler.

83. BLOCK DIAGRAM (fig II-86)

a. General. The r-f signal generator consists of a d-c restorer circuit which contains duodiode V1 and associated circuit components; the repeller tracking network, which contains resistors R2 through R9 and dual potentiometer R34; and the klystron V2 with its associated circuit components.

so that a fixed value of gain is introduced. This is done by connecting the cathode of V2A directly to R46 through the PWR METER CAL and TEST SELECTOR switches. In normal operation, the gain of the amplifier is adjusted by the RF POWER DB switch. This switch adjusts gain by introducing various values of resistance which determine the amount of negative feedback voltage applied to V2A. The range of the RF POWER DB switch is from 0 to 14 db in readings of 0, 3, 6, 7, 8, 9, 10, 11, 12, 13, and 14 db. In a power measurement the position of the RF POWER DB switch and the reading of the RF POWER meter must be added together in order to attain an accurate measurement of the power of the r-f signal. For example, if the RF POWER meter indicates 1, and the RF POWER DB switch is set to 8, the value is -8-1 = -9 dbm. Note that the RF POWER meter always indicates in -dbm, which is the power in db below one milliwatt. When the PWR METER CAL switch is set to the MEAS position, all d-c calibrating voltages are removed, and the RF POWER DB switch is connected back into the circuit for all positions of the TEST SELECTOR switch positions except position 1, RF TEST SIG. For this position of the TEST SELECTOR switch, the 12-db position of the RF POWER DB switch is automatically chosen.

f. Microwave components in the r-f power meter circuit. The microwave components of the r-f power meter circuit are the thermistor, the frequency meter, and a short section of waveguide. The thermistor mount consists of the two thermistors RT1 and RT2 mounted in a stub section of waveguide. RT1 is mounted vertically in the waveguide and adjusted to absorb maximum energy. This is a factory adjustment. The frequency meter is a variable coaxial resonator, coupled by a short electric probe to the waveguide. The cavity resonates when the length of the cavity is adjusted to 15 quarter-wavelengths of the frequency present in the waveguide. The size of the cavity is adjusted by means of the MEAS FREQ control which moves a plunger in and out of the cavity with the use of a worm gear mechanism. When the cavity resonates, it absorbs power from the waveguide. This results in less power applied to RT1 and a correspondingly smaller output to the RF POWER meter, which will cause the reading of the RF POWER meter to fall off. When the reading of the RF POWER meter is at a minimum, the cavity resonator is adjusted to the correct multiple of the wavelength and is absorbing maximum power. The frequency of the cavity resonator is indicated on a counter-type dial assembly on the front panel of the r-f power meter circuit. The dial assembly indicates to three places, and a fourth must be interpolated. A calibration table furnished with each r-f test set and mounted on the front panel of the r-f power meter circuit lists dial assembly readings for frequencies spaced at 50-mc intervals over the 8,500-9,600-mc band. At each calibration point, the rate of change of frequency in megacycles per division is also given. These data are used for interpolation between calibration points. Mechanical design and manufacturing and electrical

This results in an alternating voltage across the resonator, which is applied to the buncher grids. This voltage speeds up or slows down the electrons in the electron beam, depending upon when they enter the space between the grids in relation to the polarity of voltage present on the grids at that particular instant. Electrons that pass through the buncher grids at the instant that the a-c voltage is zero leave the buncher grids with unchanged velocity. Electrons passing through the grids a little earlier when the voltage is negative are slowed down, and electrons passing through the grids when a positive voltage is present are accelerated. This action results in bunches of electrons formed at some point beyond the buncher grids. These bunches are separated by areas containing few electrons. After passing through the buncher grids, the bunches of electrons encounter a strong negative potential produced by the repeller, which is maintained at a voltage which is negative in respect to the cathode. This negative voltage serves to repel the electrons that have been bunched by the action of the bunching grids. After being repelled by the repeller, the electrons now pass back through the buncher grids. Energy will be coupled to the cavity resonator through the buncher grids if the bunches pass through the grids at times when the voltage across the grids is of such a polarity to decelerate each bunch. Since the bunches travel in the direction opposite to that of the unbunched electrons, the bunches must return to the grids when grid 2 is positive in respect to grid 1. The energy delivered by the bunches is coupled from the cavity resonator to the waveguide assembly by means of a coaxial probe. Part of the energy delivered by the bunches serves as a feedback voltage to sustain oscillations in the klystron. The operating frequency of the klystron may be changed by mechanically varying the size of the cavity, which also changes the spacing of the buncher grids. This is done with the FREQ control, which is connected to a tuning mechanism by means of a shaft and coupling assembly. Turning the FREQ control in a clockwise direction decreases the distance between the bunching grids and effectively increases the capacitance of the cavity resonator thus decreasing the frequency of oscillation. The tuning range is from 8,500 to 9,600 mc. A second method of changing the frequency is to change the repeller voltage. If the repeller voltage is set to some value which causes the bunches of electrons to return to the grids at the same frequency as the resonant frequency, the output power is comparatively high. If the repeller voltage is changed in either direction, the rate at which the bunches of electrons return to the grids is also changed. Provided that the change in repeller voltage is not too great, the tube will not cease oscillating but will shift slightly in frequency, and the power output will be decreased. Varying the repeller voltage in this manner may cause the oscillator frequency to vary 25 to 75 mc within its tuning range.

b. Operation of repeller-tracking network. The frequency of the oscillator may be changed by varying the FREQ control, and if this is done, the output power will change also unless the repeller voltage is changed. In order that

b. Operation of the r-f signal generator. Pulses from the pulser circuit are coupled to the input of the r-f signal generator. The d-c restorer circuit clamps these pulses negatively in reference to a negative voltage. The clamping reference voltage is obtained from the repeller tracking network, which is a voltage divider network connected between the -250v supply and ground. The amplitude of the clamping voltage is determined by the position of the FREQ control, which varies a potentiometer that is part of the tracking network. The TRACK HIGH and TRACK LOW controls are also potentiometers which vary the maximum and minimum limits of the voltage across the FREQ control potentiometer. The pulse outputs of the d-c restorer circuit are coupled to the klystron, which acts as an r-f oscillator. The pulses cause the klystron to generate one r-f pulse for each pulse received from the d-c restorer circuit. If no pulses are received from the pulser circuit, the klystron will generate a c-w signal. Pulses are removed from the input of the r-f signal generator by setting the TIME-MICROSECONDS dials to 00.00 and the TEST SELECTOR switch to the RF TEST SIG position. The c-w output is necessary to adjust the klystron power output to its maximum value. The frequency at which the klystron will oscillate is determined by the FREQ control, which varies the distance between the control grids of the tube.

84. DETAILED CIRCUIT OPERATION (figs II-87 and II-88)

a. Operation of the 2K25 klystron. The 2K25 klystron, known as a reflex oscillator, is a velocity-modulated microwave oscillator. It consists of an electron gun, a cavity resonator tuneable from 8,500 to 9,600 mc, and two buncher grids, which are connected to the cavity resonator. These components are contained in a housing which is designed to prevent r-f leakage and has a loss above 90 db to the outside. Connections to the repeller, cavity resonator, and ungrounded side of the heater are made through rods which pass into the housing and are surrounded with polyiron. The polyiron prevents r-f leakage. This arrangement of a rod, polyiron, and hole into the housing forms a low-pass filter (LPF) in that the d-c and low-frequency a-c are passed, but the high-frequency microwaves are attenuated. The output of the oscillator feeds into the waveguide section through an antenna probe which extends into the waveguide. The uncalibrated OUTPUT attenuater AT1 is a vane-type attenuator which is moved from the side to the middle of the waveguide by a gear mechanism actuated by the OUTPUT control. The electron gun, which is held at ground potential, emits an electron beam of uniform velocity. This beam of electrons is then passed through the buncher grids, each of which is connected to one side of the cavity resonator. The positive potential present on the buncher grids will accelerate the electron beam. When the tube is operating, the resonant cavity operates in the same manner as a tuned circuit, and will therefore oscillate.

of setting the TIME-MICROSECONDS dials to 00.00 and the TEST SELECTOR switch to the RF TEST SIG position. If this is done, the r-f signal generator will operate continuous wave. When the TIME-MICROSECONDS dials are set to 04.00, pulses are formed by the pulser, and capacitor C1 increases its charge by the peak voltage of the pulses. The effect is the same as increasing the negative repeller voltage by an amount equal to the pulse peak voltage. This is sufficient to prevent the klystron from oscillating at all times except when a pulse is present. When a pulse occurs, the repeller voltage is momentarily returned to the value of voltage which will allow the tube to operate c-w for the duration of the pulse only. These r-f pulses are coupled from the klystron to the waveguide assembly, and from the waveguide assembly to the missile.

85. WAVEGUIDE ASSEMBLY AND ANTENNA COUPLER (fig II-88)

The GS-15734 waveguide assembly (fig II-64) and the GS-16888 waveguide assembly (antenna coupler) consist of microwave components interconnected by sections of waveguide. Their function is to provide the microwave signal paths between the r-f signal generator, the r-f power meter, and the missile. The waveguide assembly interconnects the r-f signal generator, r-f power meter, response indicator, and the antenna coupler. The connection from the waveguide assembly to the antenna coupler is made through a flexible waveguide. The antenna coupler connects to the missile to be tested. The circuit of the waveguide assembly is shown on figure II-88. The circuit consists of the following microwave components: directional coupler DC1, hybrid junctions HY1, HY2, and HY3, switch attenuators AT1, AT2, and AT3, waveguide terminations AT4 and AT6, variable attenuator AT5 (ATTEN DB), and crystal detector CR1. The circuit of the antenna coupler is also shown on figure II-88 and consists of directional coupler DC1, hybrid junction HY1, switch attenuators AT1 and AT2, waveguide termination AT4, antenna couplings 1, 2, and 4, and the antenna terminator 3. A description of each of these components follows:

a. Waveguide. The waveguides are principally rectangular in shape and are either rigid or flexible. Rigid waveguide sections consist of straight sections and E- and H-bends. The waveguides are equipped with end flanges for fastening the sections together. Waveguides which are readily separable have choke joint flanges to minimize losses at the joint. Dielectric plugs are used at the ends of separable joints. These plugs preclude the entrance of foreign matter into the waveguide and are essentially transparent to the microwaves.

maximum power may be obtained over the entire frequency range (8,500 - 9,600 mc), it is necessary to adjust both controls. This presents difficulties, since the oscillator may operate in several modes of efficiency and at various frequencies, depending upon the setting of the two controls. This difficulty has been overcome by gearing the two controls together. To operate efficiently, they must be set initially so that the effect of one control will compensate for the other by the correct amount. The initial setting and adjustments are made in the repeller tracking network. The tracking network contains resistors R2 through R9 and dual potentiometer R34, all of which are connected between the -250v supply and ground. Potentiometer R5 is the tracking potentiometer, and is geared to the FREQ control. The voltage range covered by R5 is determined by the rest of the repeller tracking network. Potentiometer R8 determines the minimum voltage, and potentiometer R3 determines the maximum voltage. These potentiometers are designated the TRACK LOW and TRACK HIGH controls respectively. Dual potentiometer R34 is the REPELLER control and is used to adjust the amount of voltage applied to R3 and R8. All these controls determine the mode of efficiency in which the klystron operates. The range over which they may be adjusted is limited in order that the klystron cannot be made to operate outside the limits of the mode of highest efficiency in which the power output is of sufficient amplitude and the life of the tube is the longest.

c. Operation of d-c restorer circuit. The d-c restorer circuit is actually a clamping circuit which clamps the input signal from the pulser negatively with respect to a negative voltage reference. This voltage reference is established by means of a voltage from the tracking network. If FREQ control potentiometer R5 is set in a position which will cause a potential of -125v to appear at the cathodes of V1 and no output from the pulser is present on C1, duodiode V1 will conduct, applying -125v to C1, and C1 will charge to this value. At this time, V1 will no longer conduct since no difference in potential is now present between the cathodes and plates of V1. Simultaneously C2 will charge to the value of -125v. The input to the r-f signal generator is in the form of 30-volt positive pulses from the pulser circuit. The input pulses cause C1 to charge to -155 volts. The only possible discharge path for C1 is through resistor R1 to capacitor C2. The time constant however is so long that C1 will discharge an extremely small amount between input pulses. The voltage present at the plate of V1 will therefore be equal to -155v with no input pulse present on C1. When input pulses are applied, corresponding 30v pulses will appear on the plates of V1, changing the potential to -125v. These pulses are coupled to the repeller of the klystron. Prior to pulsing, the r-f signal generator is set to operate at an efficient c-w level by removing the pulses from the input of the d-c restorer circuit and then adjusting the REPELLER control for maximum output of the highest power output possible within the mode in which the klystron is operating. The procedure for removing the pulses consists

e. Directional coupler. A directional coupler interconnects two microwave signal paths. The microwave signal is attenuated by a specified amount when it travels from one path to the other. The signal is sent into one arm of the directional coupler and appears as an output at two other arms. The output arm that is located in the same waveguide as the input arm will receive most of the signal power while the other output arm located in the second path will receive a small but definite part of the signal power. The directional coupler has four arms. Practically complete transmission takes place in traveling across opposite arms, the loss being essentially 0 decibels. For directional coupler DC1, in the waveguide assembly, the loss through right-angle arms is 25.6 decibels and is constant within ±0.1 decibel from 8,500 to 9,600 megacycles. In directional coupler, DC1, in the antenna coupler, this loss is 20 decibels. The directivity and the attenuation of the directional coupler are determined by the size and placement of the coupling slots. The proper functioning of the directional coupler is dependent upon the impedance into which and from which it is operated. Termination AT4 in the antenna coupler and termination AT6 in the waveguide assembly are used to present the proper impedance to one arm of these directional couplers. These terminations are essentially closed-end pieces of waveguide containing a vane of lossy material.

f. Switch attenuators. The function of switch attenuators AT1, AT2, and AT3 in the waveguide assembly and AT1 and AT2 in the antenna coupler is to open or block signal paths in the microwave circuit. The TEST SELECTOR switch controls the operation of the switch attenuators by either applying or removing a 28-volt, d-c energizing voltage. A switch attenuator consists of a short section of rectangular waveguide containing a movable vane. This vane is made of a carbon-coated phenolic material. A 28-volt, d-c solenoid is used to move the vane in the waveguide. With no voltage applied to the solenoid, the switch attenuator remains in the nonoperating or OUT condition. In this condition, the vane is held against the waveguide wall by a spring, and the loss is only about 0.3 decibel through the switch attenuator. Under this condition the switch attenuator permits almost 100 percent transmission through it. When the 28-volt potential is applied, the solenoid is energized, and the vane is moved into the waveguide. The switch attenuator is now in the IN position. The loss is greater than 45 decibels through the attenuator and prevents any effective transmission through the path in which the switch attenuator is located. When the 28-volt energizing voltage is removed, the spring pulls the vane against the wall to return it to the OUT position. Table IX shows the switch attenuator positions for the various positions of the TEST SELECTOR, the RF POWER meter, and the ANT2-ANT4 switches. The switch attenuator positions for both the waveguide assembly and the antenna coupler are shown in this table.

b. Antenna couplings. The connection from the antenna coupler to the missile antennas is made through the antenna couplings. An antenna coupling consists of an antenna connector and transducer. The antenna connector connects the missile antennas to the waveguide in the antenna coupler. The butt joint is surrounded by a lossy iron dielectric to keep r-f signal leakage at a minimum. Since the missile waveguide is circular and the test set waveguide is rectangular, a transducer is used to convert the waves from circular to rectangular polarization (or vice versa for the reverse direction of transmission). The circular-rectangular waveguide transducer is a waveguide section with a circular flange at one end and a rectangular flange at the other end. Inserted in this waveguide is a polystyrene dielectric card phase shifter and a vane. This vane suppresses unwanted wave transmission modes. The polystyrene dielectric card phase shifter is the element that changes the polarization. The angle at which the card phase shifter is placed in the waveguide is determined by the change of polarization required. Therefore, in antenna couplings 2 and 4 which connect to the receiving antennas on the missile, the microwaves are converted from the rectangularly polarized waves in the rectangular waveguide within the antenna coupler to the circularly polarized waves at the ends of the antenna couplings. In antenna coupling 1, which connects to the missile transmitting antenna, the signal waves are converted from the circularly polarized waves received from the missile to rectangularly polarized waves within the antenna coupler.

c. Antenna terminator. Transmitting antenna 3 is not used for testing purposes. To prevent leakage, the open end is covered by an antenna terminator consisting of an antenna connector and a tapered lossy dielectric termination for the circular waveguide. The tapered lossy dielectric absorbs the microwave energy sent into it and minimizes reflections back into the waveguide circuits within the missile.

d. Hybrid junctions. A hybrid junction is basically a device that divides a microwave signal applied to one arm into two signals which are sent out from two other arms. This enables a microwave signal obtained from one source to be sent into two different waveguide circuits simultaneously. There are four arms in a hybrid junction. Signal transmission occurs through arms that are located at right angles to each other, but there is essentially no transmission through arms located opposite each other. The loss between two arms at right angles to each other is 3.2 decibels provided the two remaining arms are terminated properly. The loss between opposite arms is at least 23 decibels. The exact loss depends upon the closeness of the impedance match of the two remaining arms.

of test signal power. The calibrated attenuator is a waveguide element containing two parallel energy-absorbing vanes which are coated with an energy resistant material. For the zero loss condition, these vanes are set at the sides of the waveguide. As the vanes approach the center, the power absorption and, hence, the attenuation increases. The mechanism to move the vanes comprises a rotating cam and spring for each vane. The cams are rotated by a shaft equipped with a calibrated dial. The cams move the vanes in and out as required. The springs prevent backlash and keep contact between the vane-moving elements and the cams. The ends of the attenuating vanes are tapered to eliminate abrupt changes in impedance as the r-f energy progresses through the waveguide. The calibrated dial is on the front panel of the test set and is designated ATTEN DB. This dial is calibrated over the range from 0 to 35 decibels in 1-decibel steps. At any setting below 20 db of the ATTEN DB calibrated attenuator, the loss is constant within ±0.5 db from 8,500 to 9,600 megacycles and at 9,000 megacycles, the measured loss is within ±0.3 db of the indicated loss at each dial mark. Above 20 db the loss is less precise, but accuracy in this range is not required.

Section IX. RESPONSE INDICATOR

86. GENERAL

a. The GS-15732 response indicator is used in checking the response of the missile transmitter to a signal from the r-f test set.

b. The response indicator may function either as a response indicator or as a coincidence indicator, depending upon the setting of the TEST SELECTOR switch (TSS). As a response indicator, the circuit indicates that the missile is transmitting. As a coincidence indicator, it receives pulses from the crystal detector in the waveguide and from the pulser. It indicates when two of these pulses arrive in coincidence at a gate tube in the circuit. It is in this function that the microsecond oscillator is used as a yardstick for comparison of pulse time positions with those of the pulses from the crystal detector. For the following TSS positions, the functions of the response indicator are as shown:

(1) TSS 1 (RF TEST SIG) inoperative; RESPONSE OR VOLTAGE meter is used to check the negative 250-volt power supply output.

(2) TSS 2 (REC SENS) response indicator.

(3) TSS 3 (TRANS TEST) response indicator.

Table IX. Switch attenuator operation.

PWR METER CAL switch positions	TEST SELECTOR switch positions	Waveguide Assembly AT1-AT2	AT3	Antenna Coupler AT1	AT2
1. ADJ V	RF TEST SIG	IN	IN	IN	IN
2. ADJ ∞	------------	IN	IN	IN	IN
3. ADJ 0	------------	IN	IN	IN	IN
4. MEAS	1. RF TEST SIG	IN	OUT	IN	IN
	2. REC SENS	IN	IN	Either*	
	3. TRANS TEST	OUT	IN	Either*	
	4. RESP TIME A	OUT	OUT	IN	IN
	5. RESP TIME B	OUT	IN	Either*	
	6. COMM SIG		IN	Either*	

*NOTE: Switch attenuators AT1 and AT2 of the antenna coupler are under control of the ANT2-ANT4 switch on the panel of the oscilloscope, except in the RF TEST SIG and RESP TIME A positions, when both AT1 and AT2 are in the IN condition. On other test positions when the ANT2-ANT4 switch is in the ANT2 position, AT2 is moved into the IN condition, and, when this switch is placed in the ANT4 position, AT1 is in the IN condition.

g. Crystal detector. The crystal detector converts the high-frequency microwave signals into video pulses which are then sent into the response indicator for measuring purposes. The crystal detector is located between the top and bottom walls of a closed-end section of the waveguide. No tuning adjustments are necessary to get adequate detector sensitivity over the 8,500 - 9,600 megacycle band. However, the crystal holder provided permits easy replacement of the crystal whenever its sensitivity falls below a desirable value.

h. Calibrated variable attenuator. The calibrated variable attenuator AT 5, in the waveguide assembly, is used in establishing an accurate value front panel is a potentiometer which varies the amount of signal amplitude at the input of the response indicator. This prevents pegging the meter when high amplitude r-f signals are present in the waveguide.

c. Operation as a coincidence indicator. As a coincidence indicator, the response indicator has two separate inputs: one from the crystal detector in the waveguide and the other from the pulse amplifier in the pulser. The input from the pulser consists of positive pulse pairs occurring every 500 microseconds. The time interval between pulses of these pulse pairs is determined by the setting of the time dials on the microsecond oscillator. In TSS 4 the r-f energy in the waveguide detected by the crystal originates in the r-f signal generator and is not being sent to the missile. This signal consists of r-f pulse pairs occurring every 500 microseconds. The time interval between pulses of these pulse pairs is determined by the setting of the ADJ CODE control on the pulser. In the determination of delta time (delay time) of the r-f test set, the time relationship of the pulse pairs from the pulser is compared with that of the pulse pairs from the r-f signal generator. The pulse pairs from the r-f signal generator will be delayed in time by an amount introduced by the pulser, r-f signal generator, and the waveguide. The pulse pair from the pulser circuit provides the time reference with the second pulse of the pair being variable in time in accordance with the setting of the time dials. In TSS 4, the pulse pairs from the r-f signal generator are fed into grid 1 (CG) of the gating stage of the response indicator through the video amplifier. Simultaneously the reference pulse pairs from the pulser are applied to grid 3 (SG) of the gating stage through the TEST SELECTOR switch. Bias for the gating or coincidence stage is taken from a voltage divider between the positive 300-volt supply and ground. This positive potential is applied to the cathode of V3 and is large enough to hold V3 cut off with respect to both grid 1 and grid 3. When any two positive pulses from both sources are in time coincidence, the gating tube will conduct and send a signal to the amplifier-rectifier and RESP OR VOLTAGE meter thus giving an indication of coincidence. This coincidence is brought about by adjusting the time dials until the second pulse of the pulse pair on grid 3 of the gating tube is in coincidence with the second pulse of the pulse pair on grid 1 of the gating tube. To preclude any possibility of coincidence occurring between the first pulse of each pulse pair due to delta time being less than the pulse width, a negative squelch pulse from the single pulser stage in the pulser circuit is applied to the cathode of the video amplifier stage V2. The squelch pulse slightly leads in time the first pulse of the pulse pair going to grid 1 of the gating stage and has sufficient duration to overlap it. The squelch pulse therefore cancels the first pulse of the pair and prevents it from being applied to the gating stage. In TSS 5, operation of the response indicator is the same as in TSS 4 except that the signal detected in the waveguide and applied to grid 1 of the gating stage consists of a train of single pulses from the missile transmitter. As in TSS 4, the time dials are adjusted to bring about coincidence between the second pulse of the pulse pair on grid 3 and the missile transmitter pulse on grid 1 of the gating stage. In TSS 5 the squelch pulse is still present but serves no useful purpose.

(4) TSS 4 (RESP A) coincidence indicator.

(5) TSS 5 (RESP B) coincidence indicator.

(6) TSS 6 (COMM SIG) response indicator.

87. LOCATION AND PHYSICAL CHARACTERISTICS (figs II-53 and II-66)

The response indicator chassis is located in the r-f test set upper drawer assembly. The chassis measures 9.5 x 5 x 4 inches and weighs approximately 1.5 pounds. It is secured in the upper drawer assembly by Airloc fasteners. Plug P11 provides the connections to the TEST SELECTOR switch, power supply, and the RESPONSE OR VOLTAGE meter. Jack J22 is the input connection from the crystal in the waveguide assembly. This output from the crystal detector is conducted to the response indicator chassis via the RESPONSE control on the burst timer chassis.

88. BLOCK DIAGRAM (fig II-91)

a. General. The response indicator consists of a video amplifier V1 and V2, a gating stage V3, an amplifier-rectifier V4 and CR2 through CR5, a meter M2, and the B-deck of the TEST SELECTOR switch S1. The RESPONSE OR VOLTAGE meter M2 is physically located on the front panel of the lower drawer assembly attached to the command modulator chassis. The TEST SELECTOR switch is located on the front panel of the upper drawer assembly attached to the pulser chassis.

b. Operation as a response indicator. In TEST SELECTOR switch positions 2, 3, and 6 the response indicator circuit functions as a response indicator. A crystal in the waveguide assembly rectifies the r-f pulses from the missile transmitter. In TSS 2 and 3, one of these pulses arrives every 500 microseconds. In TSS 6 the pulses are frequency modulated and arrive from 416 to 625 microseconds apart. The d-c envelopes of the pulses are amplified by a video amplifier consisting of pentodes V1 and V2 and are applied to grid 1 of the gating stage V3. At this time, V3 is functioning as an ordinary pentode amplifier with grid 3 connected to the cathode through the TEST SELECTOR switch. Cathode bias for the stage is established by a voltage divider between the +300-volt supply and ground. This bias is sufficient to hold V3 cut off. A ringing coil in the output circuit of V3 is shocked into oscillation by the signal pulses and continues to ring for several cycles. This ringing makes the effect of the pulses last longer and thus raises their energy content. The signal is further amplified by V4 and applied to a bridge rectifier consisting of crystal diodes CR2, CR3, CR4, and CR5. The d-c output from the rectifier is filtered by a shunt capacitor and sent to the RESPONSE OR VOLTAGE meter. The RESPONSE control on the making it necessary for both grids to be driven out of cutoff simultaneously in order to cause V3 to conduct. In TSS 1, a negative 17-volt cutoff bias is applied to grid 3 through the B-deck of the TEST SELECTOR switch. This potential keeps V3 cut off thereby disabling the response indicator circuit. In TSS positions 2, 3, and 6, grid 3 is connected to the cathode through the B-deck of the TEST SELECTOR switch, and V3 functions as an ordinary pentode amplifier. In TSS positions 4 and 5, positive pulses from the video amplifier are applied to grid 1 and the positive time reference pulses from the pulser are applied to grid 3 through the B-deck of the TEST SELECTOR switch. Capacitor C5 prevents cathode degeneration in V3. Positive screen grid potential for V3 is taken from a voltage divider consisting of R19 and R20 connected between the positive 300-volt supply and ground. Inductor L3, together with distributed circuit capacitances, is set into oscillation at a frequency of 10 kc by each output pulse from V3. L3 is lightly damped and will continue to ring for a few cycles after the shock pulse. The damped wavetrain on the trailing edge of each pulse raises the total energy content of the pulses, providing a higher average d-c output voltage from the rectifier to the meter. This increases the sensitivity of the response indicator. C8 maintains the screen grid and the lower end of L3 at a-c ground potential. The network composed of CR1, R21, L4, and C6 partially peaks the incoming pulses from the pulser. L4 accomplishes the actual peaking while C6 keeps the lower end of the inductor at a-c ground potential. CR1 offers slightly less resistance than R21 to positive portions of the pulses thereby increasing the peaking action on the positive parts of the pulses. This pulse-shaping enables more accurate triggering of V3. The output pulses from V3 are developed across L3 and are coupled through C7 to the grid of triode V4A.

c. Amplifier-rectifier. Triodes V4A and V4B are connected as an ordinary R-C coupled amplifier. R22 and R25 are the d-c grid returns which also provide an impedance for developing the grid signals. R24 and R27 are plate load resistors. Cathode bias for V4A is developed across R23, and for V4B across R26. C10 bypasses R26 to prevent degeneration. R28 in the grid circuit of V4B suppresses high-frequency parasitic oscillations. The output signal from V4B is applied through C11 to a full-wave bridge rectifier composed of CR2, CR3, CR4, and CR5. Negative feedback is provided by connecting the junction of CR3 and CR5 to the cathode of V4A. This increases the cathode follower action of V4A and R23 by coupling back a signal in phase with that on the grid of V4A. The negative feedback stabilizes the circuit with respect to variations introduced by unbalance in the bridge rectifier and aging of components in the amplifier. Capacitor C12 filters the d-c output of the rectifier.

d. Meter M2 and pattern modulator test. Meter M2 is used not only to measure the output of the amplifier-rectifier but also to measure the -250-volt output of the power supply. A nonlocking switch S5 in the microsecond oscillator is used to change the connections to the meter and is designated -250 V and when

89. DETAILED CIRCUIT OPERATION (fig II-92)

a. Video amplifier. Positive input pulses from the crystal in the waveguide assembly are adjusted in amplitude by RESPONSE control R33 and applied to the control grid of pentode V1. Cathode bias for V1 is established by resistor R2 which is bypassed by capacitor C1C to prevent degeneration. Resistor R4 is a screen-dropping resistor, and C1A a screen bypass capacitor. R7 and C1B provide decoupling for V1. Inductor L1 is a series-peaking coil which resonates with tube capacitances and stray circuit capacitances to increase the gain of V1 at frequencies in the vicinity of 6 mc. This preserves the steep leading edge of the pulses. Resistor R5 damps ringing oscillations of L1. Resistor R3 connected directly in series with the screen grid of V1 serves to suppress high-frequency parasitic oscillations. The negative output pulses from V1 are developed across plate load resistor R6 and are coupled through C2 to the grid of pentode V2. Cathode bias for V2 is developed across R9 with the d-c grid return R8 connected to the most negative end of R9. Crystal CR6 functions as a biased negative limiter. Positive bias for the crystal is developed across R31 and applied to the cathode of CR6 through R8. Whenever the amplitude of the negative pulses from V1 exceeds the positive bias on CR6, CR6 will then conduct with the result that a small proportion of the signal will be developed across it and applied to the grid of V2. During conduction of CR6, most of the signal from V1 is dropped across C2 because of its relatively high reactance. The negative squelch pulses from the single pulser stage in the pulser circuit are coupled through capacitor C16 and applied to the cathode of V2. Capacitor C15 integrates the squelch pulses slightly to insure that their width is greater than that of the pulses from V1. Since only grid-to-cathode voltage changes are reflected as an output of a vacuum tube, the negative squelch pulses cause the cathode of V2 to go as much or more negative than the grid is driven negative by the pulses from V1. This action effectively suppresses positive output pulses from V2 when the squelch pulses are present. Due to the limiting action of CR6, the negative pulses from V1 will never be large enough to override the squelch pulses. Capacitor C3A maintains the junction of R9 and R31 at a-c ground potential. The series-peaking combination of L2 and R12 functions exactly like L1 and R5 in the plate circuit of V1. R11 is a screen-dropping resistor and C3B a screen bypass capacitor. R10 is a parasitic suppressor. R14 and C3C accomplish decoupling for V2. The positive output pulses of V2 are developed across plate load resistor R13 and coupled through C4 to the gating stage V3.

b. Gating or coincidence stage V3. The 6AS6 type of gating or coincidence tube is similar to an ordinary pentode except that the suppressor grid (grid 3) has almost as much control over plate current as the control grid. Sufficient cathode bias is developed by the voltage divider consisting of resistors R16, R15, and R18 to maintain the cathode positive enough with respect to grid 1 and grid 3 to keep V3 cut off. Therefore, either grid 1 or grid 3 by itself can keep V3 cut off

91. LOCATION AND PHYSICAL CHARACTERISTICS (figs II-46 and II-67)

The burst timer chassis is located in the r-f test set upper drawer assembly. It is mounted in the upper right-hand corner. The chassis measures 9.5 x 7 x 5.5 inches and weighs approximately 3 pounds. The burst counting tubes which are used as indicators are mounted in a recess in the center of the panel. The START and RESET switches are mounted along the right edge of the panel. The REPELLER and RESPONSE knobs are not associated with the operation of the burst timer, but are located along the top edge of the panel. Jack J10 provides a connection to the pulse selector. Plug P4 provides the necessary connections to the pulse selector and command modulator.

92. BLOCK DIAGRAM (fig II-93)

a. General. The burst timer consists of a bistable multivibrator V1A and V1B, a driver amplifier V2A and V2B, burst counting tubes V3 and V4, the START and RESET switches, and associated circuit components.

b. Operation of the burst timer. The burst timer is actuated by a 2-kc train of negative pulses from the pulse selector when the START switch is depressed. These pulses are coupled into the bistable multivibrator through J10. Each input pulse will cause the polarity of the multivibrator to change in one direction, from positive to negative or from negative to positive. A complete output waveform will occur for each pair of input pulses from the pulse selector. The output of the bistable multivibrator is therefore 1 kc, since the frequency of the input signal is 2 kc. Two outputs are taken from the bistable multivibrator. These outputs, tapped from the grids of V1A and V1B, are in the form of square waves whose negative portions are peaked and are 180° out of phase. These signals are coupled to the driver amplifier, which serves as an isolation stage and wave squarer. Since V2A and V2B are biased at cutoff, the peaked portions of the square waves are eliminated. The outputs of the driver amplifier are two 1-kc square waves 180° out of phase. These signals are coupled to V3, the X1 counting tube. Tube V3 is a cold cathode counting tube. It consists of a neon-filled envelope containing a plate or anode, 2 strings of 10 cathodes each, alternately connected and arranged in a circle, an auxiliary anode and a normalizing cathode. Each output of the driver amplifier is connected to one string of cathodes. The resulting potential difference between the cathodes and the plate results in a glow discharge. The potential differences between the two strings of cathodes will cause the glow discharge to be transferred from one cathode to another as these potentials reverse. The input to the counting tubes consists of two 1-kc square waves 180° out of phase. Therefore, since the input signal changes polarity 2,000 times per second, the glow discharge will move from one cathode to another 2,000 times per second, or once every 0.5 millisecond. This movement of the glow discharge is visible in the front panel of the burst timer, in the normal position connects meter M2 to the output of the response indicator. Associated with meter M2, and also in the microsecond oscillator circuit, is an output jack J9 and another nonlocking switch S6. This switch and jack are both designated MON. When the receiver in HG1/U handset-headset, or the equivalent, is plugged into the MON jack and the MON switch depressed, meter M2 is disconnected from the output of the response indicator, and the telephone set receiver is connected in place of the meter. The receiver in the telephone set may then be used to listen to the output of the response indicator. This listening test is made to determine whether or not the pattern modulator motor in the missile is operating. When the motor is operating, a warbling note is heard. This note has a frequency of 2 kc and is modulated by a frequency of 50 cps. If the motor is not operating, the 2-kc note is relatively steady.

Section X. BURST TIMER

90. GENERAL

a. The GS-15729 burst timer is a device used to measure the burst time of the missile.

b. A delay in time is present between the time a burst signal is issued by the missile-tracking radar and the burst of the missile. This time delay is compensated for in the computer. The time compensation is made to equal the burst time of the missile, which must be 64 ± 5 milliseconds. If the burst time is not the required value, a corresponding error in the missile position at burst will occur. For example, at a missile speed of 1,400 mph, an error of 1 millisecond in burst time will cause an error of approximately 2 feet in missile position at the time of burst.

c. The burst signal is given by the radar by replacing the pitch and yaw steering orders with a burst command. This is done by means of a relay circuit. A similar relay circuit in the r-f test set command modulator performs the same function in test. Upon receipt of the burst command by the missile, the burst circuit begins to operate. When the operation of the burst circuit is completed, a signal is transmitted through the arming device to the warheads causing them to detonate. The time interval present between the energizing of the relay in the command modulator and the transmission of the burst command through the arming device is measured by the r-f test set, and is equal to the burst time of the missile.

TEST SELECTOR switch, a 2-kc signal from the reference oscillator is coupled to the pulse selector, where it is squared and differentiated by the wave squarer and pulser circuits into a train of sharp pulses with a repetition rate of 0.5 millisecond. When the START switch is depressed, K1 and K2, physically located in the command modulator, energize. K1 causes pitch and yaw orders to be replaced by the burst command. The operation of the gate tube and pedestal multivibrator are discussed in detail in section III, but the operation of these circuits in conjunction with the burst timer are here summarized. Gate tube V3 is a pentode with the potential of the suppressor grid in control of the gate function. V6A and V6B form a bistable multivibrator actuated by the start and burst signals. The output of the pedestal multivibrator is coupled to the suppressor grid of V3 and thus controls the gating function of this tube. At the start of burst time measurement, if V6A is conducting, the plate current of V6A causes a voltage drop across plate load resistor R32. This voltage drop is sufficient to drive V6B into cutoff, and reduces the potential at the suppressor grid of V3 to an amount capable of closing the gate. The train of timing pulses is thus prevented from being transmitted to the output of the pulse selector. Capacitor C23 is normally positively charged by the action of the voltage divider composed of R29 and R30. When the START switch is depressed, K1 energizes, applying ground to the positive side of C23. The entire charge of C23 will then be felt on the negative side of the capacitor in the form of a very strong surge of current in the negative direction. This surge of current is coupled to the grid of V6A through CR3, and is sufficient to drive V6A into cutoff. The potential at the plate of V6A will now rise, causing the potential of the suppressor grid of V3 to rise also. The gate is opened, allowing the transmission of the timing wave to the burst timer. The pulse selector will operate in this manner until a burst signal is received from the missile. This signal is in the form of a negative pulse, which is applied to the grid of V6B, driving it into cutoff, causing V6A to conduct, and thus removing the positive potential from the gate. At this time, the gate will close, and the timing pulses can no longer be transmitted. Since the transmitting of the burst command opens the gate, allowing the timing pulses to enter the burst timer, and the received signal from the missile stops the action, it may be seen that burst time is measured in the burst timer by means of actually counting the number of timing pulses passed by the pulse selector in the interval between the depressing of the START switch and the receipt of the burst signal from the missile.

b. Operation of relays K1 and K2. Relays K1 and K2 are physically located in the command modulator. The relays are energized and deenergized by the action of the START and RESET switches. It may be seen from the schematic (figs II-79, and II-52) that current may flow from ground through the deenergized contacts of K2 and the normally closed START switch to +300v, or from ground through the windings of K1 and K2 and the normally closed RESET switch to +300 volts. With both switches in the closed position, the greater part of the current flow will be through the deenergized contacts of K2 and the START switch.

and serves as an indication of burst time. There are 20 cathodes in the tube, and the tube will execute one complete cycle of operation every 10 milliseconds. When V3 has completed one complete cycle of operation, a negative pulse is coupled through the auxiliary anode to V4, the X10 counting tube. Tube V4 operates in the same manner as V3 except that it counts in 10-millisecond steps, and is triggered once each time V3 completes one cycle of 10-milliseconds. When the burst signal is returned from the missile, the pulse selector gate closes, and the 2-kc train of negative pulses no longer flows to the burst timer. The counting tubes immediately cease counting, and the value of burst time may be read directly from the counting tubes themselves. In order to accomplish another measurement of burst time, the RESET switch must be operated. The RESET switch deenergizes relays K1 and K2 in the command modulator, thus insuring that no signal flow is possible into the pulse selector and burst timer. The RESET switch also insures that the pulse selector is closed by removing the -60v bias from the grid of V6A. In addition, the RESET switch cuts off one section of the bistable multivibrator, insuring that no counting voltages are present at the input of V3, and normalizes the burst counting tubes. When the RESET switch is depressed, a high amplitude negative pulse is coupled to the normalizing cathodes in the counting tubes, causing a large potential difference between the anode and the normalizing cathode. This potential difference is large enough to assure that the glow discharge will be transferred to the normalizing cathode, regardless of its previous position in the tube. With the operation of the RESET switch, the circuit is prepared for another measurement of burst time. In order to measure burst time, the START switch must be pressed. Depressing the START switch energizes relays K1 and K2 in the command modulator, which allows the burst command to be transmitted to the missile, opens the gate in the pulse selector, allowing the 2-kc train of negative pulses to flow to the burst timer, and cuts off the r-f power meter circuit, preventing a false indication of missile response from appearing on the RF POWER meter.

c. Burst-time measurement. Transmission of the burst command opens the gate and allows the timing pulses to enter the burst timer. This action is stopped by the received signal from the missile. Thus, burst time is measured by an actual count of the timing pulses passed by the pulse selector between depressing the START switch and receiving the burst signal from the missile.

93. DETAILED CIRCUIT OPERATION (fig II-94)

a. Operation of pulse selector gate. Measurement of burst time is made with the TEST SELECTOR switch in the COMM SIG position. In this position of the

d. Operation of burst counting tubes. Two 6167 counting tubes are used as indicators in the burst timer circuit. The 6167 tube consists principally of 20 helically wound cathodes, an anode or plate, a normalizing cathode, and an auxiliary anode. All components are sealed in a neon-filled glass envelope. The method of cathode-stepping in V3, the X1 counting tube, is as follows: twenty cathodes are utilized in V3, and alternate cathodes are connected together. The cathodes are arranged in a circle. When connected together, the cathodes form two series combinations of 10 cathodes each. The upper end of each cathode helix is extended toward its neighboring cathode by means of a wire extension. Each cathode is therefore shaped like a cat whisker used in elementary crystal receivers. If one series of cathodes is labeled A, and the other series labeled B, and the cathodes are numbered A1, B1, A2, B2, A3, B3, ---A10, B10, and if then a positive potential is applied to the anode and a negative voltage at A1 sufficient to cause ionization of the neon gas surrounding the cathode A1, A1 will emit a glow discharge. If the A-cathode voltage is made more positive and the B-cathode voltage is made more negative by an amount capable of ionizing the portion of gas surrounding B1 with aid from the ionized area surrounding A1, the glow discharge will then be transferred to a B-cathode. If the voltage relationships reverse, the glow discharge will be transferred to an A-cathode. Preferential stepping, or progression of the glow discharge in a desired direction, is determined by the physical configuration of the cathodes themselves. As previously stated, each cathode is similar to a crystal receiver cat whisker. The straight end of each cathode is extended into the region of high ionization density of the previous cathode (B1 projects into A1, A2 into B1, B2 into A2, etc.). If A1 is ionized, and the B-cathode voltage made more negative, the glow discharge will be transferred to B1 rather than B10 because the extension of B1 projects toward A1 and will tend to conduct the glow discharge from A1 to B1. If the A-cathodes are then made more negative than the B-cathodes, the glow discharge will be transmitted to cathode A2 in the same manner. The 2-kc square wave outputs of the driver amplifier provide the changes in cathode potential necessary to cause the counting tubes to count in the manner described above. Since the input signal changes potential 2,000 times a second, the glow discharge in the counting tubes will step from an A- to a B- or a B- to an A-cathode every half-millisecond. There are 20 cathodes used in the counting tubes. Therefore, a complete cycle will be executed every 10 milliseconds. When the glow discharge reaches the last cathode in V3, the ionization in that region will cause a current flow between the cathode and the auxiliary anode. The resulting reduction in potential due to the flow of current through resistor R26 results in the application of a negative pulse to the B-cathodes of the X10 counting tube, V4. In V4, the B-cathodes are employed only as a means of transferring the glow discharge from one A-cathode to another, since the tube counts only in steps of 10 milliseconds. A-cathodes are alternately connected together, forming two A-cathode circuits of 5 cathodes each. Each string of A-cathodes is provided with its own cathode resistor. These resistors are R20 and R21. The

Current flow will exist in the windings of K1 and K2, but not in sufficient amount to energize the relays. At the beginning of burst time measurement, K1 and K2 may or may not be energized. To insure that the relays are deenergized at the commencement of burst time measurement, the RESET switch is depressed. This removes the current path through the relay coils, forcing current to flow through the deenergized contacts of K2 and the closed contacts of the START switch. The START switch is next depressed, opening the latter current path, and forcing current to flow through the relay coils and the closed contacts of the RESET switch. At this time, the relays will energize. With K2 energized, the connection between ground and the START switch is broken, making deenergization through the START switch impossible. The relays will now remain energized. K1 removes pitch and yaw commands and couples the burst command to the input of the command modulator. K2 removes B+ (300v) from the amplifier in the r-f power meter circuit, thus preventing the RF POWER meter from erroneously indicating missile response during burst and fail-safe time measurement, and applies ground to capacitor C23 in the pulse selector, thus causing tube V6A to cut off and the gate to open. This allows the timing pulses from the reference oscillator to pass to the burst timer. In order to perform another burst time measurement, the entire procedure is repeated. The RESET switch is depressed, opening the current path through the coils of K1 and K2, which will deenergize. Current will again flow through the deenergized contacts of K2 and the closed contacts of the START switch until the START switch is again depressed.

c. Operation of burst timer multivibrator and driver amplifier. The multivibrator used in the burst timer is of the bistable type; that is, it has two quiescent states. Two input triggering pulses are necessary to cause one complete cycle to appear at the output. When the START switch is depressed, the pulse selector gate opens, allowing the 2-kc train of timing pulses to trigger the bistable multivibrator. Assume V1B to be conducting when the START switch is depressed. The plate current of V1B causes a voltage drop across R5 of sufficient magnitude of hold V1A cutoff. It must be remembered that although applied to both grids, the negative timing pulses affect only the triode in conduction. The first timing pulse drives V1B into cutoff. The plate of V1B will not draw current, and its plate voltage rises, causing V1A to conduct. The next pulse has the same effect upon V1A, the reversals of the polarity of the multivibrator occurring with each successive pulse. The outputs of the bistable multivibrator are two square waves with peaked negative portions and are 180° out of phase. These signals are coupled from the grids of V1A and V1B to the grids of V2A and V2B, which form the driver amplifier. V1A will conduct simultaneously with V2A and V1B will conduct simultaneously with V2B. Since V2A and V2B are biased at cutoff, the negative peaked portions of the input signal are removed. The positive portions of the input will drive the tube into conduction, producing a square wave at the output. The output of the driver amplifier is therefore two square waves 180° out of phase. These square waves are used to drive the burst counting tubes.

amplitude of the negative voltage at the A-cathodes is sufficient to capture the glow discharge from the normalizing cathode. Normalization of V4 is similar to that of V3, except that the normalizing cathode is supplied a positive bias by a voltage divider composed of R22, R23, R24, and R25. This positive bias prevents back-stepping from the normalizing cathode to an A-cathode. Another function of the RESET switch is to insure that other circuits are in the correct condition of operation before burst time measurement by resetting the pedestal multivibrator and the bistable multivibrator. When the contacts of the RESET switch are opened, the -60v potential is removed from V6A in the pedestal multivibrator and V1b in the burst timer. The grids go positive, and the tubes conduct, driving V6B and V1A into cutoff. When V6B cuts off, the pulse selector gate closes, insuring that no stray pulses will reach the burst timer before the START switch is operated. When V1A cuts off, only one of the two signals necessary to power the burst counting tubes will be present, thus making it impossible for the tubes to operate at the wrong time or operate erratically if stray voltages are present.

Section XI. OSCILLOSCOPE

94. GENERAL

The GS-15728 oscilloscope is used in r-f test set calibration for adjustment of the output frequencies of the command modulator and microsecond oscillator circuits. The frequencies to be calibrated are compared with standard frequencies generated by crystal oscillators in the reference oscillator circuit. The setting of the COMMAND CAL switch in the command modulator determines which frequencies are applied to the oscilloscope. The oscilloscope circuit consists of a horizontal and a vertical deflection amplifier and a cathode ray tube. The 2BP1 cathode ray tube is 2 inches in diameter and uses electrostatic focusing and deflection. Figure II-97 is a block diagram of the oscilloscope circuit, showing the input switching circuit. As is evident from the block diagram, section S1D of the COMMAND CAL switch connects the frequencies from the command modulator and microsecond oscillator to the horizontal amplifier input and simultaneously connects the different standard frequencies to the vertical amplifier input. The interaction of the vertical and horizontal deflections within the cathode ray tube results in the formation of Lissajous patterns. In operation, the frequency of the signal applied to the horizontal amplifier is adjusted until the pattern stops rotating, which indicates that the frequency is adjusted to the required value. The various frequencies which are applied to the horizontal and vertical inputs of the oscilloscope through the nine corresponding positions of the COMMAND CAL switch are shown in table X. In the YAW, PITCH, and BURST positions of the COMMAND ionized A-cathode (A_1 string) has a positive bias due to the current flow through its cathode resistor. The other A-cathodes (A_2 string) are at ground potential, and the B-cathodes maintained at a positive value by the voltage divider network consisting of R22, R23, R24, and R25. The receipt of the negative pulse from V3 drives the B-cathodes negative in respect to the ionized A_1 cathode. The B-cathode adjacent to the ionized A_1 cathode will also ionize. The additional current flow through the anode resistor R30 reduces the anode potential, thus extinguishing the glow discharge at the A_1 cathode. At the end of the negative pulse, the bias on the B-cathodes will turn toward the fixed positive value. The next A_2 cathode, which is at ground potential, is therefore negative with respect to the ionized B-cathode. This A_2 cathode will then ionize, and the glow discharge at the B-cathode will be extinguished. Thus, a single pulse from V3 causes V4 to step from one A-cathode to the next A-cathode. Connecting the A-cathodes in two circuits each with separate cathode circuits, biases the ionized cathode at approximately 40 volts above the next cathode. This 40-volt potential facilitates stepping in a forward direction and reduces the possibility of back-stepping from a B-cathode to the previous A-cathode. Connection to the last A-cathode is omitted in V4, preventing the tube from counting beyond 90 milliseconds. Since the normal burst time interval will always be less than this value, the 90-millisecond limit will prevent confusion if the burst time should ever exceed 100 milliseconds.

e. Operation of the RESET switch. The RESET switch, which must be operated before all burst and fail-safe time measurements, insures that relay K2 is in the proper position and that all circuit elements are supplied the proper potentials at the start of burst time measurement. Operation of the RESET switch normalizes the burst counting tubes. When the contacts of the switch open, a -60v signal is applies to capacitors C6A and C6B, which couple the rapid change in voltage. This change in voltage appears in the form of a sharp negative pulse on the normalizing cathodes in V3 and V4. The amplitude of this pulse is sufficient to raise the amplitude of the anode to normalizing cathode voltage by an amount capable of capturing the glow discharge from any other cathode in the counting tube. When the glow discharge is captured by the normalizing cathode, the counting tube is normalized. When the RESET switch is released and its contacts closed, the counting tubes will remain normalized because no input signal is present to cause a change in position of the glow discharge. In V3, the normalizing cathode is biased to the potential of the A-cathode through CR1. No potential on the normalizing cathode is applied to the A-cathodes, but any potential on the A-cathode will be felt on the normalizing cathode. When the START switch is depressed, the first negative signal output of V2A will be applied to the A-cathodes. Because of the action of CR1, the negative half-cycle will not be coupled to the normalizing cathode. The

96. DETAILED CIRCUIT OPERATION (fig II-98)

a. Deflection amplifiers. The two deflection amplifiers in the oscilloscope are single-stage R-C coupled, pentode amplifiers. Only the vertical amplifier circuitry will be discussed because the circuitry of the horizontal amplifier is identical. Sine waves from the reference oscillator are coupled through C1 and applied to the grid of V1. The grid signal is developed across R1, which is the d-c grid return for V1. Cathode bias for the stage is developed across R2. Resistor R3 is a screen-dropping resistor, and C2 is a screen bypass capacitor. The output signal from V1 is developed across the series combination of R4 and R5 and is coupled through C3 to one of the vertical deflection plates in the cathode ray tube V2. Capacitor C3 isolates the deflection plate potential from that on the plate of the amplifier. The input to the horizontal amplifier in the 2,000-cps, 1,600-cps, and 2,400-cps positions is an integrated square wave (triangular wave) from the frequency-modulated multivibrator in the command modulator circuit. This input provides a back-and-forth sweep so that the trace and retrace of the 24-kc sine wave standard produces a Lissajous type of pattern. In the YAW, PITCH, BURST, and TIME positions, the horizontal inputs are always sine waves. The horizontal deflections from these sine waves combine with the vertical deflections from the reference oscillator outputs to produce ordinary Lissajous patterns.

b. Cathode ray tube V2. Operating potentials for V2 are derived from voltage dividers between the +300-volt supply and ground, and from the +900-volt source in the power supply. The cathode of V2 is kept at a positive 60-volt potential by the voltage divider R8, R9, and R10. A variable positive potential is applied to the focusing anode from potentiometer R8. SCOPE BRIGHTNESS control R12 furnishes a variable potential to the control grid. If the control grid is grounded, it becomes negative with respect to the cathode and the tube is cut off. Blanking is obtained by grounding in this manner through section S1E of the COMMAND CAL switch. In the BAL position the ground is applied through terminals 5 and 4 of S1E. In the MEAS position the ground is applied through terminals 10 and 9, and resistor R53 in the command modulator. This resistor is low in value compared with R10 in the oscilloscope, and the grid becomes effectively grounded. The +900-volt potential is applied to the deflection plates as well as to the accelerating anode of V2. A positive 900-volt potential on the accelerating anode alone is not sufficient to produce a bright enough pattern on the tube face because V2 is designed to operate at a higher accelerating anode potential. For this reason, additional acceleration of the electrons is provided by maintaining the deflection plates at a high positive potential. The vertical deflection signal is applied to only one vertical deflection plate and the horizontal deflection signal is applied to only one horizontal deflection plate. Signal developing resistors R6 and R7 prevent the deflection signal voltages from

Table X. Oscilloscope calibration frequencies.

Position of COMMAND CAL switch.	Frequency applied to horizontal input.	Frequency applied to vertical input.
2,000 cps	2,000 cps	24 kc
1,600 cps	1,600 cps	24 kc
2,400 cps	2,400 cps	24 kc
BAL	Oscilloscope blanked out	in this position.
YAW	150 cps	6 kc
PITCH	500 cps	6 kc
BURST	857.15 cps	6 kc
TIME	Microsecond oscillator	1 mc
MEAS	Oscilloscope blanked out	in this position.

CAL switch, the oscilloscope merely monitors the frequencies of the corresponding oscillators. Frequency calibration of these oscillators is not a part of the r-f test set calibration procedure. The output of the burst oscillator is set at 857.14 cps because the burst frequency of 880 cps is not an even factor of 6 kc and therefore will not form a stationary Lissajous pattern with the 6-kc reference. In the TIME position, the output of the microsecond oscillator is adjusted to the nearest full microsecond to the battery code.

95. LOCATION AND PHYSICAL CHARACTERISTICS (fig II-46)

The oscilloscope chassis (fig II-69) is located in the test set upper drawer assembly (fig II-53). It is a front panel subassembly with the cathode ray tube face and the SCOPE BRIGHTNESS control on the panel. Also mounted on this panel are the r-f signal generator OUTPUT and FREQ controls and the ANT2-ANT4 switch. These last three controls have nothing to do with oscilloscope operation. The oscilloscope chassis measures 11.5 x 5.5 x 5 inches and weighs approximately 3 pounds It is secured to the upper drawer framework by captive (Phillips-type) screws. Signal and blanking inputs from the COMMAND CAL switch enter the oscilloscope chassis through J3. Operating potentials from the power supply are also brought into the oscilloscope via J3.

99. BLOCK DIAGRAM (fig II-95)

a. The ⨍300 volt supply. The high-voltage 400-cycle, a-c output from the power transformer is full-wave rectified and filtered by V1, V2, and L1 and fed into a series regulator V3, V4, and V5. The amplifier-regulator circuit consists of a reference tube V7, a comparator stage V6B, and an amplifier stage V6A. A reference potential is established by V7. Comparator V6B compares the power supply output voltage with the reference voltage. If the correct relationship between the two voltages does not exist, an error voltage is fed from V6B to the amplifier V6A. This error voltage is amplified by V6A and applied to series regulator V3, V4, V5. The error voltage changes the impedance of the series regulator so as to return the power supply output voltage to its correct value. When the output voltage is of the correct value, no error voltage will be produced by the comparator stage. This voltage regulator circuit is actually a closed servo loop having the basic characteristics of any servo system.

b. The -250-volt supply. The -250-volt supply consists of a rectifier, filter, series regulator, and amplifier-regulator. Operation of this circuit is the same as for the ⨍300-volt supply. Differences from the ⨍300-volt supply are in the rectifier and series regulator which use only a single tube each because of the lower current requirements of the -250-volt supply. Tube connections in the amplifier-regulator section are also changed to conform to the negative output polarity.

c. The ⨍900-volt supply. The peak a-c voltage of approximately 650 volts from one-half of the power transformer secondary winding is rectified, filtered, and connected in series with the output of the ⨍300-volt supply to provide the ⨍900-volt output. This ⨍900-volt potential will vary over considerable limits because it is unregulated. This variation, however, is permissible since the ⨍900 volts is used only as an accelerating potential for the cathode ray tube in the oscilloscope circuit.

100. DETAILED CIRCUIT OPERATIONS (fig II-96)

a. The ⨍300-volt rectifier and filter. Secondary 5, 6, and 7 of T1 provides a peak a-c potential of about 1,300 volts. This voltage is applied to the plates of two parallel-connected rectifier tubes V1 and V2. The centertap of the secondary of T1 is grounded. Fullway rectification of the transformer output is performed by V1 and V2. A filter section consisting of inductor L1 and capacitors C1 and C2 partly smoothes the rectifier output. Resistors R1 and R2 insure that equal voltages will be across C1 and C2, and also provide a bleeder resistance so that C1 and C2 will not regain their charge after the power being grounded out in the +900-volt supply. None of the +900-volt accelerating potential is dropped across R6 and R7 because the deflection plates do not draw current from the electron stream.

Section XII. POWER SUPPLY

97. GENERAL

a. The GS-15741 power supply furnishes the necessary operating potentials for the various circuits in the missile r-f test set. The input to the power supply is 120-volt, 400-cycle, single-phase power. The outputs are:

+ 300 volts at 500 milliamperes.

\- 250 volts at 50 milliamperes.

+ 900 volts at 100 microamperes.

6.3 volts a-c.

b. The +300-volt and -250-volt supplies are regulated, but the +900-volt supply is unregulated. The regulation of the +300-volt supply maintains the output constant within ±0.1 volt for current drains varying from 250 to 500 milliamperes, and ±0.3 volt for line voltage changes of ±6 volts. The regulation of the -250-volt supply is ±0.4 volt for load changes from 15 to 50 milliamperes, and ±0.25 volt for line voltage changes of ±6 volts.

c. A 28-volt d-c supply for the operation of the switch attenuations in the waveguide and antenna coupler is located in the burst oscillator chassis. This 28-volt supply is unregulated and unfiltered.

98. LOCATION AND PHYSICAL CHARACTERISTICS

The power supply chassis (fig II-68) is located in the test set lower drawer assembly. The chassis measures 12.5 x 11.5 x 6.5 inches and weighs approximately 18 pounds. It is secured in the lower drawer assembly by Airloc fasteners. The CAL V control for adjustment of the output of the +300-volt supply is located on the front panel of the r-f power meter chassis. The ADJ -250v screwdriver adjustment for the -250-volt supply output is located on the front panel of the microsecond oscillator chassis. Power supply input and output voltage connections are made through plugs P13 and P14.

d. The -250-volt supply. Operation of the -250-volt supply is essentially the same as that of the +300-volt supply. The a-c voltage from secondary 8, 9, and 10 of T1 is full-wave rectified by V8 and filtered by L2, C11, and C12. Duotriode V9 is a series regulator tube. Resistors R33 and R34 are parasitic suppressors, and R35 and R36 equalize current flow through both sections of V9. The amplifier-regulator section consists of reference tube V11, comparator stage V10B, and amplifier stage V10A. Tubes V10B and V10A together with associated circuit components make up a direct-coupled amplifier. The reference tube V11 holds the cathode of V10B at a constant potential of 87 volts. A portion of the variations in output voltage is applied to the grid of V10B by a voltage divider consisting of R25, R43, and R42. Rapid changes in output voltage are coupled to the grid of V10B by C14. Rheostat R25 determines the operating point of the direct-coupled amplifier and series regulator and therefore the output voltage of the supply. Increases in the negative output voltage produce a negative error voltage input to V10B with a resulting negative voltage output from the direct-coupled amplifier at the plate of V10A and grid of series regulator tube V9. This negative voltage increases the voltage drop across V9 and restores the output voltage to its correct value. If the output voltage becomes less negative, the regulator functions as described above, but the regulating process is reversed.

e. The +900-volt supply. The +900-volt supply consists of capacitor C3, half-wave rectifier CR1, and a pi-section filter. Capacitor C3 is charged to a potential of 300 volts by the +300-volt supply. The charge path is from ground through terminal 6 of T1, from terminal 5 of T1 to the left plate of C3, and from the right plate of C3 through R15 to the +300-volt supply. The 650-volt peak a-c voltage from terminal 5 of T1 is biased positively to a +300-volt reference by C3 and is applied to rectifier CR1. The rectifier CR1 passes only the 950-volt positive peaks and blocks the 350-volt negative peaks of the sine wave. This pulsating d-c is filtered by C5, R16, and C6. Due to voltage drop across CR1 and the voltage divider action of R16 with bleeder resistors R17 and R18, the final output voltage will be in the vicinity of +900 volts.

supply has been turned off. The output from the filter to the series regulator tubes is about 400 volts.

b. The +300-volt series regulator section. Tubes V3, V4, and V5 comprise the series regulator section of the +300-volt supply. All three tubes are connected in parallel to provide the required current carrying capacity. The voltage drop across the regulator tubes is controlled by the potential on their control grids. Voltage drop across the tubes increases with a more negative potential on their grids and decreases as the grid voltage goes in a positive direction. The error voltage output from the amplifier-regulator section is applied to the grids of the series regulator tubes, controlling their voltage drop and consequently the d-c output of the +300-volt supply. Resistors R3 through R8 suppress high-frequency parasitic oscillations. Cathode resistors R9 through R14 aid in equalizing the current flow through each tube section by increasing the negative bias of the section that tends to pass more than its share of current.

c. The +300-volt amplifier-regulator. The amplifier-regulator section of the +300-volt power supply consists of a reference tube V7, a comparator stage V6B, and an amplifier stage V6A. Tube V7 is a cold-cathode, gas-discharge tube which maintains a constant potential of 87 volts across it. Variations in power supply output voltage are dropped across R30. The grid of V6B is held at the fixed reference voltage by V7. Resistor R29 and capacitor C9 act as an R-C filter to prevent small sudden voltage variations across V7 from being applied to the grid of V6A. Triodes V6B and V6A together with associated resistors make up a two-stage, direct-coupled amplifier. A portion of the power supply output voltage changes are applied to the cathode of V6B by a voltage divider consisting of R24, R25, R26, R27, and R52. Rapid changes in output voltage are coupled directly to the cathode of V6B by C7. If the power supply output changes in a positive (negative) direction, the cathode of V6B also goes in a positive (negative) direction, and the output of the direct-coupled amplifier at the plate of V6A goes in a negative (positive) direction. This negative (positive) going voltage increases (decreases) the drop across the series regulator tubes and restores the output voltage to its correct value. Potentiometer R26 establishes the operating point of V6B and therefore the output voltage. Rheostat R52 is a fine adjustment that does the same thing as R26. Resistor R19 and capacitor C4 reduce the gain of V6A at high frequencies to reduce the possibility of oscillations being set up by the error voltage feedback loop. Capacitor C8 provides additional filtering of the output voltage. Power is supplied to the pitch, yaw, and burst oscillators from the +300-volt supply through R-C filters which further smooth the 800-cps ripple. Only a small portion of the available B+ to the oscillators is dropped across the 2,200-ohm resistors in the R-C filters.

Holddown fitting, separation switch	8013805
Hydraulic test stand	8001840
Lower drawer assembly	GS-15725
Microsecond oscillator	GS-15737
Oscilloscope	GS-15728
Pitch oscillator	GS-15738
R-F power meter circuit	GS-15730
Power supply	GS-15741
Pulse selector	GS-15731
Pulser	GS-15727
Reference oscillator	GS-15742
Response indicator	GS-15732
R-F signal generator	GS-15733
R-F test set	GS-15722
Stagnation pressure pump	8001829
Test control unit	8001834
Test power control unit	8001832
Upper drawer assembly	GS-15724
Waveguide assembly	8015657
Waveguide, flexible	8175489
Yaw oscillator	GS-15739

GLOSSARY

Antenna coupler	GS-16888
Blower, guidance section	8020096
Burst oscillator	GS-15740
Burst timer	GS -15729
Cabinet assembly, r-f test set	GS-15723
Cabinet, test equipment	8001813
Cables	
A-C power	8004456
Switching attenuator	8015648
Battery simulator	8004459
Blower, guidance section	8020090
Ground power	8004461
Guidance section test	8004458
Missile test	8004457
R-F test	8004460
Case, electrical test equipment	8001828
Command modulator	GS-15736
Common equipment, lower drawer	GS-15735
Common equipment, upper drawer	GS-15726
Dolly, missile	8001838

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