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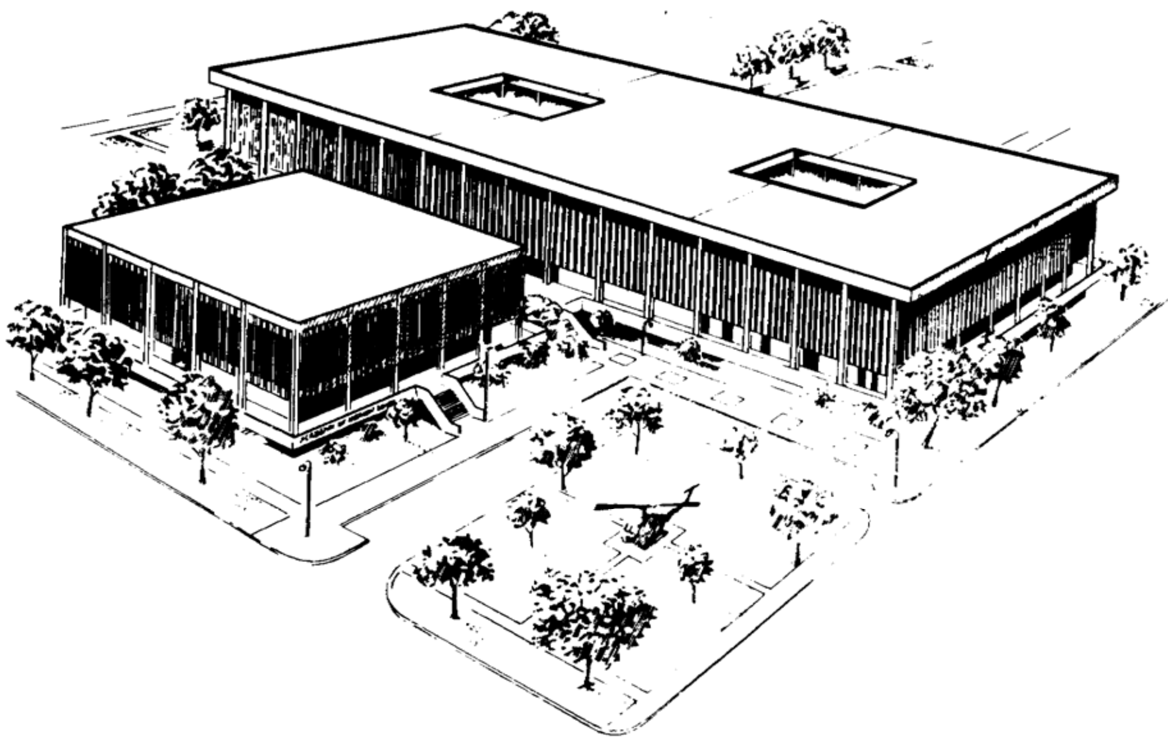

SUCTION/PRESSURE APPARATUS

SUBCOURSE MD0365 EDITION 100

DEVELOPMENT

This subcourse is approved for resident and correspondence course instruction. It reflects the current thought of the Academy of Health Sciences and conforms to printed Department of the Army doctrine as closely as currently possible. Development and progress render such doctrine continuously subject to change.

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CORRESPONDENCE COURSE OF
THE U.S. ARMY MEDICAL DEPARTMENT CENTER AND SCHOOL

SUBCOURSE MD0365

SUCTION/PRESSURE APPARATUS

INTRODUCTION

In hospitals, clinics, and physicians' offices, there is a need for compressed air (positive pressure) and suction (negative pressure). Suction and/or pressure is required by the ear, nose, and throat specialists, proctologists, surgeons (during and after surgery), and general practitioners.

Suction is used to clear mucus, saliva, blood accumulation, and solutions used for bronchoscopes and in tracheotomy tubes. Suction is also used in connection with pressure to operate sinus and tonsil cleansing equipment.

Pressure operates atomizers and nebulizers and breaks solutions down into fine sprays, mists, and vapors. It is used in conjunction with special nebulizers for aerosol administration of penicillin or other antibiotics. It is also used to power the hypodermic-injection apparatus when giving mass inoculations to a large number of personnel.

The Emerson 55-JS suction pump performs similar to the rotary compressor unit. It is a high-volume, low-pressure unit. Suction is produced by a permanently attached (fixed) vane system in a one-piece motor assembly. The suction pump works on the same principle as a vacuum cleaner. The amount of suction produced is controlled by increasing or decreasing the speed of the motor. The pressure produced is very small and cannot be used to operate other items of equipment. As one of the primary "care pieces" of medical equipment, a good working knowledge of this unit is essential.

Subcourse Components:

This subcourse consists of two lessons.

Lesson 1, High-Volume Suction Apparatus.

Lesson 2, Programmable Suction Apparatus.

Here are some suggestions that may be helpful to you in completing this subcourse:

--Read and study each lesson carefully.

--Complete the subcourse lesson by lesson. After completing each lesson, work the exercises at the end of the lesson, marking your answers in this booklet.

--After completing each set of lesson exercises, compare your answers with those on the solution sheet that follows the exercises. If you have answered an exercise incorrectly, check the reference cited after the answer on the solution sheet to determine why your response was not the correct one.

Credit Awarded:

Upon successful completion of the examination for this subcourse, you will be awarded 5 credit hours.

To receive credit hours, you must be officially enrolled and complete an examination furnished by the Nonresident Instruction Branch at Fort Sam Houston, Texas.

You can enroll by going to the web site http://atrrs.army.mil and enrolling under "Self Development" (School Code 555).

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LESSON ASSIGNMENT

LESSON 1	High-Volume Suction Apparatus
TEXT ASSIGNMENT	Paragraphs 1-1 through 1-8
TASKS TAUGHT	Isolate Malfunctions to Component Level in High-Volume Suction Apparatus. Perform Preventive Maintenance Checks and Services (PMCS) on the High-Volume Suction Apparatus.
LESSON OBJECTIVES	When you have completed this lesson, you should be able to: 1-1. Identify procedures used to operate the high volume suction apparatus. 1-2. Identify action taken to calibrate operating components of the high-volume suction apparatus. 1-3. Identify procedures required to troubleshoot the high-volume suction apparatus and isolate malfunctions. 1-4. Identify periodic preventive maintenance checks and services on the high-volume suction apparatus.
SUGGESTION	Work the lesson exercises at the end of this lesson before beginning the Examination. These exercises will help you accomplish the lesson objectives.

LESSON 1

HIGH-VOLUME SUCTION APPARATUS

Section I. OPERATIONAL PROCEDURES

1-1. GENERAL

The high-volume, low-pressure suction apparatus is found in most hospital wards and recovery and emergency rooms. Its most common use is in recovery. For example, following chest surgery, a catheter is placed in the patient's pleural cavity. The catheter is connected to a collection bottle and the suction source. The high-volume suction pump supplies a vacuum of 0 to 60 centimeters of water (cmH_2O) to keep body fluids drained. The removal of fluids is vital as it aids in prevention of infection and allows the wound to heal faster. The unit, once set, maintains a constant suction.

1-2. COMPONENTS

Now that you know what the suction apparatus does, the lesson will discuss the major components which make it function.

a. **Vacuum Motor**. The vacuum motor is identified as M1 in the schematic wiring diagram shown in figure 1-1. It operates in the vane method, but in this case, the vanes are fixed (non-movable). The vanes extend from the motor to the housing. As the motor spins, the vanes pull a vacuum at one or more openings and push the air out of another opening. This creates suction to the collection bottle. The motor is replaced as a unit.

b. **Off/On Switch**. The off/on switch is identified as S1 in the schematic (figure 1-1).

c. **Convenience Outlet**. The convenience outlet is shown in the schematic. It is neither a load device <u>nor</u> is it controlled by the off/on switch.

d. **Pilot Light**. The pilot light is lit when the switch (S1 in the schematic) is closed.

e. **Variac Switch**. Labeled A1 in the schematic (figure 1-1), the Variac is a speed control. The winding between A1-2 and A1-3 is the power source for the M1 circuit.

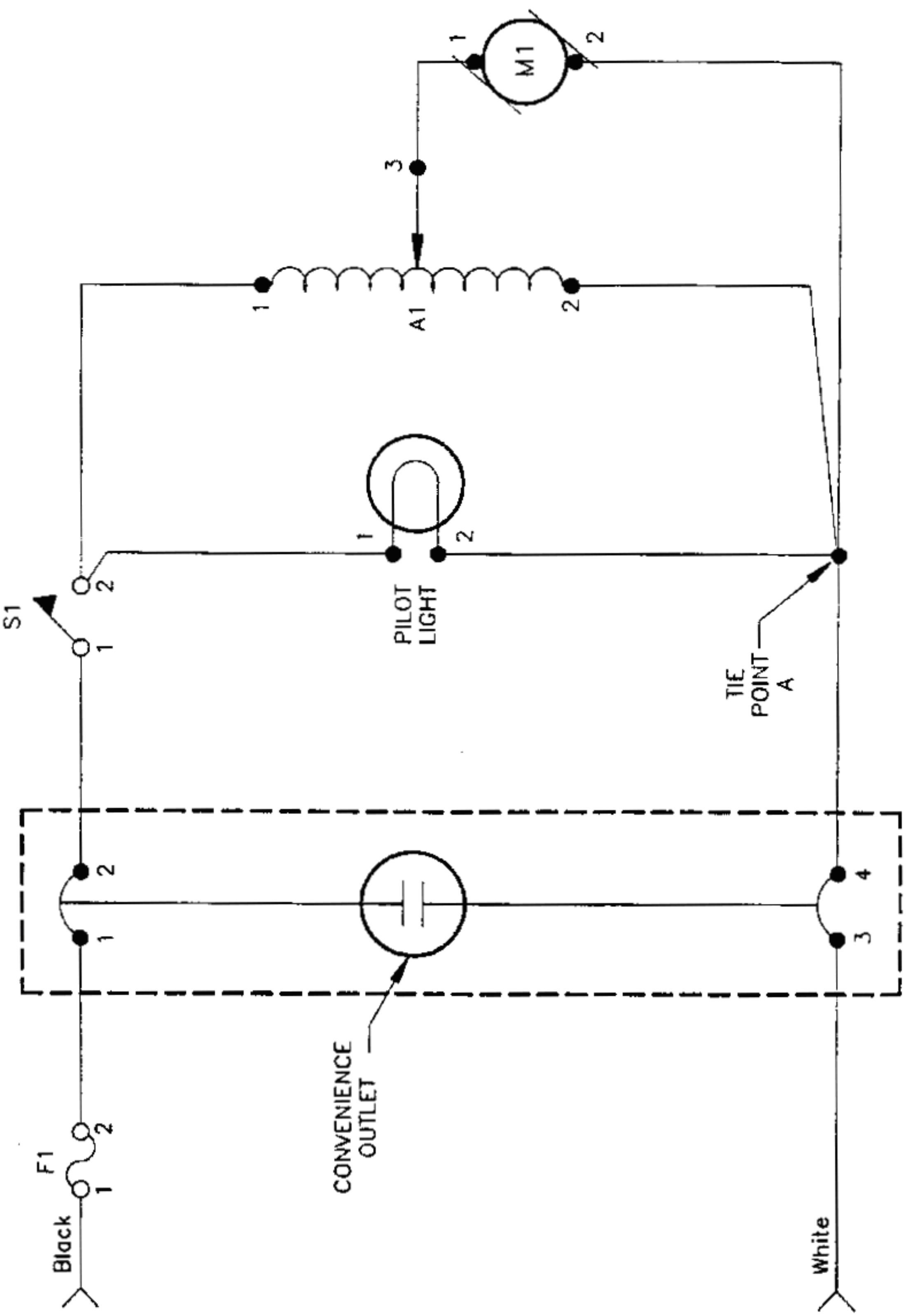


Figure 1-1. Schematic wiring diagram of the Emerson 55-JS suction apparatus.

1-3. CIRCUIT OPERATION

The electrical power requirement for the suction apparatus is 120 volts of alternating current (vac). The unit has the aforementioned convenience outlet which you can use as an additional power source for another item of electrical equipment. As you can see from the schematic, the convenience outlet is hot (energized) as soon as the power cord is plugged into a grounded wall outlet.

CAUTION: Before plugging the power cord into a wall outlet, ensure the power switch is off and the speed control (Variac) is turned to the minimum or OFF position.

a. When S-1 is closed, the pilot light is energized and the 120vac is also applied to A1-1 and A1-2, energizing the primary side of the Variac (A1). The secondary side of A-1 is from A1-1 to A1-3 and is the power source for M1, the motor.

b. By rotating the Variac speed-control knob clockwise or counterclockwise, the operator varies (increases or decreases) the speed of the motor and the amount of suction produced. To verify the unit is creating negative pressure (or suction), attach the tubing and collection bottle to the unit. Fill another bottle with water, attach it to the system, and turn the unit on. Increase the speed (RPM) of the motor and observe the vacuum gauge. The gauge should indicate 20 to 30 centimeters of water (cmH_2O) as water is being drawn from the water-filled bottle into the collection bottle.

Section II. MAINTENANCE AND REPAIR PROCEDURES

1-4. PREVENTIVE MAINTENANCE CHECKS AND SERVICES

Preventive maintenance checks and services (PMCS) is the Army's way of ensuring every piece of its equipment is ready to perform properly when called upon for service. A maintenance allocation chart (MAC) is not yet available for this piece of equipment.

a. **Suggested Maintenance Plan**. The manufacturer suggests the following maintenance procedures be followed.

(1) The equipment operator (EO) inspects and cleans the apparatus on a daily basis.

(2) The operator also checks apparatus tubing daily for any holes, splits, or breaks incurred during use.

(3) The EO cleans the collection and overflow bottles daily unless disposable collection bottles are used.

(4) Preventive Maintenance Checks and Services is performed every six months by a medical equipment repairer.

(5) All repairs, except user items, are to be performed during PMCS or on an as-needed basis.

b. **General Maintenance Information**. If everyone does his part to maintain the equipment, the common problems causing equipment malfunctions can be avoided.

(1) Common problems. Following are the common problems:

(a) Filters not changed when necessary.

(b) Collection and overflow bottles allowed overfilling, allowing fluid to enter system components.

NOTE: If fluid enters the compressor assembly, you must replace the motor.

(c) Split suction tubing.

(d) Bottle tops and jars not tightly sealed.

(2) Methods of measurement. The following are the methods of measurement.

(a) Pressure, including negative pressure (suction), is measured in millimeters of mercury (mmHg) or centimeters of water (cmH_2O).

(b) The Emerson high-volume suction apparatus measures suction in cmH_2O which is also the most common method of measurement.

(c) The measurement differential between mmHg and H_2O is 13.6. This means that one measurement mmHg equals 13.6 mm of H_2O. Since one cm equals ten mm, 1mmHg = 1.36cmH_2O. One atmosphere (the normal pressure of air at sea level) is 760mmHg or 1034cmH_2O.

(3) Operating specifications. Ensure the vacuum level is 0 to 60cmH_2O (0 to 44mmHg). Ensure the unit operates to the parameters specified in Table 1-1.

Static Vacuum of	$10cmH_20$	$20cmH_20$	$60cmH_20$
Flow @ pump inlet	120 lpm	160 lpm	280 lpm
Flow w/glass bottles & 4 ft 3/8 in ID tubing	32 lpm	55 lpm	95 lpm
Flow w/disp. bottles & 6 ft 3/8 in ID tubing	35 lpm	55 lpm	100 lpm

Table 1-1. Approximate flow rates.

(4) Vacuum testing. Perform the following procedures to test the vacuum.

(a) Use a 4 foot piece of 3/8 inch tubing and a water manometer that measures at least 0 to $70cmH_20$ or a mercury manometer capable of measuring a vacuum of 0 to 50mmHg.

(b) Connect the manometer to the patient connection part via the tubing.

NOTE: The manometer should read $0cmH_2O$.

(c) Turn the Emerson 55 JS on and slowly rotate the suction dial from the MIN position clockwise to the MAX position.

NOTE: While rotating this dial, the manometer level should rise as the vacuum increases. Within 10 seconds of reaching the MAX setting, the manometer should read $60cmH_2O$ (44mmHg). The vacuum indicator on the front panel should read ± $2cmH_2O$ of what the H_2O manometer reads across the full range of settings on the suction dial.

1-5. CIRCUIT EXPLANATION

Refer to figure 1-1 as we begin to trace the electrical circuit with the white wire also known as the neutral or ground wire.

a. The white wire from the wall outlet to the convenience outlet.

b. Through convenience outlets 3 and 4 to tie point A.

c. From tie point A to the pilot light 2, and to A1-1, and to M1-2.

d. Through the pilot light to pilot light 1 and on to S1-2.

e. Through A1 to A1-1 and on to S1-2.

f. Through M1 to M1-1 to A1-3 to A1, through the winding of A1 to A1-1 and on to S1-2.

g. Through S1 to convenience outlets 2 and 1.

h. To F1-2 and F1-1 and out the black wire.

NOTE: When troubleshooting the Variac (A1), take extreme care to avoid accidental shorting of A1-1, A1-2 or A1-3. To test for an open A1, the unit must be de-energized (turned off), the power cord removed from the grounded wall outlet, and the primary side of A1 isolated from the circuit. Then and only then can an ohmmeter be used to test for continuity in A1.

1-6. TROUBLESHOOTING TEST POINTS

You have learned the high-volume suction pump's circuits, now the lesson will discuss troubleshooting procedures on the system's electrical circuits. Troubleshooting the electrical circuit consists of testing for continuity between various points in the circuit. Test continuity between the following circuit points or terminations.

a. With the reference at convenience outlets 3 and 4, test at the following points:

(1) F1-1, F1-2.

(2) Convenience outlets 1 and 2.

(3) S1-1, S1-2.

(4) Pilot light 1.

(5) M1-1 and the armature brush.

b. With the reference at F1-2, test at the following points:

(1) Convenience outlets 3 and 4.

(2) Tie point A.

(3) Pilot light 2.

(4) A1-2.

(5) M1-2 and the armature brush.

c. With the reference back at convenience outlets 3 and 4, make the following voltage test.

(1) Test between A1-1 and A1-3 (rotate the speed-control knob to vary voltage at A1-3).

(2) Voltage should not be variable at any test point on the white side of the line when A1-3 is moved up or down on A1.

1-7. TROUBLESHOOTING GUIDE

In addition to troubleshooting the electrical circuit, the following troubleshooting guide will help you isolate system malfunctions. Table 1-2 lists the symptoms, probable causes, and corrective actions to remedy the symptoms you will likely encounter with the Emerson 55-JS High-Volume Suction Apparatus.

1-8. REMOVE AND REPLACE DEFECTIVE COMPONENTS

Once you have isolated the causes of equipment malfunctions or defective components, disassemble the apparatus and remove or service the malfunctioning parts. The following paragraphs show you how to accomplish this.

a. **On/Off Switch**. Disconnect the power cord from the wall outlet. Remove the 12 sheet-metal screws securing the front panel. Tip the front panel forward, face down. Mark the black and white wires for proper re-soldering on the new switch. Remove the bad switch and install the new one. Re-solder the previously marked wires and reassemble the unit in reverse order.

b. **Variac Control.** Refer to figure 1-2. Disconnect the three wires to the Variac speed control (A1). Loosen the Allen screw on the speed-control knob and pull the knob off. Remove the shaft nut and machine screw securing the Variac control to the panel. Two adjusting screws are used to adjust the speed. Replace the defective Variac with the new control. Reassemble the speed-control assembly in the reverse order.

PROBLEM	POTENTIAL CAUSE	CORRECTIVE ACTION
1. Unit does not energize.	1. Power cord not plugged in. 2. Circuit breaker open.	1. Connect power cord. 2. Reset circuit breaker
2. Unit energizes but Motor does not rotate.	1. Worn brushes.] 2. Speed control at minimum. 3. Speed control at maximum. 4. Armature commutator dirty. 5. Open motor windings.	1. Replace brushes (para 1-8) 2. Adjust speed control (para 1-8b) 3. Replace speed control (para 1-8) 4. Clean with #400 emery paper. 5. Replace motor
3. Pilot light does not glow.	1. Open pilot light.	1. Replace lamp.
4. Unit runs, but no suction.	1. Tubing not connected. 2. Bottles not sealed. 3. Patient or bottle tubes blocked. 4. Tubing split or cracked.	1. Connect tubing. 2. Tighten bottle tops. 3. Clear obstruction. 4. Replace tubing.
5. There is suction but no reading on gauge.	1. Defective gauge.	1. Replace vacuum gauge.
6. There is no suction but unit runs.	1. Plugged inlet connector.	1. Replace inlet connector.

Table 1-2. Troubleshooting guide.

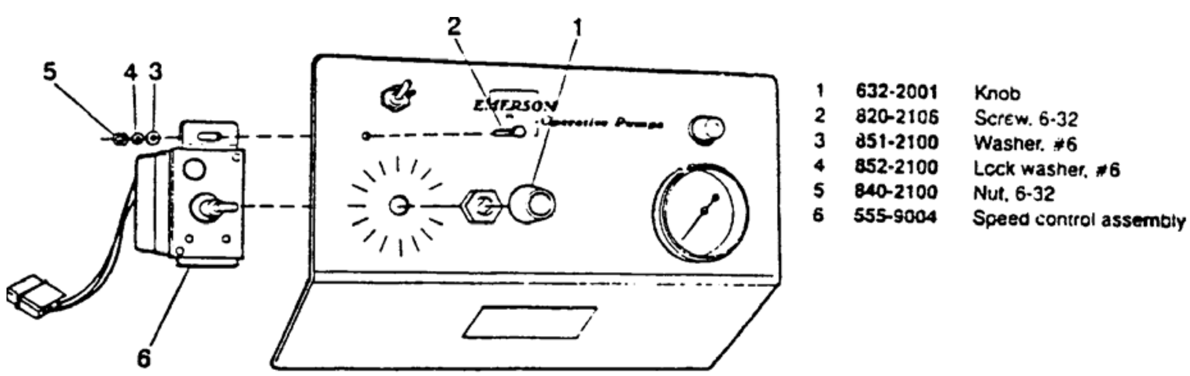


Figure 1-2. Removal of Variac speed control.

c. **Electric Motor.** Refer to figure 1-3. Disconnect the power cord from the wall outlet. Remove the 12 sheet-metal screws securing the front panel. Tip the panel forward and disconnect the black lead at the unit circuit break, unplug the two-pin Jones plug (15) to the motor, and disconnect the white wire at the power cord. Lay the panel out of the way. Remove the one-inch flex tubing (not shown) from the left side of the motor. Disconnect the white 3/8-inch breather tube (3) from the bottom of the cabinet. Remove the hex nuts (11) from the three rubber feet (9) at the three motor-mount brackets. Lift the motor up to clear the studs on the rubber feet. Move the motor to the back of the cabinet, push the motor down and tilt it forward to clear the lip on the front of the cabinet and pull the motor out toward you. Reassemble and replace the motor in the reverse order.

d. **Motor Brushes**. Remove the motor as described above and illustrated in the upper portion of Figure 1-3. Place the motor on its side. Refer to the bottom of Figure 1-3. Remove the two screws on the motor's bottom holding each brush mount. Replace the brushes and reassemble in reverse order.

<u>NOTE</u>: After installing a new motor or motor brushes, always run the motor at a slow to medium speed to allow the brushes to "break-in" and seat properly.

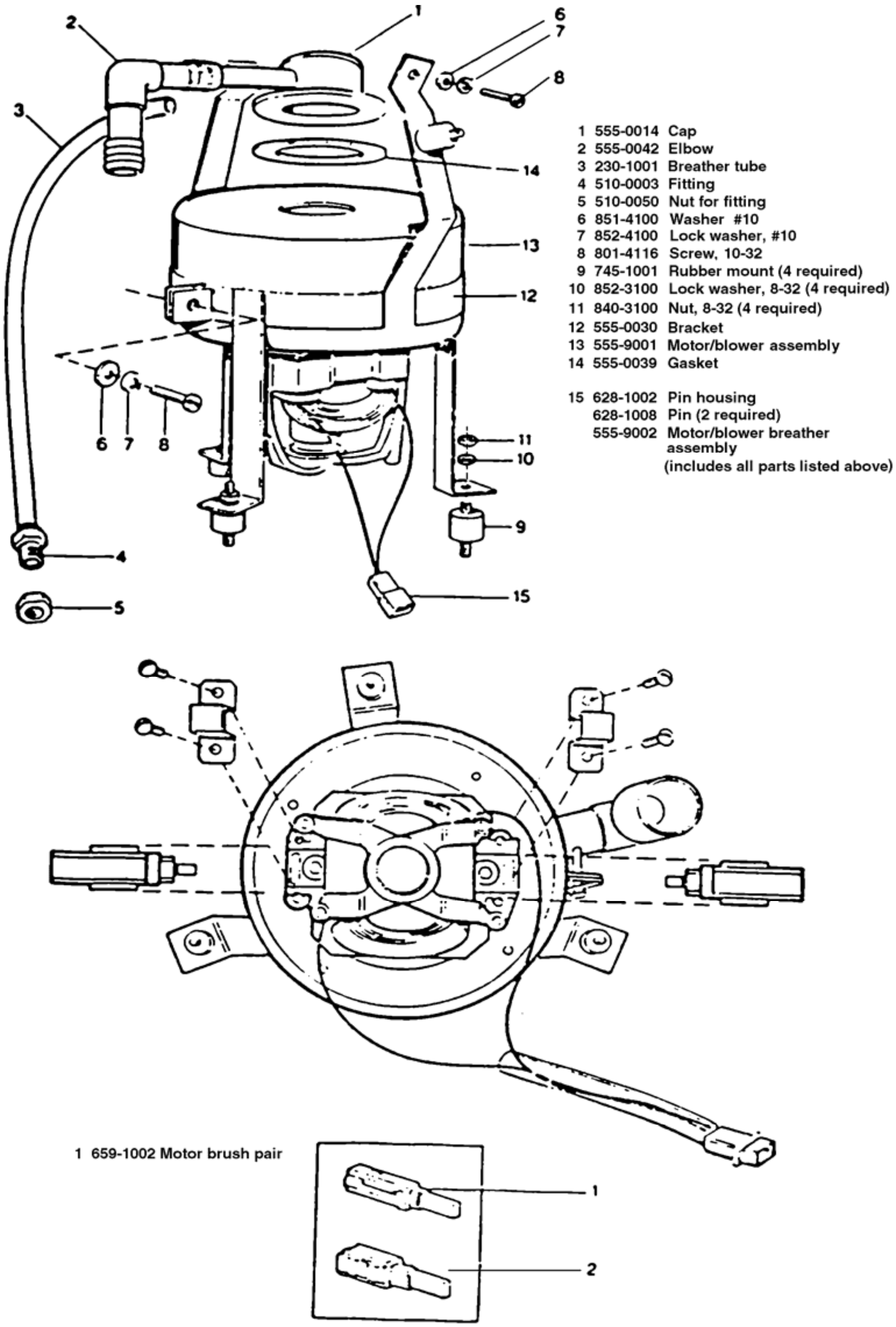


Figure 1-3. Motor removal and brush installation.

Continue with Exercises

EXERCISES, LESSON 1

INSTRUCTIONS: Answer the following exercises by circling the lettered response that best answers the question.

After you have answered all of the exercises, turn to "Solutions to Exercises" at the end of the lesson and check your answers. For each exercise answered incorrectly, reread the lesson material referenced after the solution.

1. Which of the following statements about the convenience outlet on the Emerson 55-JS suction apparatus is correct?

    a. The convenience outlet is controlled by the off/on switch.

    b. The convenience outlet controls the pilot light.

    c. The convenience outlet is a load device.

    d. The convenience outlet is energized when the power cord in plugged in to a wall outlet.

2. You are verifying negative pressure with a bottle of water. As the water is drawn to the collection bottle, what is the pressure gauge reading?

    a. 20 to 30mmHg.

    b. 20 to 30cmH_2O.

    c. 2 to 3mmHg.

    d. 45 to 60cmH_2O.

3. How often is PMCS performed on the 55-JS suction apparatus by a medical equipment repairer?

    a. Daily.

    b. Weekly.

    c. Semi-annually.

    d. Annually.

4. Which of the following is a common maintenance problem of the 55-JS vacuum pump?

   a. Collapsed tubing.

   b. Unchanged filters.

   c. Variac speed-control failure.

   d. Burnt-out motor windings.

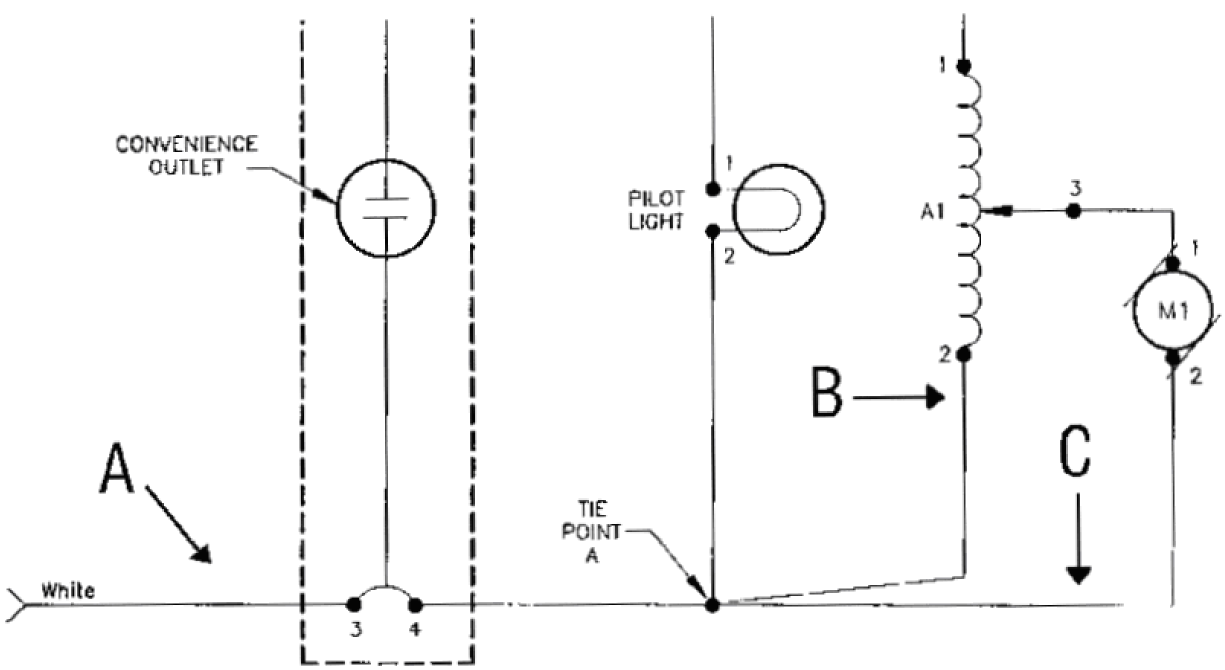
5. Refer to the figure below. Which of the following statements describes the circuit leg labeled "C?"

   a. Tie point A to M1-2.

   b. Through convenience outlets 3 and 4 to tie point A.

   c. Through A1 to A1-1 and on the S1-2

   d. From S1 to convenience outlets 2 and 1.



6. Which of the following are good troubleshooting reference points for the Emerson 55-JS suction pump?

   a. A1-2 and A1-3.

   b. Pilot light 2 and tie point A.

   c. A1 and M1-1.

   d. Convenience outlets 3 and 4 and F1-2.

7. A clinician reports a problem with the 55-JS suction pump. The pump runs but the motor does not turn. You inspect the brushes and Variac control, which are functioning properly. You inspect the armature commutator and find it is dirty. What corrective action do you take?

   a. Replace the commutator.

   b. Clean the commutator with #400 emery paper.

   c. Remove the commutator and clean it with solvent.

   d. Remove the commutator and clean it with Lubewick.

8. You are removing the Variac control to adjust the motor speed. You first unscrew the Allen screw securing the control knob and remove the knob. What's next?

   a. Tip the front panel toward you and slide the control sideways.

   b. Remove the 12 screws holding the front panel in place.

   c. Remove the four screws holding the control in place and push the control into the assembly.

   d. Remove the shaft nut and machine screw holding the control to the front panel.

Check Your Answers on Next Page

SOLUTIONS TO EXERCISES: LESSON 1

1. d (paras 1-2c, 1-3)
2. b (para 1-3b)
3. c (para 1-4a(4))
4. b (para 1-4b(1)(a))
5. a (para 1-5c)
6. d (para 1-6a, b)
7. b (Tables 1-2, 2-4)
8. d (para 1-8b)

End of Lesson 1

LESSON ASSIGNMENT

LESSON 2 Programmable Suction Apparatus.

TEXT ASSIGNMENT Paragraphs 2-1 through 2-7.

TASKS TAUGHT Perform PMCS on the Programmable Suction Pump.

Isolate Malfunctions to the Component Level in the Programmable Suction Pump.

Remove and Replace or Repair Defective Components of the Programmable Suction Pump.

LESSON OBJECTIVES When you have completed this lesson, you should be able to:

2-1. Identify the procedures used to operate the programmable suction pump and identify major components of the apparatus.

2-2. Identify procedures used to perform an operational checkout of the programmable suction pump.

2-3. Identify procedures required to calibrate the programmable suction pump.

2-4. Identify the common actions required to isolate and correct malfunctioning components in the programmable suction pump.

2-5. Identify the procedures used to perform PMCS, troubleshoot the system, and remove and replace or repair malfunctioning components of the programmable suction pump.

SUGGESTION Work the lesson exercises at the end of this lesson before beginning the examination. These exercises will help you accomplish the lesson objectives.

LESSON 2

PROGRAMMABLE SUCTION PUMP

Section I. OPERATIONAL PROCEDURES

2-1. GENERAL

Lesson 1 discussed operation and maintenance of the high-volume suction apparatus and traced its electrical circuits. Lesson 1 also provided a number of troubleshooting techniques to help you isolate and remedy malfunctions in the system. Lesson 2 deals with the same topics, applying them to a different suction apparatus, a programmable suction pump. The title of this piece of equipment identifies its function and difference from the previously discussed suction apparatus: the Impact Model 306M Programmable Intermittent Suction System. With the programmable feature, the clinician may determine periods of intermittent suction rather than being constrained to continuous suction. Discussed below are some of the system's unique aspects.

a. **Electronic Vacuum Regulator**. This circuit differs from conventional mechanical regulators in several ways. First, the regulator is eliminated from the vacuum path and, therefore, cannot leak, clog, jam, or stick. Second, the regulator is energy efficient; it only draws current proportional to the amount of vacuum required. Third, the regulator can precisely select vacuum levels with micrometer precision for the most critical suction needs.

b. **Electronic Intermittent Suction Circuits**. These circuits determine ON and OFF times, selectable in 144 different combinations. The off circuit shuts down virtually the entire unit during its time period, thereby maximizing energy efficiency. The on circuit immediately energizes the system for prompt response.

c. **Emergency Battery**. A sealed lead-acid (GEL Cell) battery is provided for emergency and transitory use. Its operating life varies depending upon what vacuum levels are drawn. With this in mind, a high-capacity battery was chosen which can provide over one hour of continuous use at maximum vacuum (550mmHg). At 200mmHg, cycled intermittently at five seconds ON and five seconds OFF, the battery will provide more than 12 hours of continuous use. Because this battery is not considered the primary power source, restrict its use to emergencies and transport to ensure available power.

2-2. MAJOR COMPONENTS

This paragraph discusses other major components within the suction system not dealt with above.

a. **Collection Jar System**. Always use an overflow-trap bottle to protect the suction mechanism from overflows which may permanently damage the vacuum pump. Vacuum tubing is provided for connection of collection canisters to the rear-panel barbed hose inlet. A disposable filter, which is both hydrophobic and bacterial (i.e., repels liquids and retains bacteria), is provided. This filter connects between the rear-panel barbed hose inlet and final collection canister (trap unit). This filter should be replaced when discoloration of its membrane occurs, the membrane contacts aspirate, or following 150 cumulative hours of use. This filter is designed to retain bacteria which would otherwise be exhausted into the immediate vicinity. Do not bypass this filter.

b. **Batteries**. The model 306M utilizes sealed gel-cell batteries which offer excellent charge retention characteristics, particularly during long periods of storage. This ensures an ample amount of power during emergencies and transitory procedures. The battery pack in this device is not intended for routine, day-to-day use; therefore, it should be used with discretion and its design thoroughly understood. To provide long life and maximum performance capabilities, the model 306M requires sixteen hours to fully recharge its fully discharged batteries. Of course, the batteries are rarely discharged this much, so the subsequent recharge-time is usually less. GEL Cell batteries require little user care to provide optimum performance and life expectancy. Because their self-discharge rate is extremely low (approximately 1.5 percent per month), lengthy periods of disuse without replenishment charging are possible.

(1) Battery care. The life of these batteries depends to a great extent upon the care they receive. Following these simple guidelines will prevent premature charge depletion and reduction of battery life.

(a) Do not operate this unit where the temperature range exceeds minus 60 degrees Celsius (C) to 60 degrees C (-76 degrees Fahrenheit (F) to 140 degrees F).

(b) Do not charge this unit where the temperature range exceeds -20 degrees C to 50 degrees C (-4 degrees F to 122 degrees F).

(c) Do not store this unit with the batteries discharged. Always store the apparatus in a charged condition.

(d) For long-term storage, the optimum temperature range is 10 degrees C to 30 degrees C (50 degrees F to 80 degrees F).

(2) Battery cleaning. Periodically, or when applicable, clean the exterior case using mild, non-abrasive cleansers. Do not allow liquids to enter the control system; a damp cloth will, in most cases, suffice. Disinfectant spraying is recommended at regular intervals. Clean and dispose of collection-jar systems in accordance with their respective instructions.

c. **Circuit Descriptions**.

(1) Ac-to-dc rectifier, power and charging circuits. Refer to figure 2-1. Components P4, S1A, F1, S2A, D1 through 4, and C1 represent a full-wave-bridge rectifier circuit which enables simultaneous operation and recharging capability. Lamp L2 (which is part of S2) indicates the presence of battery charging current which is limited by R1. Charging current will be higher, initially, when a discharged-battery state exists, but will taper downward towards the 50-75 mil amp (ma) level as the batteries replenish. Switch S1A and S1B acts as a master ac/dc power control which, unless activated, prevents operation from internal or external power sources and battery recharge. Components D5 and D6 are blocking diodes which prevent false illumination of L2 during battery operation. Lamp L1, associated with the master-power switch, illuminates in both internal- and external-power modes via battery power or rectified ac. Note the S2A and S2B reciprocate which prevents simultaneous operation from internal and external power. F3 protects the battery pack from high current discharges in excess of 10a. S8 (model 306M) permits user selection of the input ac source; either 117vac (nominal) or 220-240vac. F4 (model 306M) enables operation from an external 12vdc source whenever the master power switch is activated. Blocking diode D7 isolates the external 12vdc from any other power source. This allows simultaneous battery recharge from ac power while operating from external 12vdc. Components D1 through 6, C1 and R1 are mounted to heat sink #2 (the flat heat sink), T1 is chassis mounted, while the other components of this section appear at the front and rear panels.

(2) Suction level and motor speed control circuits. Refer to figure 2-2. Components F2, L3, S3/R3, R2, S4A, S5A, Q1 through 3, and M1 comprise this section. Motor M1 is mechanically coupled to a rotary-vane vacuum pump. The vacuum or airflow generated by this pump is relative to the motor speed driving it. Therefore, the motor speed-control circuit acts as an electronic vacuum regulator. Component S3/R3 is a rotary-switch/potentiometer which provides base drive to a two-stage emitter-follower amplifier, Q1 through Q3.

(a) Increasing the positive potential at the base of Q1 increases the paralleled outputs of Q2 and Q3 causing M1 to turn faster and generate higher vacuum and airflow levels. Two vacuum ranges are possible, depending upon the position of S4A. When S4A is closed, you can apply full power potential to the base of Q1 which generates maximum vacuum levels (550mmHg). However, if S4A is opened, the maximum potential available to the base of Q1 is limited by the setting of R2 and can only provide a maximum pump output level of 200mmHg when properly calibrated. Switch S5A, when closed, provides a direct input to the base of Q1.

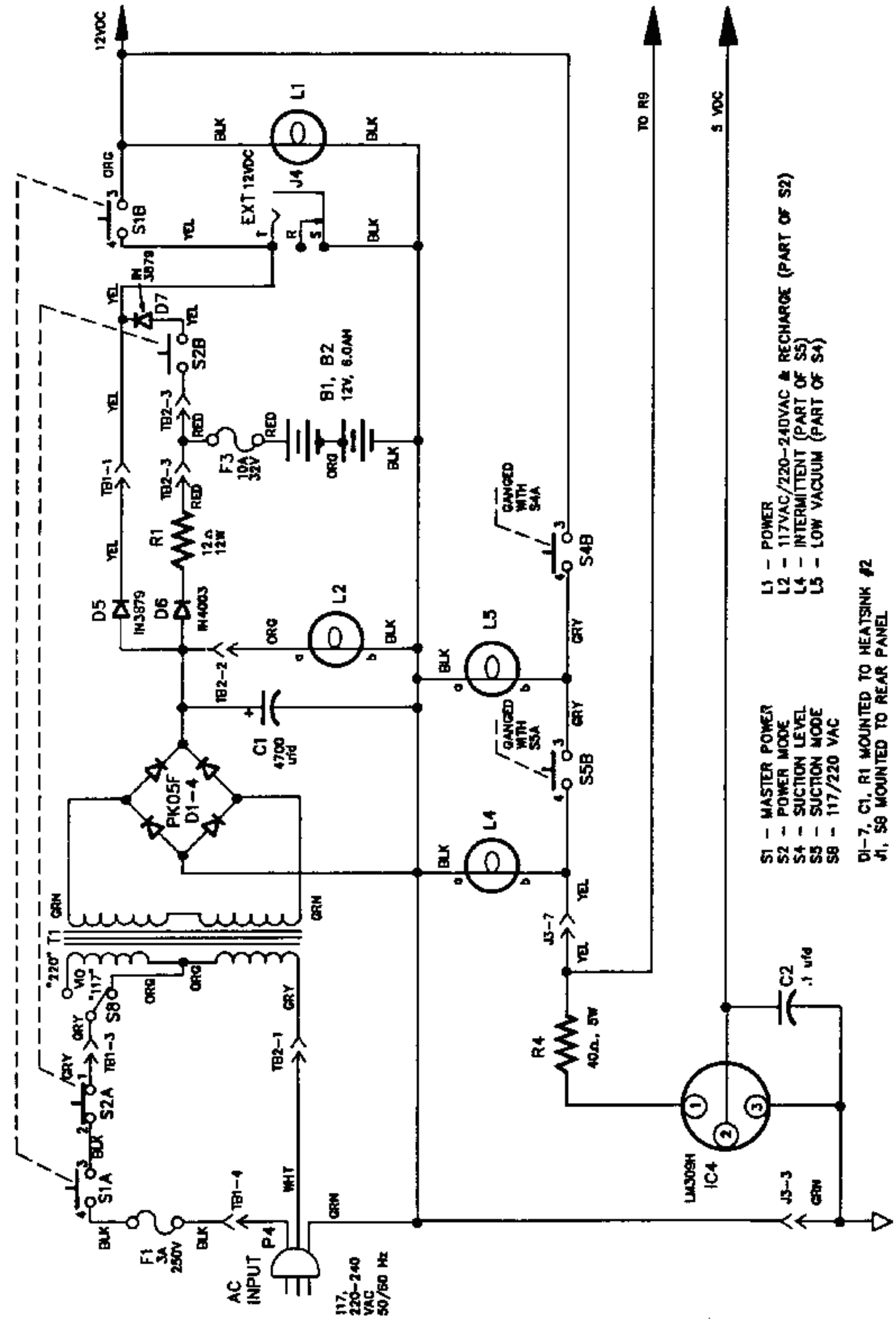


Figure 2-1. Power-supply and charging circuits schematic.

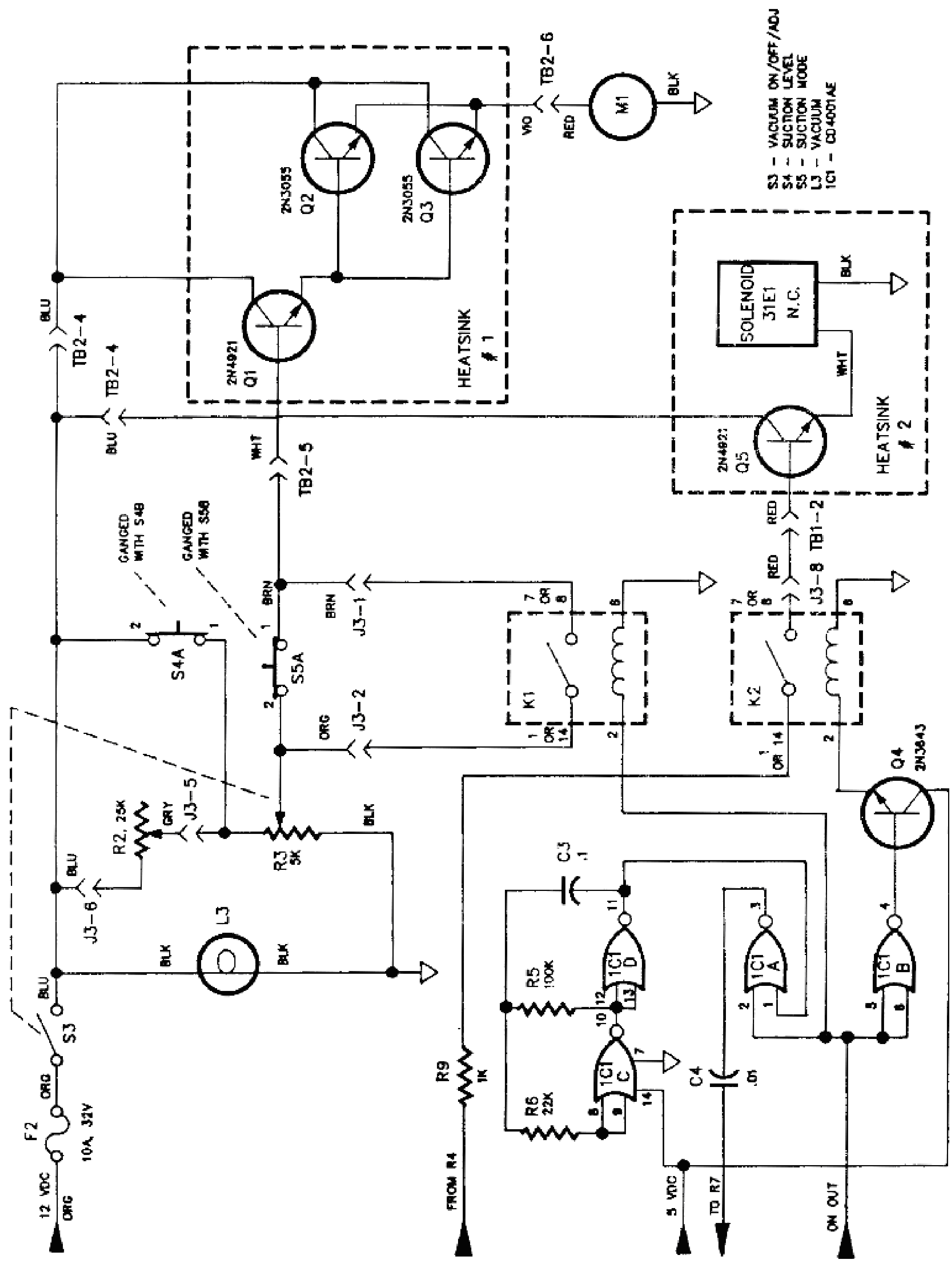


Figure 2-2. Master-clock, control, and regulator circuit schematic.

(b) Note that S4A and S4B and S5A and S5B are reciprocating switches whose alternate functions will be described in the following sections. Lamp L3 illuminates whenever S3 is closed. S3/R3, S4A, and S5A are front-panel mounted, R2 is located on the printed circuit board, Q1 through 3 on heat sink #1, and M1 is chassis mounted.

(3) Intermittent operation circuit. Refer to figure 2-1. Components S4B, S5B, L4, and L5 comprise this circuit. In order to prevent dangerously high vacuum levels from being presented to the patient, switches S4B and S5B must both be closed. This guarantees intermittent operation can exist only in the low-vacuum mode. Lamp L4 which is part of S5 illuminates in the intermittent mode and L5, which is part of S4, illuminates when low vacuum is selected. All components in this section are front-panel mounted.

NOTE: The remaining descriptions apply to circuitry in use only during intermittent operation.

(4) Five-volt power supply circuit. Refer to figure 2-1. Components R4, IC4 and C2 provide a regulated low-voltage power supply for the intermittent timing and switching circuitry. Resistor R4 acts as a current limiter to the regulator input while C2 provides output-voltage filtering of transient power surges. The regulator output is typically 4.8v at maximum low-vacuum levels (motor off), approximately 3v during motor turn-on (initial surge), and rises to about 4.5v for the duration of the motor-on cycle. All components are mounted to the printed circuit board.

(5) Clock oscillator circuit. Refer to figure 2-2. The clock oscillator is a 50 Hz, self-starting, square-wave generator consisting of 1C1 pins 8 through 13, R5, R6, and C3. Its purpose is to provide an initiating input to the OFF-time monostable. 1C1 is a quad-2 input NOR (not OR), dual in-line package. All components are mounted to the printed circuit board (PCB).

(6) Type 555 timer operation. These integrated circuits are used as functional monostables for the off-time and on-time circuits. When a negative impulse brings the trigger input (pin 2) below 1/3 collector supply voltage (Vcc), the output (pin 3) goes to a high-logic level (Vcc). Simultaneously, the voltage across the timing capacitor rises exponentially through the timing resistor and, after a period of time, the comparator input (pins 6 and 7) reaches 2/3 Vcc, resetting the internal flip-flop, causing the capacitor to discharge to ground and the output to return to a low-logic level (ground). The timer, in this application, is sometimes 20 percent triggered when intermittent operation is initiated, thus, the unit may cycle once before stabilizing to its correct time period.

NOTE: The following two paragraphs describe each timing circuit.

(7) Off-time monostable circuit. Refer to figures 2-2 and 2-3. The purpose of this circuit is to control the time period the on-time monostable output remains low. The off-time monostable consists of 1C1 pins 1 through 3, IC2, C4, C6, C9, R7, R11 through 22, R35, and R37. 1C1 pins 1 through 3 comprise a NOR gate of which pin 3 is its output. This output is an inversion of the clock oscillator when the on-time monostable is low. Pin 3 is held in low when the on-time monostable is high. R7 and C4 shape the NOR gate (not OR gate) output into positive and negative impulses, biased at Vcc to prevent mistriggering of the monostable and are applied to IC2 pin 2. C6 and R11 through 22 determine the time periods for which the off-time monostable is high. Components C9, R35, and R37 are used to adjust the delay multiplier in the time-period equation as follows:

$$T = (.975 \pm .125)\ RC.$$

Where R equals the value of the resistor expressed in Ohms times C, the capacitance of the capacitor expressed in microfarads.

(8) On-time monostable. Refer to figure 2-3. The on-time monostable controls the relay system and determines how long the off-time monostable remains low. Components IC3, C5, C7, C8, R8, R23 through 34, R36, and R38 comprise this circuit. Essentially, this monostable and its corresponding components act in the same manner as the off-time monostable. The on-time output triggers the off-time monostable via 1C1 pin 3 and the relay system, both directly and through 1C1 pin 4. All components are mounted on the printed circuit board as seen in figure 2-4.

(9) Relay system. Refer to figure 2-2. The relay system provides two functions; first, it interfaces the on-time monostable with the motor-speed-control circuit and, as a secondary function, dumps the vacuum-collection system to atmospheric pressure during off cycles. The relay system consists of K1, K2, Q4, Q5, R9, and the solenoid. During on-time cycles, relay K1 is closed and provides base bias to Q1 from the R2, R3 series combination. The motor speed is then fixed by the R2, R3 combination during each on cycle unless changed by the operator. Relay K2 is not energized during the "on" cycle, thus allowing the vacuum to exist. During off cycles, K1 is normally open and stops M1. Relay K2 is energized as 1C1 pin 4 goes high and turns Q4 on. When K2 closes, Q5 turns on and energizes the solenoid to a normally open state. When the solenoid opens, the vacuum collection system is dumped to atmospheric pressure and remains so until the next on cycle. Switch S3 must be closed to operate the motor-speed-control circuit and solenoid. Components K1, K2, Q4, and R9 are mounted to the printed circuit board. Component Q5 and the solenoid are mounted to heat sink #2.

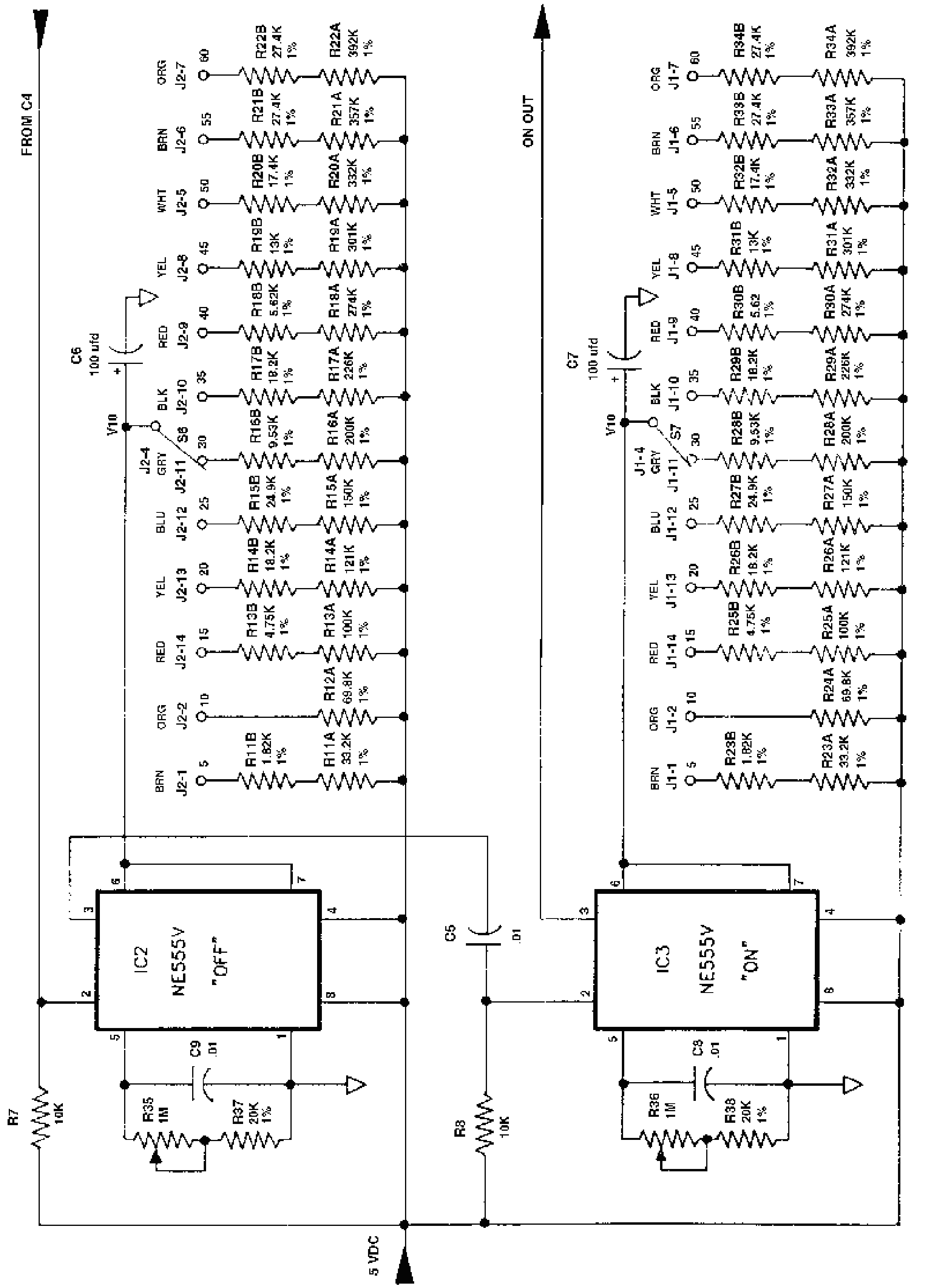


Figure 2-3. On/off clock schematic.

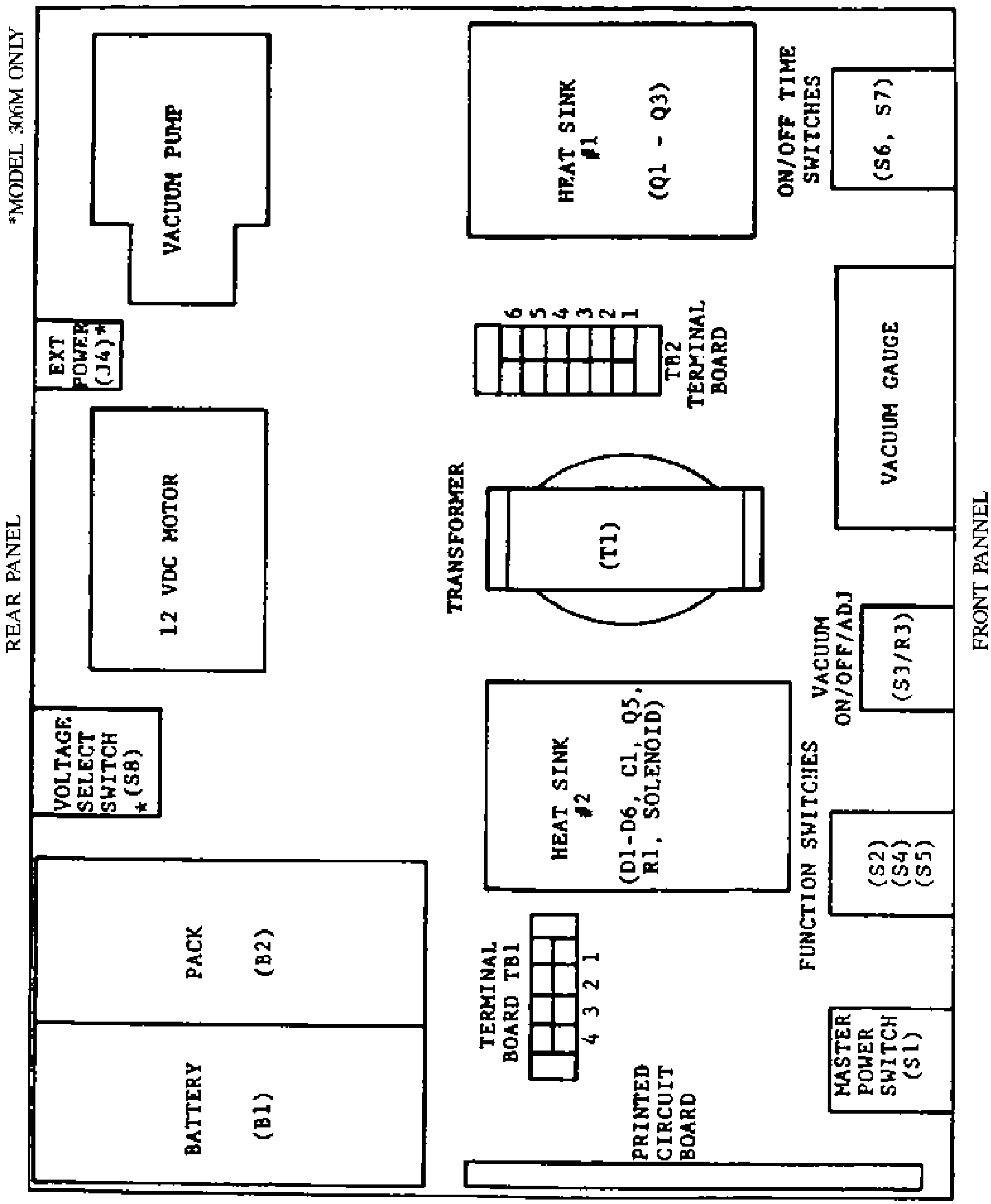


Figure 2-4. Printed circuit board layout.

2-3. OPERATIONAL CHECKOUT

Understanding the circuits and how components function will help you identify malfunctions and repair or replace components. Before you calibrate the programmable suction pump, an operational checkout ensures the various systems involved are performing properly. The following paragraphs provide the steps of a brief operational check.

a. **Continuous Suction Operation (120v/220v) Switch**. Plug the unit into a wall outlet. Push in the master-power switch. The pilot lamp and power-mode lamp should be lit. Rotate the vacuum-control knob fully clockwise. The vacuum-control lamp should now be lit. Pinch the rubber tubing and watch the vacuum gage, which is calibrated in mmHg rather than cmH_2O. It should read 300mmHg or more.

b. **Intermittent Suction Operation (120v/220v)**. Plug the unit into a wall outlet. Push the master-power switch in. The pilot lamp and the power-mode lamp should light. Push the suction-mode and suction-level switches in. Both the suction-mode and suction-level switches should be lit. Rotate the vacuum-control knob fully clockwise. The vacuum-control lamp should be lit. Set the on-time control knob to five seconds. Set the off-time control knob to five seconds. The unit should cycle on and off every five seconds. Pinch the rubber tubing. The vacuum gage should read 200mmHg.

c. **Continuous Suction Operation (Internal 12vdc)**. Unplug the unit from the wall outlet. Push the master-power switch in. Push the power-mode switch in. The master power lamp should be lit. Rotate the vacuum-control knob fully clockwise. The vacuum control lamp should now be lit. Pinch the rubber tubing. The vacuum gauge should be reading 300mmHg or more.

d. **Intermittent Suction Operation (Internal 12vdc)**. Unplug the unit from the wall outlet. Push the master-power switch in. Push the power-mode switch in. The master-power lamp should be lit. Push the suction-mode and suction-level switches in. Both the suction-mode and suction-level switches are lit. Rotate the vacuum-control knob fully clockwise. The vacuum control lamp should now be lit. Set the on-time control knob to five seconds. Set the off-time control knob to five seconds. The unit should cycle on and off every five seconds. Pinch the rubber tubing. The vacuum gage should read 200mmHg at this setting.

e. **External 12vdc Operation**. Plug the external 12vdc-power-supply into the jack on the back of the unit. Set the controls up for continuous or intermittent operation according to the instructions given above.

Section II. MAINTENANCE AND REPAIR PROCEDURES

2-4. CALIBRATION PROCEDURE

Before the suction apparatus is put into service, you must calibrate it to ensure the unit performs within tolerances and specifications. The following paragraphs list the steps to properly calibrate the programmable suction system for reliable operation.

a. **Required Equipment**. Only two items are required for calibration of the programmable suction system.

(1) Oscilloscope, direct current (dc), triggered, with a minimum five-second horizontal sweep. Some storage capability is desirable.

(2) A small, slot-head screwdriver.

b. **Procedures**.

(1) <u>Maximum low-vacuum-level limit</u>.

(a) Set the controls for either alternating current (ac) or direct current (dc) operation (ensure the batteries have been <u>fully</u> charged if you are calibrating from battery power).

(b) Select the CONTINUOUS and LOW VACUUM modes of operation.

(c) Turn the vacuum-control knob ON and fully clockwise.

(d) Occlude (plug or otherwise seal) the rear-panel-vacuum inlet and adjust the resistor R2 for a 200mmHg reading on the front-panel vacuum gauge.

(e) You can verify this reading by using a calibrated vacuum gauge applied to the vacuum inlet.

(2) <u>Intermittent ON/OFF timing circuits</u>.

(a) Set the controls for either ac or dc operation (ensure the batteries have been fully charged if you are calibrating from battery power).

(b) Select INTERMITTENT and LOW-VACUUM operation.

(c) Set the ON/OFF times for five seconds ON, five seconds OFF.

(d) Turn the vacuum-control knob ON and fully clockwise.

(e) Trigger the oscilloscope sweep to begin when the motor turns ON and adjust variable resistor R36 to set the ON-time circuit for a five second sweep. Close verification can be made using a storage-type oscilloscope. Adjust to within plus or minus 0.5 seconds.

(f) Trigger the oscilloscope to begin when the motor turns off and adjust variable resistor R35 to set the OFF-time circuit for a five-second sweep. Adjust to within plus or minus 0.5 seconds. A storage-type oscilloscope simplifies measurement.

NOTE: Steps (e) and (f) above may be monitored at various points. For simplicity and convenience, the positive-voltage motor input should be used, and the oscilloscope triggering slope set for the ON circuit, then reset for the OFF circuit.

2-5. PREVENTIVE MAINTENANCE PROCEDURES

Preventive maintenance checks and services (PMCS) are provided by the equipment operator (EO) who regularly operates the equipment and a medical equipment repairer who provides repair and troubleshooting capabilities. Table 2-1 shows the PMCS tasks, who performs them [equipment operator (EO) or medical equipment repairer (MER)], and the frequency of performance.

PREVENTIVE MAINTENANCE PROCEDURE	**FREQUENCY**	
	EO	**MER**
Clean item (remove dust, lint, rust, etc.)	D	A
Properly store accessories	AO	
Change filter	Z	
Visually inspect and perform operating tests	BO	
Lubricate casters with graphited oil		Q
Perform leakage-current tests		S
Estimated average annual man-hour requirements		Z
Abbreviations: AO = after operations; D = daily; Q = quarterly; S = semiannually; A = annually; Z = as necessary; BO = before operation.		

Table 2-1. Preventive maintenance checks and services procedures.

CAUTION: Do not overfill vacuum bottles. If simultaneous ac recharging and external 12vdc operation is being employed, ensure the external 12vdc source is "diode protected" against potentially high currents.

a. **Preparation for In-Place Storage**. If no one will be using the unit for a period of time, properly prepare it for storage. Always store the unit with the batteries in a charged condition.

(1) Remove, clean, and dry all rubber tubing, bottles, and accessories. Wrap each item individually and pack it in a carton.

(2) Disconnect the line cord from the electrical outlet, coil, and tape it to the back of the cabinet.

(3) Lubricate the casters.

b. **Precautions in Packing**. Before shipping the suction apparatus, take the following precautions to prepare it for shipment.

(1) Remove, clean, and dry all rubber tubing, bottles, and accessories. Wrap each item individually, and pack it in a carton. (Sprinkle talcum powder on the rubber goods).

(2) Remove the base, casters, and fasten the cabinet to the base of the shipping container.

(3) Place the carton containing the accessories in the container and brace it to prevent shifting.

(4) Mark the shipping container "THIS SIDE UP."

2-6. TROUBLESHOOTING

If the equipment is not performing to standards or specifications, you must troubleshoot the problem. The following troubleshooting procedures will enable you to easily isolate malfunctioning or defective items of equipment.

a. **Continuous Suction**. Use the following steps to troubleshoot the programmable suction pump in the continuous suction mode of operation.

(1) <u>Symptom</u>: No vacuum or weak vacuum.

(a) Controls: Push the master-power switch ON, power mode in the continuous-suction mode, select the high-vacuum suction level and adjust the vacuum ON/OFF/ADJUST control ON, by turning fully clockwise.

(b) Check the following:

1 Hose and hose connections for cracks or crimps. Verify the pump turns easily and the coupling set screws are tight between the pump and the motor.

2 If L1 and L3 are illuminated, check for voltage at the motor input, Q1 through Q3, S5A, and R3. Momentarily select the low-vacuum level and verify the presence of voltage at R2.

3 If L1 is on and L3 fails to light, test L3 for an open circuit. Check F2 (a 10A fuse) and S3 for a voltage presence.

4 If L1 and L3 are both off, test L1 for an open circuit. Check S1A and S1B connections. Check for voltage outputs from D1 through D5, T1, S2A, and F1 on ac power. Check for voltage output from B1, B2, and S2B on internal 12vdc power.

(2) Symptom: No internal battery power.

(a) Controls: Master-power switch: select ON VAC and RECHARGE.

(b) Check the following:

1 Verify the presence of voltage at D6. Check for a charging current going through R1 into B1 and B2. Ensure L2 illuminates. Select internal 12vdc power and test for the output of B1 and B2 through S2B (allow adequate recharge time before testing for the battery output).

2 Verify the in-line "fast-on's" (yellow) leads are not interchanged thus reversing the D7 anode and cathode connections.

b. **Intermittent Suction**. Use the following troubleshooting procedures to troubleshoot the programmable suction pump in the intermittent suction mode of operation.

(1) Symptom: Poor intermittent operation.

(a) Controls:

1 Push the master-power switch ON. Select the intermittent-suction mode by pushing the suction-mode button in.

2 Select the low-vacuum level by pushing in the suction-level button.

3 Turn the vacuum control ON/OFF/ADJUST knob fully clockwise.

4 Adjust the on-time control for five seconds.

5 Adjust the off-time control for five seconds.

(b) Check the following:

1 Check relay K2 for the proper solenoid input signal. Verify there is no voltage to the base of Q5 during on cycles and about 12vdc during the off cycle. This voltage can also be checked at the solenoid and collector of Q5.

2 Check relay K1 to ensure the proper turn-on and turn-off signals are being applied to its coil and the voltage is switched across S5A to the base of Q1.

3 Check for proper control-signal gating on 1C1 and Q4.

4 Check the 5v regulator for proper output, and the overall appearance of the PCB for shorts, bad solder connections, and/or loose connector cables when erratic operation occurs.

(2) Symptom: The motor will not turn on, but the solenoid activates properly. Check IC3 and its associated elements.

(3) Symptom: The on or off cycle does not end. Check for loose or open connections between timing resistors R11 through 34 to IC2 pins 6 and 7, or IC3 pins 6 and 7. For an on-cycle problem, check resistors R23 through 34 and IC3. For an off-cycle problem, check resistors R11 through 22 and IC2.

2-7. REMOVE AND REPLACE OR REPAIR COMPONENTS

Once you have isolated the causes of equipment malfunctions or defective components, you must be able to disassemble the apparatus and remove or service the parts in question. The following paragraphs show you how to accomplish this.

a. **Tools Required.** You need the tools listed below to remove and replace components of the Impact programmable suction pump.

(1) A medium-size, slot-head screwdriver.

(2) A medium-size, Phillips-head screwdriver.

(3) A 1/16-inch Allen wrench.

(4) Medium-size pliers.

(5) 3/8-inch open-end wrench (or a 3/8-inch socket with drive handle).

b. **General Access**. For calibration and many servicing procedures, you need only remove the top cover of this device. For greater accessibility, however, the front panel should also be disengaged. When disassembling, snap open all cable clamps before removing any wires.

(1) Top cover. The top cover is secured by six screws: three located along the rear lip and three along the top edge. Remove these and lift off the top panel. Insert and tighten each screw when reassembling.

(2) Front panel. Take the following steps only to disengage the front panel from the model 306 case. Additional steps to "electrically" disconnect the front panel are contained in the next paragraph below. Do not disengage the front panel to perform calibrations. When ribbon cables P1 and P2 are disconnected, the on/off time circuits cannot be adjusted.

(a) To disengage the front panel, disconnect ribbon cables P1 and P2 from their respective PCB jacks. Disconnect the vacuum tubing attached to the rear of the vacuum gauge. The front panel is secured by seven screws located at each front corner and three across the front-bottom edge (access from underneath). The front panel can now be pulled away from the chassis and positioned flat (on its facing surface). The front panel is still attached to the chassis by the wire harness service loop and ribbon cable P3. All sub-assemblies may be serviced or removed with the front panel in this position.

(b) To reassemble, carefully reposition the front panel in place and secure it tightly with the seven screws. Connect the two pieces of vacuum tubing to the rear of the vacuum gauge and connect P1 and P2 to their respective PCB jacks (observe pin polarity). See the schematics in figures 2-1 and 2-2 and the printed circuit board assembly in figure 2-4.

c. **Sub-Assembly Access**.

(1) Printed circuit board. The Printed circuit board (PCB) is located on the left sub-side, sub-assembly. Disconnect ribbon cables P1, P2, and P3 from their respective PCB jacks. Remove the four screws which secure the PCB to the sub-side panel. A green wire connected to a ring terminal is secured to the sub-side panel by one of these four screws. Its purpose is to maintain a ground connection with the front panel whenever the front panel is disengaged for general access. To reassemble, position the PCB over the four threaded female studs and secure with screws. Make sure the green wire is secured beneath the lower left-hand screw. Connect P1, P2, and P3 to their respective PC board jacks (observe pin polarity--see the schematics and PCB assembly figures).

(2) Battery pack. The battery pack is secured to the left, sub-side panel and the main chassis by two brackets. One bracket straddles across the battery pack, connecting at the chassis and left, sub-side panel with two number 10-32 Keps nuts. The other bracket, located in front of the battery pack, is secured to the chassis with two number 10-32 Keps nuts. To remove the battery pack, disconnect the "fast-on" connected red and black wires from B1 and B2 then remove the four Keps nuts, earlier described, using the 3/8-inch open-end wrench or a 3/8-inch socket with drive handle. B1 and B2 are "fast-on" connected in series with a small orange jumper. Reassemble the battery pack by securing it in place and tightening the four Keps nuts. Connect the batteries, B1 and B2, in series with the small orange jumper, the black wire to the remaining negative terminal and the red wire to the remaining positive terminal. Refer to figure 2-1 for the wiring of the battery pack.

(3) Motor and pump assembly. The motor and pump assembly is mechanically secured to the chassis with six number 10-32 Keps nuts. A flexible coupling joins the motor and pump shafts together. Each side of the coupling is secured to its respective shaft by two set screws (1/16-inch hex) stacked one on top of the other. Stacking prevents the coupling from loosening caused by vibration or temperature extremes. To disassemble the motor and pump assembly, disconnect the black and red wires coming from the motor. The black wire is connected to the chassis ground, the red wire to TB2-6. Disconnect the vacuum tubing from the pump inlet. The motor and pump can now be disengaged as one unit by removing the six Keps nuts or individually by removing the stacked set screws and respective Keps nuts. Reassemble as follows. Mount and loosely secure the motor and pump to the chassis, allowing the coupling to "float" freely on the shaft. Carefully position the motor and pump shafts for in-line alignment. Tighten the Keps nuts without disturbing the alignment. Position the motor shaft so the flat edge will receive the set screw and tighten the respective coupling set screw to the shaft. Do the same with the pump shaft. Insert and tighten the stacked (second) set screws in each half of coupling. Connect the red and black wires.

(4) Heat sink number 1. Heat sink number 1 is mounted to the right, subside panel. It is secured by two number 10 Keps nuts. To disassemble, disconnect the violet wire going to TB2-6, the white wire going to TB2-5, and the blue wire going to TB2-4. Use the 3/8-inch open-end wrench to remove the Keps nuts. Reassemble by securely mounting heat sink number 1 to the right, sub-side panel and then reattaching the violet, white, and blue wires.

(5) Heat sink number 2. Heat sink number 2 is indirectly chassis mounted through two standoffs. Two slot-head screws secure heat sink #2 to these standoffs. Before removing these screws, six wires must be disconnected at terminal boards 1 and 2 (TB1 and TB2) and other wires at locations as noted. Disconnect the yellow wire with the male in-line "fast-on" terminal positioned along the side of transformer (T1). Disconnect the two yellow wires going to TB1-1, the red wire going to TB1-2, the orange wire going to TB2-2, the blue wire going to TB2-4, and the red wire going to TB2-3. The two green wires from T1 (secondary) can be removed at the D1-4 "fast-on" terminals. Remove the two screws, previously mentioned. Note two black wires are ring-terminal connected to ground through one screw. Disconnect the vacuum tubing entering the solenoid. To reassemble, position heat sink #2 over its respective standoffs and secure, ensuring both ground wires (black) are tightened beneath the front screw. Connect the vacuum tubing to the solenoid and reattach the remaining wires to their respective locations.

(6) Transformer. The transformer is secured to the chassis by two number 10-32 Keps nuts. Disconnect the two green wires (transformer secondary) at D1-4 ("fast-on" connections), one gray wire at TB1-3 (model 306 only) and the other gray wire at TB2-1. (Model 306M only. Disconnect the orange and violet wires connected to the transformer primary ["fast-on" connections].) The transformer can now be removed using the 3/8-inch open-end wrench. To reassemble, reconnect all the wires as indicated. Secure the rear panel to each sub-side panel. Connect the vacuum tubing. Remount the bottom cover.

Continue with Exercises

EXERCISES, LESSON 2

INSTRUCTIONS: Answer the following exercises by circling the lettered response that best answers the question.

After you have answered all of the exercises, turn to "Solutions to Exercises" at the end of the lesson and check your answers. For each exercise answered incorrectly, reread the lesson material referenced after the solution.

1. Why is it theoretically impossible for the vacuum regulator of the model 306M programmable suction system to leak, clog, jam, or stick?

   a. Because it is removed from the vacuum path.

   b. Because the system has no vacuum regulator.

   c. Because its interior is coated with Teflon.

   d. Because of the system's unique immersion-bath feature.

2. The collection-jar system of the programmable suction pump features a disposable filter which is both hydrophobic and bacterial. What does this mean?

   a. The filter absorbs liquid and is composed of bacteria.

   b. The filter is afraid of water and composed of bacteria.

   c. The filter passes liquid and kills bacteria.

   d. The filter repels liquids and retains bacteria.

3. What feature in the charging circuit prevents simultaneous operation from external and internal power sources?

   a. Blocking diode D5.

   b. Reciprocation of switches S2A and S2B.

   c. The power-out feature.

   d. The isolation provided by blocking diode D7.

4. You wish to examine the intermittent operation circuit. Where do you find it?

   a. On the front panel.

   b. Mounted on heat sink number 2.

   c. On the printed circuit board.

   d. Next to the transformer.

5. You are checking the intermittent suction mode of operation with external power. The suction-mode, suction-level, and vacuum-regulator lamps are lit and the unit is cycling on and off every five seconds. Next, you pinch the vacuum hose. What should the vacuum gauge read?

   a. 30cmH_2O.

   b. 300mmHg.

   c. 82cmHg.

   d. 200mmHg.

6. You are calibrating the maximum low-vacuum-level limit function of the programmable suction pump. You select continuous and low-level modes, seal the rear-panel vacuum inlet, and achieve a reading of 200mmHg. How do you achieve this gauge reading?

   a. By turning the vacuum regulator knob fully counterclockwise.

   b. By turning the vacuum regulator knob fully clockwise.

   c. By adjusting resistor R2.

   d. By occluding the rear-panel vacuum inlet.

7. The equipment operator reports poor intermittent operation of his Impact programmable suction pump, and you must correct the condition. You set the controls in the proper positions and ensure the proper solenoid signal at relay K2. You verify no voltage at the base of Q5 during the ON cycle and 12.5vdc during the OFF cycle. Where else could you have taken the last reading?

   a. T1.

   b. The output of Q5.

   c. Resistor R22.

   d. The solenoid and collector of Q5.

8. Which wires must be disconnected to accomplish removal of the battery packs?

   a. Red, black, and orange.

   b. Red and black.

   c. Red and white.

   d. Black, white, and green.

Check Your Answers on Next Page

SOLUTIONS TO EXERCISES: LESSON 2

1. a (para 2-1a)

2. d (para 2-2a)

3. b (para 2-2c(1))

4. a (para 2-2c(3))

5. d (para 2-3b)

6. c (para 2-4b(1)(d))

7. d (para 2-6b(1)(b))

8. a (para 2-7c(2))

End of Lesson 2