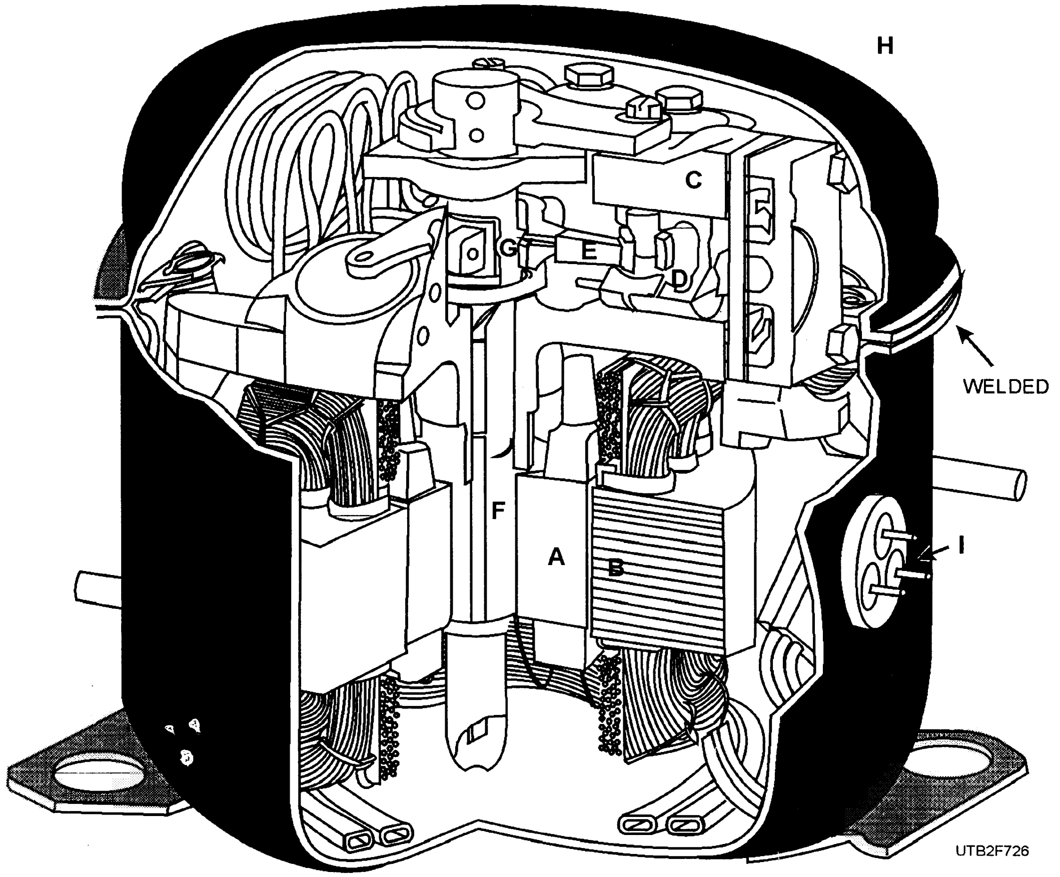


Figure 7-26.—Reciprocating hermetic compressor. (A) Motor rotor; (B) Motor stator; (C) Compressor cylinder; (D) Compressor piston; (E) Connecting rod; (F) crankshaft; (G) Crank throw; (H) Compressor shell (I) Glass sealed electrical connection.

hermetically sealed units whose motor windings may be attacked by acids or other corrosive substances introduced into the system or formed by the chemical reaction of moisture, air, or other foreign substances.

HERMETIC.—The term *sealed* or *hermetic* unit merely means that the motor rotor and compressor crankshaft of the refrigeration system are made in one piece, and the entire motor and compressor assembly is put into a gastight housing that is welded shut (fig. 7-26). This method of assembly eliminates the need for certain parts found in the open unit. These parts are as follows: motor pulley, belt, compressor flywheel, and compressor seal. The elimination of the preceding parts in the sealed unit similarly does away with the following service operations: replacing motor pulleys, replacing flywheels, replacing belts, aligning belts, and repairing or replacing seals. When it is realized there are major and minor operations that maintenance personnel must perform and the sealed unit dispenses with only five of these, it can be readily seen that servicing is still necessary.

Rotary Compressors

Rotary compressors are generally associated with refrigerators, water coolers, and similar small capacity equipment. However, they are available in larger sizes. A typical application of a large compressor is found in compound compressor systems where high capacity must be provided with a minimum of floor space.

In a rotary compressor (fig. 7-27), an eccentric rotor revolves within a housing in which the suction and discharge passages are separated by means of a sealing blade. When the rotating eccentric first passes this blade, the suction area is at a minimum. Further rotation enlarges the space and draws in the charge of refrigerant. As the eccentric again passes the blade, the gas charge is shut off at the inlet, compressed, and discharged from the compressor. There are variations

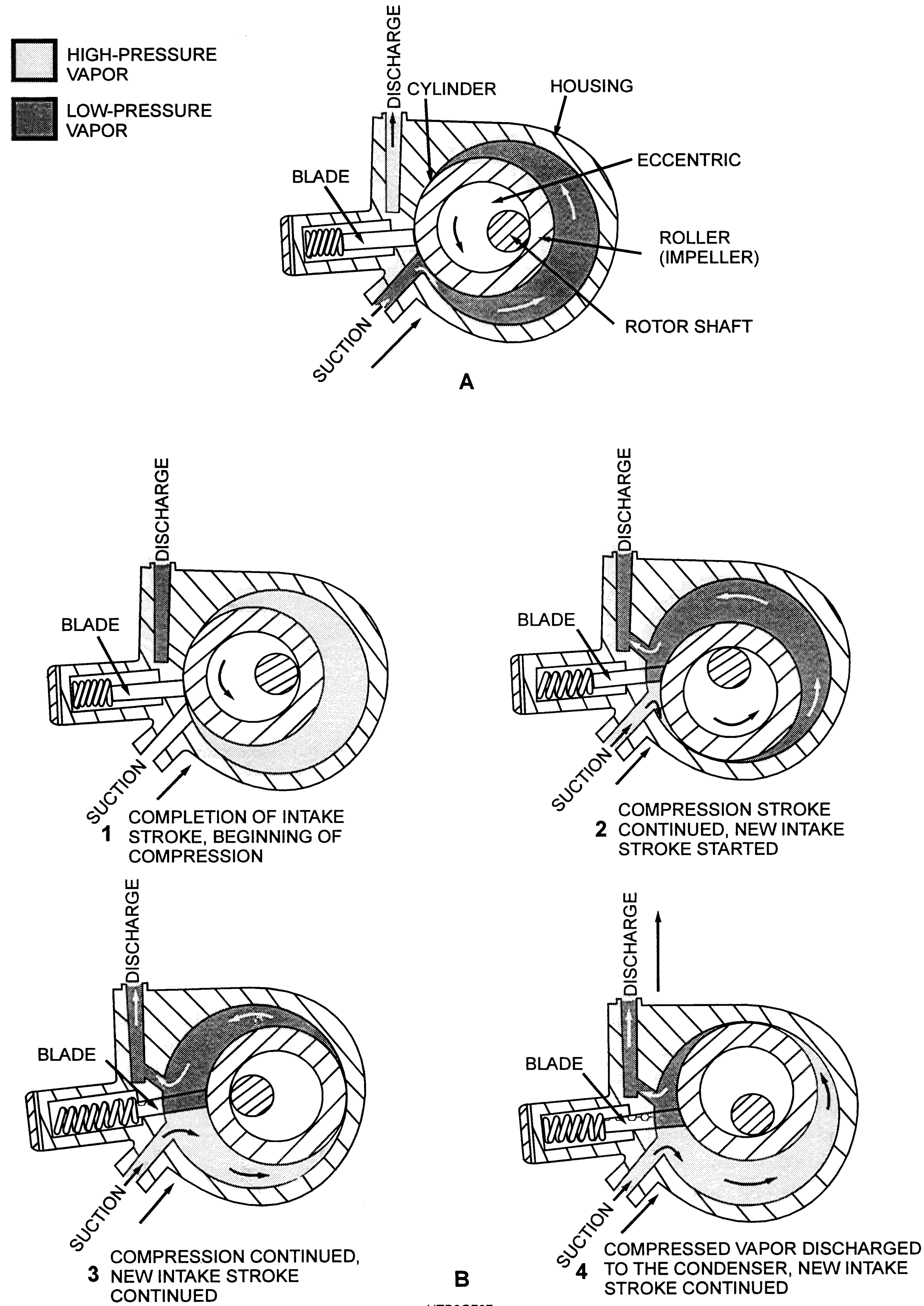


Figure 7-27.—Rotary compressor: A. Part identification; B. Operation.

of this basic design, some of which provide the rotor with blades to trap and compress the vapor.

Centrifugal Compressors

Centrifugal compressors are used in large refrigeration and air-conditioning systems, handling large volumes of refrigerants at low-pressure differentials. Their operating principles are based on the use of centrifugal force as a means of compressing and discharging the vaporized refrigerant. Figure 7-28 is a cutaway view of one type of centrifugal compressor. In this application, one or two compression stages are used, and the condenser and evaporator are integral parts of the unit. The heart of this type of compressor is the impeller wheel.

Scroll Compressors

A scroll compressor has two different offset spiral disks to compress the refrigerant vapor. The upper scroll is stationary, while the lower scroll is the driven scroll. Intake of refrigerant is at the outer edge of the driven scroll, and the discharge of the refrigerant is at the center of the stationary scroll. The driven scroll is rotated around the stationary or "fixed" scroll in an orbiting motion. During this movement, the refrigerant vapor is trapped between the two scrolls. As the driven scroll rotates, it compresses the refrigerant vapor through the discharge port. Scroll compressors have few moving parts and have a very smooth and quiet operation.

CONTROLS

Controls used in air conditioning are generally the same as for refrigeration systems—thermostats, humidistats, pressure and flow controllers, and motor overload protectors (fig. 7-29).

Thermostats

The thermostat is an adjustable temperature-sensitive device, which through the opening and closing of its contacts controls the operation of the

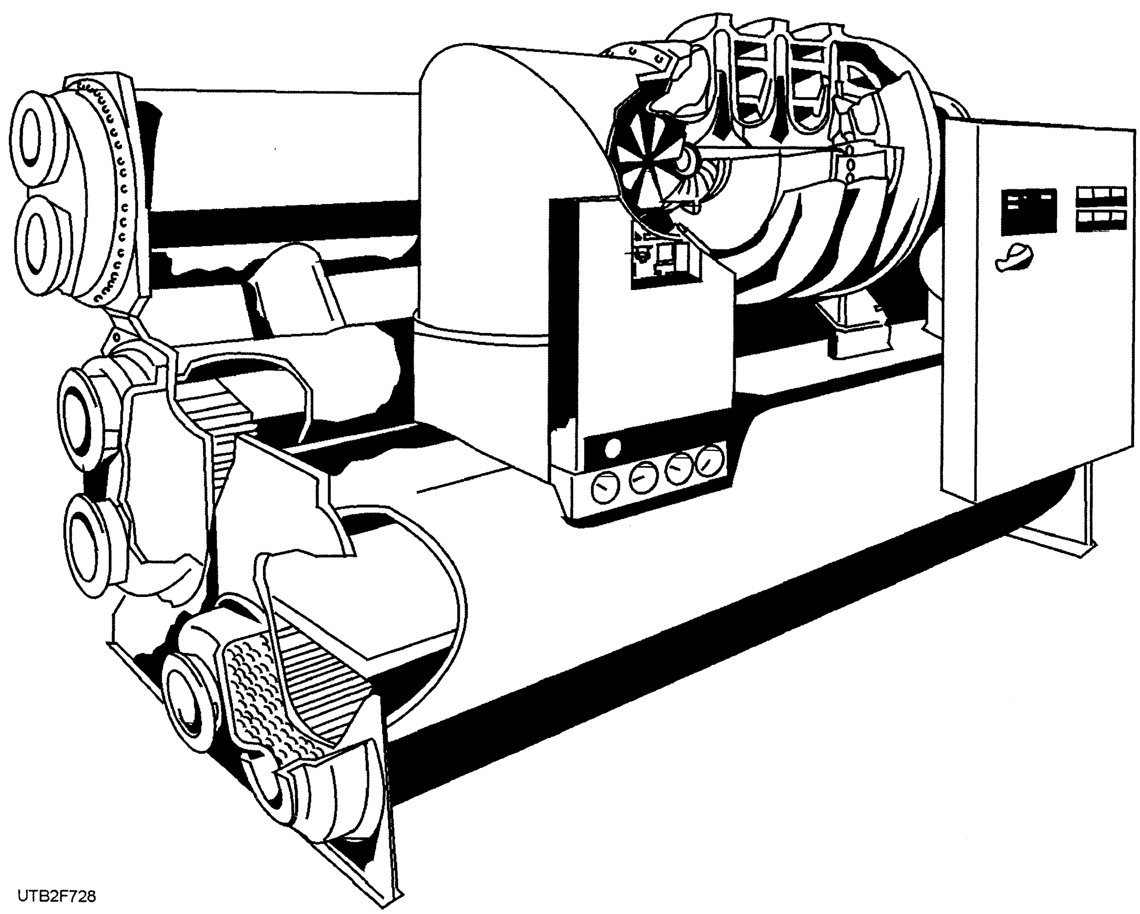
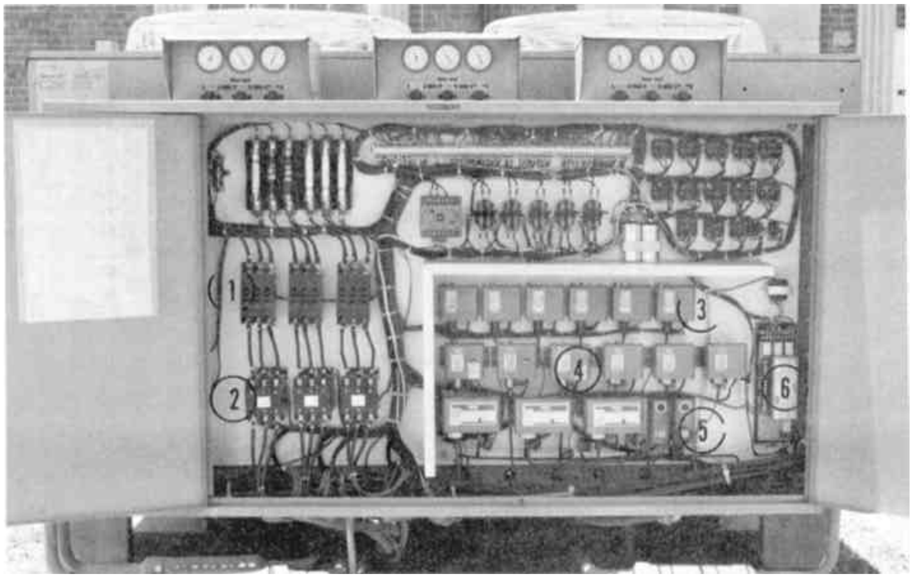


Figure 7-28.—Cutaway view of one type of centrifugal compressor.



1. Commpressor breakers.
2. Compressor starters.
3. Fan cycle controls.
4. High-pressure controls.
5. Oil failure controls.
6. Solid-state staging thermostat.

Figure 7-29.—Packaged air-cooled chiller controls.

cooling unit. The temperature-sensitive element may be a bimetallic strip or a confined, vaporized liquid.

The thermostats used with refrigerative air conditioners are similar to those used with heating equipment, except their action is reversed. The operating circuit is closed when the room temperature rises to the thermostat control point and remains closed until the cooling unit decreases the temperature enough. Also, cooling thermostats are not equipped with heat-anticipating coils.

Wall type of thermostats most common for heating and air conditioning in the home and on some commercial units use a bimetallic strip and a set of contacts, as shown in figure 7-30. This type of thermostat operates on the principle that when two dissimilar metals, such as brass and steel, are bonded together, one tends to expand faster than the other does when heat is applied. This causes the strip to bend and close the controls.

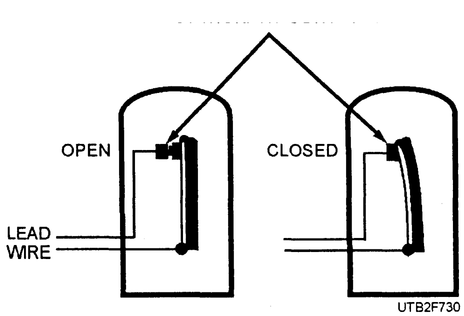


Figure 7-30.—Bimetallic thermostat.

As a Utilitiesman, you may be required to make an adjustment that sets the temperature difference between the cut-in and cutout temperatures. For example, if the system is set to cut in at 76°F and cut out at 84°F, then the differential is 8°F. This condition prevents the unit from cycling continually as it would if there were no differential.

Humidistats

A room "humidistat" may be defined as a humidity-sensitive device controlling the equipment that maintains a predetermined humidity of the space where it is installed. The contact of the humidistat is opened and closed by the expansion or contraction of natural blonde hairs from human beings, which is one of the major elements of this control. It has been found that these types of hairs are most sensitive to the moisture content of the air surrounding them.

Pressure-Flow Controllers

Pressure-flow controllers are discussed in chapter 6. The purpose of these controllers in air conditioning is to act as safety switches for the system, so if either the head pressure is too high or suction pressure too low, the system will be secured regardless of the position of the operating switches.

Refrigerant-Flow Controllers

The refrigerant-flow controllers used with air conditioners are also similar to the ones discussed in chapter 6. These controllers are either of the capillary type or externally equalized expansion valve type and are usually of larger tonnage than those used for refrigerators.

Motor Overload Protectors

When the compressor is powered by an electric motor, either belt driven or as an integral part of the compressor assembly, the motor is usually protected by a heat-actuated overload device. This is in addition to the line power fuses. The heat to actuate the overload device is supplied by the electrical energy to the motor, as well as the heat generated by the motor itself. Either source of heat or a combination of the two, if too much, causes the overload device to open and remove the motor from the line.

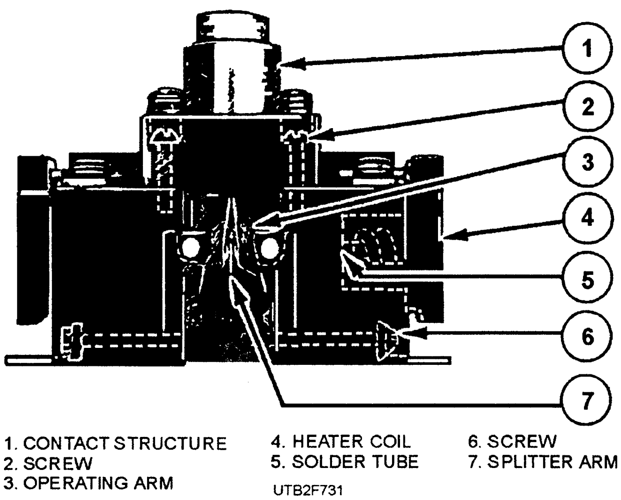


Figure 7-31.—Thermal overload relay.

Figure 7-31 shows a thermal-element type of overload cutout relay. It is housed in the magnetic starter box. On current overload, the relay contacts open, allowing the holding coil to release the starting mechanism, thereby stopping the motor.

An oil failure cutout switch is provided on many systems to protect the compressor against oil failure. The switch is connected to register pressure differential between the oil pump and the suction line. Figure 7-32 shows a typical oil failure cutout switch. The switch contains two bellows, which work against each other, and springs for adjusting. Tubing from the oil pump is connected to the bottom bellows of the switch. Tubing from the suction line is connected to the upper bellows. When a predetermined pressure differential is not maintained, a pair of contacts in the switch is opened and breaks the circuit to the compressor motor. A heating element with a built-in delay is in the switch to provide for starting the compressor when oil pressure is low.

The water-regulating valve used with a water-cooled condenser responds to a predetermined condensing pressure. A connection from the discharge side of the compressor to the valve transmits condensing pressure directly to a bellows inside the

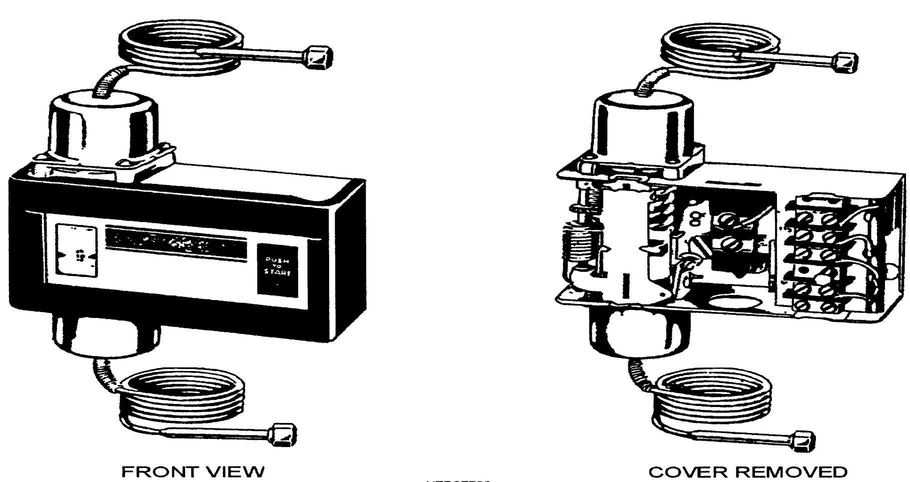


Figure 7-32.—Oil failure cutout switch.

valve. High pressure opens the valve, allowing a greater flow of water; low pressure throttles the flow. Use of such a valve provides for a more economical use of water for condensing. Figure 7-33 shows a typical water-regulating valve. When condenser water is supplied by a cooling tower, water-regulating valves are not customarily used because the cooling tower fan and circulating pump are wired into the compressor motor control circuit.

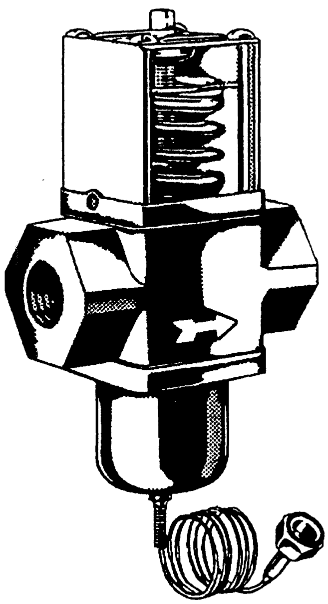


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Figure 7-33.—Water-regulating valve.

Step Controller

The step controller contains a shaft upon which is mounted a series of cams. Rotation of the cams, in turn, operates electrical switches. Through adjustment of the cams on the shaft, the temperature at which each switch is to close and open (differential) is established. In addition, the switches may be adjusted to operate in almost any sequence (fig. 7-34).

TROUBLESHOOTING

Table Z of appendix II is a troubleshooting chart generally applicable to all types of air conditioners. Most manufacturers include more detailed and specific information in publications pertaining to their units. If you find that there is no manual with the unit when it is unpacked, write to the manufacturer and request one as soon as possible.

Q21. How are cooling towers classified?

Q22. A wind velocity of 8 mph is generally used to design natural draft cooling towers. True /False

Q23. Counter flow, parallel flow, and cross flow are types of what class of cooling tower?

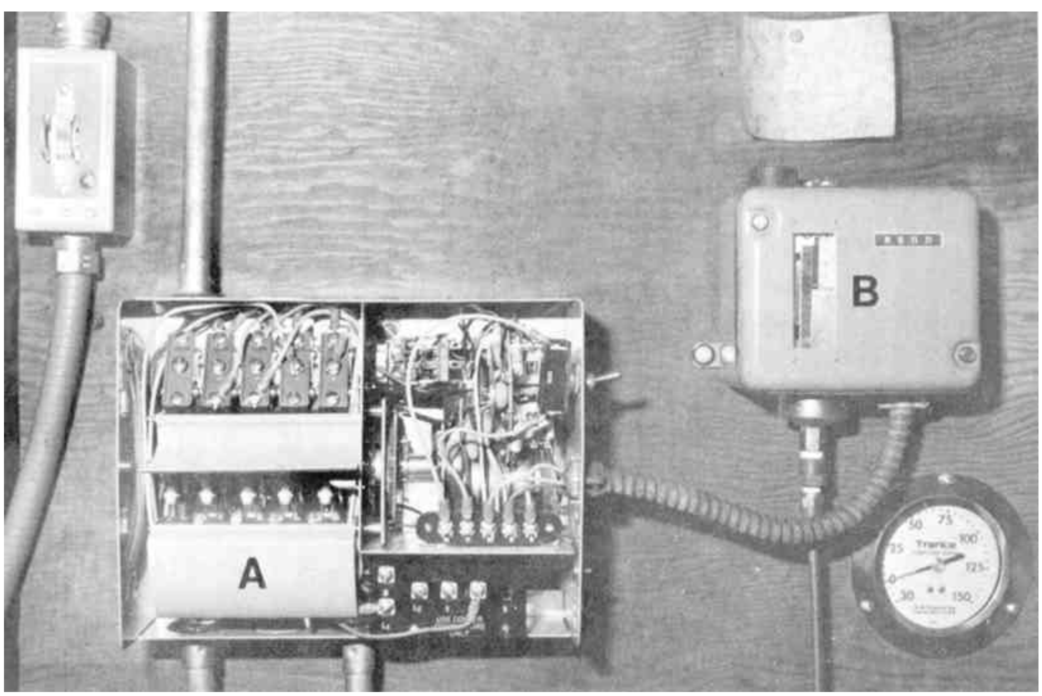

Figure 7-34.—Step controller and pressure-sensor configuration. (A) Step controller with modulating motor, single-pole double-throw mini switches, and mouse trap relay assembly; (B) Pressure sensor that controls the step controller.

Q24. What type of cooling tower is installed indoors?

Q25. Forced draft underflow towers retain the advantages of what other type of cooling tower?

Q26. Air intake louvers and fill are made of what material?

Q27. Cooling towers evaporate approximately how much water every hour for each ton of refrigeration?

Q28. Rotary compressors are used in what type of units?

Q29. Semisealed and sealed compressors have reduced service requirements because of the elimination of what part?

Q30. What control is temperature sensitive and controls the operation of the cooling unit?

Q31. What device maintains humidity at a predetermined point?

Q32. What causes a motor to shut down when a motor is too hot?

AUTOMOTIVE AIR CONDITIONING

Learning Objective: Understand the basic principles of operation, maintenance, and repair of automotive air conditioning.

Vehicle air conditioning is the cooling (refrigeration) of air within a passenger compartment. Refrigeration is accomplished by making practical use of three laws of nature—heat transfer, latent heat of vaporization, and the effects of pressure on boiling or condensation. The first two laws are discussed in chapter 6 of this TRAMAN; the practical application of the third is outlined below.

EFFECT OF PRESSURE ON BOILING OR CONDENSATION

The saturation temperature (the temperature where boiling or condensation occurs) of a liquid or vapor increases or decreases according to the pressure exerted on it.

In the fixed orifice tube refrigerant system, liquid refrigerant is stored in the condenser under high pressure (fig. 7-35). When the liquid refrigerant is released into the evaporator by the fixed orifice tube,

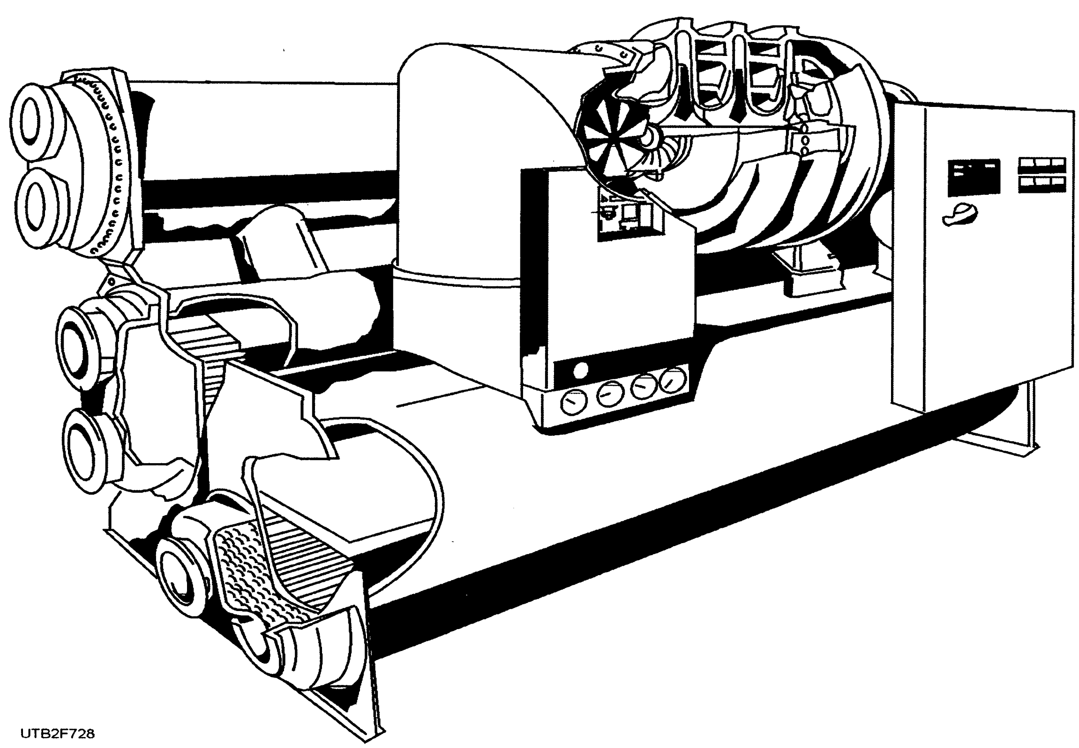

Figure 7-35.—Air-conditioning refrigeration system-fixed orifice.

the resulting decrease in pressure and partial boiling lowers its temperature to its new boiling point. As the refrigerant flows through the evaporator, passenger compartment air passes over the outside surface of the evaporator coils. As it boils, the refrigerant absorbs heat from the air and thus cools the passenger compartment. The heat from the passenger compartment is absorbed by the boiling refrigerant and hidden in the vapor. The refrigeration cycle is now under way. The following functions must be done to complete the refrigeration cycle:

1. Disposing of the heat in the vapor
2. Converting the vapor back to liquid for reuse
3. Returning of the liquid to the starting point in the refrigeration cycle

The compressor and condenser (fig. 7-35) perform these functions. The compressor pumps the refrigerant vapor (containing the hidden heat) out of the evaporator and suction accumulator drier, then forces it under high pressure into the condenser which is located in the outside air stream at the front of the vehicle. The increased pressure in the condenser raises the refrigerant condensation or saturation temperature to a point higher than that of the outside air. As the heat transfers from the hot vapor to the cooler air, the refrigerant condenses back to a liquid. The liquid under high pressure now returns through the liquid line to the fixed orifice tube for reuse.

It may seem difficult to understand how heat can be transferred from a comparatively cooler vehicle passenger compartment to the hot outside air. The answer lies in the difference between the refrigerant pressure that exists in the evaporator and the pressure that exists in the condenser. In the evaporator, the compressor suction reduces the pressure and the boiling point below the temperature of the passenger compartment. Thus heat transfers from the passenger compartment to the boiling refrigerant. In the condenser, the compressor raises the condensation point above the temperature of the outside air. Thus the heat transfers from the condensing refrigerant to the outside air. The fixed orifice tube and the compressor simply create pressure conditions that permit the laws of nature to function.

AUTOMOTIVE COMPRESSORS

There are three basic types of air-conditioning compressors in general use in automotive applications. Each of these uses a reciprocating (back-and-forth motion) piston arrangement—two-cylinder reciprocating, swash plate, and scotch yoke. Most automotive compressors are semihermetic.

Two-cylinder compressors (fig. 7-36) usually contain two pistons in a parallel V-type configuration. The pistons are attached to a connecting rod, which is driven by the crankshaft. The crankshaft is connected to the compressor clutch assembly, which is driven by an engine belt. Reed valves generally are used to control the intake and exhaust of the refrigerant gas during the pumping operation. These compressors are usually constructed of die cast aluminum.

In the swash plate or "wobble plate" compressor (fig. 7-37), the piston motion is parallel to the

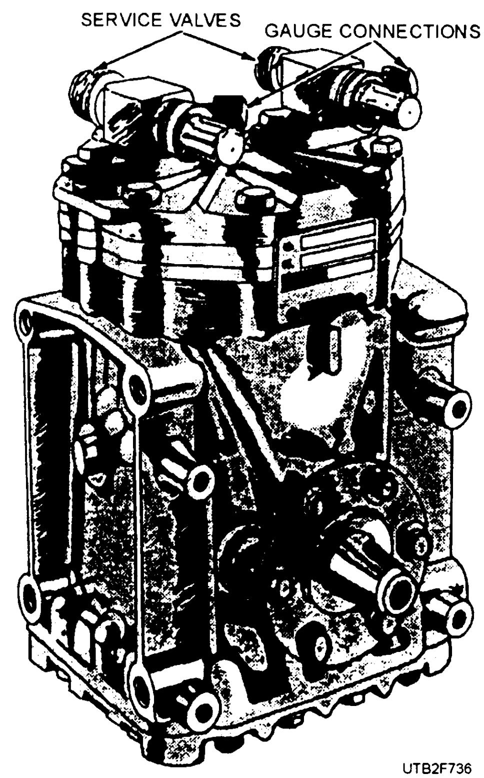

Figure 7-36.—Two-cylinder reciprocating compressor.

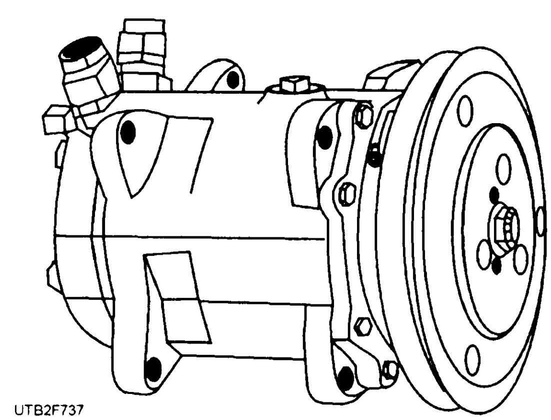

Figure 7-37.—Five-cylinder swash plate compressor.

crankshaft. The pistons are connected to an angled swash plate using ball joints. Swash plate compressors are of three types—five-cylinder, six-cylinder, and five-cylinder variable.

The five- and six-cylinder swash compressor has, in effect, three cylinders at each end of its inner assembly. A swash plate of diagonal design is mounted on the compressor shaft. It actuates the pistons, forcing them to move back and forth in the cylinders as the shaft is rotated. Reed valves control suction and discharge; crossover passages feed refrigerant to both high- and low-service fittings at the rear end of the compressor. A gear type of oil pump in the rear head provides for compressor lubrication.

The five-cylinder variable swash plate compressor is different from the other swash plate compressors. It uses a plate connected to a hinge pin that permits the swash plate to change its angle. The angle of the swash plate is controlled by a bellows valve that senses suction pressure. During high load conditions the swash plate angle is large, and during low load conditions, the swash plate is smaller. The displacement of the compressor is high at a large angle and low at a small angle.

A scotch-yoke compressor changes rotary motion into reciprocating motion. The basic mechanism of the scotch yoke contains four pistons mounted 90 degrees from each other. Opposed pistons are pressed into a yoke that rides on a slide block located on the shaft eccentric (fig. 7-38). Rotation of the shaft provides a reciprocating motion with no connecting rods. Refrigerant flows into the crankcase through the rear and is drained through the reeds attached to the piston tops during the suction stroke. Refrigerant is then discharged through the valve plate out the connector block at the rear. These compressors are shorter in length and larger in diameter than other compressors.

Compressor Service Valves

Compressor service valves are built into some systems. They serve as a point of attachment for test gauges or servicing hoses. The service valves have three position controls—front seated, back seated, and midposition (fig. 7-39).

The position of this double-faced valve is controlled by rotating the valve stem with a service valve wrench. Clockwise rotation seats the front face of the valve and shuts off all refrigerant flow in the system. This position isolates the compressor from the rest of the system.

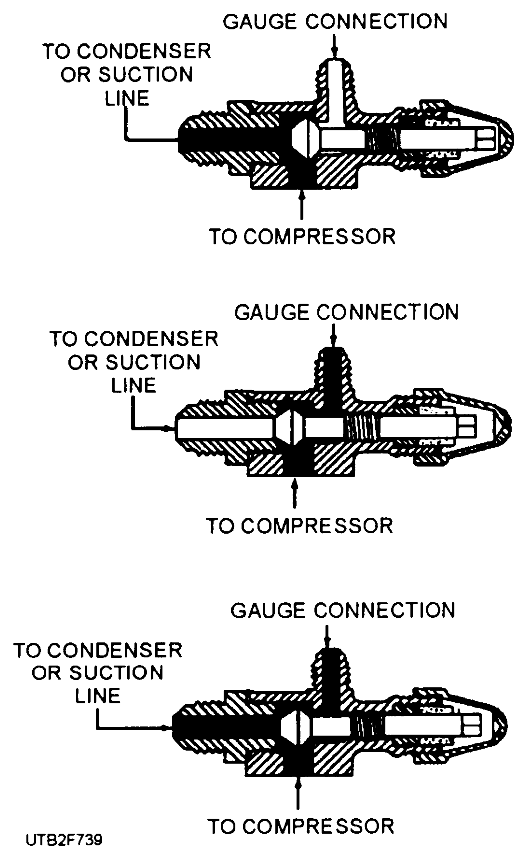

Figure 7-39.—Three-way service valve positions.

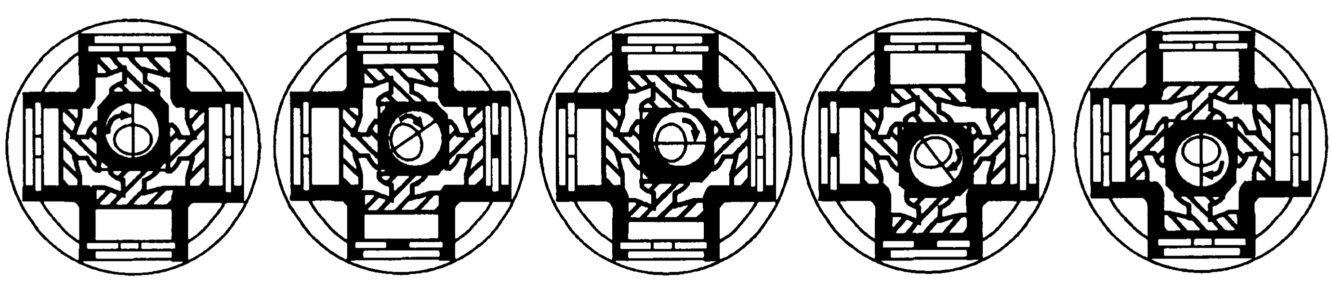

Figure 7-38.—Four-cylinder scotch-yoke mechanism.

Counterclockwise rotation unseats the valve and opens the system to refrigerant flow (midposition). Systematic checks are performed with a manifold gauge set with the service valve in midposition. Further counterclockwise rotation of the valve stem seats the rear face of the valve. This position opens the system to the flow of refrigerant but shuts off refrigerant to the test connector. The service valves are used for observing of operating pressures; isolating the compressor for repair or replacement; and discharging, evacuating, and charging the system.

Compressors used in automotive air-conditioning systems generally are equipped with an electromagnetic clutch that energizes and de-energizes to engage and disengage the compressor. Two types of clutches are in general use-the rotating coil and the stationary coil.

The rotating coil clutch has a magnetic coil mounted in the pulley that rotates with the pulley. It operates electrically through connections to a stationary brush assembly and rotating slip rings. The clutch permits the compressor to engage or disengage as required for adequate air conditioning. The stationary coil clutch has the magnetic coil mounted on the end of the compressor. Electrical connections are made directly to the coil leads.

The belt-driven pulley is always in rotation while the engine is running. The compressor is in rotation and operation only when the clutch engages it to the pulley.

Air-conditioning and refrigeration systems use various control devices, including those for the refrigerant, the capillary tube usually found on window units, the automatic expansion valves also found on window units and small package units, the thermal expansion valve, and various types of suction pressure-regulating valves and devices. A brief description of a suction pressure-regulating valve is given below. A suction pressure-regulating valve is used on automotive air conditioning because the varying rpm of the compressor unit must maintain a constant pressure in the evaporator.

Suction Pressure-Regulating Valves

Suction pressure-regulating valves may be installed in the suction line at the outlet of the evaporator when a minimum temperature must be maintained. Suction pressure-regulating valves decrease the temperature difference, which would otherwise exist between the compartment temperature and the surface of the cooling coils. The amount of heat that can be transferred into the evaporating refrigerant is directly proportional to the temperature difference. Figure 7-40 shows an exploded view of a typical suction pressure-regulating valve, sometimes called a suction throttling valve in automotive air conditioners.

Three types of suction pressure-regulating valves are used—suction throttling valve (STV), evaporator pressure regulators (EPR), or pilot-operated absolute valve (POA), developed by General Motors Corporation. These valves, in most cases, are adjustable.

The POA valve uses a sealed pressure element that maintains a constant pressure independent of the altitude of the vehicle. There are two basic types of metering devices built into a single container—the VIR (Valves-In-Receiver) and the EEVIR (Evaporator Equalized Valves-In-Receiver). These units combine the POA valve, receiver-drier, thermostatic expansion valve, and sight glass into a single unit.

The VIR assembly is mounted next to the evaporator, which eliminates the need for an external equalizer line between the thermostatic expansion valve and the outlet of the POA valve. The equalizer function is carried out by a drilled hole (equalizer port) between the two-valve cavities in the VIR housing.

The thermostatic expansion valve is also eliminated. The diaphragm of the VIR expansion valve is exposed to the refrigerant vapor entering the VIR unit from the outlet of the evaporator. The sight glass is in the valve housing at the inlet end of the thermostatic valve cavity where it gives a liquid indication of the refrigerant level.

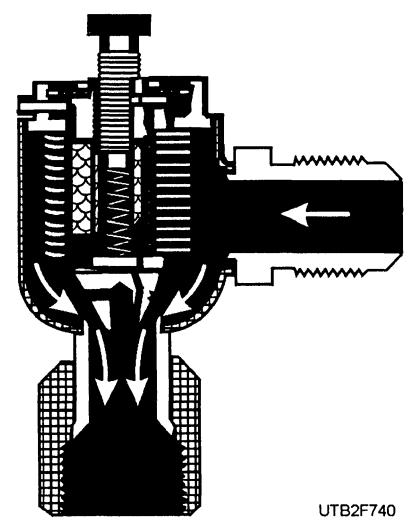

Figure 7-40.—A typical suction pressure-regulating valve.

The VIR thermostatic expansion valve controls the flow of refrigerant to the evaporator by sensing the temperature and pressure of the refrigerant gas, as it passes through the VIR unit on its way to the compressor. The POA valve controls the flow of refrigerant from the evaporator to maintain a constant evaporator pressure of 30 psi. The VIR and the POA valves are capsule type of valves. When found to be defective, you must replace the complete valve capsule.

The drier desiccant is in a bag in the receiver shell. It is replaceable by removing the shell and removing the old bag and installing a new bag of desiccant.

Service procedures for the VIR system differ in some respect from the service procedures performed on conventional automotive air-conditioning systems.

SERVICE PRECAUTIONS

Observe the following precautions whenever you are tasked to service air-conditioning equipment:

- Never open or loosen a connection before discharging the system.
- A system that has been opened to replace a component or one which has discharged through leakage must be evacuated before charging.
- Immediately after disconnecting a component from the system, seal the open fittings with a cap or plug.
- Before disconnecting a component from the system, clean the outside of the fittings thoroughly.
- Do not remove the sealing caps from a replacement component until you are ready to install it.
- Refrigerant oil absorbs moisture from the atmosphere if it is left uncapped. Do not open an oil container until it is ready to use, and install the cap immediately after using. Store the oil only in a clean, moisture-free container.
- Before connecting to an open fitting, always install a new seal ring. Coat the fitting and seal with the refrigerant oil before connecting.
- When installing a refrigerant line, avoid sharp bends. Position the line away from the exhaust or any sharp edges that may chafe the line.
- Tighten the fittings only to specified torque. The copper and aluminum fittings that are used in refrigerant systems will not tolerate over-tightening.
- When disconnecting a fitting, use a wrench on both halves of the fitting to prevent twisting of refrigerant lines or tubes.
- Do not open a refrigerant system or uncap a replacement component unless it is as close as possible to room temperature. This prevents condensation from forming inside a component that is cooler than the surrounding air.
- Keep the service tools and work area clean. Contamination of a refrigerant system through careless work habits must be avoided.

DIAGNOSIS, TESTING, AND SERVICING

Diagnosis is more than just following a series of interrelated steps to find the solution to a specific condition. It is a way of looking at systems that are not functioning the way they should and finding out why. Also, it is knowing how the system should work and whether it is working correctly. All good diagnosticians use the same basic procedures.

There are basic rules for diagnosis. If these rules are followed, the cause of the condition will usually be found the first time through the system.

1. Know the system; know how the parts go together. Also, know how the system operates and its limits, and what happens when something goes wrong. Sometimes this means comparing a system that is working properly with the one you are servicing.

2. Know the history of the system. How old or new is the system? What kind oftreatment has it had? Has it been serviced in the past in such a manner that might relate to the present condition? What is the service history? A clue in any of these areas might save a lot of diagnosis time.

3. Know the probability of certain conditions developing. It is true that most conditions are caused by simple things, rather than by complex ones, and they occur in a fairly predictable pattern. Electrical problem conditions, for instance, usually occur at connections, rather than in components. An engine "no-start" is more likely to be caused by a loose wire or some component out of adjustment than a sheared off camshaft. Know the difference between impossible and improbable. Many good technicians have spent hours diagnosing a system because they thought certain failures were "impossible," only to find out the failures

eventually were just "improbable" and actually had happened. Remember, new parts are just that—new. It does not mean they are good functioning parts.

4. Don't cure the symptom and leave the cause. Recharging a refrigerant system may correct the condition of insufficient cooling, but it does not correct the original problem unless a cause is found. A properly working system does not lose refrigerant over time.

5. Be sure the cause is found; do not be fooled into thinking the cause of the problem has been found. Perform the proper tests; then double-check the results. The system should have been checked for refrigerant leaks. If no leaks were found, perform a leak test with the system under extremely high pressure. If the system performed properly when new, it had to have a leak to be low in charge.

6. No matter what form charts may take, they are simply a way of expressing the relationship between the basic logic and a physical system of components. It is a way of determining the cause of a condition in the shortest possible amount of time. Diagnosis charts combine many areas of diagnosis into one visual display that allows you to determine the following:

- The probability of certain things occurring in a system
- The speed of checking certain components, or functions, before others
- The simplicity of performing certain tests before others
- The elimination of checking huge sections of a system by performing simple tests
- The certainties of narrowing down the search to a small area before performing in-depth testing

The fastest way to find a condition is to work with the tools that are available, which means working with proven diagnosis charts and the proper special tools for the system being worked on.

Servicing procedures for automotive air-conditioning units are similar to those used to service conventional air-conditioning systems. Discharging, evacuating, charging procedures, connections, and positions of valves on the gauge manifold set are shown in figure 7-41.

Servicing procedures for the VIR system are also similar to those used when servicing conventional air-conditioning systems. However, the hookup of the manifold gauge set is to the VIR unit. The high-pressure fitting is located in the VIR inlet line. The low-pressure fitting is located in the VIR unit.

SYSTEM VISUAL INSPECTION

It is often possible to detect a problem caused by a careful visual inspection of the air-conditioning refrigerant system. This includes broken belts, obstructed condenser air passages, a loose clutch, loose or broken mounting brackets, disconnected or broken wires, and refrigerant leaks.

A refrigerant leak usually appears as an oily residue at the leakage point in the system. The oily residue soon picks up dust or dirt particles from the surrounding air and appears greasy. Through time, this builds up and appears to be heavy, dirt-impregnated grease.

Most common leaks are caused by damaged or missing O-ring seals at various hose and component connections. When these O rings are replaced, the new O rings should be lubricated with refrigerant oil. Care should be taken to keep lint from shop towels or cloths from contaminating the internal surfaces of the connection. Leakage may occur at a spring lock coupling if the wrong O rings are used at the coupling.

Another type of leak may appear at the internal Schrader type of air-conditioning charging valve core in the service gauge port valve fittings. If tightening the valve core does not stop the leak, it should be replaced with a new air-conditioning charging valve core.

Missing service gauge port valve caps can also cause a refrigerant leak. If this important primary seal (the valve cap) is missing, dirt enters the area of the air-conditioning charging valve core. When the service hose is attached, the valve depressor in the end of the service hose forces the dirt into the valve seat area, and it destroys the sealing surface of the air-conditioning charging valve core. When a service gauge port valve cap is missing, the protected area of the air-conditioning charging valve core should be cleaned and a new service gauge port valve cap should be installed.

CAUTION

The service gauge port valve cap must be installed finger tight. If tightened with pliers, the sealing surface of the service gauge port valve may be damaged.

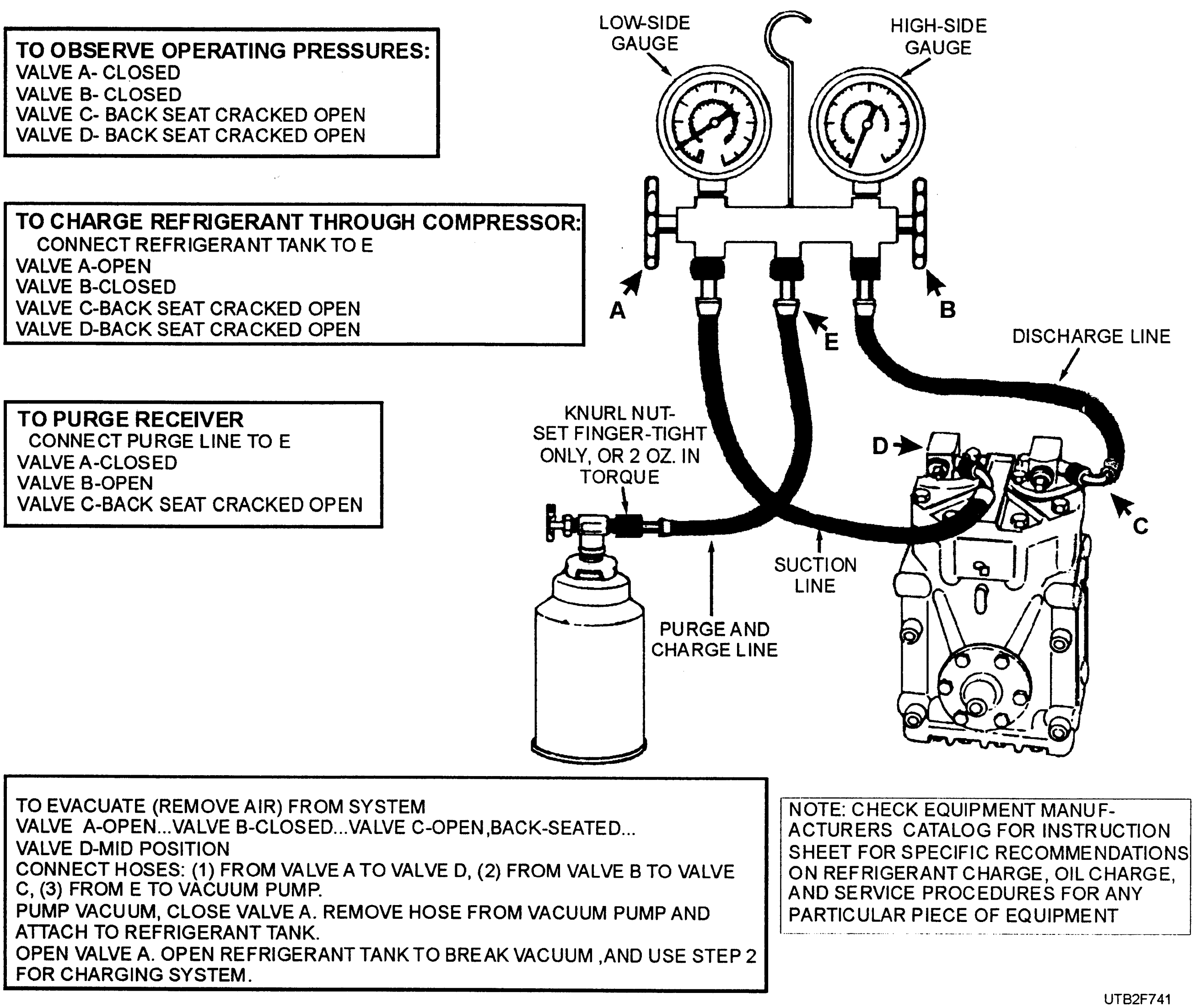

Figure 7-41.—Procedures for observing operating pressures, charging, purging, and evacuating a unit.

CLEANING A BADLY CONTAMINATED REFRIGERANT SYSTEM

A refrigerant system can become badly contaminated for a number of reasons.

- The compressor may have failed due to damage or wear.
- The compressor may have been run for some time with a severe leak or an opening in the system.
- The system may have been damaged by a collision and left open for some time.
- The system may not have been cleaned properly after a previous failure.
- The system may have been operated for a time with water or moisture in it.

A badly contaminated system contains water, carbon, and other decomposition products. When such a condition exists, the system must be flushed with a special flushing agent, using equipment designed especially for this purpose. Follow the suggestions and procedures outlined for proper cleaning.

Flushing Agents

A refrigerant to be suitable as a flushing agent must remain in the liquid state during the flushing operation to wash the inside surfaces of the system components. Refrigerant vapor will not remove contaminant particles. They must be flushed with a liquid. Some refrigerants are better suited for this purpose than others.

R-11 and R-113 are suited for use with special flushing equipment. Both have rather high vaporization points—74.7°F for R-11 and 117.6°F for R-1 13. Both refrigerants also have low closed container pressures. This reduces the danger of an accidental system discharge to a ruptured hose or fitting. R-113 will do the best job and is recommended as a flushing refrigerant. Both R-11 and R-113 require a propellant or a pump type of flushing equipment due to their low closed container pressures. R-11 is available in pressurized containers. Although not recommended for regular use, it may become necessary to use R-11 if special flushing equipment is not available. It is more toxic than other refrigerants, and it should be handled with extra care. Currently new refrigerants are being developed to replace R-11 and R-113 because these refrigerants will be phased out by the year 2000.

CAUTION

Use extreme care and adhere to all safety precautions related to the use of refrigerants when flushing a system.

System Cleaning and Flushing

When it is necessary to flush a refrigerant system, the suction accumulator/drier must be removed and replaced, as it is impossible to clean. Remove the fixed orifice tube. If a new tube is available, replace the contaminated one; otherwise, wash it carefully in flushing refrigerant or mineral spirits and blow it dry. If it does not show signs of damage or deterioration, it may be reused. Install new O rings.

Any moisture in the evaporator will be removed during leak testing and system evacuation following the cleaning job. Perform each step of the cleaning procedure carefully as outlined below.

1. Check the hose connections at the flushing cylinder outlet and flushing nozzle to ensure they are secure.

2. Ensure the flushing cylinder is filled with approximately 1 pint of R-113 and that the valve assembly on top of the cylinder is tightened securely.

3. Connect a can of R-12 or R-134a to the Schrader valve at the top of the charging cylinder. A refrigerant hose and a special, safety type of refrigerant dispensing valve are required for connecting the small can to the cylinder. Ensure all connections are secure.

4. Connect a gauge manifold and a discharge system. Disconnect the gauge manifold.

5. Remove and discard the suction accumulator/drier. Install a new accumulator/drier and connect it to the evaporator. Do not connect it to the suction line from the compressor. Ensure a protective cap is in place on the suction line connection.

6. Replace the fixed orifice tube. Install a protective cap on the evaporator inlet tube as soon as the new orifice tube is in place. The liquid line will be connected later.

7. Remove the compressor from the vehicle for cleaning and servicing or replacement, whichever is required. If the compressor is cleaned and serviced, add the specified amount of refrigerant oil before installing it on the mounting brackets in the vehicle. Install the shipping caps on the compressor connections. Install a new compressor on the mounting brackets in the vehicle.

8. Back flush the condenser and the liquid line as follows:

a. Remove two O rings from the condenser inlet tube spring lock coupling.

b. Remove the discharge hose from the condenser and clamp a piece of (1/2-inch ID) heater hose to the condenser inlet line. Ensure the hose is long enough to insert the free end into a suitable waste container to catch the flushing refrigerant.

c. Move the flushing equipment into position and open the valve on the can of R-12 or R-134a (fully counterclockwise).

d. Back flush the condenser and the liquid line by introducing flushing refrigerant into the supported end of the liquid line with the flushing nozzle. Hold the nozzle firmly against the open end of the liquid line.

e. After the liquid line and condenser have been flushed, lay the charging cylinder on its side so R-12 or R-134a will not force more of the flushing refrigerant into the liquid line. Press the nozzle firmly to the liquid line and admit the R-12 or R-134a to force all of the flushing refrigerant from the liquid line and condenser.

f. Remove the 1/2-inch hose and clamp from the condenser inlet connection.

g. Stand the flushing cylinder upright and flush the compressor discharge hose. Secure it so the flushing refrigerant goes into the waste container.

h. Close the dispensing valve of the R-12 or R-134a can (fully clockwise). If there is any flushing refrigerant in the cylinder, it may be left there until the next flushing job. Put the flushing kit and R-12 or R-134a can in a suitable storage location.

i. Install the new lubricated O rings on the spring lock coupling male fittings on both the condenser inlet and the liquid lines. Assemble the couplings.

9. Connect all refrigerant lines. All connections should be cleaned and new O rings should be used. Lubricate new O rings with clean refrigerant oil.

10. Connect a charging station or manifold gauge set and charge the system with 1 pound of R-12 or R-134a. (Do not evacuate the system until after it has been leak tested.)

11. Leak test all connections and components with a flame type of leak detector or an electronic leak detector. If no leaks are found, go to Step 12. If leaks are found, service as necessary; check the system and then go to Step 12.

12. Evacuate and charge the system with a specified amount of R-12 or R-134a. Operate the system to ensure it is cooling properly.

SAFETY PRECAUTIONS

The use of safety when handling or using refrigerants can never be stressed enough. As discussed in chapter 6 of this TRAMAN, routinely think of safety for yourself and coworkers.

Extreme care must be taken to prevent any liquid refrigerant from coming in contact with the skin and especially the eyes. A bottle of sterile mineral oil and a quantity of weak boric acid solution must always be kept nearby when servicing the air-conditioning system. Should any liquid refrigerant get into your eyes, immediately use a few drops of mineral oil to wash them out; then wash the eyes clean with the weak boric acid solution. Seek a doctor's aid immediately even though irritation may have ceased. Always wear safety goggles when servicing any part of the refrigerant system.

To avoid a dangerous explosion, never weld, solder, steam clean, bake body finishes, or use any excessive amount of heat on or in the immediate area of any part of the refrigerant system or refrigerant supply tank, while they are closed to the atmosphere whether filled with refrigerant or not.

The liquid refrigerant evaporates so rapidly that the resulting refrigerant gas displaces the air surrounding the area where the refrigerant is released. To prevent possible suffocation in enclosed areas, always discharge the refrigerant into recycling/ reclaiming equipment. Always maintain good ventilation surrounding the work area.

Although R-12 gas, under normal conditions, is nonpoisonous, the discharge of refrigerant gas near an open flame can produce a very poisonous gas. This gas also attacks all bright metal surfaces. This poisonous gas is generated when the flame type of leak detector is used. Avoid inhaling the fumes from the leak detector. Ensure that R-12 is both stored and installed according to all federal, state and local ordinances.

When admitting R-12 or R-134a gas into the cooling unit, always keep the tank in an upright position. lf the tank is on its side or upside down, liquid R-12 or R-134 enters the system and may damage the compressor.

TRUCK AND BUS AIR CONDITIONING

The cabs of many truck-tractors and long distance hauling trucks and earthmover cabs are air-conditioned. Most of this equipment is of the "hang on" type and is installed after the cab has been made.

Some truck air-conditioning units have two evaporators—one for the cab and one for the relief driver's quarters in back of the driver. Some systems use a remote condenser, mounted on the roof of the cab. This type of installation removes the condenser from in front of the radiator, so the radiator can operate at full efficiency. This is especially important during long pulls in low gear.

The system is similar to the automobile air conditioner and is installed and serviced in the same general way.

The air conditioning of buses has progressed rapidly. Because of the large size of the unit, most bus air-conditioning systems use a separate gasoline engine with an automatic starting device to drive the compressor. The system is standard in construction except for the condensing unit. It is made as compact as possible and generally is installed in the bus, so it can be easily reached for servicing.

Condensing units are often mounted on rails with flexible suction and liquid lines to permit sliding the condensing unit out of the bus body to aid in servicing.

Air-cooled condensers are used. Thermostatic expansion valve refrigerant controls are standard. Finned blower evaporators are also used.

The duct system usually runs between a false ceiling and the roof of the bus. The ducts, usually one on each side of the bus, have grilles at the passenger seats. The passengers may control the grille by opening and closing.

CERTIFICATION

The Environmental Protection Agency (EPA) has established as per the Clean Air Act (CAA) that all technicians who maintain or repair air-conditioning or refrigeration equipment or technicians who operate recycling, reclaiming, and recovery equipment must be certified. Certification is administered by organizations with certification programs that are approved by the EPA. It is important to understand, that as a Utilitiesman, if you are not certified, you cannot do any HVAC/R service that requires use or removal of refrigerants. Certification requirements are divided into two different areas—automotive air-conditioning and HVAC/R.

Automotive Air-Conditioning Certification

Automotive air conditioning is serviced or repaired more often than other types of air-conditioning systems. In today's world, automotive air-conditioning systems are heavily used as our society spends more and more time in their vehicles. Industry experts say that 25 percent of the R-12 purchased in the United States is used in automotive air conditioning. The fittings and hoses used in automotive air conditioning allow leakage to occur. Automotive air-conditioning service facilities or technicians are now changing (retrofitting) systems in vehicles to use refrigerant R-134a and removing CFC R-12 to meet new standards. From the EPA's standpoint, technicians must be meet the following requirements to be certified:

- Be aware that venting refrigerant is illegal.
- Understand why all the regulations are being created. Understand what is happening to the environment.
- Have a working knowledge of SAE standards J-1989, J-1990, and J-1991.
- Perform service in a safe manner without injuring personnel or damaging equipment. Areas that must be understood include venting, handling, transporting, and disposing of refrigerant.

Once these requirements are met through testing of the individual applicant, a certification card is issued.

Heating, Ventilating, Air Conditioning, and Refrigeration Certification

Certification requirements to service standard types of air-conditioning systems are the same as for automotive air-conditioning certification. Unlike the automotive certification program, standard air-conditioning certification is divided into levels corresponding to the type of service the technician performs. There are four types of certification:

- Type I – Servicing small appliances
- Type II – Servicing high or very high-pressure appliances
- Type III – Servicing or disposing of low-pressure appliances
- Type IV (Universal) – Servicing all types of equipment

Individuals will be required to take a proctored, closed book test. These tests are offered by organizations approved by the EPA for the specific type of certification that the individual technician requires. Technicians can only work on air-conditioning systems that they have been certified for service.

Q33. The saturation temperature increases or decreases depending upon what factor?

Q34. What are the three basic types of automotive compressors?

Q35. A scotch-yoke compressor changes rotary motion into what type of motion?

Q36. Refrigerant can be put into a system when the service valve is back-seated. True /False

Q37. The POA valve, receiver-drier, expansion valve, and sight glass are combined in what type of device?

Q38. Service procedures for VIR systems are different than conventional automotive air-conditioning systems. True/False

Q39. What is the most important thing you should know before you perform a diagnosis on a system problem?

Q40. A refrigerant leak appears in what way at the point of the leak?

Q41. What is the most common cause of leaks on automotive air-conditioning systems?

Q42. For a refrigerant to be a suitable flushing agent, it must remain in what state during flushing operations?

Q43. Which part of an automotive air-conditioning system is replaced because it is impossible to clean?

Q44. A type IV certification is also known as what type of certification?

Q45. Who approves organizations to certify technicians?

DUCTWORK

Learning Objective: Understand the basic types of ductwork systems and the components of those systems for distribution of conditioned air.

Distributed air must be clean, provide the proper amount of ventilation, and absorb enough heat to cool the conditioned spaces. To deliver air to the conditioned space, air carriers are required, which are called ducts. Ducts work on the principle of air pressure difference. If a pressure difference exists, air will flow from an area of high pressure to an area of low pressure. The larger this difference, the faster the air will flow to the low-pressure area.

CLASSIFICATION OF DUCTS

There are three common classifications of ducts—conditioned air ducts, recirculating-air ducts, and fresh-air ducts. Conditioned air ducts carry conditioned air from the air conditioner and distribute it to the conditioned area. Recirculating air ducts take air from the conditioned space and distribute it back into the air conditioner system. Fresh air ducts bring fresh air into the air-conditioning system from outside the conditioned space.

Ducts commonly used for carrying air are of a round, square, or rectangular shape. The most efficient duct is a round duct, based on the volume of air handled per perimeter distance. In other words, less material is needed for the same capacity as a square or rectangular duct.

Square or rectangular duct fits better to building construction. It fits above ceilings and into walls and is much easier to install between joists and studs.

TYPES OF DUCT SYSTEMS

There are several types of supply duct systems (fig. 7-42) that deliver air to room(s) and then return the air from the room(s) to the cooling (evaporator) system. These supply systems can be grouped into four types:

1. Individual round pipe system
2. Extended plenum system
3. Reducing trunk system
4. Combination (of two or more systems)

Return air systems are normally of three types—single return, multiple return (fig. 7-42), or combination of the two systems.

CONSTRUCTION

Ducts may be made of metal, wood, ceramic, and plastic. Most commonly used is sheet steel coated with zinc (galvanized steel). Sheet metal brakes and forming machines are used in fabricating ducts. Elbows and other connections, such as branches, are designed using geometric principles. Some types of duct connections used in constructing duct systems are shown in figure 7-43.

Sheet metal ducts expand and contract as they heat and cool. Fabric joints are often used to absorb this movement. Fabric joints should also be used where the duct connects to the air conditioner. Many ducts are insulated to lower noise and reduce heat transfer. The insulation can be on the inside or the outside of the duct. Adhesives or metal clips are commonly used to fasten the insulation to the duct. As we are only briefly discussing construction here, you can find construction and fabrication methods in the *Steelworker,* volume 2. It details design and fabrication of steel ductwork.

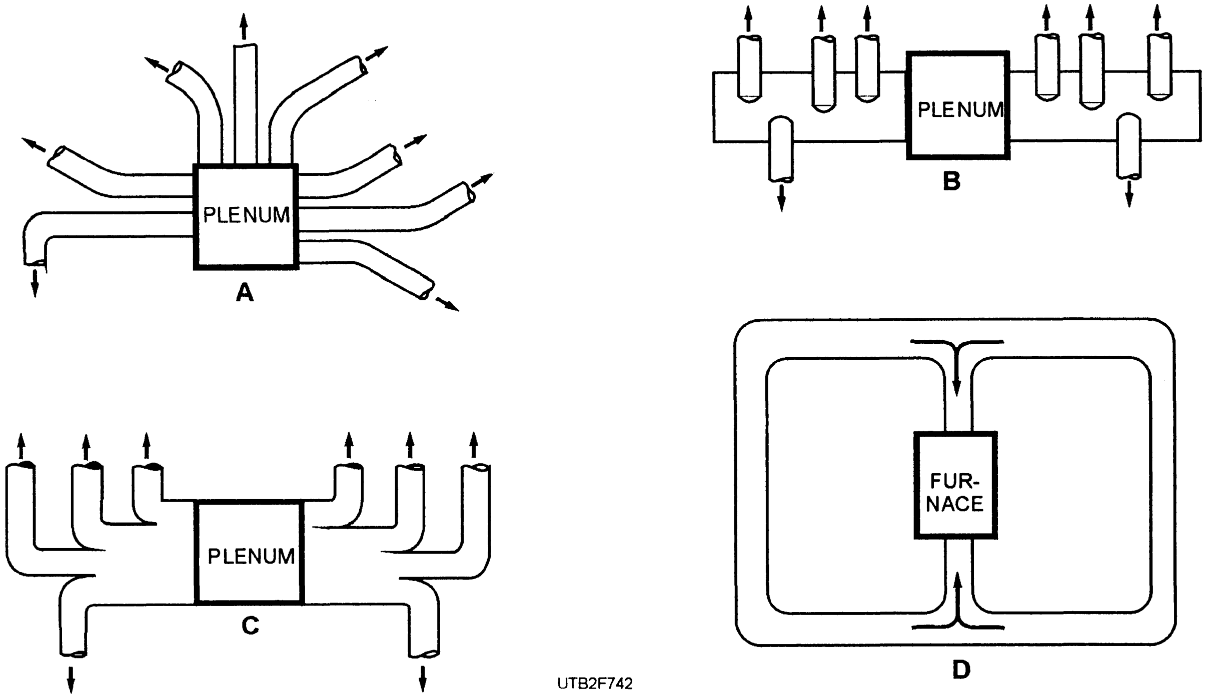

Figure 7-42.—Supply duct systems: A. Individual round pipe; B. Extended plenum; C. Reducing trunk; D. Multiple return air system.

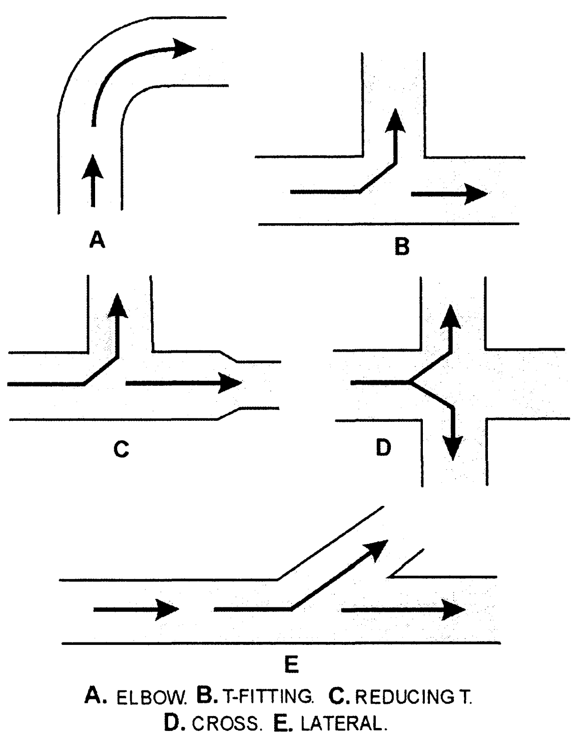

Figure 7-43.—Typical duct connections: A. Elbow; B. Tee: C. Reducing tee; D. Cross: E. Lateral.

COMPONENTS

To enable a duct system to circulate air at the proper velocity and volume to the proper conditioned areas, you can use different components within the duct system, such as diffusers, grilles, and dampers.

Diffusers, Grilles, and Registers

Room openings to ducts have several devices that control the airflow and keep large objects out of the duct. These devices are called diffusers, grilles, and registers. Diffusers deliver fan-shaped airflow into a room. Duct air mixes with some room air in certain types of diffusers.

Grilles control the distance, height, spread of air-throw, and amount of air. Grilles cause some resistance to airflow. Grille cross-section pieces block about 30 percent of the air. Because of this reason and to reduce noise, cross sections are usually enlarged at the grille. Grilles have many different designs, such as fixed vanes which force air in one direction, or adjustable to force air in different directions.

Registers are used to deliver a concentrated air stream into a room, and many have one-way or two-way adjustable air stream deflectors.

Dampers

One way of getting even air distribution is through the use of duct dampers. Dampers balance airflow or can shut off or open certain ducts for zone control. Some are located in the grille, and some are in the duct itself. There are three types of dampers used in air-conditioning ductwork—butterfly, multiple blade, and split damper (fig. 7-44). When installing a damper, always draw a line on temperature control.

Fire Dampers

Automatic fire dampers should be installed in all vertical ducts. Ducts, especially vertical ducts, will carry fumes and flames from fires. Fire dampers must be inspected and tested at least once a year to be sure they are in proper working order. There are two types of fire dampers, which are fail-safe units—spring-loaded to close and weight-loaded to close. Fire dampers are usually held open by a fusible link. Heat will melt the link and the damper will close by either gravity, weights, or springs (fig. 7-45).

Fans

Air movement is usually produced by some type of forced airflow. Fans are normally located in the inlet of the air conditioner. Air is moved by creating either a positive pressure or negative pressure in the ductwork. The two most popular types of fans are the axial flow (propeller) or radial flow (squirrel cage) (fig. 7-46).

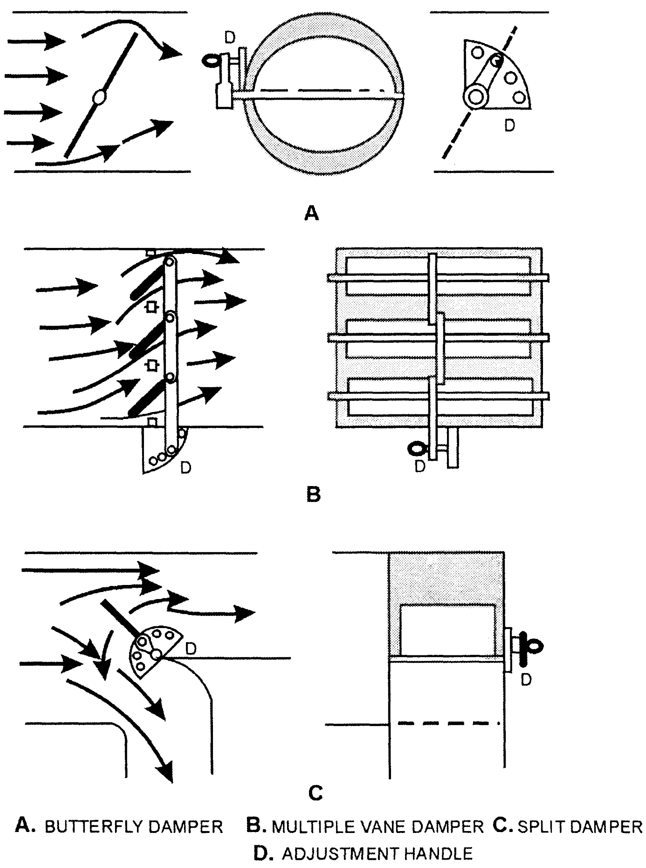

Figure 7-44.—Three types of duct dampers.

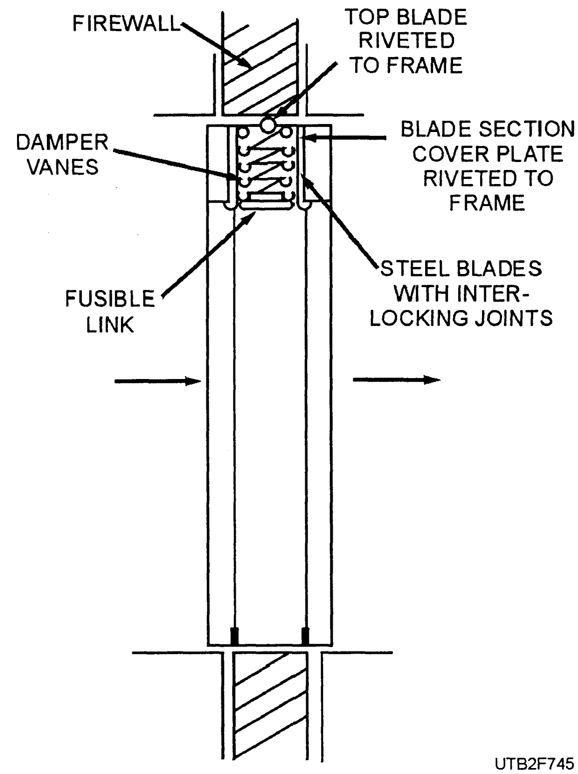

Figure 7-45.—Fire damper in OPEN position.

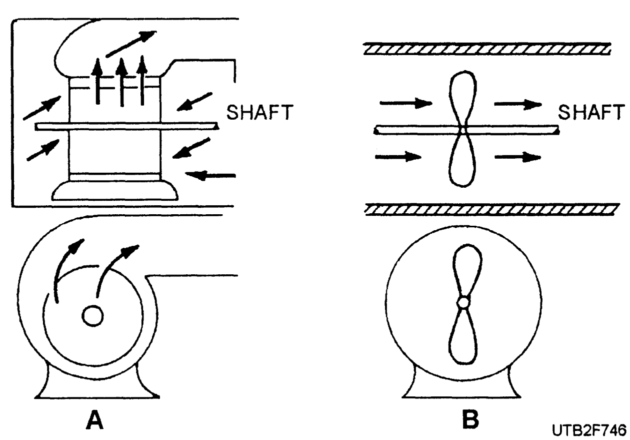

Figure 7-46.—Principal types of fans: A. Radial flow; B. Axial flow.

The axial-flow fan is usually direct-driven by mounting the fan blades on the motor shaft. The radial-flow fan is normally belt-driven but can also be direct-driven.

BALANCING THE SYSTEM

Balancing a system basically means sizing the ducts and adjusting the dampers to ensure each room receives the correct amount of air. To balance a system, follow these steps:

1. Inspect the complete system; locate all ducts, openings, and dampers.
2. Open all dampers in the ducts and at the grilles.
3. Check the velocities at each outlet.
4. Measure the "free" grille area.
5. Calculate the volume at each outlet. Velocity x Area = Volume
6. Area in square inches divided by 144 multiplied by feet per minute equals cubic feet/minute.
7. Total the cubic feet/minute.
8. Determine the floor areas of each room. Add to determine total area.
9. Determine the cfm for each room. The area of the room divided by the total floor area multiplied by the total cfm equals cfm for the room.
10. Adjust duct dampers and grille dampers to obtain these values.
11. Recheck all outlet grilles.

In some cases, it may be necessary to overcome excess duct resistance by installing an air duct booster. These are fans used to increase airflow when a duct is too small, too long, or has too many elbows.

Q46. What are the three common types of ducts?

Q47. What are the three types of return air systems?

Q48. Sheet metal ducts expand and contract as they heat and cool. True /False

Q49. What are the three types of dampers?

Q50. Once you have checked the velocities at each outlet, what is the next step when balancing the duct system?

APPENDIX I

GLOSSARY

ABSOLUTE ZERO —The point where all molecular motion ceases, -460°F.

AC — Alternating current.

AEROBIC DECOMPOSITION — Bacterial decomposition that occurs in the presence of oxygen.

AFTERCOOLER — Device which cools the final discharge from a compressor.

ANGLE VALVE — A stop valve that is actually a combination valve and elbow since its outlet branch is at right angles to its inlet branch.

ASME — American Society of Mechanical Engineers.

BILL OF MATERIAL — A list of all materials required to complete an installation based on takeoffs and estimates.

BOILER — An enclosed vessel that converts water to steam of proper temperature and pressure for an intended purpose.

BOILER SETTING — The structure that encloses a boiler and forms a furnace.

BREECHING — Connects a boiler to the stack.

BUSHING — A plumbing fitting used to reduce the pipe from one size to another size.

BUTTERFLY VALVE — A two-position valve with a vertical or horizontal disk.

CAP — A plumbing fitting used to close off a length of pipe.

CATHODIC PROTECTION — The use of material and liquid to cause electricity to flow to avoid corrosion.

CBMU — Construction Battalion Maintenance Unit.

CBR — Chemical, Biological, and Radiological.

CBU — Construction Battalion Unit.

CEC — Civil Engineer Corps.

CENTRIFUGAL FORCE — The force that impels a substance to move outward from the center of rotation.

CENTIGRADE — A thermometric scale in which 0 degrees represents the freezing point and 100 degrees represents the boiling point of water at a pressure of 1 atmosphere. Generally used with metric units of measure. Equal to the international thermometric scale of Celsius.

CHECK VALVE — An automatic non-return valve or a valve which permits a fluid to pass in one direction but automatically closes if the fluid begins to pass in the opposite direction.

CLARIFICATION OF WATER — The removal of suspended materials to produce a clear, clean liquid.

COLIFORM — The coliform groups of organisms are a bacterial indicator of contamination. This group has as one of its primary habitats, the intestinal tract of human beings. Coliforms also may be found in the intestinal tract of warm-blooded animals and in plants, soil, air, and the aquatic environment.

COMSECONDNCB — Commander, Second Naval Construction Brigade.

COMTHIRDNCB — Commander, Third Naval Construction Brigade.

COMPRESSOR — Pump of a refrigerating mechanism which draws a low pressure on the cooling side of the refrigerant cycle and squeezes or compresses the gas into the high pressure or condensing side of the cycle.

CONDENSATION — The process of changing a vapor to a liquid.

CONDENSER — Component in a refrigeration system that removes and dissipates heat from a compressed refrigerant.

CONDUCTION — The transmitting of heat from one substance or part to another substance or part that are in direct contact with each other.

CONVECTION — The transfer of heat by means of a medium, such as water, air, and steam.

COUPLING — A plumbing fitting used to join two lengths of pipe in a straight run.

DEGREE OF TEMPERATURE — Measurement of heat intensity.

DEHYDRATOR — Device used to remove moisture from a refrigerant system.

DEW POINT — Temperature at which vapor (at 100 percent humidity) begins to condense and deposit as a liquid.

DIATOMACEOUS EARTH — A porous mineral powder, used as a filtering medium for the removal of suspended materials.

ELBOW — A plumbing fitting used to change the direction of a length of pipe at 90° and 45° angles.

EVAPORATOR — Component of a refrigeration system that permits the absorption of heat from a desired medium or space.

EVAPORATION — A process of converting a liquid, by heat, into a vapor or gas.

FILTER-DRIER — Device for removing small foreign particles and moisture from refrigerant fluid.

FITTINGS — Devices which when placed in a pipe system make branch connections or changes in a direction of a line.

GATE VALVE — A sluice with two inclined seats between which the valve wedges down in closing. The passage through the valve is in an uninterrupted line, and when the valve is opened, the sluice is drawn up into a dome or recess, leaving an unobstructed passage the full diameter of the pipe.

GLOBE VALVE — A valve with a round, ball-like shell that is used for regulating or controlling the flow of gases or steam.

GPD — Gallons per day.

GPH — Gallons per hour.

GPM — Gallons per minute.

HEAT — The energy that is measured in British thermal units.

HERMETICALLY SEALED — Caused to be airtight.

HUMIDITY — The amount of water vapor in a given volume of air.

HYDROLOGIC CYCLE — Process by which water is circulated from ocean to atmosphere to earth's surface.

ID — Inside diameter.

INFLUENT — Water flow into a sewage or water treatment plant or equipment.

JOINING — All the procedures used to connect pipes together.

LATENT HEAT — Amount of heat required to change the state of a substance without a measurable change in temperature.

MATERIAL TAKEOFF — The estimate of materials required for a job based on plans and specifications.

METERING DEVICE — Valve or device used to regulate amount and state of refrigerant as it passes through the system.

NAVFAC — Naval Facilities Engineering Command.

NCR — Naval Construction Regiment.

NCTC — Naval Construction Training Center.

NMCB — Naval Mobile Construction Battalion.

OD — Outside diameter.

PACKING — Materials used to seal moving machinery joints against leakage.

P H — A value used to measure the acidity or alkalinity (basic) of a substance. A pH scale is from 0 to 14, with 7.0 as neutral. Below 7.0 on the scale is acid, and above 7.0 on the scale is alkaline or basic. Used in water treatment and purification.

PLUG — A plumbing fitting used to close off a fitting or a length of pipe by screwing into the fitting or pipe.

PPM — Parts per million.

PSI — Pounds per square inch.

PSIG — Pounds per square inch gauge.

PUMP — A mechanical device which applies a force to move any substance that flows or can be made to flow.

RADIATION — The transfer of heat through space by heat waves.

RECEIVER — Device in a refrigeration system to store refrigerant used by the system.

REDUCING VALVE — A spring-loaded or lever-loaded valve similar to a safety valve, designed to maintain a lower end constant pressure beyond the valve.

RELATIVE HUMIDITY — The percentage of water vapor in the air when compared to the amount it does hold as to the amount it could hold.

REVERSE OSMOSIS — A process whereby a solution flows through a semipermeable membrane into an area of lower solute concentration.

ROICC — Resident Officer- in-Charge of Construction.

ROUGHING IN — The installation of all parts of a plumbing system; completed before installation of fixtures.

SENSIBLE HEAT — Heat that can be measured in degrees of temperature with a thermometer.

SPECIFIC HEAT — The quantity of heat expressed in Btu required to raise 1 pound of any substance 1°F in temperature.

SUPERHEAT — The amount of heat expressed in Btu added to a substance above its boiling temperature.

TOTAL HEAT — Sensible heat plus latent heat expressed in Btu.

TRAMAN — Training manual.

VALVE — A device for regulating, stopping, or starting flow in a system and for controlling direction of flow.

VACUUM — Pressure lower than atmospheric pressure.

VAPORAZATION — The process of changing a liquid to a vapor.

VELOCIMETER — Instrument that measures air speeds using a direct-reading air speed indicating scales.

GLOSSARY OF

CHEMICALS USED IN WATER TREATMENT

ALUMINUM HYDROXIDE — AIOH, Reagent, used to decolorize water samples when preforming chloride tests on water.

ALUMINUM SULFATE — (Alum), $A1_3(SO_4)_3$, a white salt, a coagulant, used to flocculate dissolved solids in a weak acid water environment.

AMMONIA — NH_3, an alkaline colorless gas, used in solution to detect leaks in chlorine equipment and systems.

BARIUM CHLORIDE — $BaC1_2$, Reagent, used to test for sulfates in water.

CALCIUM HYPOCHLORITE — $CaC1_2O_2$, a granular white powder used to disinfect water.

CARBON DIOXIDE — CO_2, a liquid, is used to lower pH of softened and settled potable water.

CHLORINE — $C1_2$, a natural chemical element (Cl). A powerful disinfectant, used extensively in water treatment. As a gas, it's color is greenish yellow, and it is 2 1/2 times heavier than air. As a liquid, it's color is amber, and it is about 1 1/2 times heavier than water. It is an oxidizer, and is toxic to all organisms and corrosive (in the presence of water) to most metals.

DIAMINETETRACETATE — (EDTA), Reagent, used in solution with Sodium Ethylene to detect minerals which cause hardness in water.

FERRIC CHLORIDE — $FeC1_3$, a dark salt that hydrates to a yellow-orange form. A coagulant, used to flocculate dissolved solids in a strong acid water environment.

FERRIC SULFATE — FeS_3, a coagulant, used to flocculate dissolved solids in a strong acid water environment.

FERROUS SULFATE — $FeSO_4$, a coagulant, used to flocculate dissolved solids in a strong base (alkaline), water environment.

HYDRATED LIME — (Caustic Lime) $CaOH_2$, a dry white powder, a strong base (alkaline), consists of calcium hydroxide made by treating caustic lime with water. Used to balance water pH and absorb chlorine.

METHYL ORANGE — Reagent, used in solution to determine the alkalinity of water.

METHYL PURPLE — Reagent, used in solution to determine the alkalinity of water

PHENOLPHTHALEIN — $C_{20}H_{14}O_4$, Reagent, used as an pH indicator for water testing. Red color in bases (alkalines) or decolorized in an acid.

POTASSIUM CHROMATE — KC1, Reagent, used in testing for chlorine levels in water.

POTASSIUM HYDROXIDE-(Caustic Potash) K_2CrO_7, a white powder, strongly basic (alkaline), when dissolved in water produces heat. Used to balance water pH and absorb chlorine. Also used as a reagent to test water salinity.

SILVER NITRATE — $AgNO_3$, Reagent, used to determine amount of salinity and chloride in water.

SODIUM CARBONATE — (Soda ash), Na_2CO_3, salt of carbonic acid, strongly basic (alkaline). Used in water softening, and balancing water pH to aid coagulation.

SODIUM ETHYLENE — (EDTA), $Na_2CH_3CH_2$, Reagent, used in solution with Diaminetetracetate, to detect minerals which cause hardness in water.

SODIUM HYDROXIDE — (Caustic Soda) NaOH, a strong base (alkaline), white powder used to balance pH in water to aid coagulation, and absorb chlorine.

SODIUM HYPOCHLORITE — NaOC1, a salt usually furnished in solution, used for disinfection of water.

SULFURIC ACID — (Standard), H_2SO_4, strong acid, used to balance water pH and aid in coagulation.

THIOSULFATE — A salt, used to neutralize chlorine water. Used to sterilize water sample containers.

APPENDIX II

TABLES FOR MAINTENANCE PROCEDURES

Table A.—Permissible Enlargement and Ellipticity of Holes in Tube Sheets

Table B.—Preoperation Checks for Boilers

Table C.—Additional Preoperating Checks for Gas-Fired Boilers

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Table P.—Inspection and Maintenance of Coppers and other Steam-Heated Equipment

Table Q.—Troubleshooting for Dishwashing Machines

Table R.—Troubleshooting Chart for Ovens, Ranges, & Boilers

Table S.—Troubleshooting Chart for Clayton Steam Generator

Table T.—Troubleshooting Chart for Residential Washers

Table U.—Troubleshooting Chart for Residential Dryers

Table V.—Troubleshooting Refrigeration Systems

Table W.—Troubleshooting Industrial Refrigeration

Table X.—Troubleshooting Laundry Equipment

Table Y.—Troubleshooting Checklist Domestic Refrigerators and Freezers

Table Z.—Troubleshooting Chart for Air Conditioners

Table A

Permissible Enlargement and Ellipticity of Holes in Tube Sheets

Outside diameter of tube (inches)	Maximum tube hole diameter (Inches)	Maximum ellipticity (inches)
1	1 1/16	1/32
1 1/4	1 5/16	1/32
1 1/2	1 37/64	3/64
1 3/4	1 53/64	3/64
2	2 3/32	1/16
2 1/4	2 11/32	1/16
2 1/2	2 5/8	5/64
3	3 1/8	5/64
3 1/4	3 13/32	3/32
3 1/2	3 21/32	3/32
4	4 3/16	1/8
4 1/2	4 11/16	1/8

Table B

Preoperating Checks for Boilers

Equipment	Check/Action
Boiler room	Remove rags, paint cans, oil spots from deck Stow tools and equipment
Furnace/gas passages	Must be clean and clear and all doors must fit tight Must be in good repair No oil/tools in combustion chamber Must be purged
Valves	Good operating condition Bent stems Missing/broken handwheels
Piping	Inspect piping for leaks Check for proper support
Electrical systems	Oil-soaked or frayed wiring Damaged or loose conduit Improperly secured control boxes
Guards	Tight and in proper position
Water-gauge glass	Well lighted Not stained

Table C

Additional Preoperating Checks for Gas-fired Boilers

Equipment	Checks
Pilot & main gas cock	Operate smoothly
Copper tubing	No restrictions, such as kinks or flat spots
Air shutters	Operate freely Linkage must not have too much lost motion
Burner & main gas valve	Must be firmly supported
Boiler Room	No free gas. Ventilate if present and test all piping with soap solution

Table D

Additional Preoperating Checks for Oil-fired Boilers

Equipment	Checks
Strainers	Inspect & clean
Burners	Must be clean Nozzle must be clean Inspect and set electrodes Check all fittings for leaks Check operation of burner safety switch
Oil system	Inspect for leaks, and repair

Table E

Operational Checks for Boilers

EQUIPMENT	ACTION/CHECK
Water Level	–Check frequently as water expands during the heating up period.
Main steam stop bypass (if installed)	–Open if the boiler is to be cut in on a cold line; –Main steam stop can be opened when there is no other boiler on the same steam line.
Air cock	–Close after steam has formed and has blown all air from boiler.
Steam pressure	–Raise slowly, usually 1/2 to 2 1/2 hours, depending upon type, size and condition of boiler. –Temperature of water should be raised at a rate of 100°F per hour.
Safety valve	– Manually lifts when pressure is at least 75% of the valve setting –Make sure valves reseat properly; if valves fail to reseat, lift them a second time.
Boiler feedwater	–Commence feeding boiler, it probably will be automatically controlled.
Firing	–Gas; Maintain ignition; maintain air-fuel ratio; there should be no soot formation. –Oil; Maintain ignition, observe flame and adjust dampers; check accuracy by flue-gas analysis.
Water level	–Blow down gauge glass and water column (observe promptness of return of water in glass). –Keep at proper level. –Frequently, determine true level of water with different methods.
Boiler blowdown	–Watch and monitor gauge glass. –Frequency depends on water tests.
Cutting in boiler	–If closed, open main steam stop valve slowly.

Table F

Boiler Emergencies

EMERGENCY	TASK	KEY POINTS
EMERGENCY ONE: Low water condition indicated by no water level in the gauge glass.	Secure the boiler, secure electrical switches, steam stop, and feedwater stop. Prove water level by opening try cocks. Cool the boiler slowly until the water temperature is 200°F. Secure all sources of draft. Check controls. Find out the cause for low water level. Correct the trouble. After correction has been made, add water to obtain the correct water level.	DO NOT ADD WATER TO THE BOILER to raise the water level in the gauge glass column. STAY AWAY from the discharge. DON'T FORCE COOL.
EMERGENCY TWO: High water condition indicated by gauge glass full of water.	Prove water level by opening the try cocks. Blowdown the boiler by opening the blowdown valves. Find out the cause of high water condition. Check feedwater pump controls. Correct the trouble. Secure the boiler if pump controls operate improperly.	STAY AWAY from discharge. Check blowdown pit. Watch the gauge glass until normal level is reached. If control operates properly, continue to operate the boiler.
EMERGENCY THREE: Serious tube failure making it impossible to maintain water level.	Secure the boiler by securing the electrical steam and fired systems. Add water to the boiler until the ruptured tube level is reached and the boiler is cooled to a temperature of 200°F. Open the boiler to replace the tube.	For large boilers: Water should be fed to the boiler until properly cooled. Mark the gauge glass if within its range. Observe level by whatever means available.
EMERGENCY FOUR: Flareback caused by an explosion within the combustion chamber.	Secure the boiler. Find the cause of flareback and correct the trouble. Check for sufficient fuel and type of fuel contamination. Check the burner.	Ensure that a slug of water did not interrupt flame with a refire before prepurge.
EMERGENCY FIVE: Minor tube failure indicated by trouble maintaining water level under normal steam demand.	Secure the boiler if it is possible to remove it from the line for sufficient time to make necessary repairs. Secure electrical switches. Open the steam stop and feed stop if additional water is not needed to protect remaining tubes.	If unable to secure boiler because of steaming requirements and you can maintain the water level, continue to operate. If unable to maintain the water level and/or supply, secure the boiler.
EMERGENCY SIX: Broken gauge glass on water column.	Securetop and bottomvalves. Replace gauge glass Use chains or whatever method available to prevent injury to personnel.	Boiler may be kept on line, if necessary. Check the boiler water level by using the try cocks.

Table G

Fuel Gases

Fuel	**Source**	**Heating value Maximum (Btu per cuft)**	**Remarks**
Natural gas	Gas wells	700–1,300 average 1,000	Ideal fuel. It is pumped to point of use
Manufactured Gas			
Carbureted Water Gas	Manufactured from coal enriched with oil vapors	520–540	A costly good fuel that is part of most city gas
Oil Gas	Manufactured from petroleum	520–540	Used on U.S. west coast; is often mixed with coke oven gas
Producer Gas	Manufactured from coal, coke, wood, etc.	135–165	Requires cleaning
Liquefied Petroleum Gas			
Propane	By-product of gasoline	2,500	Boiling point: -44°F. Liquefies under slight pressure
Butane	By-product of gasoline	3,200–3,260	Boiling point 32°F. Liquefies under slight pressure

Table H

A Comparison of Fuel Oils

Grade Number	Approximate weight/gallon	Heating value (Btu per gallon)	Type Fuel
1	6.92	136,000	A volatile distillate oil for use in burners that prepare fuel for burning solely by vaporization.
2	7.08	138,500	A moderately volatile distillate oil for use in burners which prepare fuel for burning by a combination of vaporization and atomization
4	7.58	145,000	A residual oil for burner installations not equipped with preheaters
5 (Light)	7.83	148,500	A residual oil of intermediate viscosity for use in burners equipped with preheaters; however, preheating may or may not be required depending on climate and equipment
5 (Heavy)	Greater than 5 light	Greater than 5 light	A residual oil of greater viscosity than 5 light. Preheating may be required before burning this oil; and in cold climates, preheating may be required before handling as well
6	8.16	152,000	A residual oil of high viscosity for which preheating is always required

Table I

Troubleshooting Chart for Pot and Sleeve Oil Burners

Problem	Probable Cause	Possible Remedy
Burner Smokes	Improper fuel	Use recommended fuel
	Insufficient oil flow Excessive chimney draft Pilot casing is poorly fitted Dirty burner	Troubleshoot for low flow Check draft regulator Remove and install correctly Clean the burner
Burner goes out	Low oil supply Plugged vent on the out supply line Insufficient oil flow Improper fuel Fuel inlet plugged with carbon Dirt in the oil control valve Oil valve is not level Filter cartridge plugged Excessive chimney draft Excessive flue downdraft	Add oil if necessary Clean the vent Troubleshoot for low oil flow Use recommended fuel Clean Clean the valve Level the valve Clean the filter Check draft regulator Install downdraft hood
Burner Flooded	Dirty float valve Improper operation Needle valve stuck	Remove and clean the float valve Instruct operating personnel on proper procedures Clean or replace the valve
	Dirty burner	Clean the burner
	Excessive flue downdraft	Install downdraft hood
Low oil flow	Air trapped in oil supply line	Eliminate high points in the piping and bleed air out
	Oil control valve not level	Level the valve
	Oil may be too heavy	Only use manufacturer's recommended grade of oil
	Dirt in the supply line or in the metering mechanism	Clean the line and components
	C logged oil strainer	Clean the strainer
	Flue inlet clogged with carbon	Remove the carbon
High fuel consumption	Improper fuel	Use manufacturer's recommended grade of oil
	Heat loss	Reduce air supply to the burner
	Excessive chimney draft	Check the draft regulator
	Heat exchanger caked with slag	Clean the affected areas

Table J

Troubleshooting Chart for Gas-fired Space Heaters

Problem	Probable Cause	Possible Remedy
Motor does not run	Incorrect current Faulty wiring Defective wiring	Check and correct Rewire properly Replace and lubricate
Motor runs intermittently	Thermal overload protectors cutting out	If no external cause, such as improper current, can be found, replace the motor
Excessive fan and motor noise	Bent fan blade Excessive end play in shaft	Straighten by hand or replace if serious If end play exceeds 1/32 inch, repair or replace
Solenoid valve hums or flutters	Installed backwards Poor electrical connection or faulty solenoid	Check arrow on valve body and correct if required Check, correct, or replace
Burner does not ignite	Faulty pilot burner, thermo-couple, or thermal bulb Inoperable solenoid valve	Check, correct, or replace Impart current across the leads of the valve. A click indicates satisfactory operation. Replace solenoid if necessary
Delay in main burner operations (2 to 3 min) after fan starts	Malfunctioning limit switch	Replace limit switch
Improper burning of main burner	Primary air incorrectly set Incorrect orifice size Incorrect gas pressure	Adjust primary air after the unit has been burning for 10 to 15 minutes. Adjust the shutter down until a yellow tip appears on the flame, and then open the shutter until the yellow tip disappears. Check manufacturer's specifications for the correct size and replace. Check manufacturer's specifications regarding correct pressure for the gas being used. Measure pressure and adjust pressure regulator to correct condition.
Pilot fails to light or will not stay lit	Stopped pilot line Excessive draft Low gas pressure	Clean line or replace, if required Eliminate draft Check pressure regulator or tank level, if LPG

Table K

Oil Burner Troubleshooting

Burner fails to start

Source	Procedure	Causes	Correction
Thermostat control	Check thermostat settings	Thermostat is in OFF or COOL position Thermostat is set too low	Switch to HEAT Turn to higher
Safety overloads	Check burner motor, primary safety control, and auxiliary limit switch	Burner motor overload tripped Primary control tripped on safety Auxiliary limit switch tripped on safety	Push motor overload reset button Reset safety switch lever Push auxiliary limit switch reset button
Power	Check furnace disconnect switch and main discon-nect switch	Switch open Blown fuse or tripped breaker	Close switch Replace fuse or reset breaker
Thermostat unit	Touch jumper wire across thermostat terminals on primary control. If burner starts, then fault is in thermostat circuit	Loose thermostat screw connections Dirty contacts Thermostat not level Faulty thermostat	Tighten connection Clean contacts Level thermostat Replace thermostat
Cad Cell	Disconnect flame detector wires at primary control. If burner starts, fault is in the detector circuit	Flame detector leads shorted Flame detector exposed to light Short circuit in flame detector	Separate leads Seal off false source of light Replace detector

Table K

Oil Burner Troubleshooting (Continued)

Burner fails to start

Source	Procedure	Causes	Correction
Primary Control (1)	Place trouble light between the black and white leads. No light indicates there is no power to the control.	Primary or auxiliary control switch open Open circuit between disconnect switch and limit control Low line voltage or power failure	Check dial adjustment. Set to maximum stop setting Jumper terminals; if burner start switch is faulty, replace control. Trace wiring and repair or replace Call power company
Primary Control (2)	Place trouble light between the orange and black leads. No light indicates the control is faulty.	Defective internal control circuit	Replace control
Burner (1)	Place trouble light between the black and white leads to burner motor. No light indicates no power to the burner motor.	Blown fuse	Replace fuse
Burner (2)	Place trouble light between the black and white leads to burner motor. Light indicates power to the motor and a burner fault.	Binding burner blower wheel Seized fuel pump Defective burner motor	Turn off power and rotate blower wheel by hand. If seized, free wheel from binding or replace fuel pump. Replace motor