♻ Manufacturers recommend that when a low charge is found, find the leak, remove and recover the charge, and repair the leak. A measured charge may then be transferred into the system. ♻

Some experienced service technicians may successfully add a partial charge by the frost-line method. This method is used to add refrigerant while the unit is operating and works as follows. A point on the suction line leaving the refrigerated box is located where the frost line may be observed, possibly where the suction line leaves the back of the box, **Figure 45–96.** Refrigerant is added very slowly by opening and closing the gage manifold low-side valve until frost appears at this point. Then add no more. The suction pressure may be 10 to 20 psig at this time and should reduce to about 2 to 5 psig just before the refrigerator thermostat shuts the compressor off. Using the frost-line method of charging a domestic refrigerator is a slow, tedious process that is not recommended unless just topping off a charge. The recommended method is to start from a deep vacuum and measure the charge into the system using either a charging cylinder or accurate scales, because the charge is critical to about 1/4 ounce. ♻ If the frost line creeps toward the compressor as the box temperature reduces, refrigerant may be recovered slowly through the low side until the frost line is correct, **Figure 45–97.** ♻

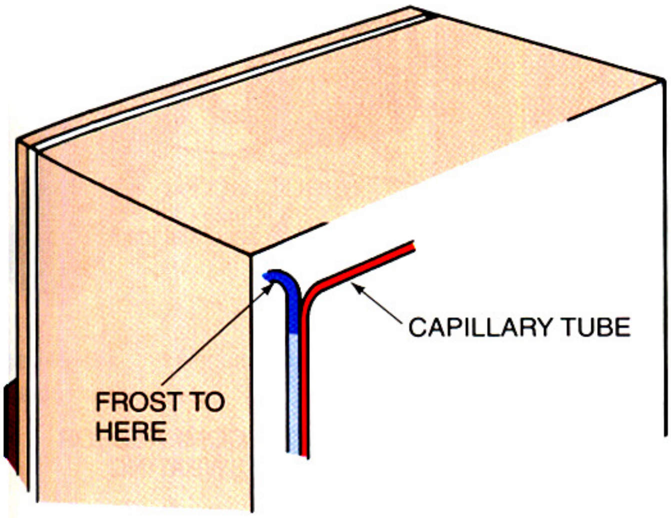


Figure 45–96 Checking the refrigerator charge using the frost-line method.

The typical operating conditions for the low-pressure side are fairly straightforward. The conditions are based on the coldest coil, the freezer coil. The typical low temperature for the freezer is 0°F. The refrigerant in the evaporator would typically be 16°F colder than the food temperature, so the refrigerant would boil at about −16°F. The corresponding pressures would be about 2 psig for R-12 and 0.7 in. Hg for R-134a at the point where the thermostat is ready to shut the compressor off. If the box temperature were to be set to a lower point, the pressures would move downward. When it is time for the compressor to start, the pressures would be higher. Typically, the temperatures may fluctuate between −5°F and +5°F with corresponding pressures.

NOTE: Many units will operate in a vacuum for a long period of time after start-up. This will occur until the refrigerant

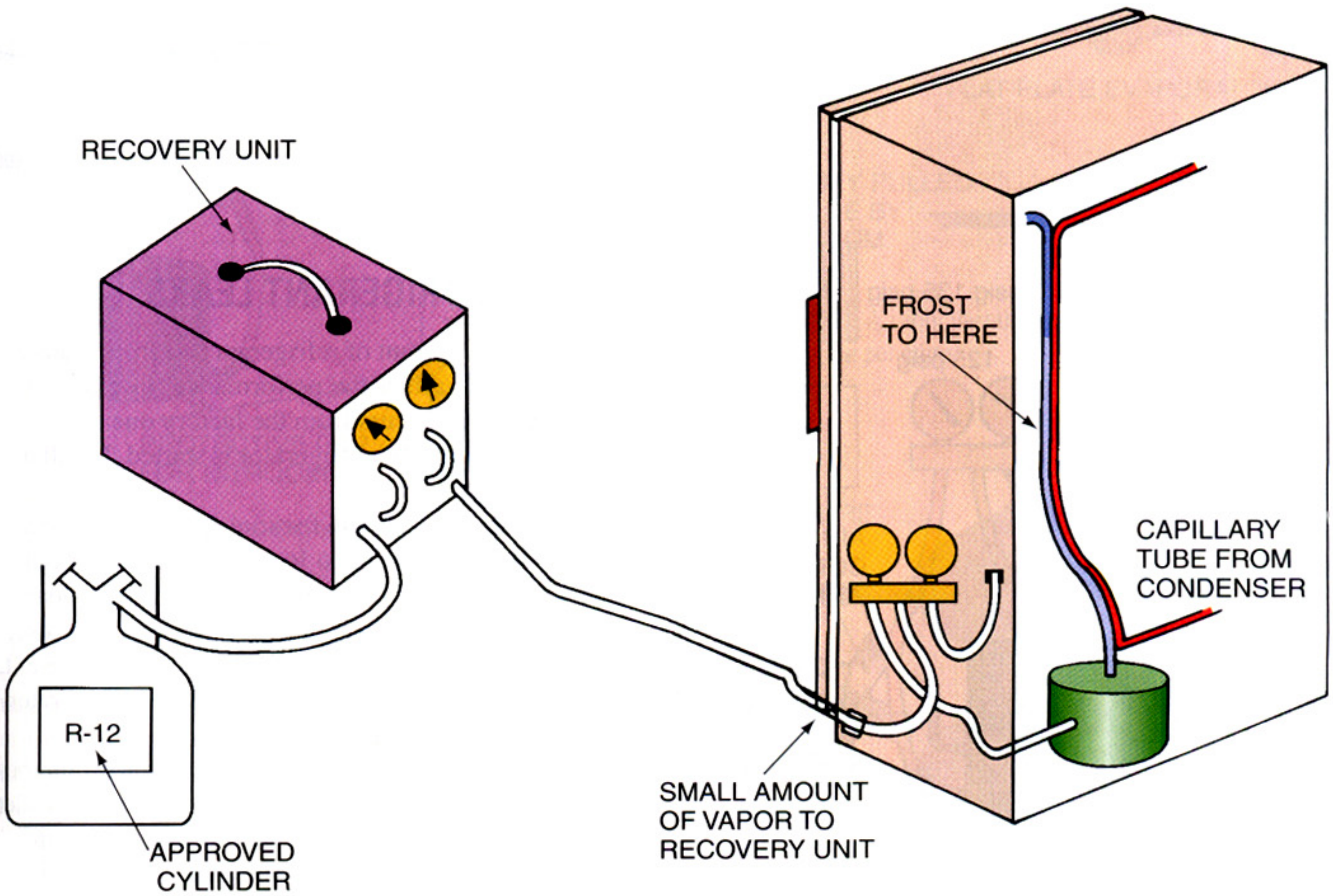


Figure 45–97 The frost line has moved toward the compressor; a small amount of vapor is recovered through the low-side gage.

UNIT 45 Domestic Refrigerators

OBJECTIVES

After studying this unit, you should be able to

- define refrigeration.
- describe the refrigeration cycle for household refrigerators.
- describe the types, physical characteristics, and typical locations of the evaporator, compressor, condenser, and metering device.
- explain the various defrost systems.
- describe how to dispose of the condensate.
- discuss typical refrigerator designs.
- explain the purpose of mullion and panel heaters.
- describe the electrical controls used in household refrigerators.
- discuss ice-maker operation.
- describe various service techniques used by the refrigeration technician.

SAFETY CHECKLIST

✔ Never use a sharp object to remove ice from an evaporator.
✔ Remove refrigerator doors or latch mechanisms before disposing of a refrigerator.
✔ Use proper equipment when moving refrigerators.
✔ Use a back belt brace when lifting.
✔ Do not raise the low-side pressure in a refrigerator above the manufacturer's low-side specified design pressure.
✔ Tubing lines may contain oil that may flare up and burn when soldering. Always keep a fire extinguisher within reach when soldering.
✔ Use all electrical safety precautions when servicing or troubleshooting electrical circuits.

45.1 REFRIGERATION

You should have a firm understanding of Section 1 of this text before proceeding into this unit. The term *refrigeration* means to move heat from a place where it is not wanted to a place where it makes little or no difference. The domestic refrigerator is no exception to this statement. Heat enters the refrigerator through the walls of the box by conduction, by convection, and from warm food placed inside. When the food is warmer than the box temperature, it raises the temperature in the box. Heat travels naturally from a warm to a cold substance, **Figure 45–1**. The refrigerator moves this heat from inside the box to the room where it makes little or no difference, **Figure 45–2**.

The domestic or household refrigerator is a plug-in appliance and can be moved from one location to another. Typically no license is required to install plug-in appliances. It is a package unit that is completely factory assembled and charged with refrigerant.

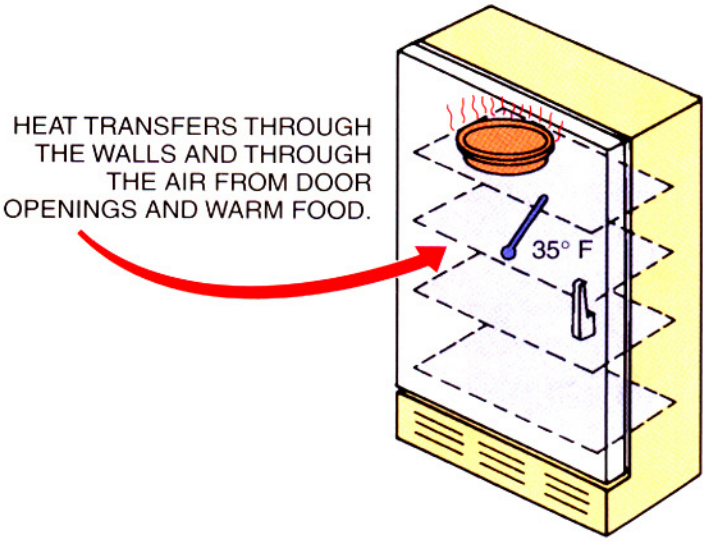


Figure 45–1 Warm food brings heat into the refrigerator.

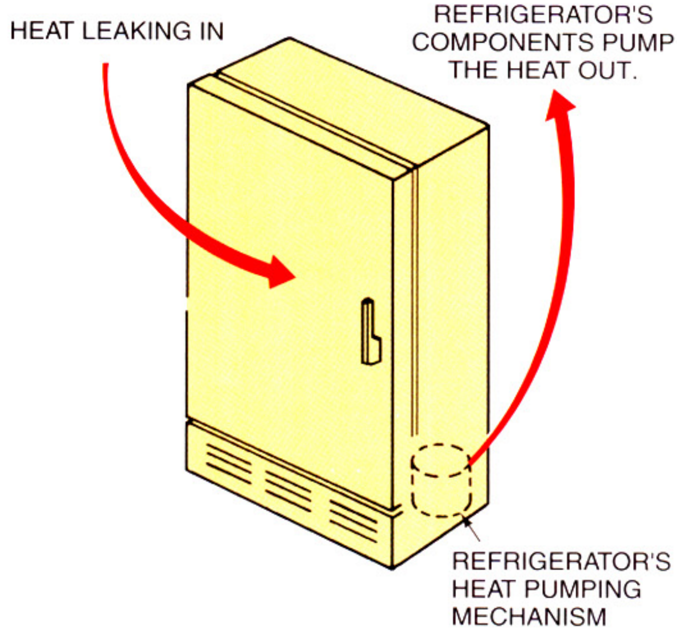


Figure 45–2 The refrigeration cycle moves the heat from the refrigerated box to the room, where it makes little or no difference.

The refrigeration system circulates air inside the box across a cold refrigerated coil, **Figure 45–3.** The air gives up sensible heat to the coil, and the air temperature is lowered. It gives up latent heat (from moisture in the air) to the coil, and dehumidification occurs. This causes frost to be formed on the evaporator coil. When the air has given up heat to the coil, it is distributed back to the box at a much colder temperature so that it can absorb more heat and humidity, **Figure 45–4.** This process continues until the box temperature is reduced to the desired level. The typical domestic box inside temperature is 35°F to 40°F when the room temperature is normal. This typical box temperature is the temperature of the return air to the evaporator coil, **Figure 45–4.** If a thermometer were located in the center of the food, such as in a glass of water in the middle of the box, it would also register the average return air temperature. It would respond slowly to the air changes around it and react as an average of the return air temperature from the start to the end of the refrigeration cycle. These temperatures are typical of a domestic refrigerator located in the comfort conditions of a residence. The refrigerator does not perform within these temperatures if it is located in a place of extreme temperature, such as outside in the summer and winter, **Figure 45–5.**

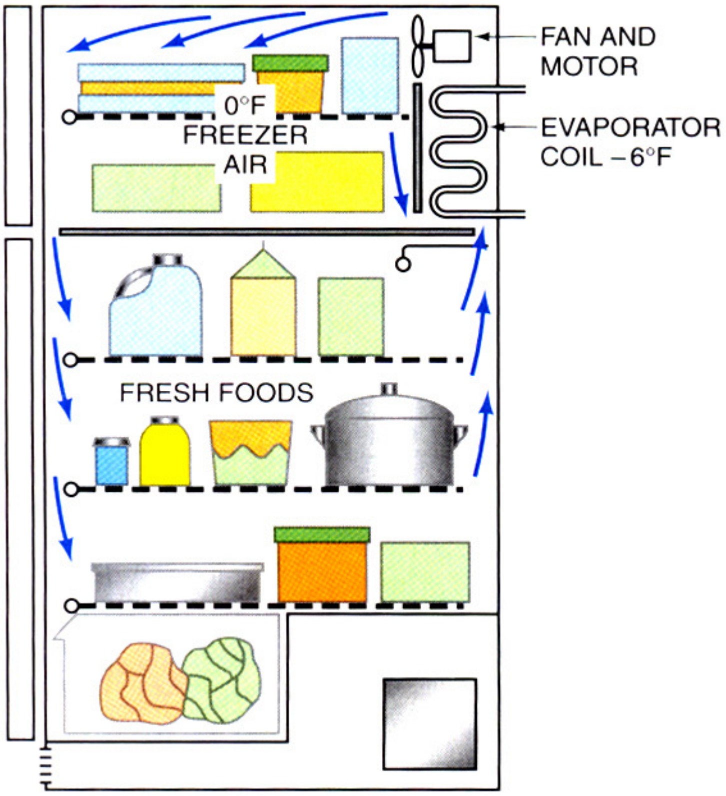


Figure 45–3 Air gives up heat to the cold coil.

45.2 THE EVAPORATOR

The household refrigerator evaporator absorbs heat into the refrigeration system. To accomplish this it must be cooler than the air in the refrigerated box. In a typical commercial box application there is one box for maintaining frozen food and a separate one for fresh food such as vegetables and dairy products. The household refrigerator does both with one box. Therefore, the single compressor operates under conditions for the lowest box temperature. The freezing compartment is the lowest temperature. It is typically operated at −10°F to +5°F.

The evaporator in the household box also must operate at the low-temperature condition and still maintain the fresh-food compartment. This may be accomplished by allowing part of the air from the frozen-food compartment to flow into the fresh-food compartment, **Figure 45–6.** It may also be ac-

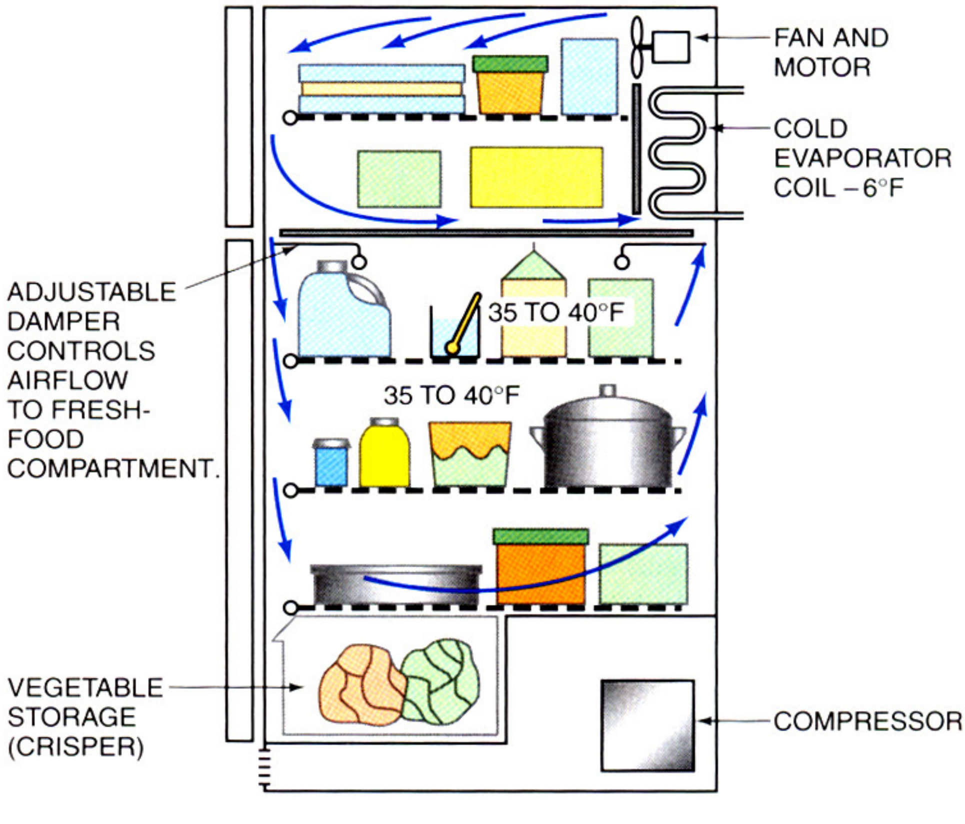


Figure 45–4 Cold air enters the box from the coil.

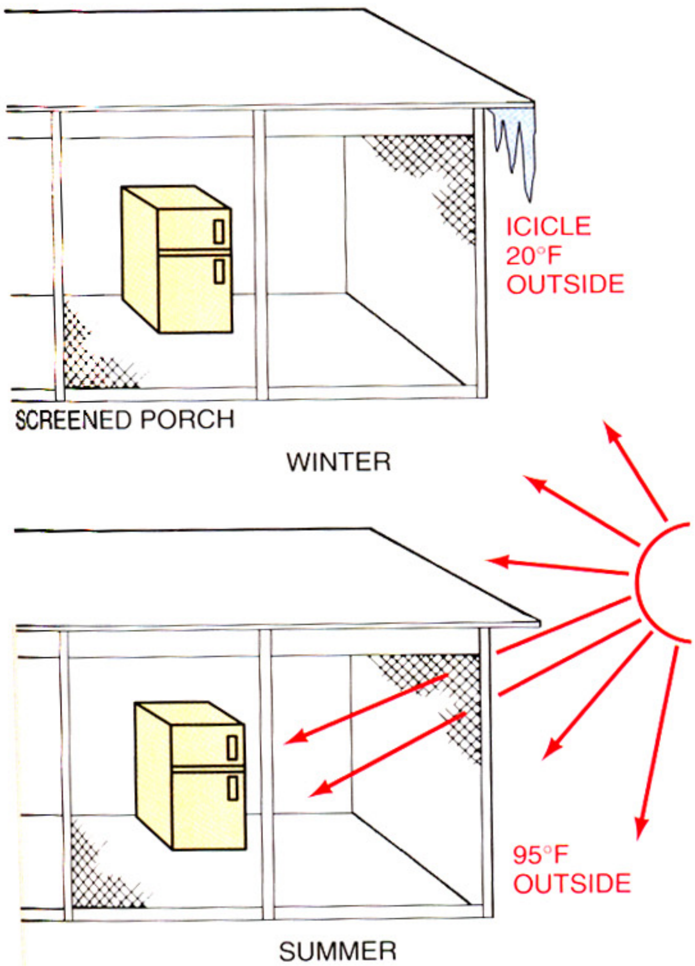


Figure 45–5 The ambient temperature for these refrigerators is not within their proper operating range.

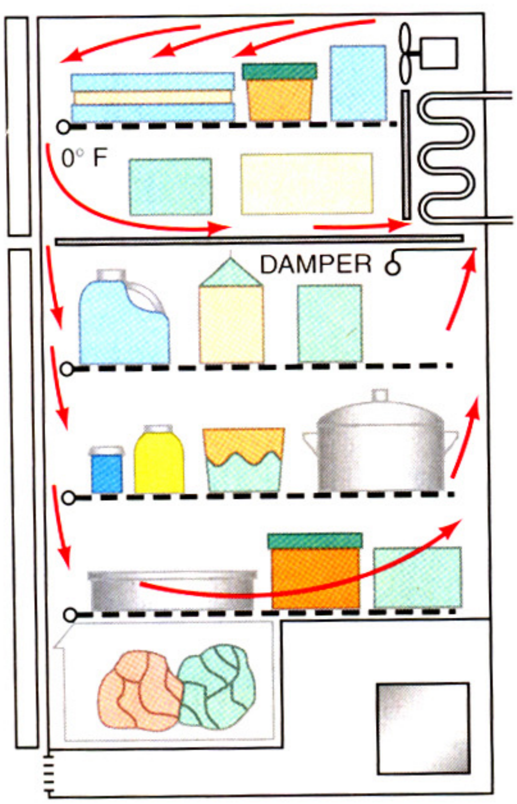


Figure 45–6 Air flows inside the refrigerated box from the low-temperature compartment to the medium-temperature compartment.

complished with two evaporators that are in series, one for the frozen-food compartment and the other for the fresh-food medium-temperature compartment, **Figure 45–7.** In either case, frost will form on the evaporator and a defrost method must be used. This is described in more detail later.

The evaporators in household refrigerators can be of two types, natural draft or forced draft, **Figure 45–8.** The fan

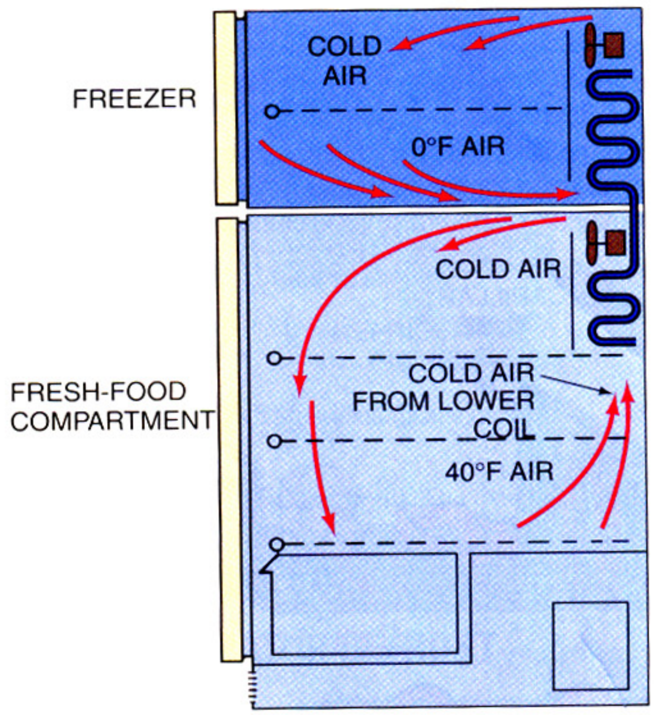


Figure 45–7 A two-evaporator box.

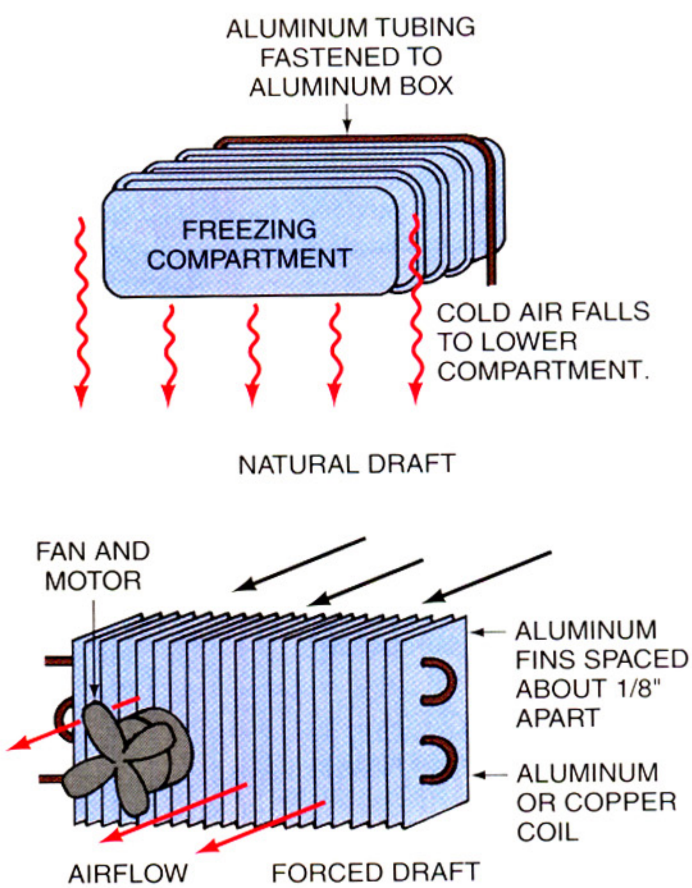


Figure 45–8 Natural-draft and forced-draft evaporators.

improves the efficiency of the evaporator and allows for a smaller evaporator. Space saving is desirable in a household refrigerator so most use forced-draft coils. However, other units are manufactured with natural-draft coils for economy and simplicity.

45.3 NATURAL-DRAFT EVAPORATORS

These evaporators are normally the flat plate type with the refrigerant passages stamped into the plate, **Figure 45–9.** They are effective from a heat transfer standpoint and require natural air currents to be able to flow freely over them. The food in the frozen-food compartment may be in direct contact with the flat plate evaporator. Air from the bottom and sides may flow to the fresh-food compartment, **Figure 45–10.**

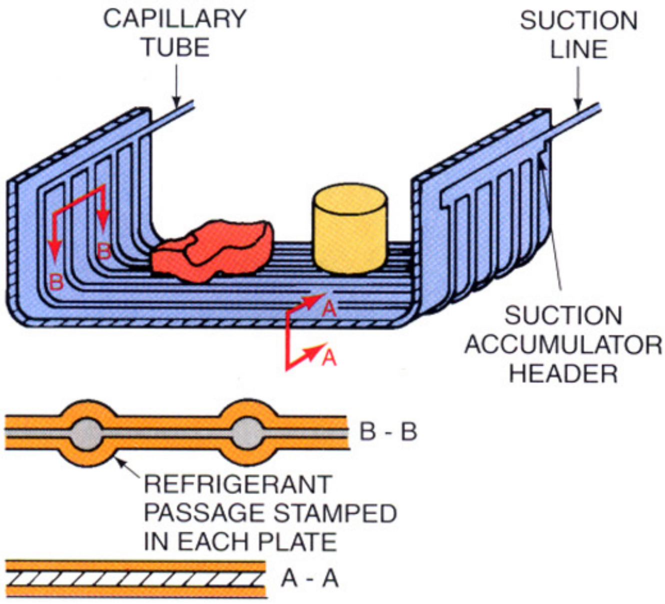


Figure 45–9 A stamped-plate evaporator.

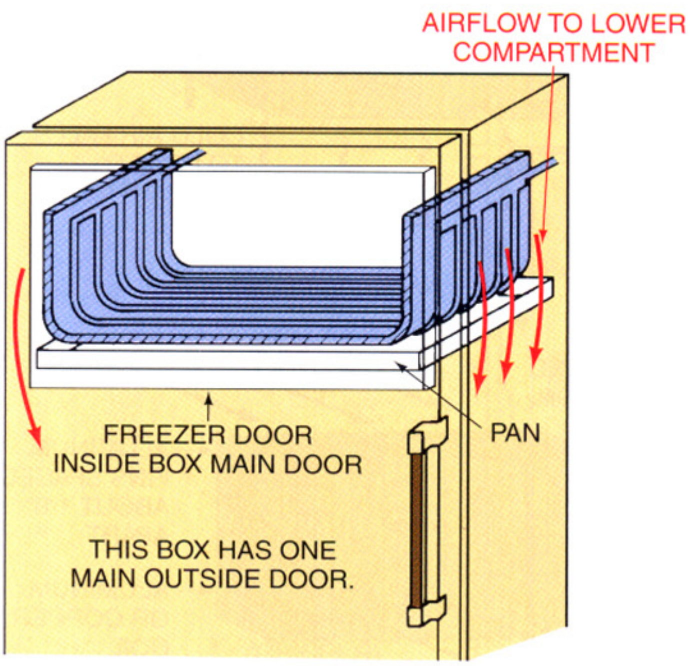


Figure 45–10 Air flows to the fresh-food compartment from the flat plate evaporator.

These natural-draft evaporators are more visible than the forced-draft evaporators and are subject to physical abuse. Models use either automatic defrost systems or manual defrost. A manual defrost system requires that the unit be shut off and the door to the compartment normally left open to accomplish the defrost. Frost is melted by room temperature, **Figure 45–11.** In a few instances, owners have become impatient and have used sharp objects to remove the ice. This may puncture the evaporator. SAFETY PRECAUTION: Sharp objects should never be used around the evaporator, **Figure 45–12.** Defrost may be more quickly accomplished with a small amount of external heat, such as a hair drier or a small fan that blows room air into the box until the ice is melted. A pan of warm water may be placed under the coil. The melted ice normally drips into a pan below the evaporator, **Figure 45–13.**

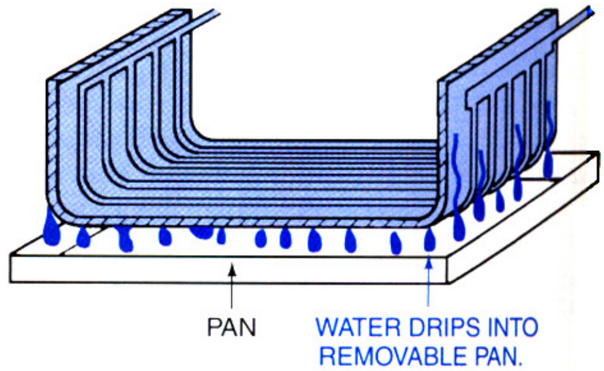


Figure 45–11 Manual defrost.

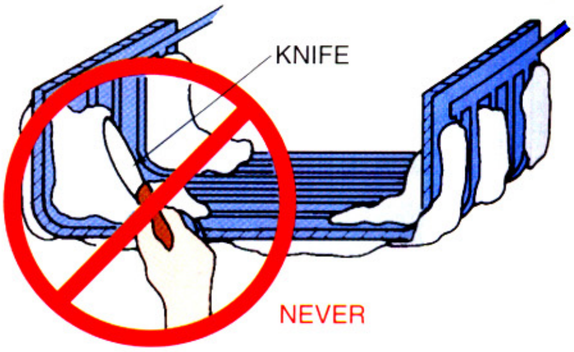


Figure 45–12 Sharp objects may puncture the evaporator. SAFETY PRECAUTION: Do not use sharp objects to chip frost and ice.

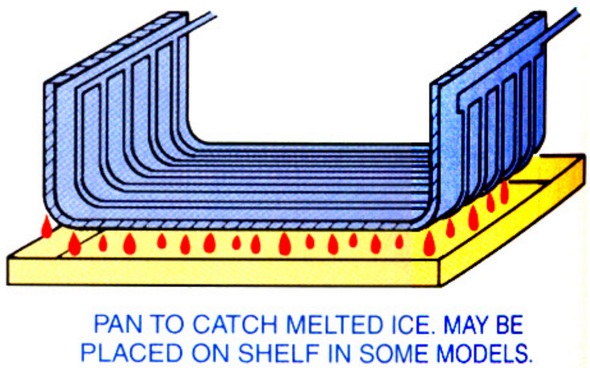


Figure 45–13 Melted ice (condensate) is caught in the pan.

Fan/coil-type (finned) evaporators are used to reduce the space the evaporator normally uses. The smaller the evaporator, the more internal space is available for food. The evaporator fan and coils are normally recessed in the cabinet and not exposed, **Figure 45–14.** Because the coils and fans are recessed, air ducts may provide the airflow direction, and dampers may help control the volume of the air to the various compartments. NOTE: Each manufacturer of refrigerators has its own method of locating the evaporator and fan, so its literature should be consulted for specific information. **Figure 45–15** shows typical examples of some methods of manufacturing and locating evaporators. Most evaporators have an accumulator at the outlet of the evaporator. The accumulator allows the evaporator to operate as full as possible with liquid refrigerant and still protect the compressor by allowing liquid to collect and boil to a vapor.

The evaporator is normally made of aluminum tubing that may have fins to give the tubes more surface area. The fins are spaced fairly wide apart to allow for frost to build up and not block the airflow, **Figure 45–16.** The evaporator does not require regular maintenance because air is recirculated within the refrigerated box, and it has no air filters.

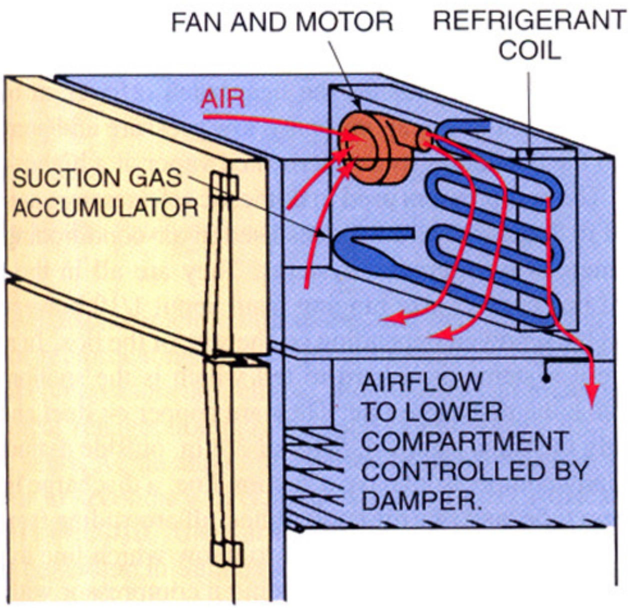


Figure 45–14 A forced-draft evaporator.

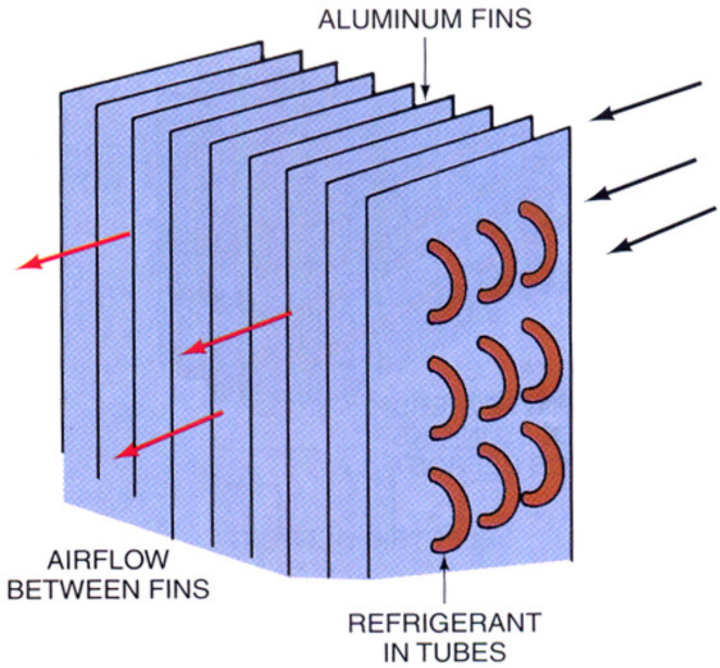


Figure 45–16 A forced-draft evaporator and fin spacing.

45.4 EVAPORATOR DEFROST

Manual defrost is accomplished by turning off the unit, removing the food, and using room heat, a pan of hot water, or a small heater. A large amount of frost may accumulate on an evaporator by the time it is defrosted. The water from this type of defrost must be disposed of manually. Units that require manual defrost normally have coils that food has touched. The shelves should be cleaned and sanitized when the frost is removed.

Automatic defrost is accomplished either with internal heat by the compressor supplying hot gas or external heat supplied by electric heating elements located in the evaporator fins, **Figure 45–17.**

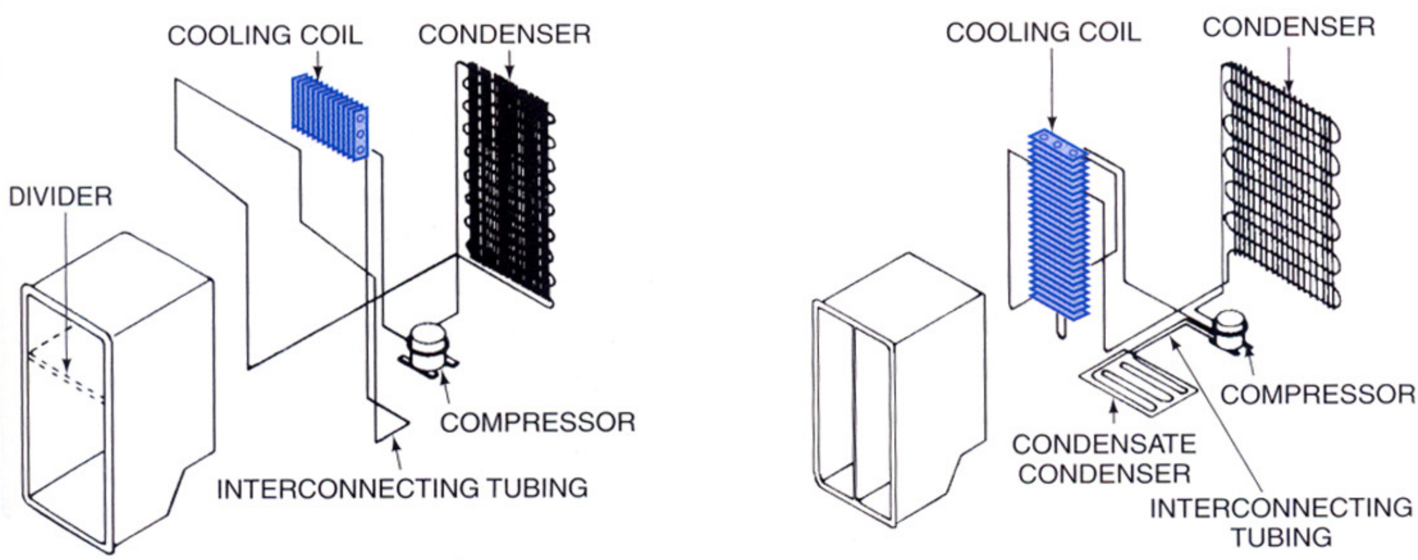


Figure 45–15 Typical evaporator locations in a refrigerator. *Courtesy White Consolidated Industries, Inc.*

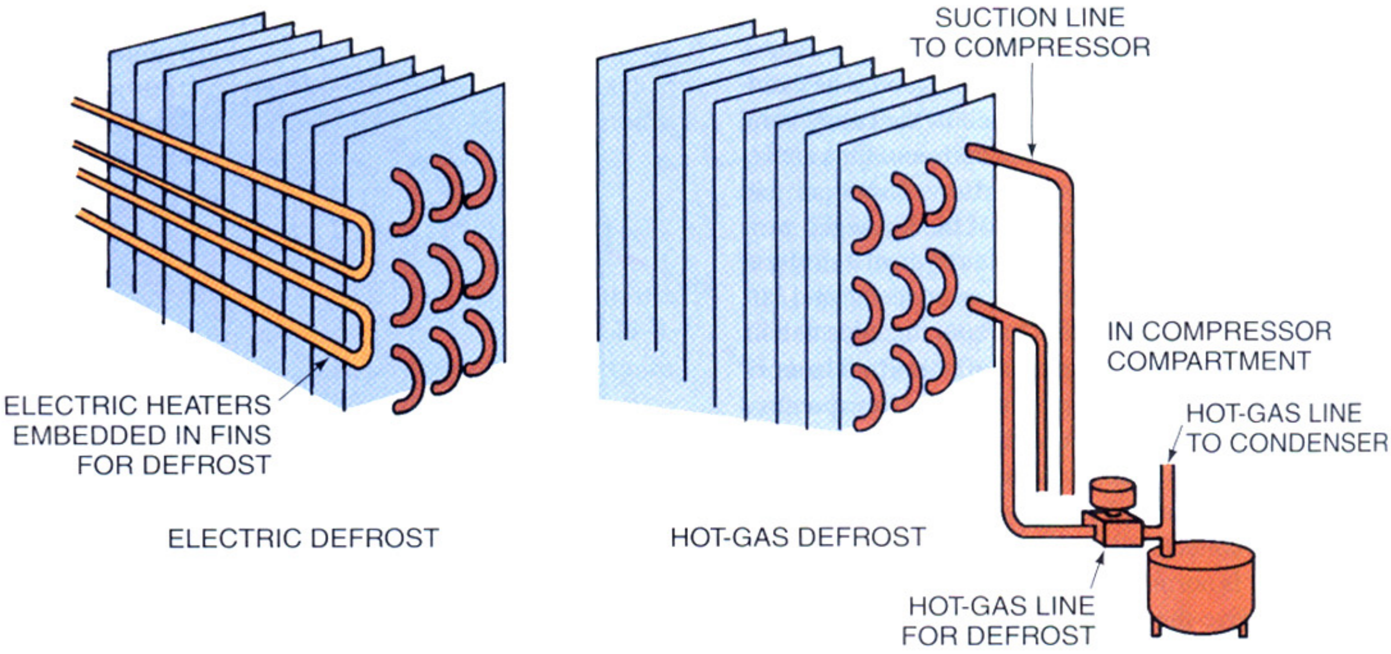


Figure 45–17 Electric and hot gas defrost.

No matter how the defrost is accomplished, the water from the coil must be dealt with. With automatic defrost, a pint of water may be melted from the evaporator with each defrost. This water is typically evaporated using the heat from the compressor discharge line or by heated air from the condenser. This is discussed in more detail in Section 45.6, "The Condenser."

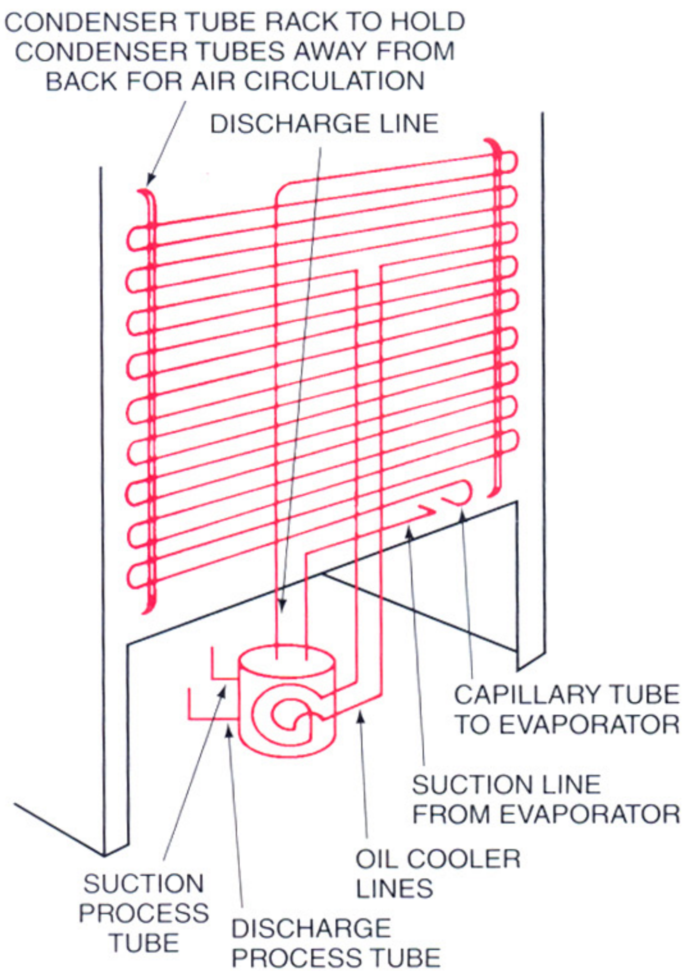


Figure 45–18 An illustration of a compressor and related piping at the refrigerator.

45.5 THE COMPRESSOR

The compressor circulates the heat-laden refrigerant by removing it from the evaporator at a low pressure and pumping it into the condenser as a superheated vapor at a higher pressure. The compressors used in domestic refrigerators are very small in comparison to the ones used in air-conditioning and commercial refrigeration systems. They are all in the fractional horsepower size ranging from about 1/10 horsepower to 1/3 horsepower, depending on the size of the box. In many of these systems, it is hard to tell which is the suction and which is the discharge line. They are copper or steel and are usually the same size, 1/4, 5/16, or 3/8 in. outside diameter.

Many compressors have a suction line, a discharge line, a process tube, and two oil-cooler lines, all protruding from the shell. A shell diagram is needed to know which line to pipe to which connection when replacing a compressor with one that is not an exact replacement, **Figure 45–18.**

The compressors used in household refrigerators are all welded hermetically sealed types, **Figure 45–19.** They are

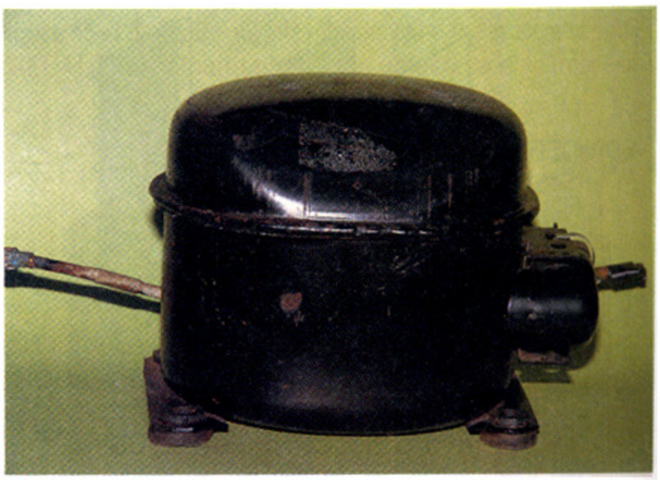


Figure 45–19 A welded, hermetically sealed compressor. *Photo by Bill Johnson*

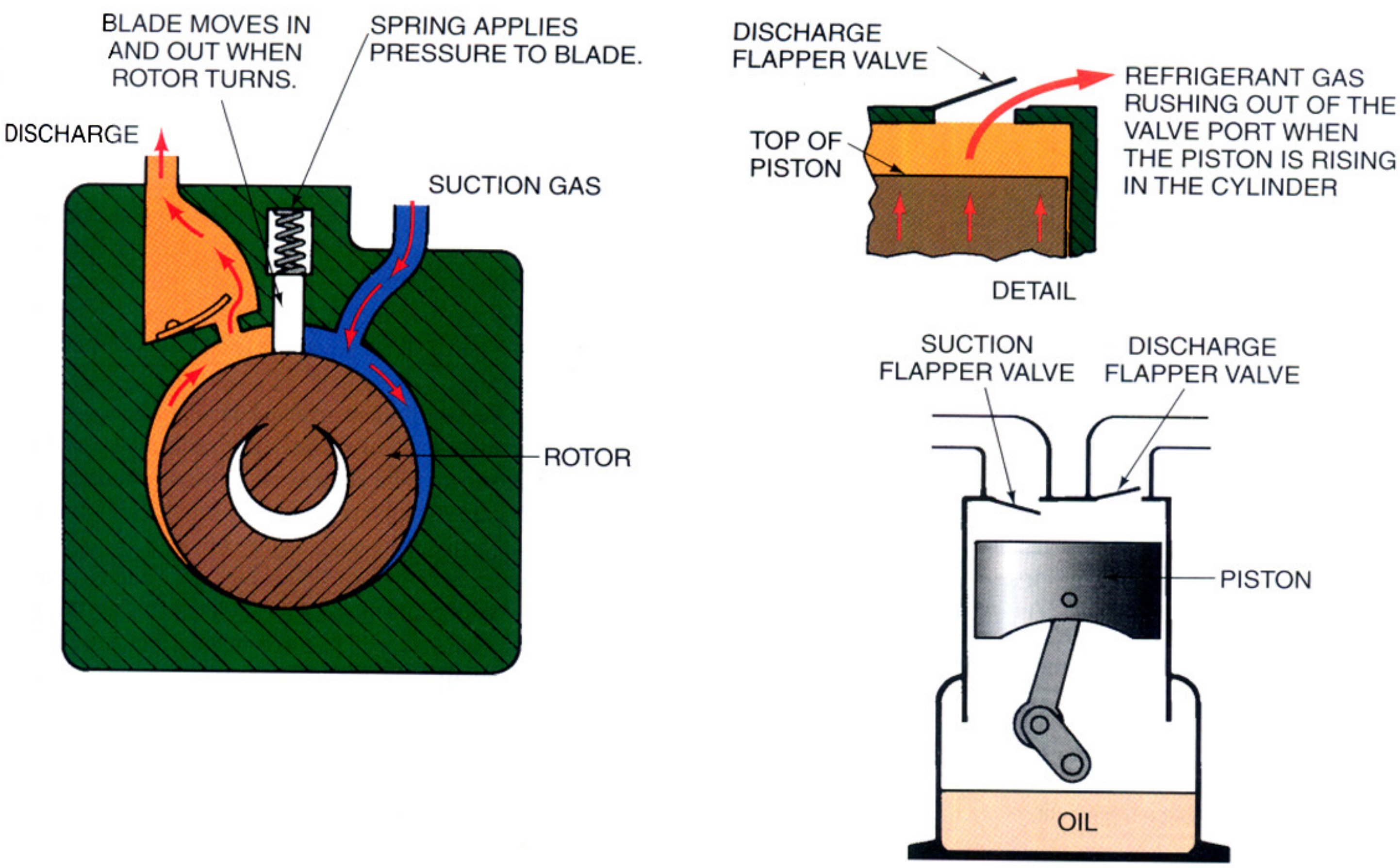


Figure 45–20 Rotary and reciprocating compressor action.

positive displacement compressors and may use either a rotary or reciprocating type of pumping action, **Figure 45–20.** These compressors are reliable and made to last many years. A typical refrigerator may be used continuously for 20 or more years. At the end of this period of its service, it is often moved to secondary duty, traded and resold, or discarded. SAFETY PRECAUTION: Careful disposal of refrigerators is vital as described in Section 45.10.

Household refrigerators manufactured for the U.S. market operate on 115 V, 60-cycle alternating current. A power supply of 220 V, 50-cycle is used in some other countries. American refrigerators may be used in foreign countries with the correct adapters.

The compressor is located at the bottom of the refrigerator and accessed at the back of the box. The refrigerator must be moved away from the wall to service the compressor, **Figure 45–21.** Most modern, large refrigerators have small wheels to enable you to move the box out for cleaning and to provide easy access for service, **Figure 45–22.**

Compressors are typically mounted on internal springs and external flexible, rubber-like feet, **Figure 45–23.** The refrigerator is located in the living area and must produce a low noise level.

The lines connecting the compressor to the refrigerant piping may be of copper or steel. Correct solder must be used when repairing any piping connections.

The household refrigerator was the first common application for the welded hermetic compressor. Service requires a skilled technician. Many units do not even have service ports

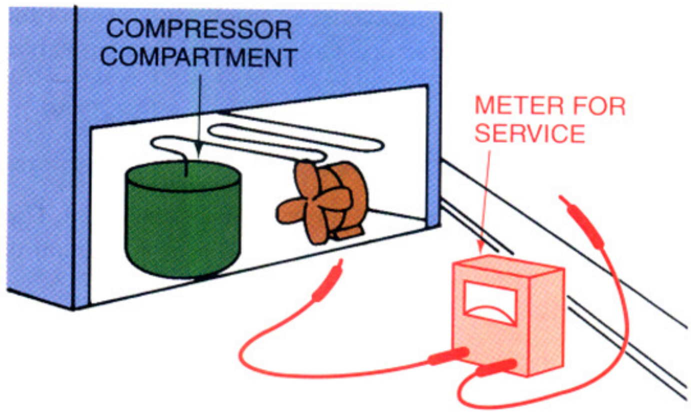


Figure 45–21 The refrigerator is moved from the wall to service the compressor.

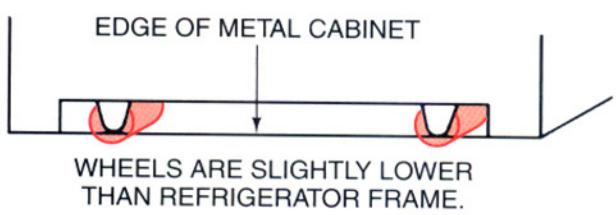


Figure 45–22 Wheels on a modern refrigerator.

for the service technician to attach gages for compressor suction and discharge readings. When the manufacturer does furnish a service port, it may be in the form of a special port

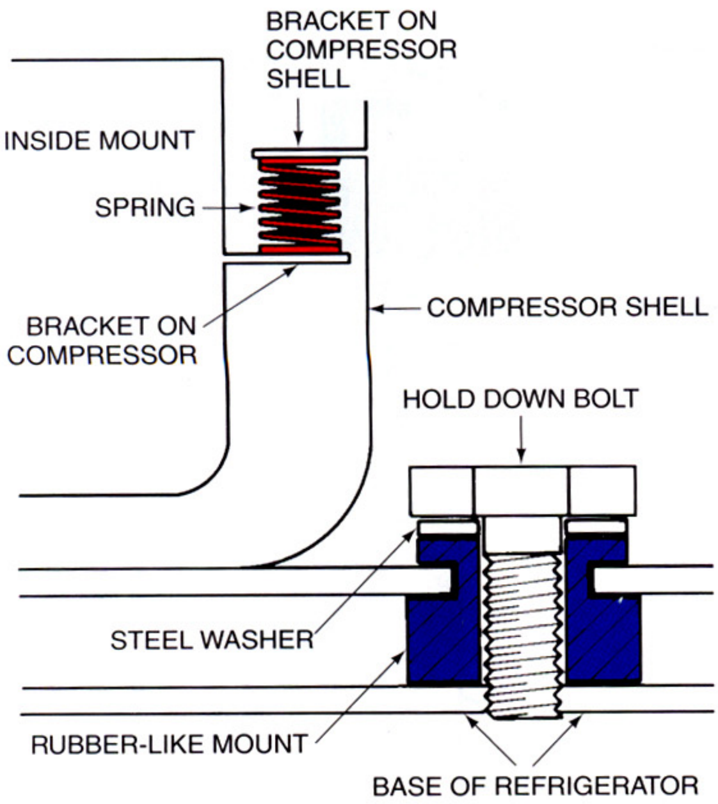


Figure 45–23 A compressor mount.

that requires special connectors, **Figure 45–24.** When the special connectors are not furnished, line tap valves are often used. These should be used only when necessary, and the manufacturer's instructions must be strictly followed, or the results will be unsatisfactory. Only soldered line tap valves may be left on line.

45.6 THE CONDENSER

Condensers for domestic refrigerators are all air cooled. This permits the refrigerator to be moved to a new location or house as needed. The condensers are either cooled by natural convection or by small forced air fans, **Figure 45–25.**

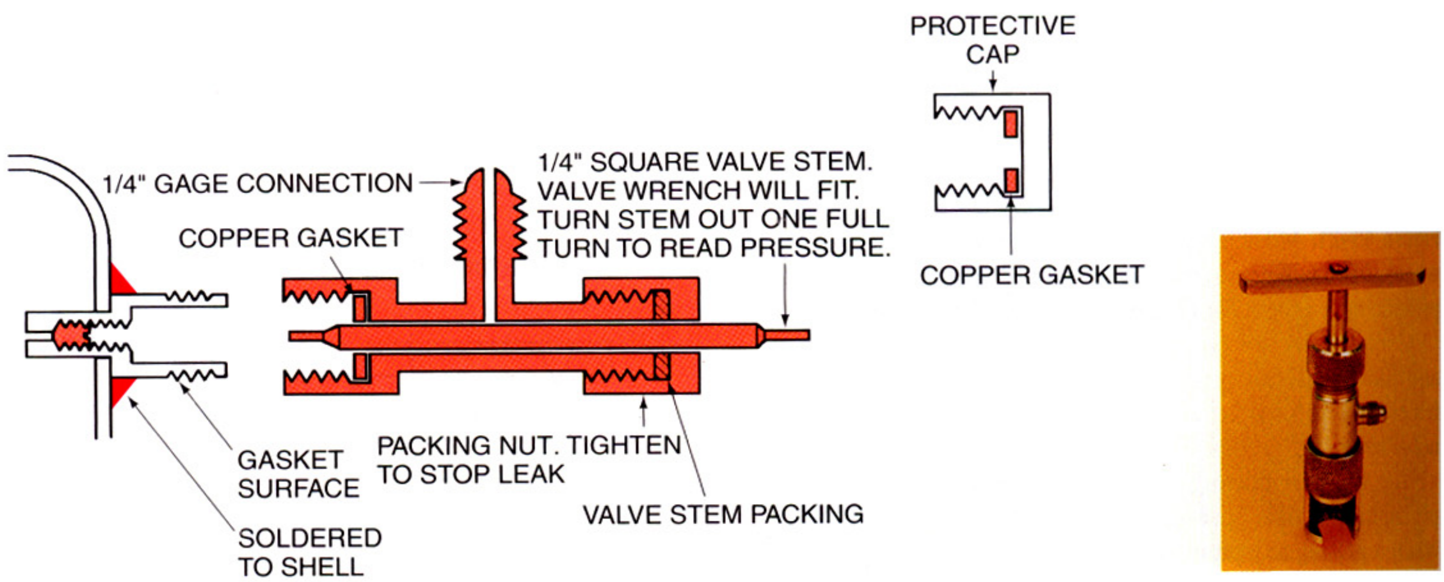
Natural convection (static) condensers were the first and are more simple. They may be located on the back of the unit, and care must be used when locating the refrigerator to ensure that air can flow freely over it. Many of these units may have been abused by locating them under low overhanging cabinets. This causes poor air circulation and high head pressures. The unit may then have extra long running times because the capacity is reduced. In severe cases, the unit may run all the time and still not keep the food compartment cool, **Figure 45–26.**

Care must be used when moving any appliance, but the external condenser type of refrigerator requires special care or the condenser may be damaged. If a two-wheeled hand truck is used, care must be used by placing the belt under the condenser and around the unit, **Figure 45–27.**

Some natural convection condensers have been located in the outside wall of the refrigerator by fastening the condenser tubes to the inside of the outer sheet metal shell. This unit may work well in the open, where air can circulate over it but may not work in a tight alcove.

Forced-draft condensers have solved many of these problems. The forced-draft condenser is located under the refrigerator and typically at the back, **Figure 45–28.** Air is taken in on one side of the bottom front of the box and discharged out the other side of the front, **Figure 45–29.** Because both inlet and outlet are close to the floor and at the front, they are not easily obstructed.

Forced-draft condensers must have an air pattern for the air to be forced over the finned-tube condenser. This air pattern is often maintained by cardboard partitions and a cardboard back to the bottom of the compressor compartment, **Figure 45–30.** NOTE: All partitions must be in the correct position, or high head pressures and long or continuous running times will occur. Many service technicians and homeowners may have discarded the cardboard back cover



(A) (B)

Figure 45–24 A special service port valve. *(B) Photo by Bill Johnson*

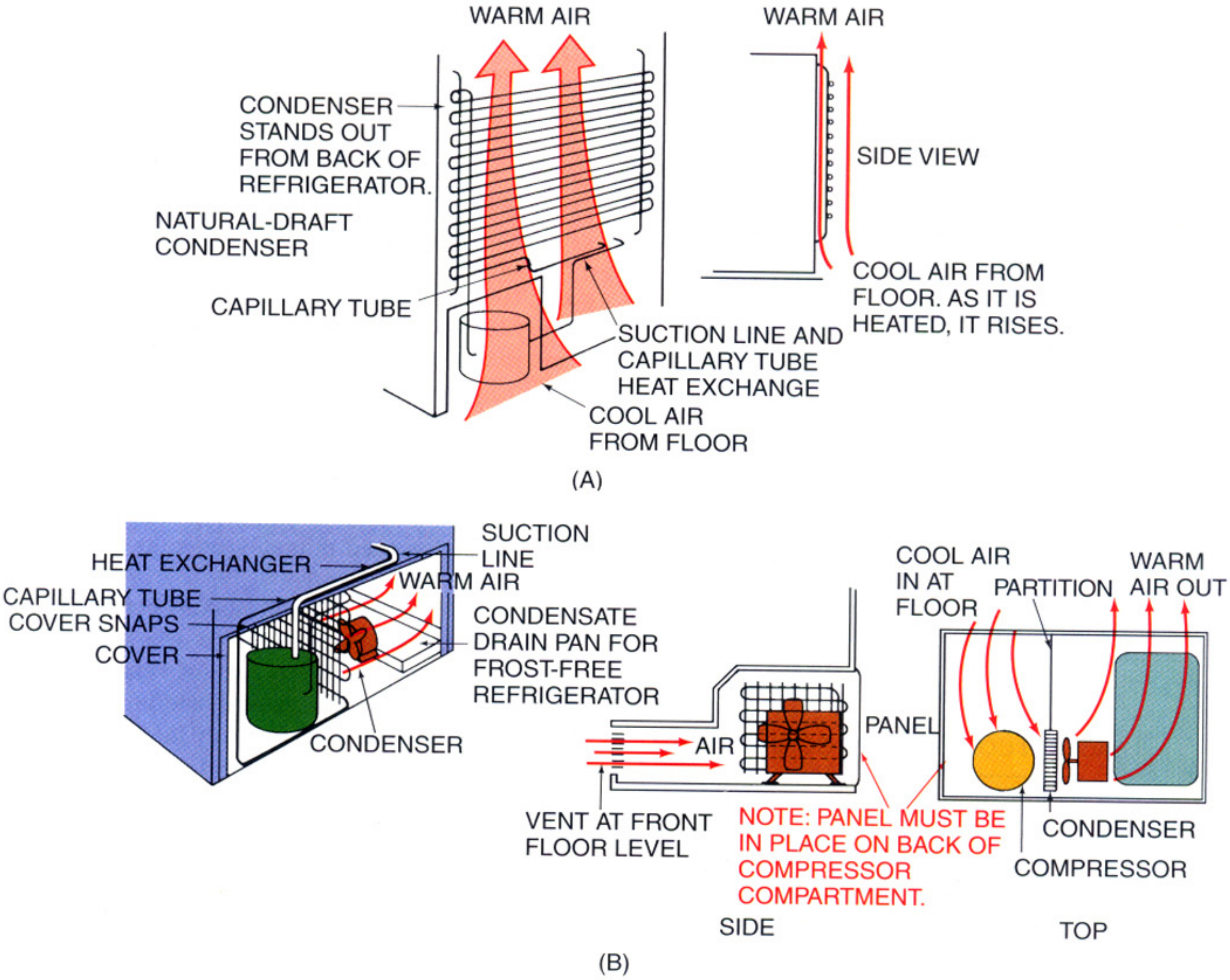


Figure 45–25 (A) Natural- and (B) forced-draft condensers.

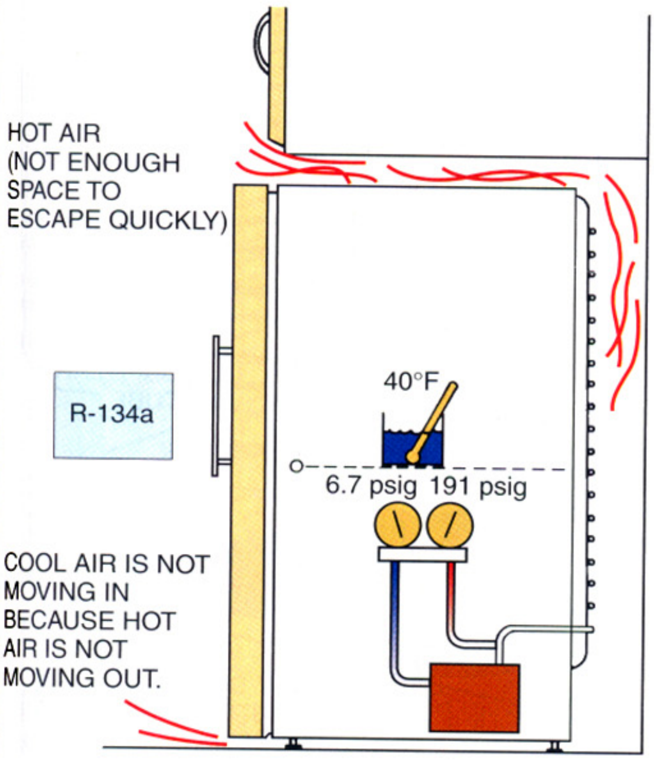


Figure 45–26 A unit running all the time due to poor location.

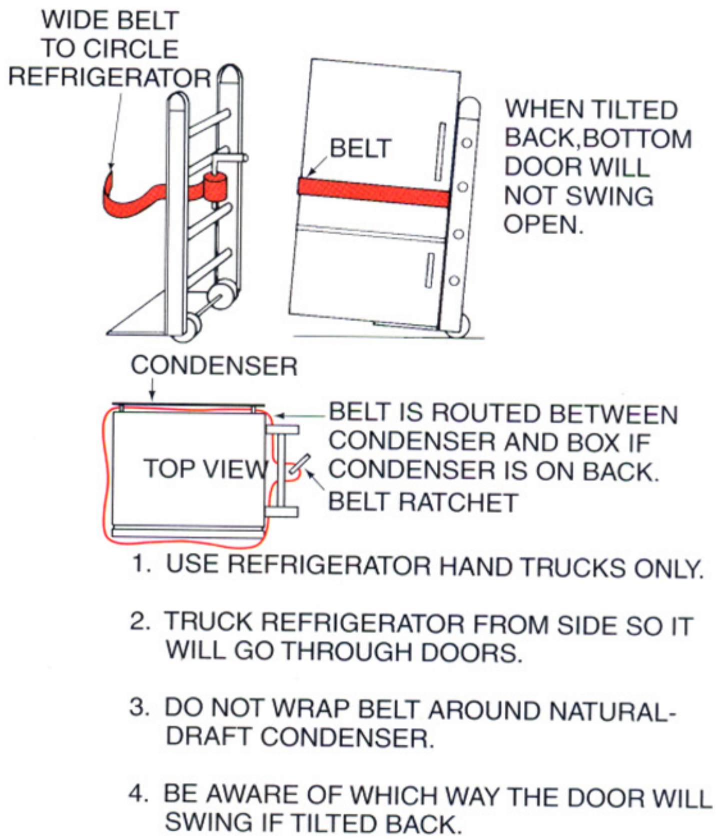


Figure 45–27 Care should be used when moving a refrigerator.

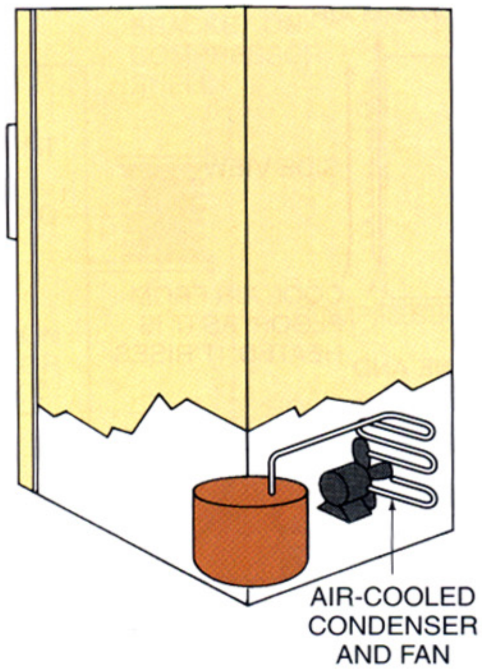


Figure 45–28 Location of a forced-draft condenser.

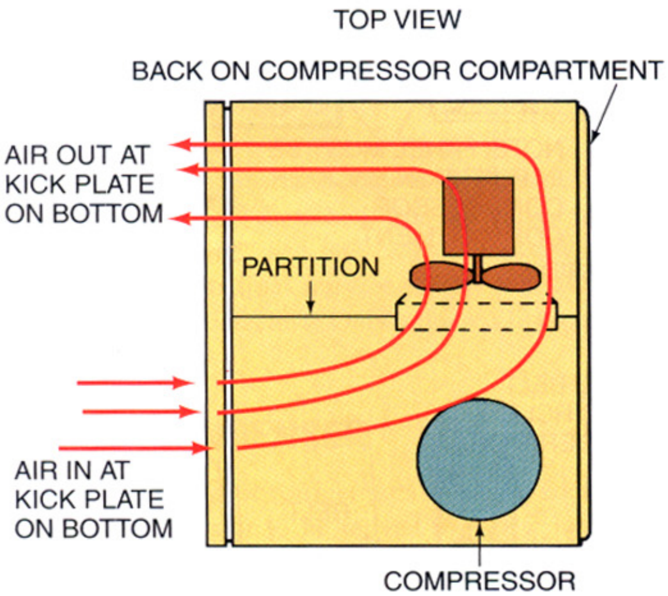


Figure 45–29 Airflow of a forced-draft condenser.

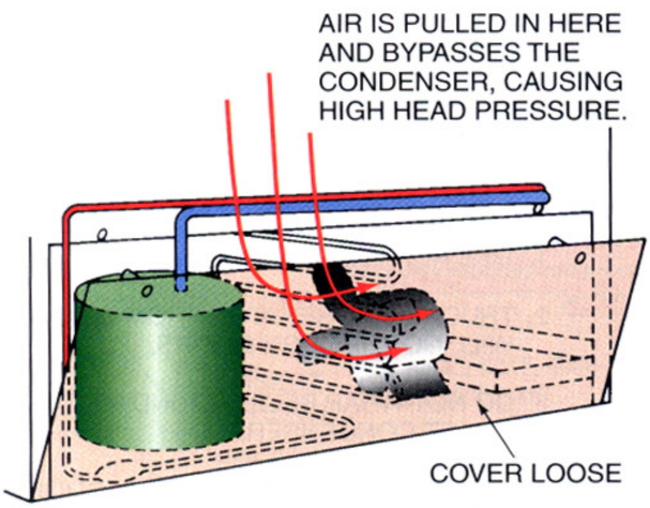


Figure 45–30 Cardboard partitions. Be sure to replace all cardboard partitions on a forced-draft condenser.

thinking it not necessary. The refrigerator will not perform correctly without the back cover, and permanent damage can result.

45.7 DEFROST CONDENSATE, AUTOMATIC DEFROST

All domestic refrigerators are low-temperature appliances, and frost accumulates on the evaporator. When defrost occurs, something must be done with the water. Automatic defrost is unattended. The compressor and condenser section of the refrigerator are used to evaporate this water.

The heat available at the compressor discharge line can be used to evaporate the water when direct contact is made. Many units are designed so that the discharge line is passed through the pan that collects the defrost water, **Figure 45–31.** This method is used primarily on units with natural-draft condensers.

When the unit has a forced-draft condenser, warm air from the condenser may be forced over a collection pan of water for the purpose of evaporation, **Figure 45–32.** In either case, the unit has the compressor running time from one defrost cycle to the next to evaporate the water depending on the manufacturer's design. Defrost may occur during the off cycle or as few as two or three times per 24 h.

The defrost water collection pan in the bottom of the unit is a place where lint and dirt may collect. This pan can and should be removed occasionally and cleaned, or it may become unsanitary.

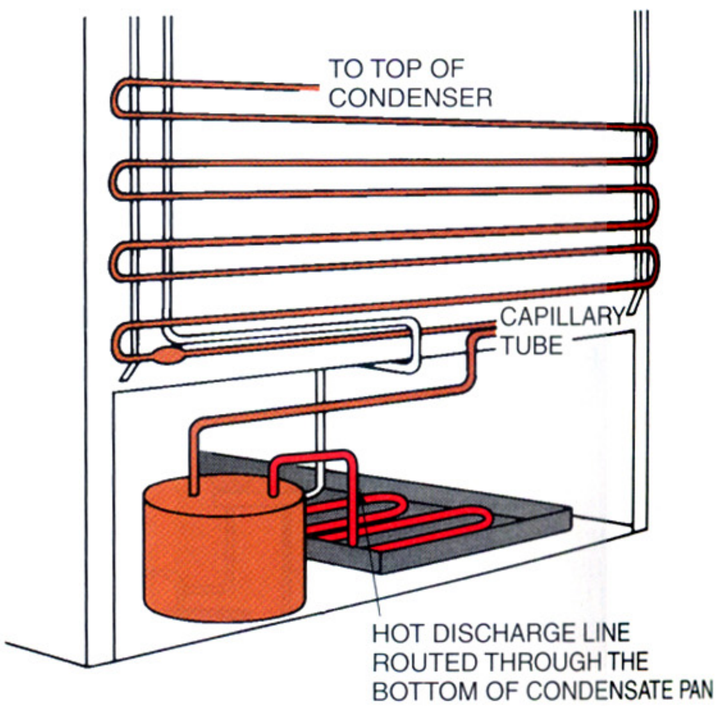


Figure 45–31 Compressor heat used to evaporate condensate.

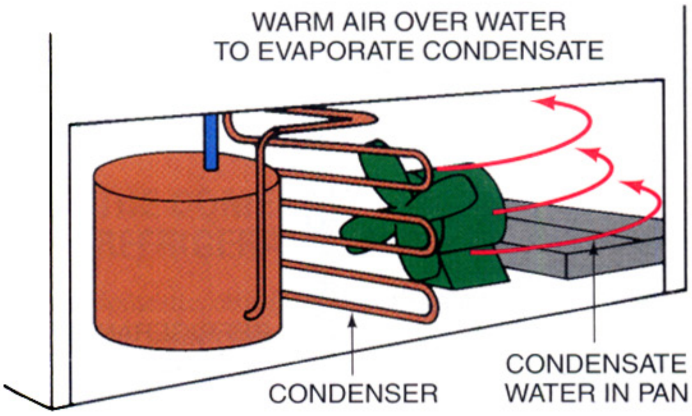


Figure 45–32 Warm air from the condenser used to evaporate condensate.

45.8 COMPRESSOR OIL COOLERS

The condenser may also contain an oil cooler for the compressor. This oil cooler keeps the crankcase oil at a lower temperature. This also cools the compressor assembly. It may be accomplished by routing the compressor discharge line through the condenser, removing some of the heat, then routing it back through the compressor crankcase in a closed loop to pick up heat from the oil, **Figure 45–33.** Extra lines are on the compressor for the oil loop.

Another method for cooling may be a gravity loop that allows the oil to leave the crankcase and circulate to a point where it may be cooled, **Figure 45–34.**

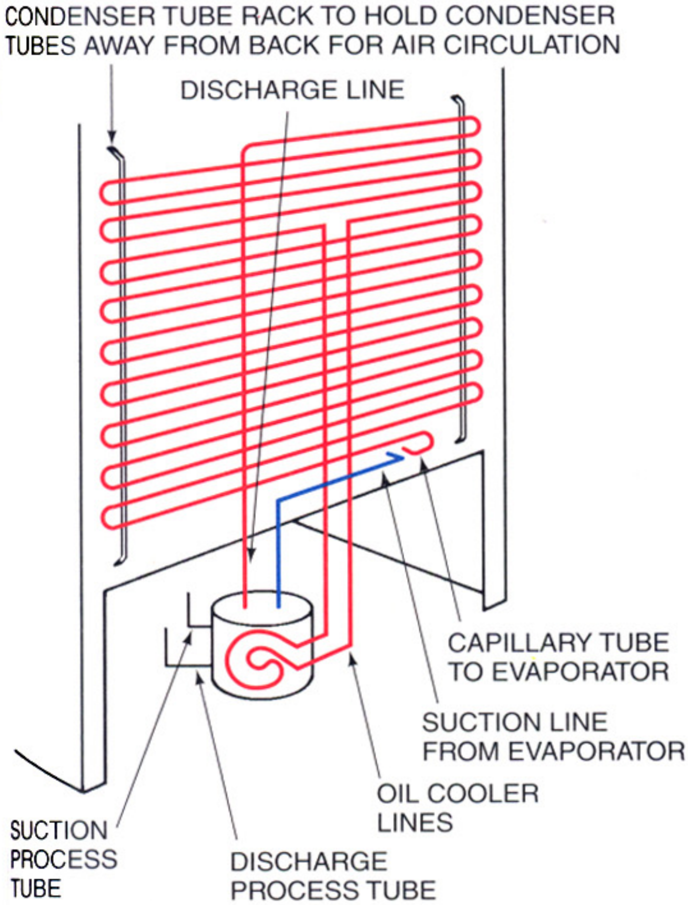


Figure 45–33 The oil cooler piping route.

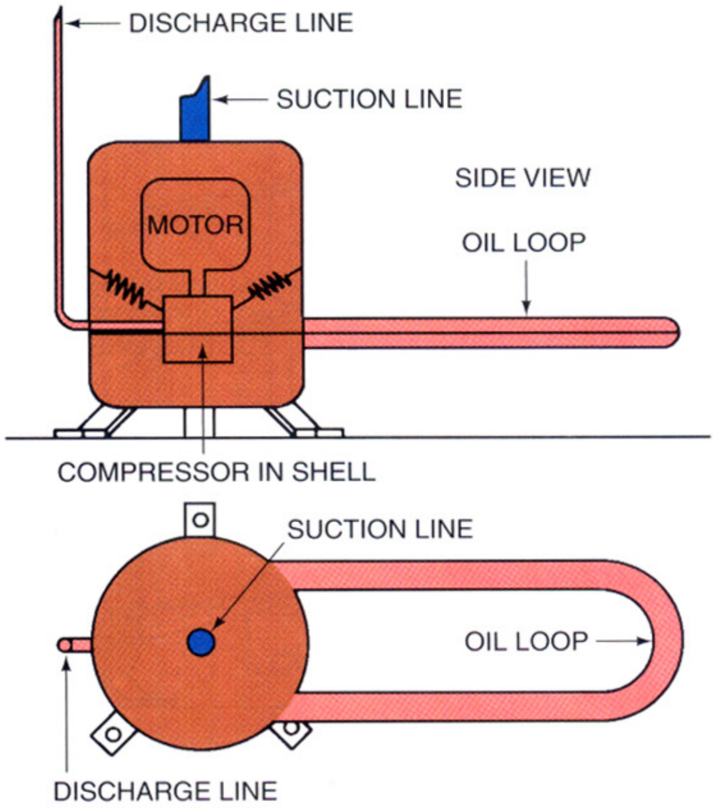


Figure 45–34 A loop to cool oil.

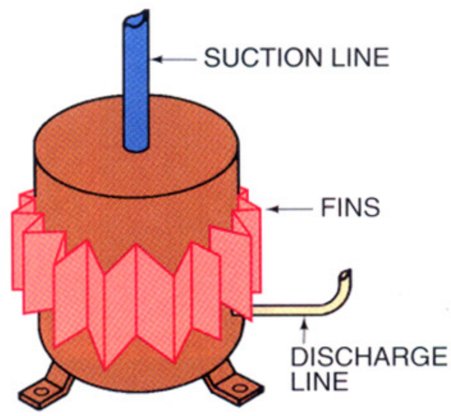


Figure 45–35 Some compressors have fins to cool them.

Some compressors have fins on the crankcase to accomplish oil cooling, **Figure 45–35.**

45.9 METERING DEVICE

Domestic refrigerators use the capillary tube metering device. This is a fixed-bore metering device, and the amount of refrigerant flow through the device is determined by the bore of the tube and the length of the tube. This is predetermined by the manufacturer. The capillary tube is usually fastened to the suction line for a heat exchange, **Figure 45–36.** In some cases the capillary tube may be run inside the suction line for this heat exchange, **Figure 45–37.** The heat exchange prevents liquid from returning to the compressor and improves the evaporator capacity by subcooling the liquid in the capillary tube, **Figure 45–38.**

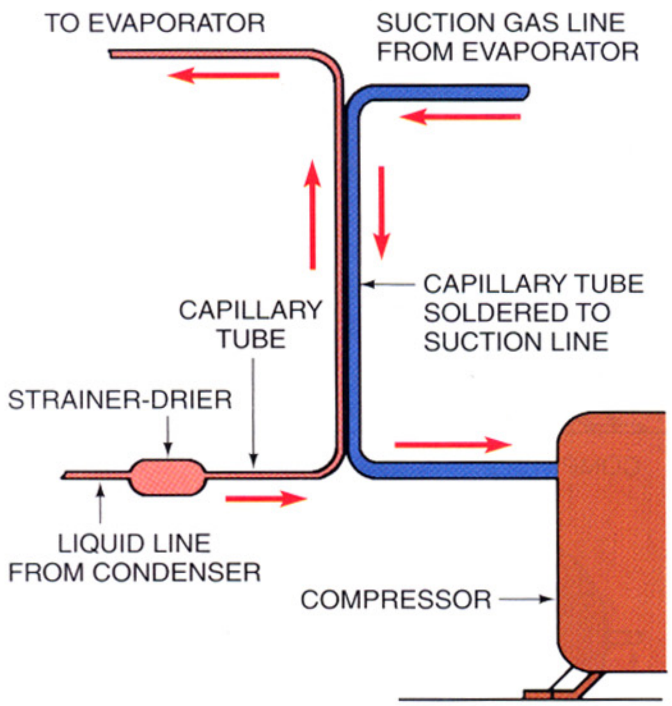


Figure 45–36 The capillary tube fastened to the suction line.

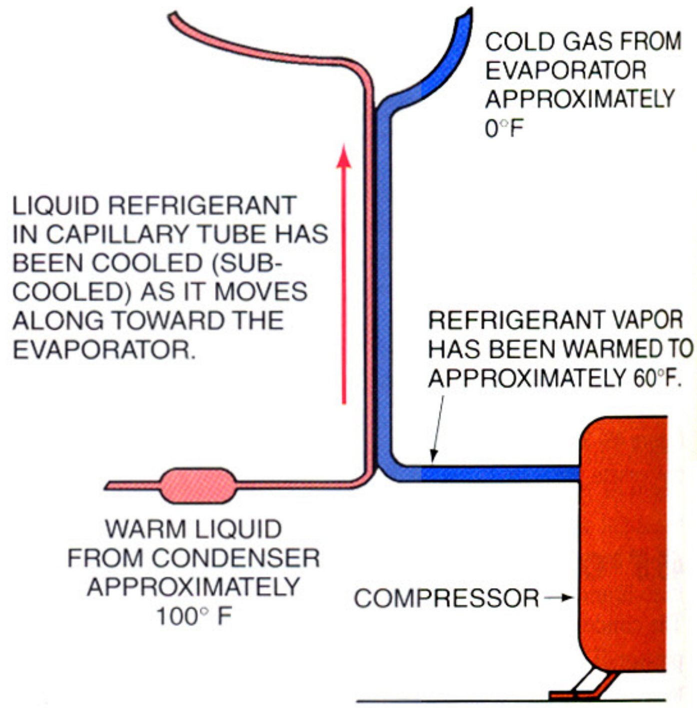


Figure 45–38 Heat exchange between the capillary tube and the suction line.

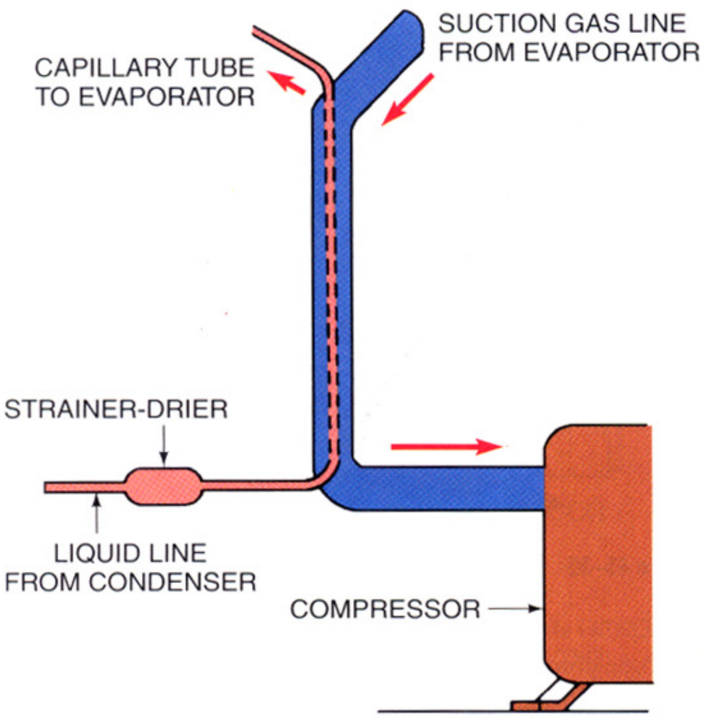


Figure 45–37 The capillary tube routed through the suction line.

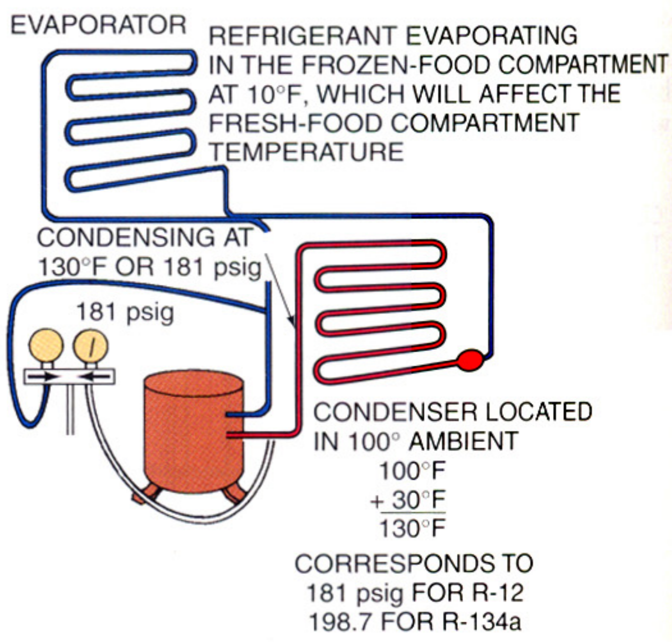


Figure 45–39 The capacity of the refrigerator is reduced by the high ambient temperature.

The capillary tube may be serviced if necessary and may in some cases be changed for another one, but this is difficult and usually not practical.

It was mentioned earlier that a domestic refrigerator would perform correctly only when located in the living space. The capillary tube metering device is one reason. This device is sized to pass a certain amount of liquid refrigerant at typical living condition temperatures. This may be considered between 65°F and 95°F. If the room ambient temperature rises above the recommended, the head pressure will climb and push more refrigerant through the capillary tube, causing the suction pressure to rise. Capacity will suffer to some extent, **Figure 45–39.**

Most residences will not exceed the extreme temperatures for long periods of time. For example, a house temperature may rise to 100°F in the daytime if it does not have air conditioning, but the house will cool down at night. The refrigerator may work all day and not cool down to the correct setting but may cycle off at night.

Domestic refrigerators and freezers are not intended to be placed outdoors or in buildings where the temperatures vary from 65°F to 95°F temperature unless the manufacturer's literature states that they can be operated at other temperatures. Poor performance and shorter life span may be expected if the manufacturer's directions are not followed.

45.10 THE DOMESTIC REFRIGERATED BOX

The first domestic refrigerated boxes were constructed of wood. In fact, some of the earlier iceboxes could be adapted to mechanical refrigeration with the addition of the evaporator, compressor, condenser, and metering device. Later, the boxes were made of metal on a wood frame. They had an open compressor and were very heavy. Just after the beginning of the twentieth century, domestic refrigeration became popular and the manufacturers began active campaigns to design more efficient systems. After World War II, foam insulation was developed and manufacturers had developed the welded hermetic compressor. Foam insulation is lighter and more efficient, **Figure 45–40.**

Box design has been used as a selling tool because of the possibilities of attractive design while the manufacturers have worked to make the box durable and long lasting. Many different colors have been developed.

The first designs were one door to the outside and a freezer compartment door on the inside, **Figure 45–41.** These doors had gaskets with air pockets inside them that compressed when the door was closed, **Figure 45–42.** The compressibility of the gasket would eventually become ineffective with fatigue as the gasket material became old. The door would then allow room air to enter the box. This increased the load on the evaporator and caused more frost accumulation, **Figure 45–43.** The doors had mechanical door latches that could be opened only from the outside. If a child were to get inside with the door closed, all of the oxygen could be consumed and death could result. SAFETY PRECAUTION: Caution must be used when one of these refrigerators is taken out of service. The door must be made safe. One method is to remove the door or door latch mechanism. Another would be to strap the door shut and turn it to the wall, **Figure 45–44.**

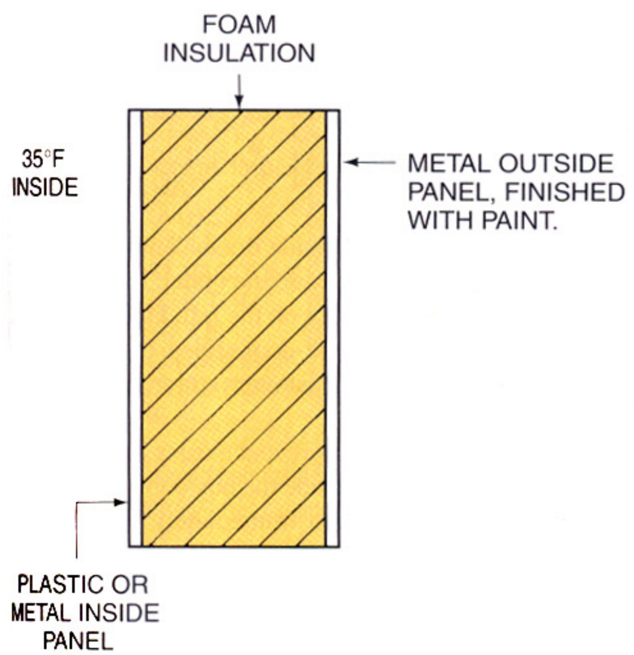


Figure 45–40 Sandwich construction of a refrigerator wall.

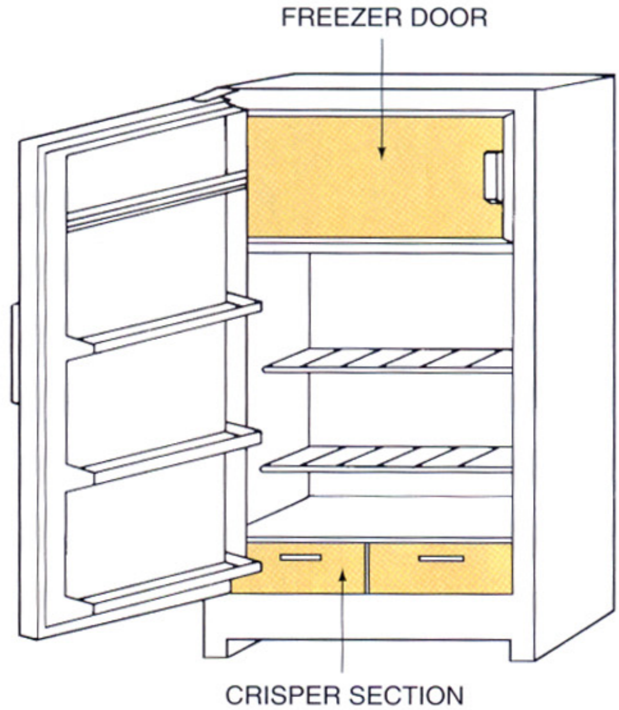


Figure 45–41 A one-door refrigerator.

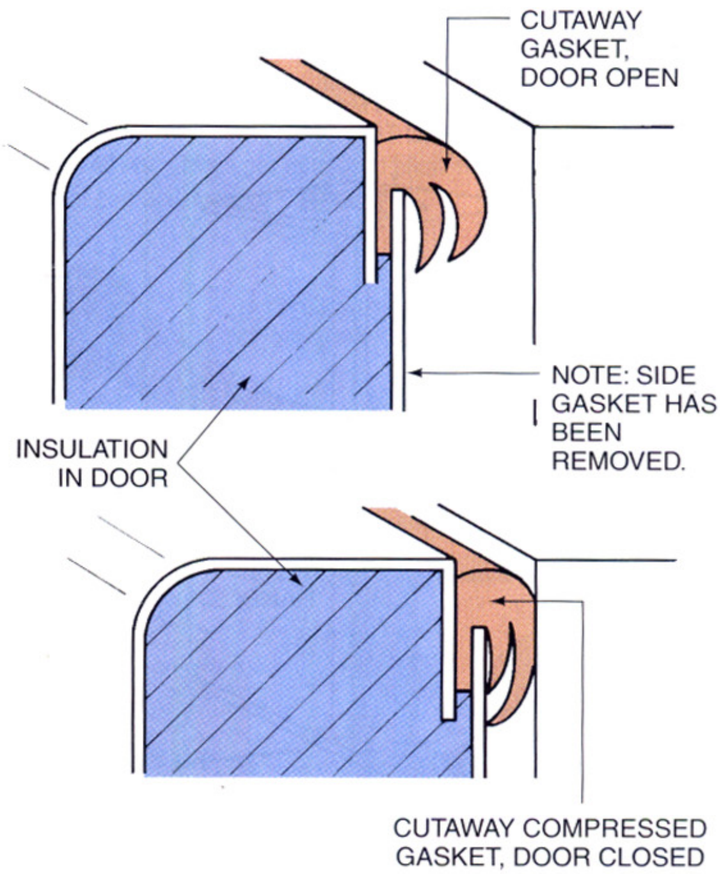


Figure 45–42 Early door gasket construction.

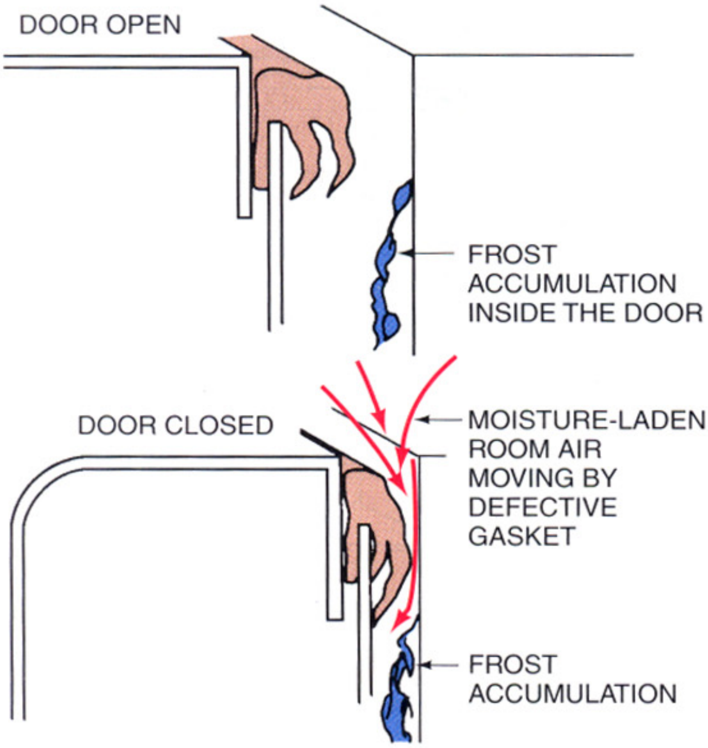


Figure 45–43 An older door gasket that is worn out, causing frost accumulation.

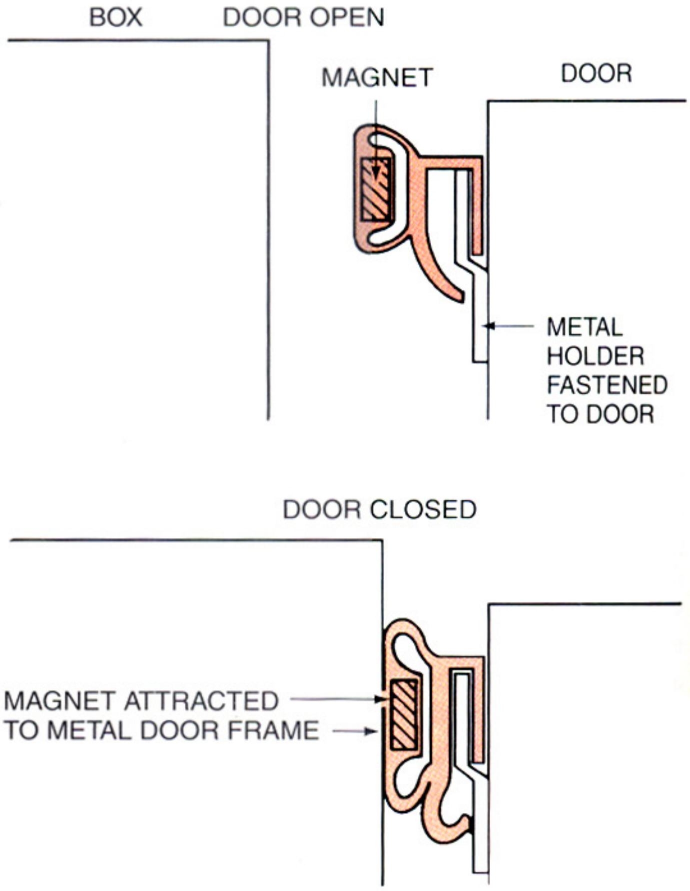


Figure 45–45 A modern refrigerator gasket with a magnet.

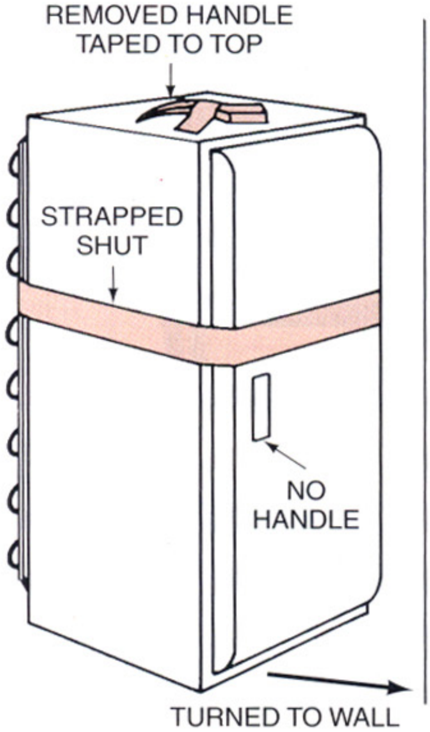


Figure 45–44 SAFETY PRECAUTION: Remove handle, turn to wall, and strap shut old refrigerators for maximum safety.

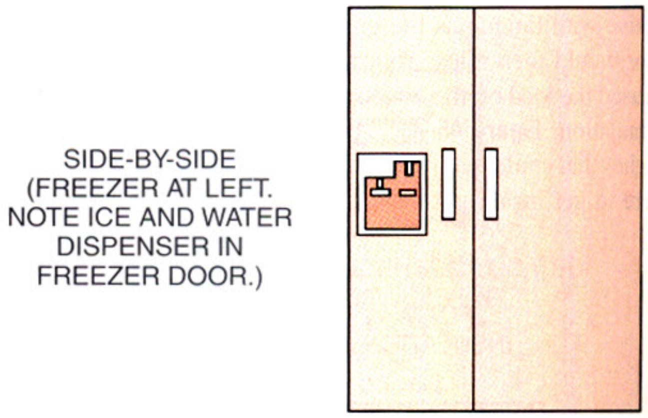


Figure 45–46 The typical side-by-side door arrangement.

The modern design has a magnetic strip gasket all around the door or doors, which also has a compression-type seal that maintains a good seal to keep air out, **Figure 45–45.** These doors can be opened from the inside. The magnetic gasket is also much easier to replace than the old type of gasket.

The typical box has two outside doors. The door combinations may be side by side or over and under. In the side-by-side styles, the freezer is usually on the left, **Figure 45–46.** In some over-and-under and single-door styles, the door opens to the left or to the right for customer convenience, **Figure 45–47.**

The box must be airtight to prevent excess load and frost. If the door is shut and the air inside the box cools and shrinks, the door may be hard to open immediately after closing, **Figure 45–48.** A relief port may be used to allow the air to equalize when there is a pressure difference.

The condensate must be allowed to travel from the inside of the box to underneath the box to the collecting pan where it is evaporated. A trap arrangement at the bottom prevents

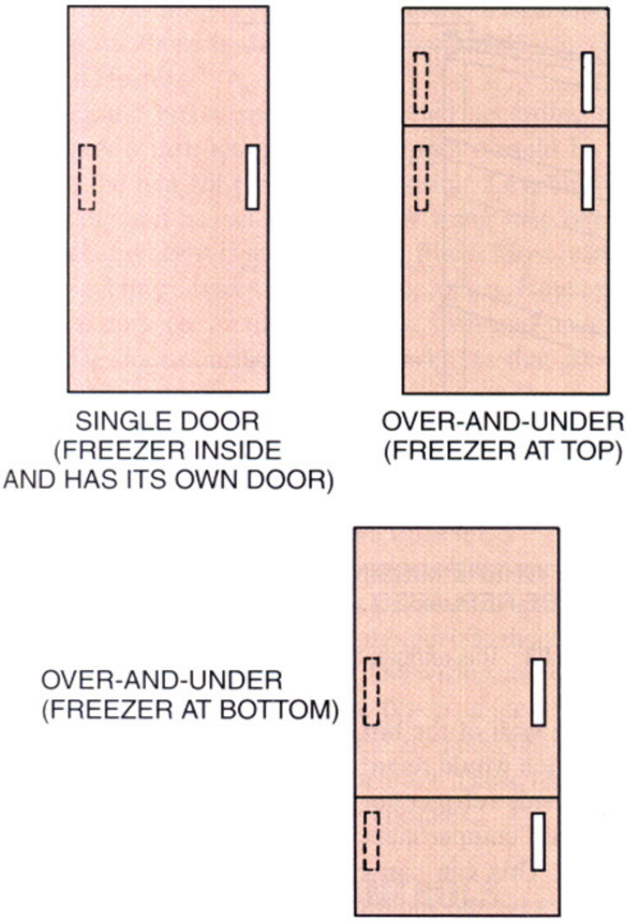


Figure 45–47 Single and over-and-under door arrangements.

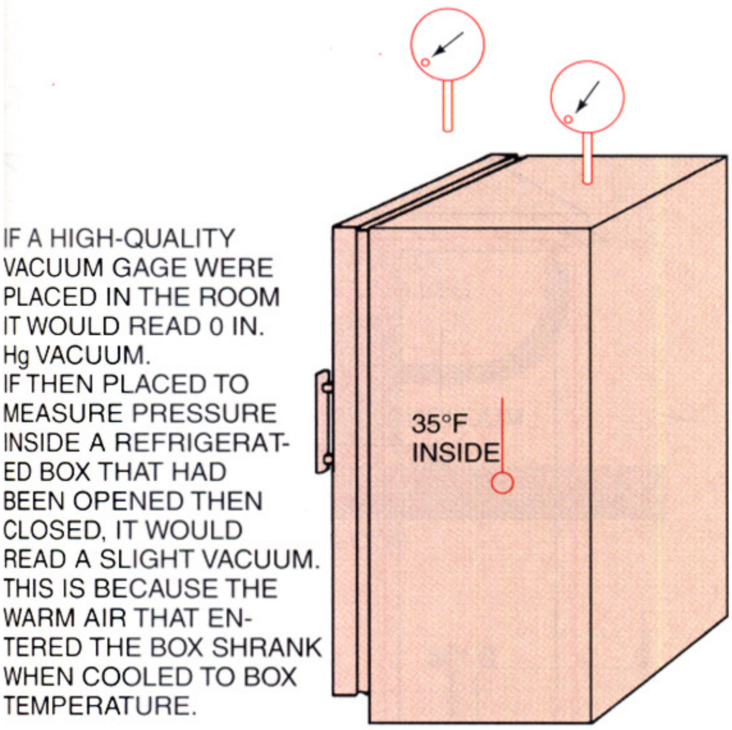


Figure 45–48 Cooled air inside the box may make it hard to open the door immediately after closing.

air from traveling into the box through this opening, **Figure 45–49.** If a refrigerator is located outside in the winter for storage or use, the water in the drain tap may freeze, **Figure 45–50.**

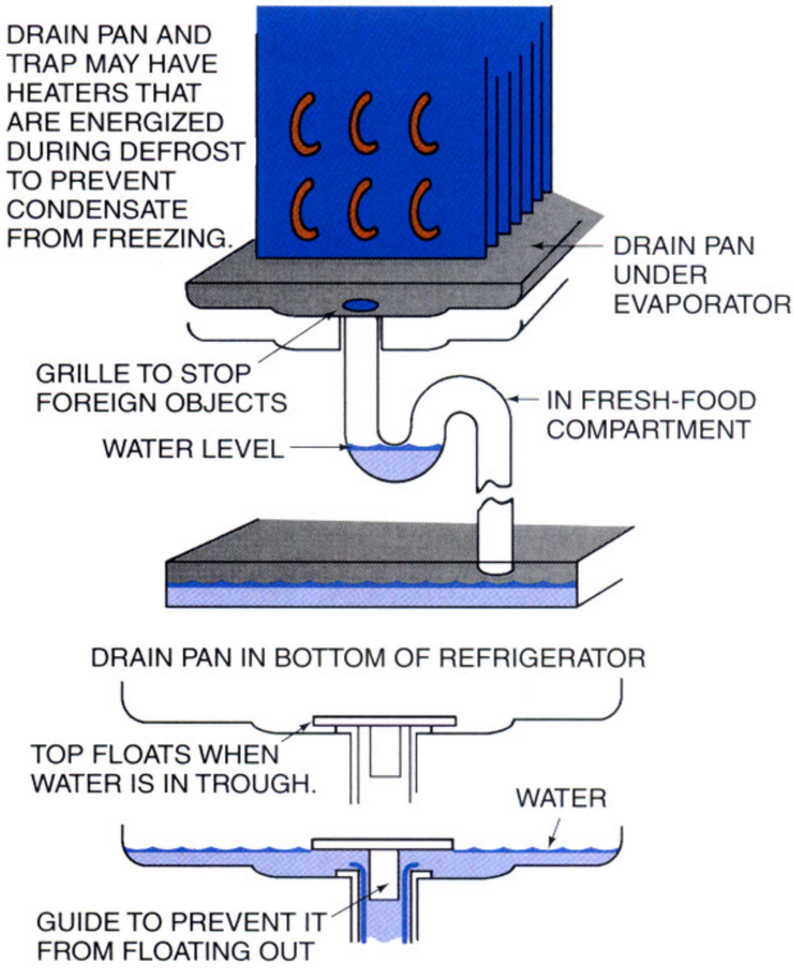


Figure 45–49 Two types of traps to allow condensate to drain and prevent air from entering.

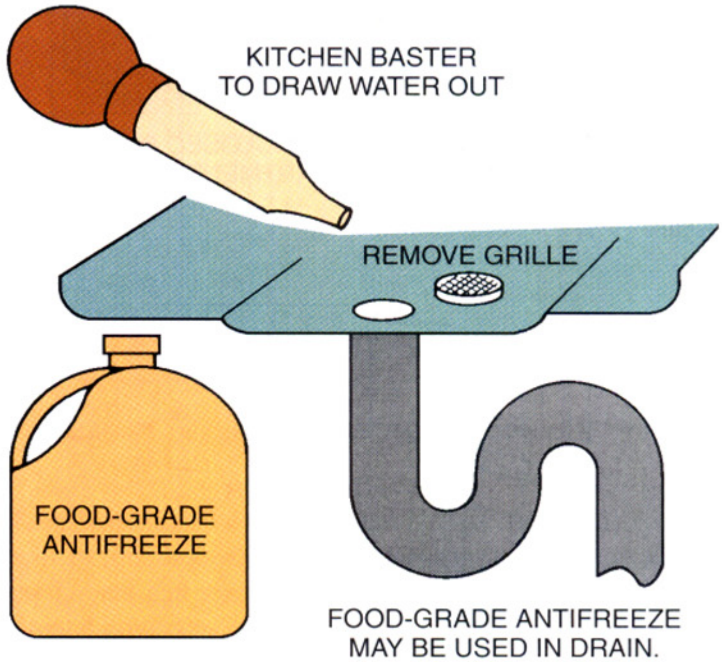


Figure 45–50 Service the drain trap for winter storage, or it may freeze.

The refrigerator may have provision for an ice maker in the frozen-food compartment. This is accomplished by furnishing a place for water to be piped to the frozen-food compartment and a bracket to which the ice maker can be fastened. A wiring harness may also be provided so the ice maker can be plugged in. This arrangement does not require any wiring by the technician.

Various compartments may be maintained at different temperatures, such as the crisper for fresh vegetables and the butter warmer. The crisper is usually maintained by enclosing it in a drawer to keep the temperature slightly cooler and prevent dehydration of the food, **Figure 45–51.** The butter warmer may have a small heater in a closed compartment to keep the butter at a slightly higher temperature than the space temperature so it will spread more easily, **Figure 45–52.**

The inside surface of the modern refrigerator is usually made of plastic. This surface is easy to keep clean and will last for years if not abused. The plastic in the freezing compartment is at very cold temperatures, so care must be taken not to drop frozen food on the bottom rail, or breakage may occur, **Figure 45–53.** If the plastic is broken, the piece should be saved. The box should be warmed to room temperature and the piece replaced with glue to prevent air from circulating in the wall of the box. The plastic may be backed with foam, which would retard air circulation.

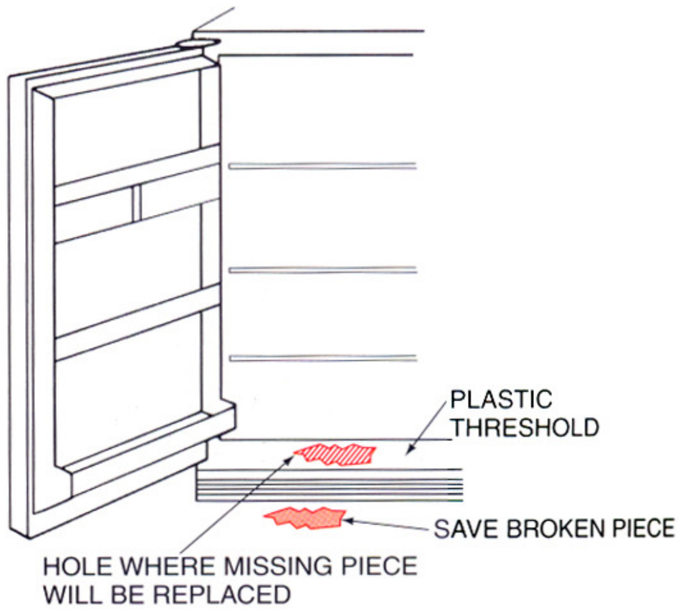


Figure 45–53 This refrigerator has a broken bottom rail.

The inside refrigerator temperature may be −5°F in the frozen-food compartment and 35°F in the fresh-food compartment. This can cause a sweating problem around the doors because the moldings may be below the dew point temperature of the room air. Special heaters, sometimes called mullion or panel heaters, are located around the doors to keep the temperature of the door facing above the dew point temperature of the room air, **Figure 45–54.** Some units have an energy-saver switch that may allow the owner to shut off some of the heaters when not needed, such as in the

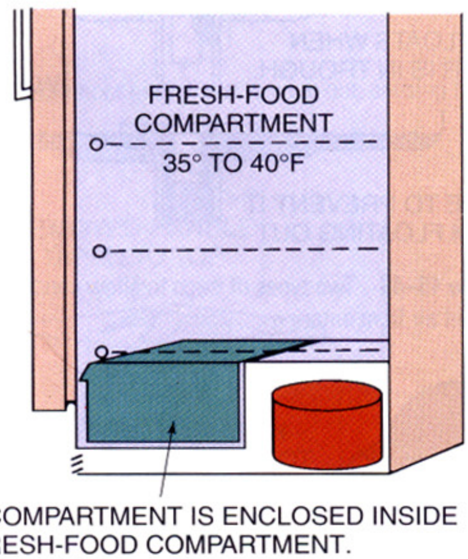


Figure 45–51 A crisper drawer.

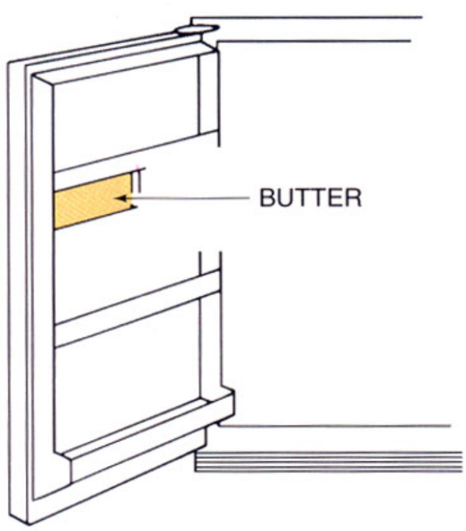


Figure 45–52 A butter warmer compartment.

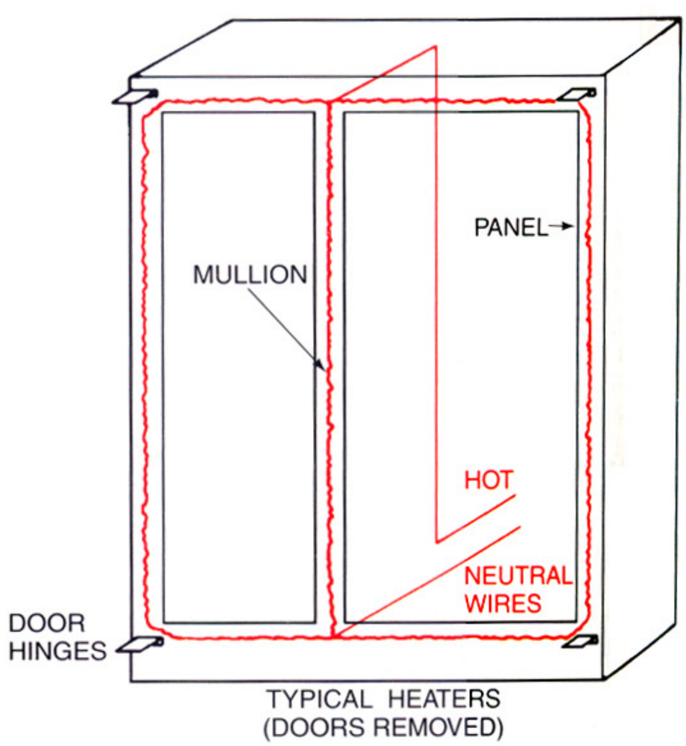


Figure 45–54 Mullion and panel heaters.

winter when the humidity is normally low. An explanation of the wiring for these is discussed in Section 45.15, "Sweat Prevention Heaters."

Refrigerated boxes should be leveled according to the manufacturer's instructions. Usually, they should be tilted slightly to the rear for proper door closing. Leveling is important if the unit has an ice maker, or water may overflow the ice maker when it is automatically filled. Most refrigerators have leveling devices for the feet or rollers, **Figure 45–55.**

Refrigerators are manufactured in over-and-under and side-by-side door configurations. The boxes that are over-and-under seem to have more room because the compartments are typically wider than the side-by-side models. The side-by-side models have the appearance of being narrow and deep, **Figure 45–56.** This will not affect the function of the box but may make service more difficult.

The refrigerator may have some extras for convenience, such as an outside ice dispenser or ice water dispenser on the outside, **Figure 45–57.** Notice that the outside dispenser may be located in a section of the door. The wiring and water connections must be made to the door. When an ice dispenser is on the front and in the door, a chute connects the ice maker in the freezer to the dispenser in the door. These features add to the cost and make service more complex.

45.11 WIRING AND CONTROLS

Each refrigerator should have a wiring diagram permanently fastened to the box, normally on the back. These wiring diagrams are usually of two types, pictorial and line. The pictorial diagram may show the outline of the control and the location of the control, **Figure 45–58.** The line diagram is used to illustrate how the circuit functions by showing all power-consuming devices between the two lines, **Figure 45–59.**

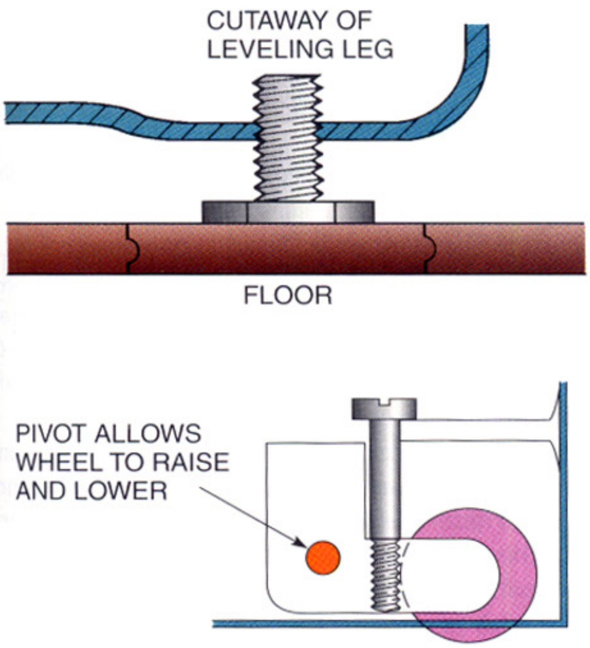


Figure 45–55 Leveling devices for feet or rollers.

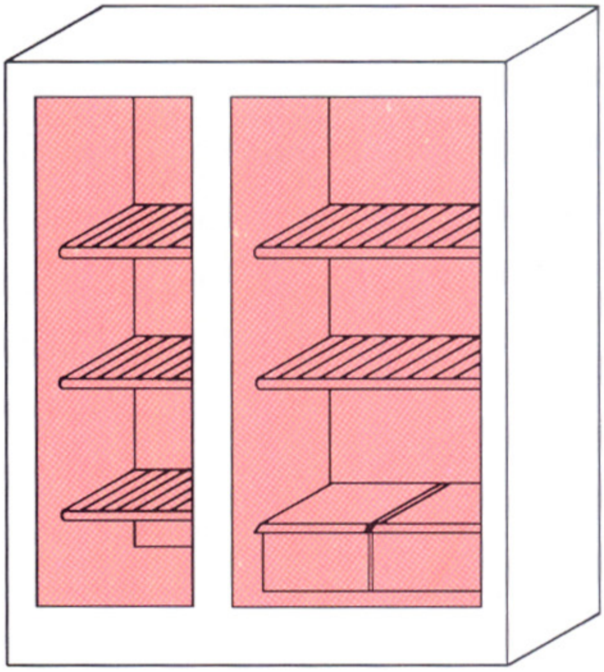


Figure 45–56 Side-by-side refrigerator compartments are narrower.

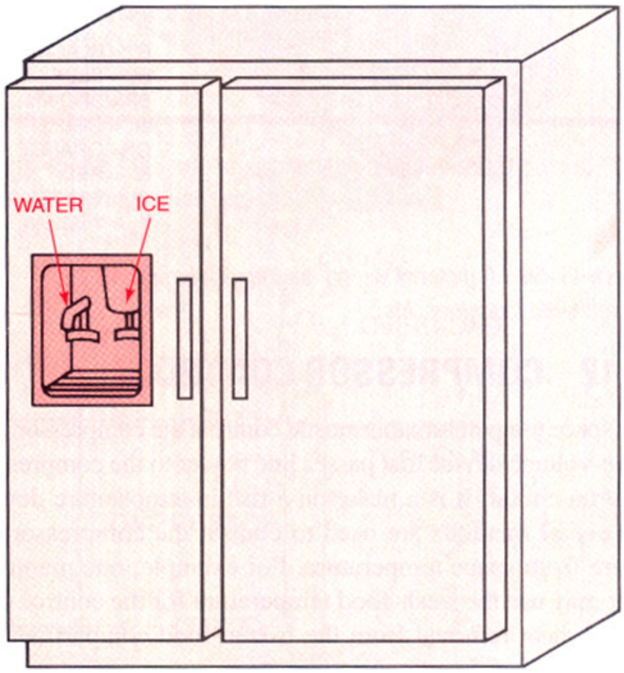


Figure 45–57 A water and ice dispenser on the outside.

Keep in mind that we will be dealing with 115 V only so there will be one hot wire and one neutral used to operate the equipment and a ground (green wire) for the frame or box ground protection.

The components of the typical refrigerator to be controlled include:

- Compressor
- Defrost components
- Various heaters, butter and panel or mullion
- Lights for the interior
- Evaporator fan
- Ice maker

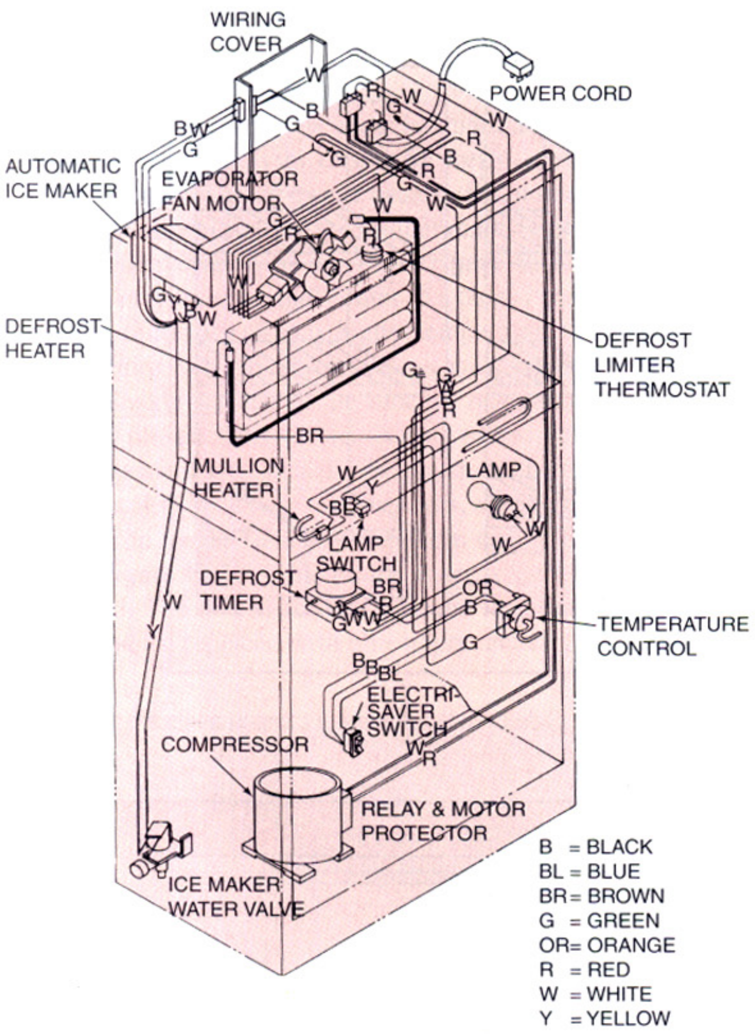


Figure 45–58 A pictorial wiring diagram. *Courtesy White Consolidated Industries, Inc.*

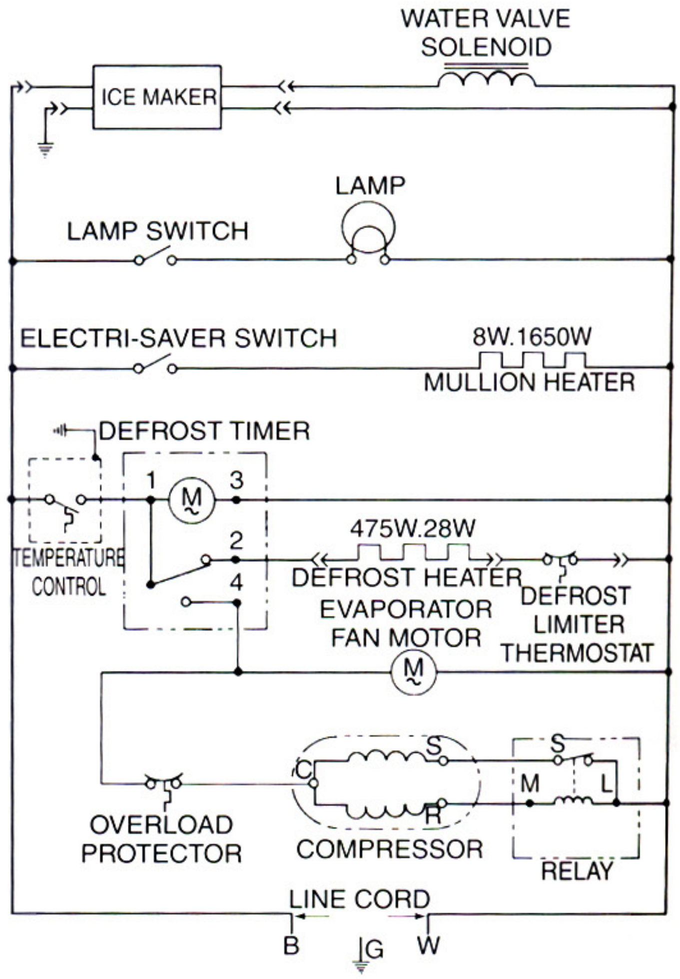


Figure 45–59 A line wiring diagram. *Courtesy White Consolidated Industries, Inc.*

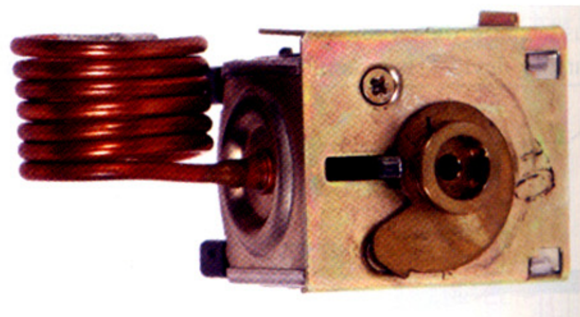


Figure 45–60 The thermostat or cold control. *Photo by Bill Johnson*

45.12 COMPRESSOR CONTROLS

The space temperature thermostat controls the compressor. It is a line-voltage device that passes line power to the compressor start/run circuit. It is a make-on-a-rise-in-temperature device.

Several methods are used to control the compressor but all are from space temperature. For example, one manufacturer may use the fresh-food temperature for the control with enough heat removal from the frozen-food compartment to keep the food frozen. Another manufacturer may use the frozen-food compartment temperature to control the compressor with enough planned heat removal from the fresh-food compartment to keep it cold. Still another manufacturer may use the evaporator plate temperature at a certain planned location as the basis for shutting off the compressor.

It does not matter which method is used; the compressor is still shut off with a thermostat based on some condition inside the refrigerated box. This is a planned condition with the intent of keeping both the frozen-food compartment and the fresh-food compartment at the correct temperature. For many years, this control has been called the thermostat or the cold control, **Figure 45–60.** It is adjustable and can be considered a remote-bulb thermostat. These are small but usually have a large dial with graduated numbers. These numbers typically run from 1 to 10 and have no relation to the actual temperature scale. The dial may read colder with an arrow pointing in the direction where the numbers will yield colder temperatures. This control must be electrically rated with contacts that are able to stop and start the compressor for years of service. They must be reliable because food will spoil if the control were to fail.

Refrigeration thermostats have a fluid inside the sensing bulb that exerts pressure against the bottom of a diaphragm or *bellows*, **Figure 45–61.** The atmosphere is on the other side of the bellows. If the atmospheric pressure is much lower than normal, the control setting must be calibrated for a new pressure, such as when a refrigerator is located at a high altitude. Altitude adjustment varies from one manufacturer to another so the manual should be consulted. See **Figure 45–62** for an example of a control with altitude adjustment. The box

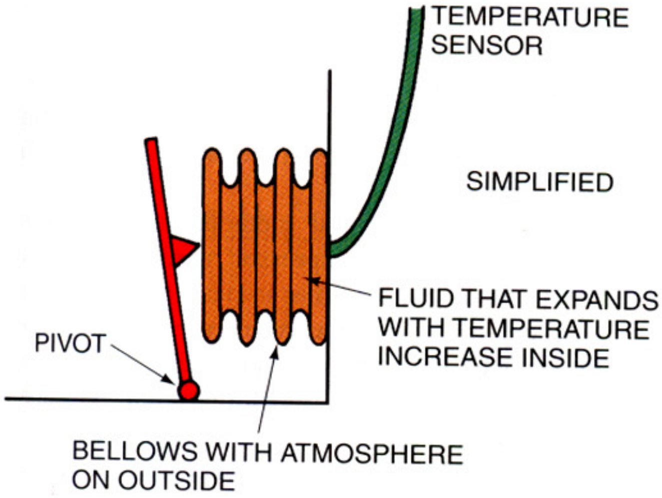
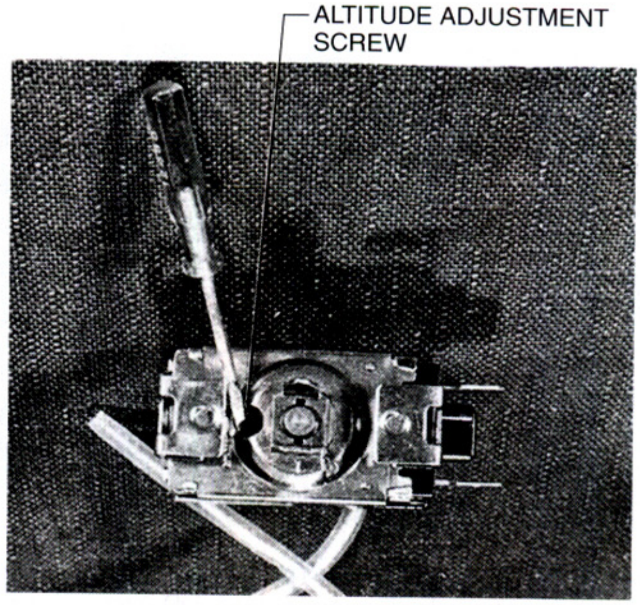


Figure 45–61 Sketch of a thermostat.

thermostat passes power to the compressor start circuit to start the compressor.

45.13 COMPRESSOR START CIRCUIT

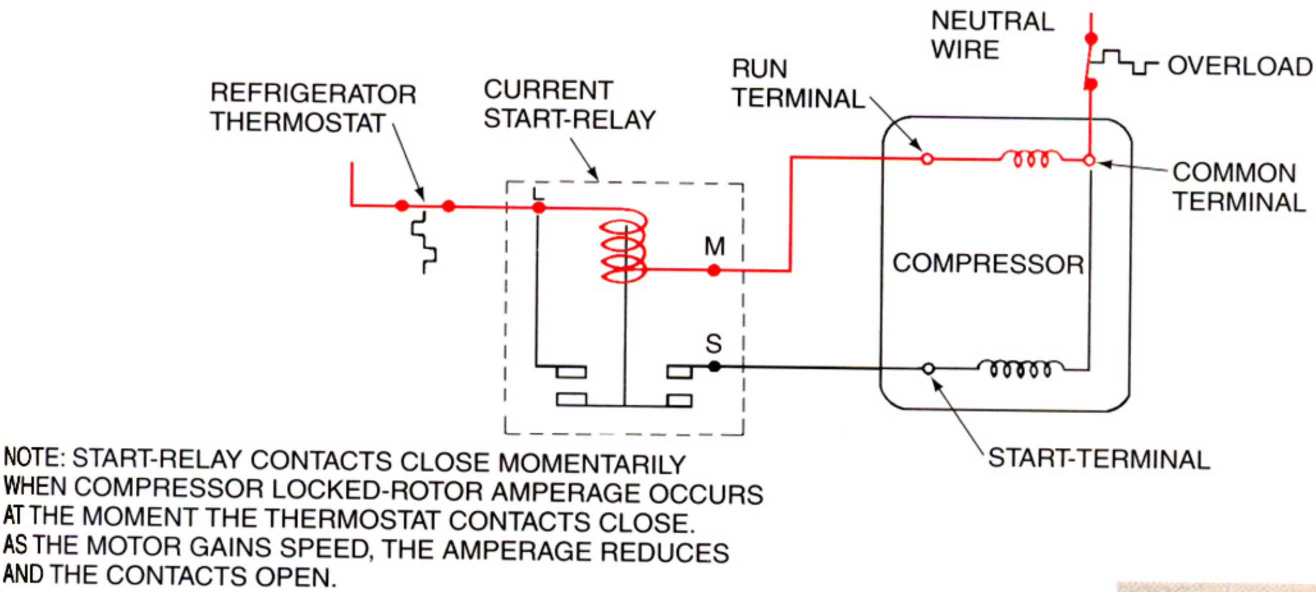
The compressor start circuit receives power from the thermostat circuit when its contacts close and then helps the compressor start. The compressor may need some additional help because the pressures may not totally equalize from the high to the low side between cycles through the capillary tube. The start circuit may consist of a start relay, usually a current type, **Figure 45–63.** The starting components and their

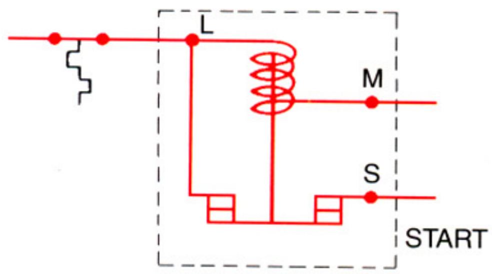


ALTITUDE ADJUSTMENT

ALTITUDE ABOVE SEA LEVEL-FEET	RANGE SCREW ADJUSTMENT (TURNS-CLOCKWISE)
2,000	1/8
4,000	1/4
6,000	3/8
8,000	1/2
10,000	5/8

Figure 45–62 Altitude adjustment on a thermostat. *Courtesy White Consolidated Industries, Inc.*





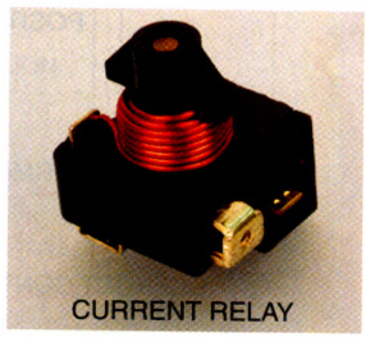


Figure 45–63 The refrigerator compressor start circuit using a current relay. *Photo by Bill Johnson*

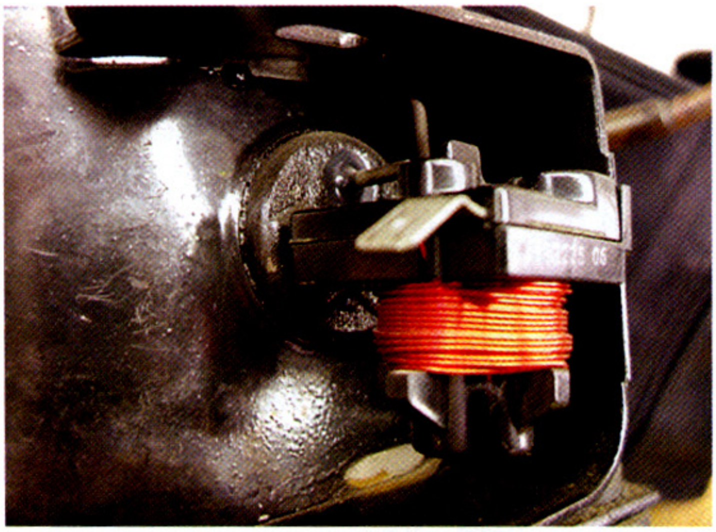


Figure 45–64 This compressor has a current relay that plugs onto the compressor terminals. *Photo by John Tomczyk, Courtesy Ferris State University*

circuit are typically located in the vicinity of the compressor in the back. **Figure 45–64** shows a relay that plugs onto the compressor terminals.

45.14 DEFROST CYCLE

All refrigerators have freezing compartments so they are low-temperature refrigeration systems. The evaporator will gather frost, and it must be removed from the evaporator. Automatic defrost is called *frost-free* by many manufacturers, customers, and service people. This automatic defrost is desirable because manual defrosting is a chore and is often not done when needed. Automatic defrost will help the refrigeration system to operate more efficiently because the frost will be kept off the coil.

Manufacturers use several methods to start defrost. Many manufacturers use compressor running time to start defrost by wiring a defrost timer in parallel with the compressor, where it builds time whenever the compressor runs, **Figure 45–65.** Compressor running time is directly associated with door openings, infiltration, and warm food placed in the box.

The defrost cycle may be terminated by two methods, time or temperature. Some units use a termination thermostat that is backed up by the timer. If the thermostat does not terminate defrost, the timer will act as a safety feature.

The hot gas defrost uses the heat from the compressor to melt the ice from the coil. A solenoid valve connects the hot gas line to the inlet of the evaporator. The compressor must be running during this cycle for the heat to be available for defrost. The evaporator fan must be stopped, or heat from the evaporator will raise the temperature of the frozen-food compartment. **Figure 45–66** shows a diagram of a unit with hot gas defrost.

Electric heat defrost is accomplished with electric heaters located close to the evaporator to melt the ice, **Figure 45–67.** When the unit calls for defrost, the compressor and evaporator fan stop, and the heaters are energized. This condition is

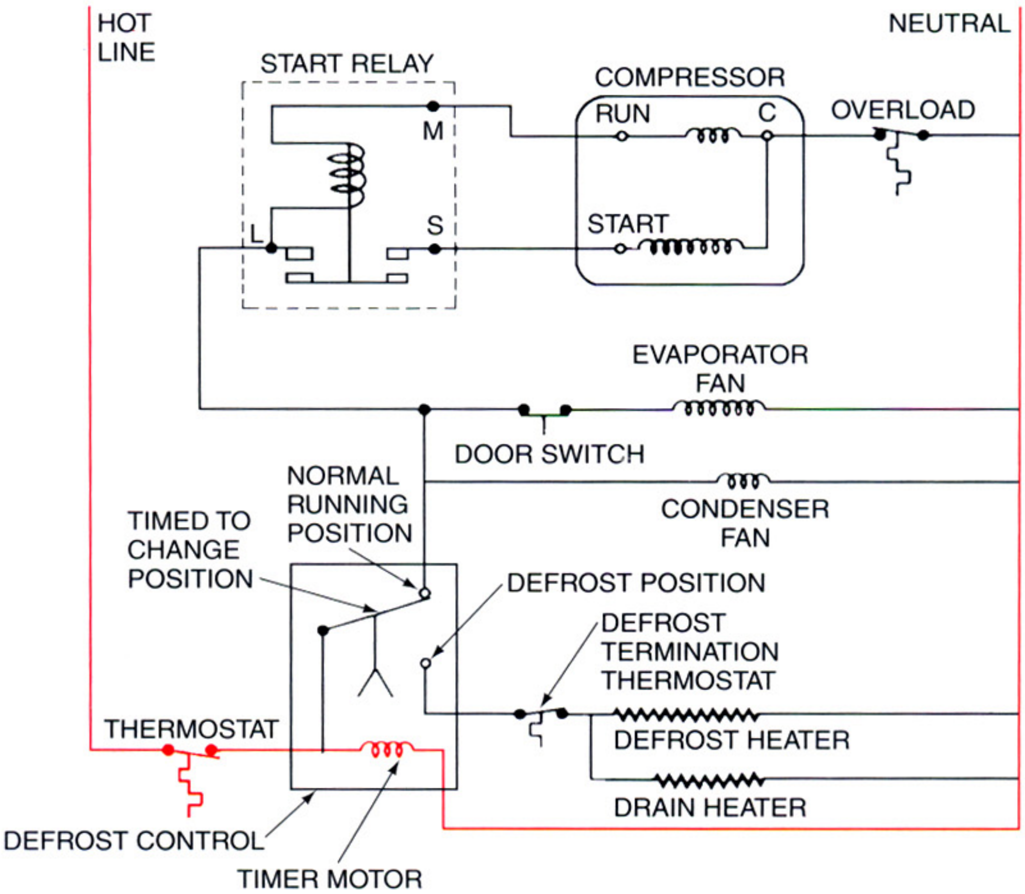


Figure 45–65 Timer wiring for refrigerator defrost.

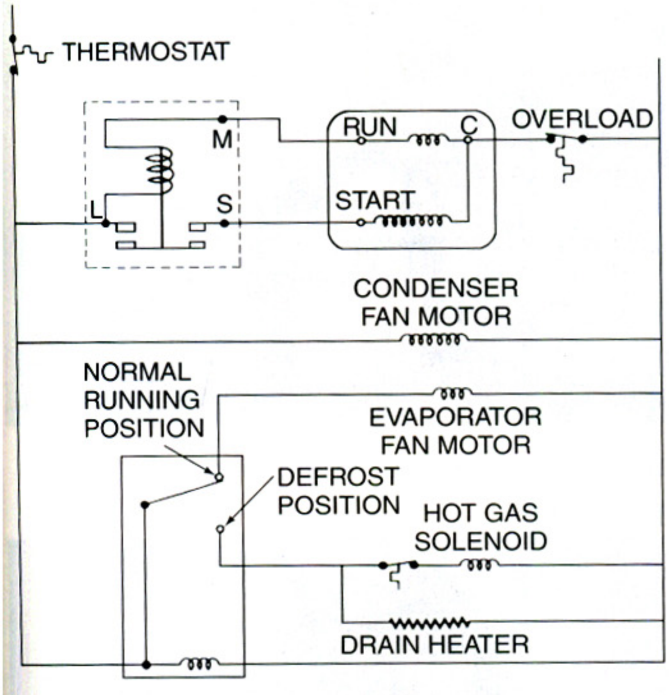


Figure 45–66 A wiring diagram for hot gas defrost.

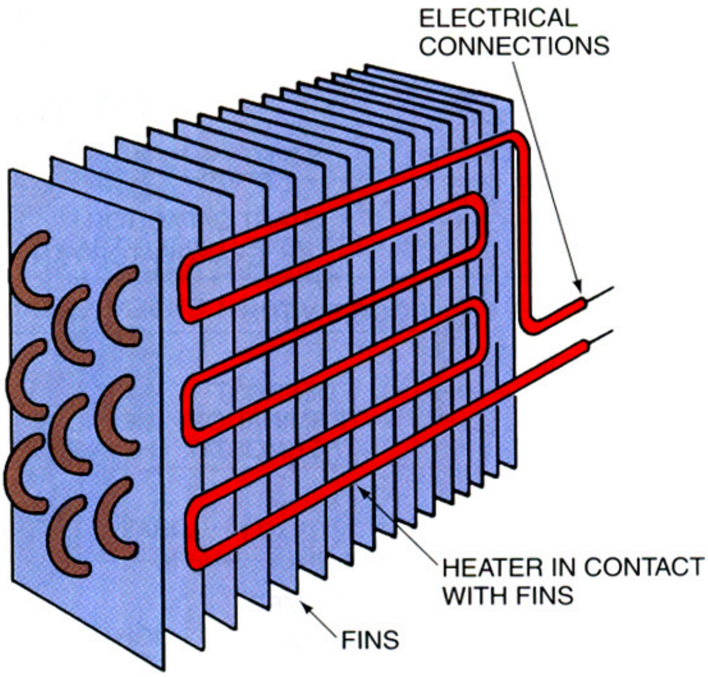


Figure 45–67 Electric heaters for defrost.

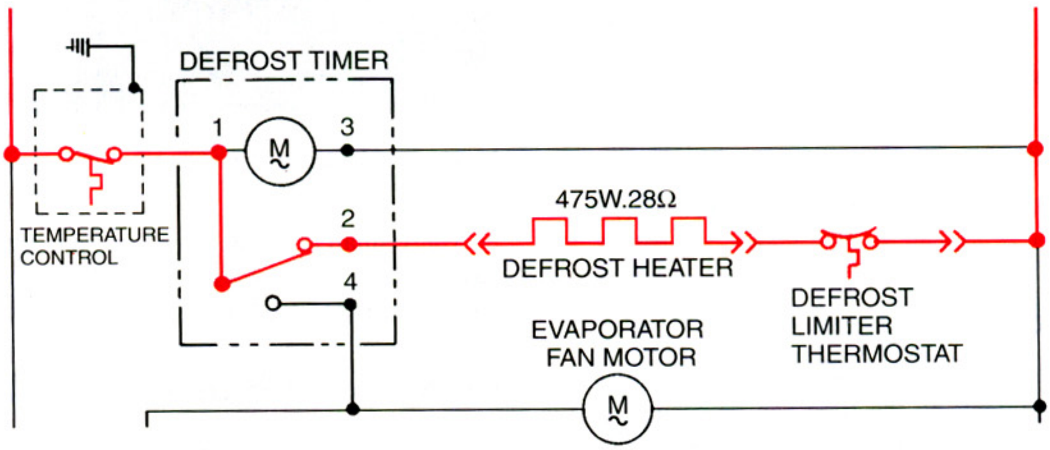


Figure 45–68 Electric heat defrost. *Courtesy White Consolidated Industries, Inc.*

maintained until the end of the defrost cycle. **Figure 45–68** shows an electric heat defrost diagram.

Drain pan heaters may be energized when either hot gas or electric heat defrost is used to keep the condensate from freezing as it leaves the drain pan.

45.15 SWEAT PREVENTION HEATERS

Most sweat prevention heaters are small electrically insulated wire heaters that are mounted against the cabinet walls at the door openings. These are to keep the outside cabinet temperature above the dew point temperature of the room so they will not sweat. Actually this condensation will not reduce capacity, but it may drop on the floor or be a nuisance on the cabinet and in some cases cause rust. **Figure 45–69** shows a diagram of a type of heater and illustrates its location. Some units may have energy-saver switches to allow the owner to switch part of the heaters off if the room

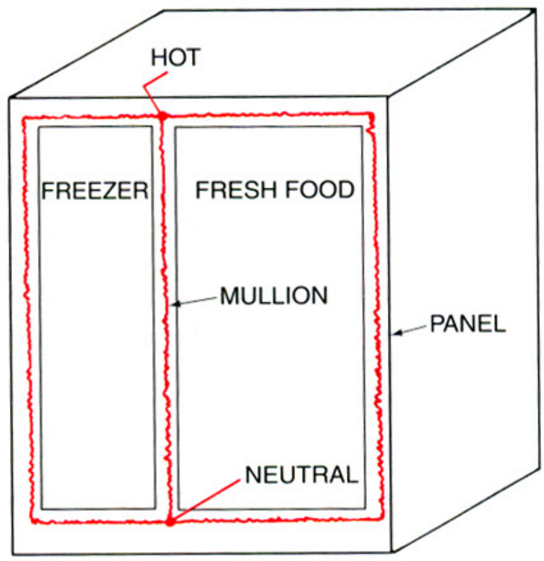


Figure 45–69 Heaters in a refrigerator showing their location.

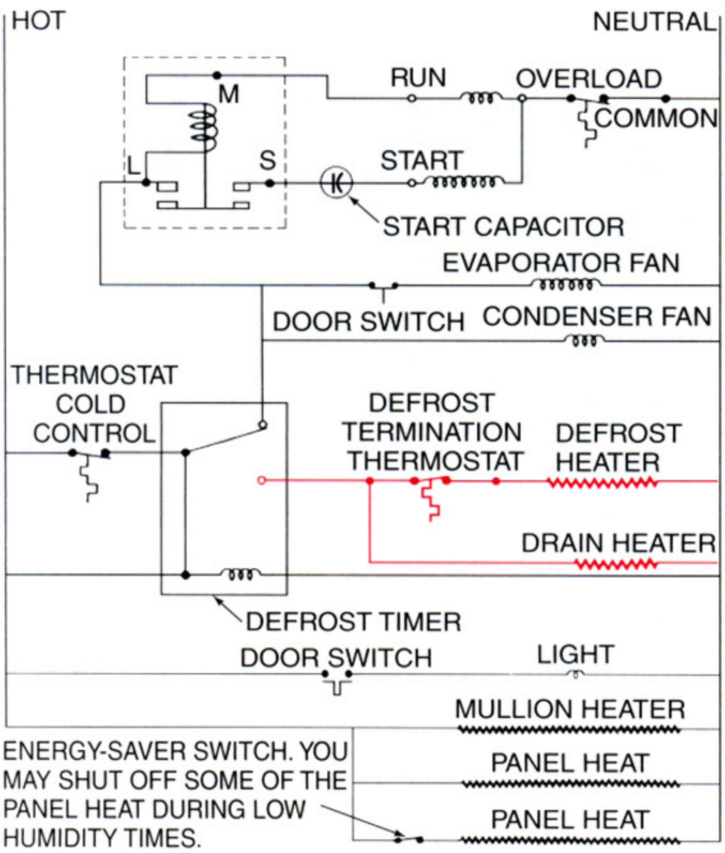


Figure 45–70 This wiring diagram shows the position of the energy-saver switch.

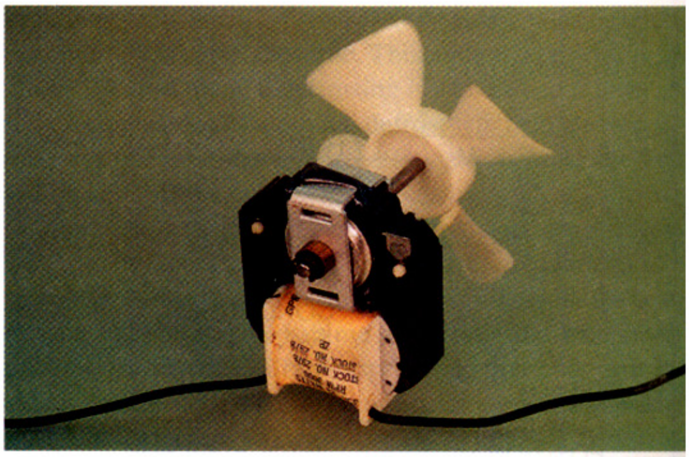


Figure 45–71 An evaporator fan motor. *Photo by Bill Johnson*

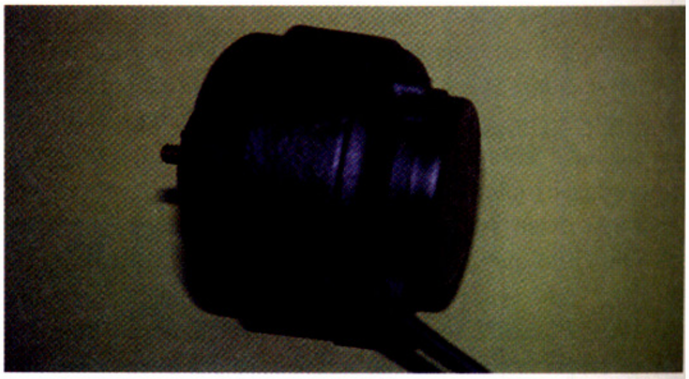


Figure 45–72 A condenser fan motor. *Photo by Bill Johnson*

humidity is low, **Figure 45–70.** These switches may be switched on if sweat is noticed.

45.16 LIGHTS

Most refrigerators have lights mounted in the fresh- and frozen-food compartments so the food can be seen. These lights are typically controlled by door switches that make a circuit when the door is opened.

45.17 REFRIGERATOR FAN MOTORS

Two types of fans are furnished on refrigerators when forced draft is used: one for the condenser and one for the evaporator. Condenser fans are usually prop-type fans with shaded-pole motors. Small squirrel cage centrifugal fans may be used for the evaporator.

The evaporator fan, used on frost-free models only, may run all the time except in defrost, so it may have many operating hours in a few years. It is typically a reliable device and is located in the vicinity of the evaporator, usually under a panel that may be easily removed for service. This motor is often an open-type motor with no covers over the windings. These fans have permanently lubricated bearings that require no service, **Figure 45–71.**

The condenser fan is located under the refrigerator in the back and is typically a shaded-pole motor with a prop-type fan. It is permanently lubricated also but is covered, not open, **Figure 45–72.**

These small fan motors are simple to troubleshoot. If you have power to the motor leads and the motor will not turn, either the bearings are tight, or the motor is defective.

45.18 ICE-MAKER OPERATION

The ice maker in a domestic refrigerator is in the low-temperature compartment of the box and freezes water into ice cubes. This is generally accomplished by filling a tray in the freezing compartment with water from the home water supply. A solenoid valve opens long enough to allow the tray to fill. Time is used to determine the water fill amount. When a predetermined time has passed, time for the water to freeze to ice, the ice maker will harvest the ice by dropping it into the holding tray. This may be accomplished by twisting the plastic tray as it turns to break the ice loose. The tray is turned and twisted by a small motor geared to have the required torque, **Figure 45–73.** When the bin is full, a bail switch may raise up, or the weight of the ice in the bin may trip a switch to stop the cycle.

Another type of ice maker makes ice in a tray with a heater inserted in the tray for defrost at harvest time. This ice maker fills and freezes the water. When a predetermined temperature is reached, the heater is energized, and a small gear motor is started, applying force to the bottom of the ice cubes with finger-like devices. When they turn loose, the gear motor moves them to the storage area and the process starts again. This is repeated until the ice bin is full, **Figure 45–74.**

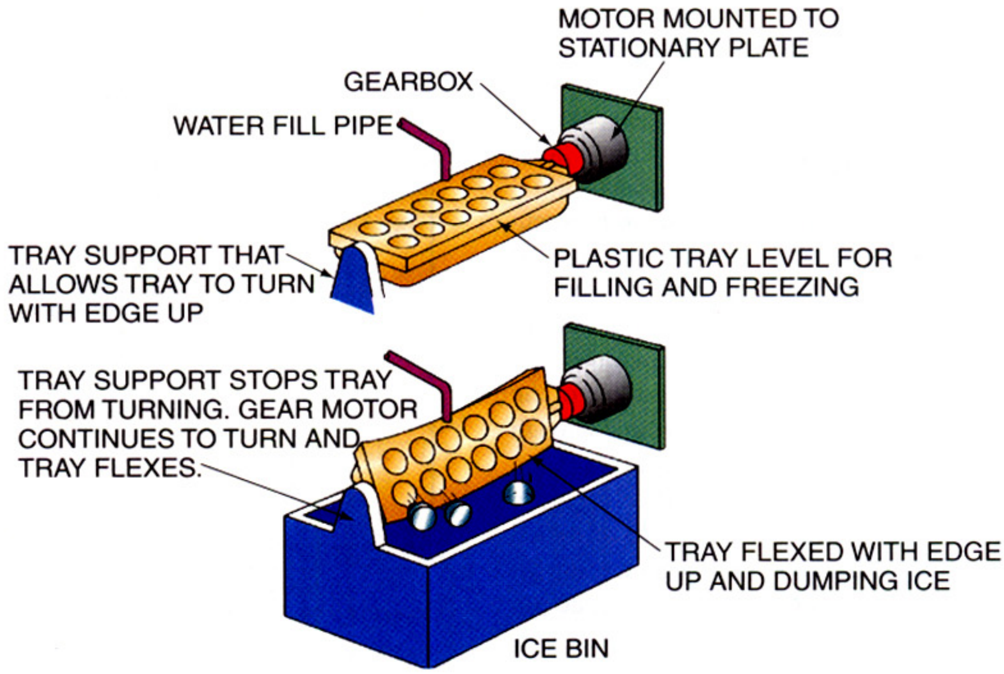


Figure 45–73 Water fills the tray and freezes. At the proper time, ice harvest is accomplished by twisting the plastic tray and dumping the ice into the ice bin.

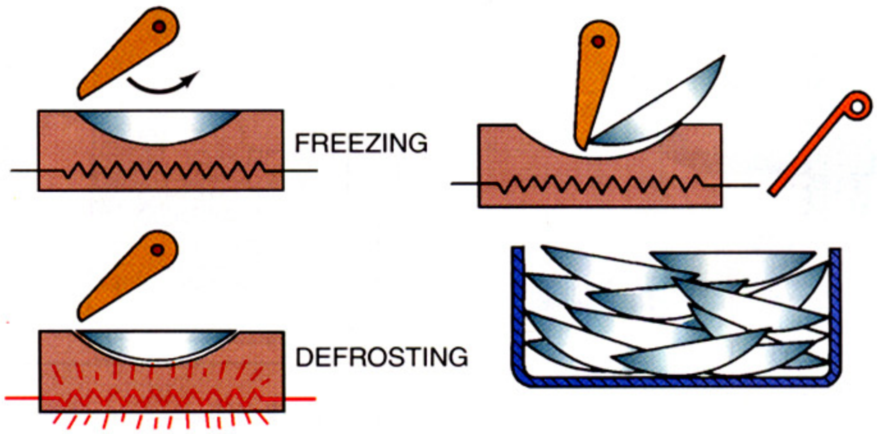


Figure 45–74 The water-filled tray freezes. When the control circuit determines that the water is frozen, the heater energizes. Then the fingers push the ice out of the tray to the storage bin. When the bin is full, the bail switch is moved to the right and will not return; production stops.

These domestic ice makers do not make ice like commercial ice makers, which use an auger or inverted evaporator with water flowing over it. Domestic ice makers use time more than any other method to determine the sequence of events. Some may use electronic circuits for these sequences, **Figure 45–75.**

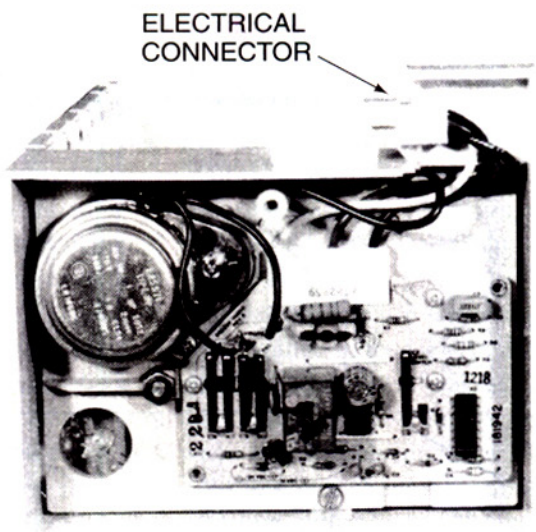


Figure 45–75 An electronic circuit board for an ice maker. *Courtesy White Consolidated Industries, Inc.*

45.19 REFRIGERATOR SERVICE

The technician should make every effort to separate problems into definite categories. Some problems are electrical, and some are mechanical.

Unit 5, "Tools and Equipment," describes tools and equipment used by technicians for the service of refrigeration equipment. A poorly equipped service technician works at a disadvantage. Lack of proper instruments may prevent the technician from determining the problem. Damage can be caused to the equipment or the customer's property, or the technician may be injured if the correct equipment to move a refrigerated box is not used. To be a professional, you must be well equipped.

45.20 CABINET PROBLEMS

Domestic refrigerators must be level to manufacturer's specifications for the refrigerant to correctly circulate through the evaporator and condenser. The ice maker may overflow when filled with water if it is not level. Condensate may not completely drain during defrost if the refrigerator is not level. The leveling screws or wheels are on the bottom of the box or cabinet. Leveling feet may be adjusted with a wrench or a pair of adjustable pliers. If the unit has wheels, there are leveling adjustments to raise and lower the wheels, **Figure 45–76.** If the floor is too low, spacers may need to be added to the lowest point so that all four feet or wheels are touching the floor or spacers, **Figure 45–77.** If all four points do not touch with equal pressure, vibration may cause the refrigerator to be noisy. Food containers are often glass and can create a lot of sound on the outside of the box, **Figure 45–78.**

If the box is not level, the door or doors may not close correctly or may tend to swing open, **Figure 45–79.** With mag-

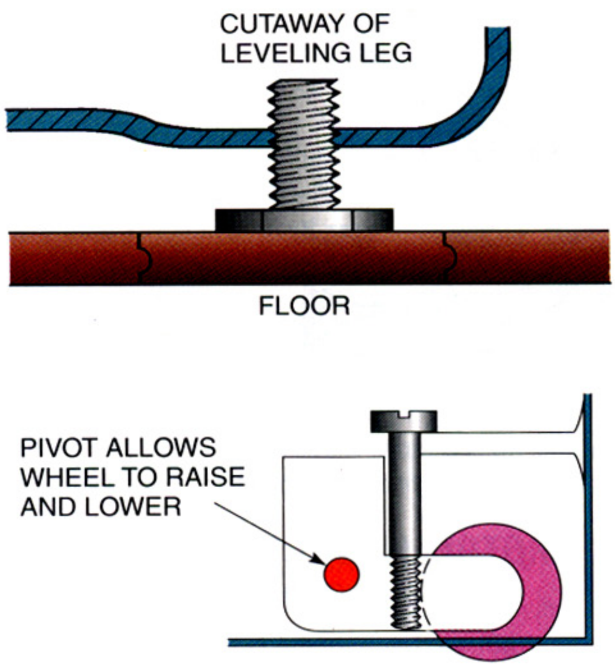


Figure 45–76 Refrigerator leveling devices.

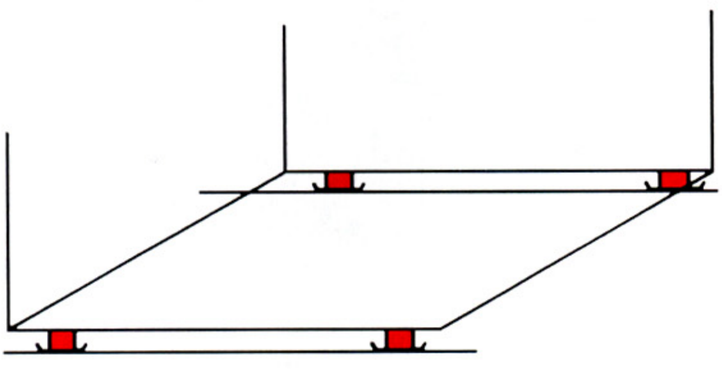


Figure 45–77 All four feet or wheels must be touching the floor.

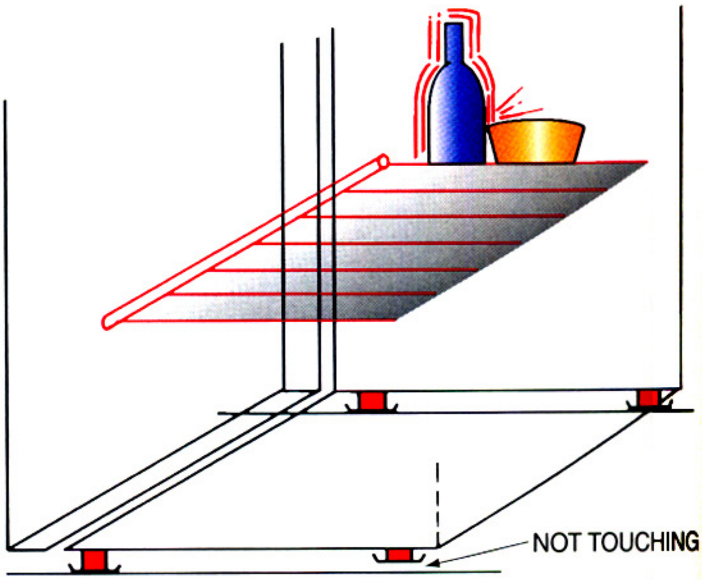


Figure 45–78 If all four contact points are not touching the floor or spacers with equal pressure, vibration will cause noise.

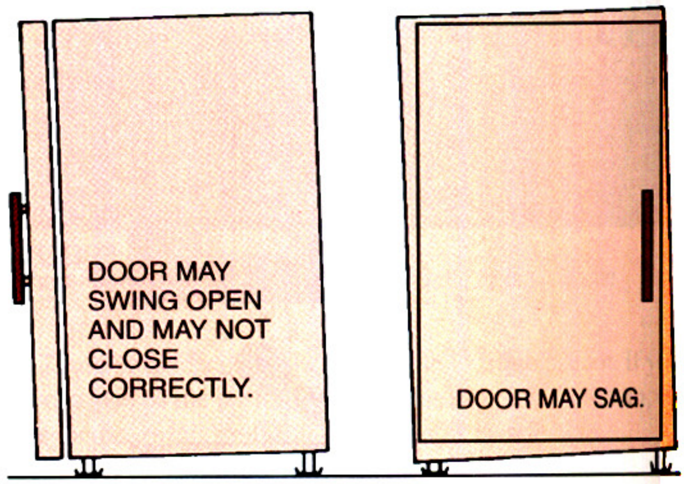


Figure 45–79 If the box is not leveled per the manufacturer's instructions, the doors may not function correctly.

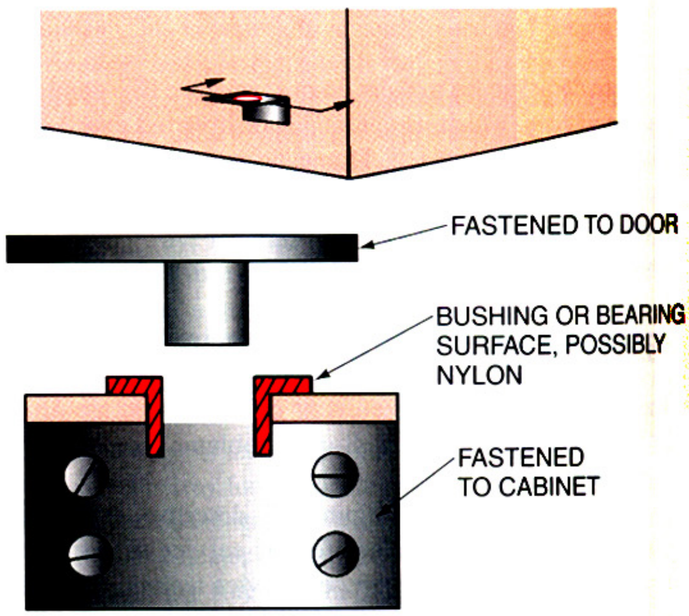


Figure 45–80 Hinges may have bearing surfaces to make the door opening easier.

netic gaskets, it is important that the box not be sloped downward toward the front.

The door gets the most abuse of any part of the box because it is opened and closed many times. It may have a lot of weight in it due to food storage. It must have strong hinges. Many have bearing surfaces built into these hinges that may need changing after excessive use, **Figure 45–80.**

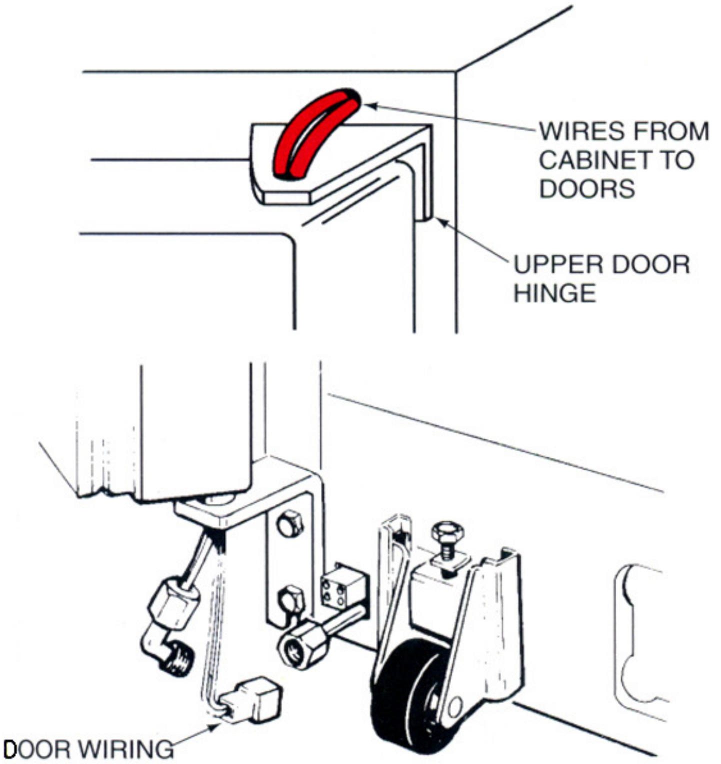


Figure 45–81 Power circuits and tubing for water may be connected to the door through the hinges. *Courtesy White Consolidated Industries, Inc.*

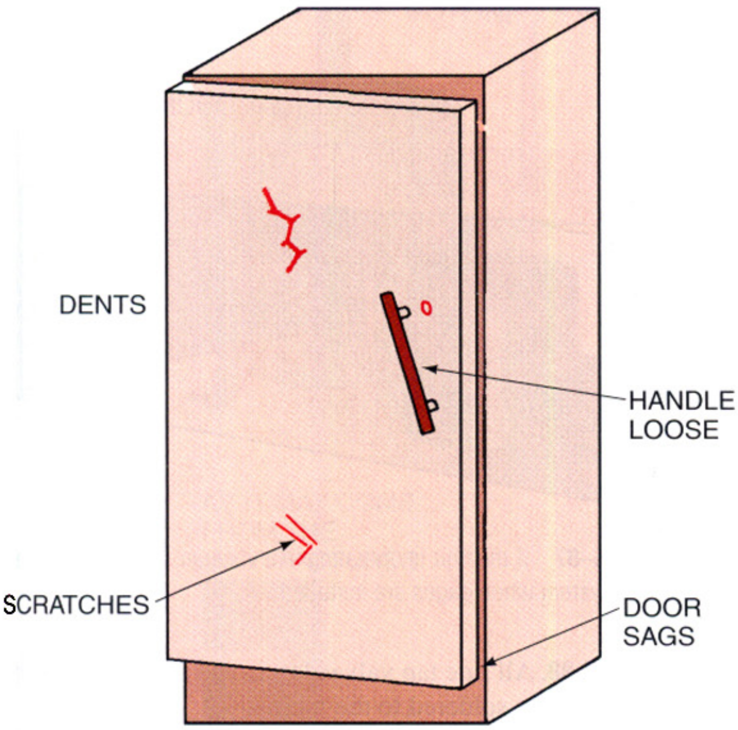


Figure 45–82 A door distorted from use or abuse.

The door may have wires and water piping through the hinges to furnish power and water to circuits that may operate ice or water dispensers located in the door, **Figure 45–81.** These connections may require service when wear occurs with use.

As door gaskets age, they may need replacement. Different manufacturers use different gaskets that may require special tools. These tools help in removing the old gaskets and replacing the new ones. The manufacturer's directions should be followed when you change the gaskets. Care should be used when the new gaskets are in place to ensure that the door is properly aligned and the gaskets fit properly. A door may be distorted from use or abuse, **Figure 45–82.**

45.21 GAGE CONNECTIONS

Domestic refrigerated devices do not have gage ports like commercial refrigeration or air-conditioning systems. The system is hermetically sealed at the factory, and the use of gages may never be needed. When a system has been charged correctly and as long as all conditions remain the same, it should never have to be adjusted. Leaks, field analysis requiring pressures, and field repair of components are the only reasons to apply gages. Many service technicians have a tendency to routinely apply gages. This can be poor practice. Taking a high-pressure reading on a high-pressure gage line full of condensed liquid refrigerant can be enough to adversely affect the operating charge. Many service technicians have started with the correct charge, but as a result of taking pressure readings have altered the charge and caused a problem. Gages should be applied as a last resort, and when applied, should be done with great care. Other methods to determine system problems without gages are discussed in Section 45.22, "Low Refrigerant Charge."

All gage manifolds and gage lines must be leak-free, clean, and free from contaminants. It is good practice to have a set of gages for each type of refrigerant you commonly use. Keep the gages under pressure with clean refrigerant from one use to the next. When you start to use a set of gages that are still under pressure from the last use, you know they are leak-free, **Figure 45–83.** You may want to remove the Schrader valve depressors furnished in the gage lines and use special adapters for depressing Schrader valve stems, **Figure 45–84.** This enables you to have clear gage lines for quick evacuation of a wet or damp system.

Some manufacturers furnish a service port arrangement in which an attachment may be fastened to the compressor for taking gage readings, **Figure 45–85.**

Other manufacturers do not furnish any service ports, and field service ports may be installed in the field in the form of line tap valves, **Figure 45–86.** These special valves should be installed using the manufacturer's instructions. Some points to remember are to always use the correct size valve based on the line size. NOTE: If there is a chance that the system pressure may be in a vacuum, either purge the gage lines with clean refrigerant or shut the unit off and let the pressures equalize before installing a low-side line tap valve, or atmosphere will enter the system, **Figure 45–87.** When

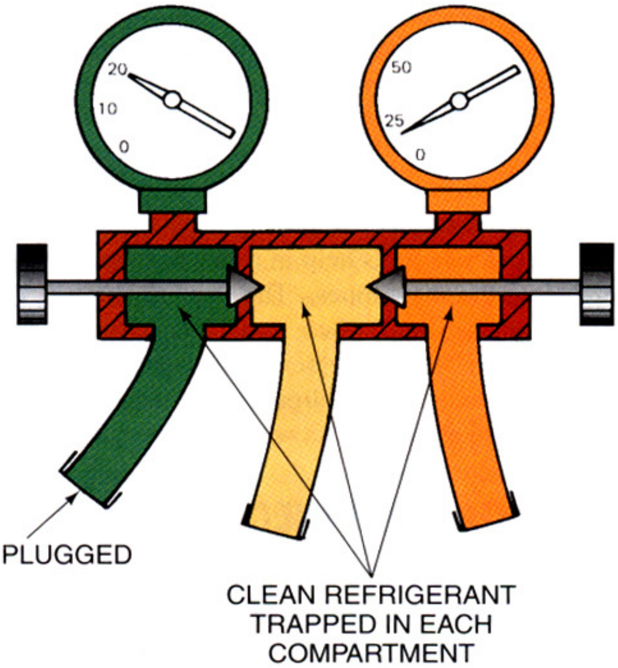


Figure 45–83 A clean, leak-free set of gages.

Figure 45–84 Remove the Schrader valve depressors from gage lines and use the special fitting on the right to depress the valve cores. *Photo by Bill Johnson*

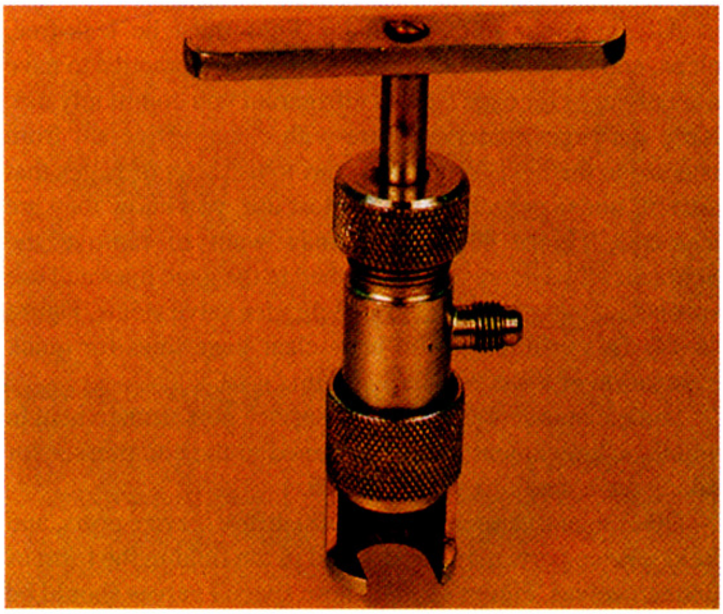
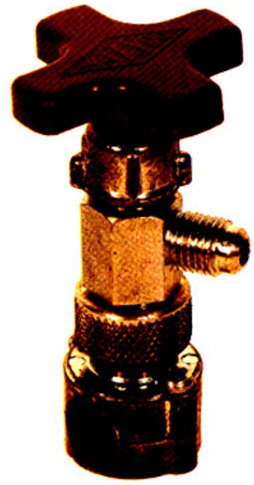
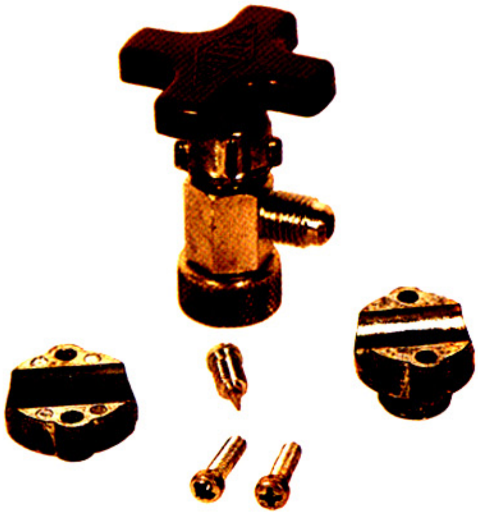


Figure 45–85 A service valve assembly. *Photo by Bill Johnson*



(A)



(B)

Figure 45–86 Line tap valves for access to refrigerant lines. *(A) Photo by Bill Johnson, (B) Courtesy J/B Industries*

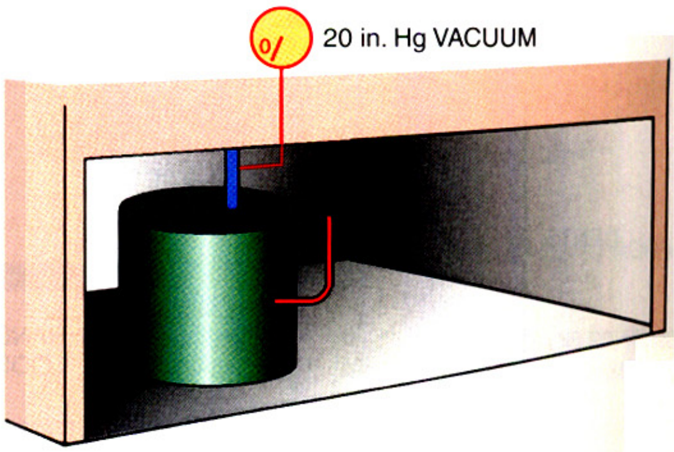


Figure 45–87 If the unit is operating in a vacuum, air may be pulled into the system when gages are installed.

installing a line tap valve on the high-pressure side of the system, it is best to install it on the compressor process tube, where it may be soldered on or removed by pinching off the process tube between the valve and compressor housing, **Figure 45–88.** All line tap valves left in the active part of the system must be soldered to the tubing.

If repairs are made to components in the refrigerant cycle or a refrigerant charge is lost completely, it is best to

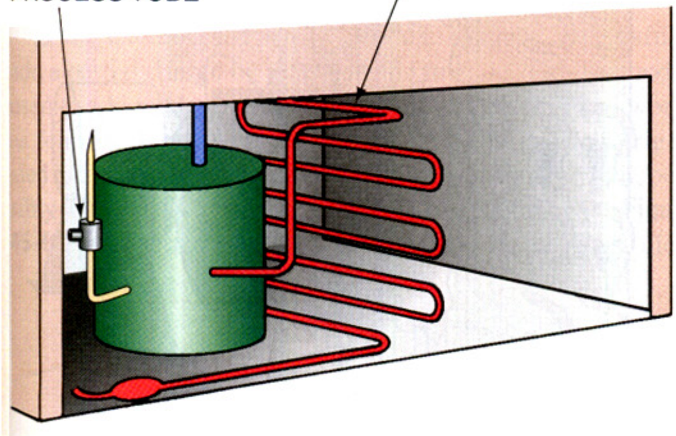


Figure 45–88 Locate the high-pressure line tap valve on the liquid line, not the hot gas line.

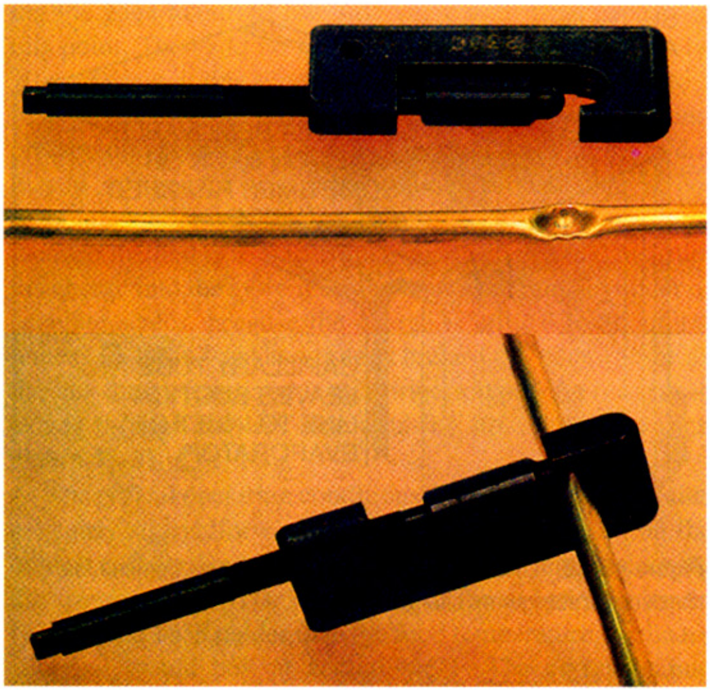


Figure 45–90 A special pinch-off tool. *Photo by Bill Johnson*

use the process tubes on the compressor for pressure readings. Fittings with Schrader valves may be soldered to the process tubes for the service work and evacuation, **Figure 45–89.** These tubes may be capped, or they may be pinched off using a special pinch-off tool, **Figure 45–90,** and soldered shut. A special pinch-off tool is necessary because you cannot pinch off refrigerant lines with pliers, **Figure 45–91.**

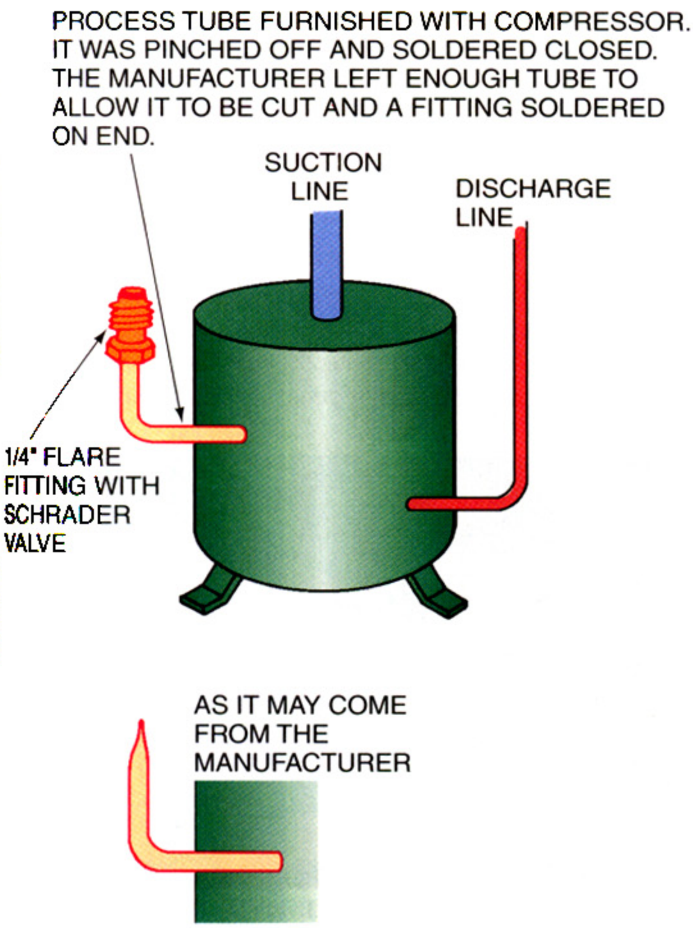


Figure 45–89 Fittings may be soldered on the process tube.

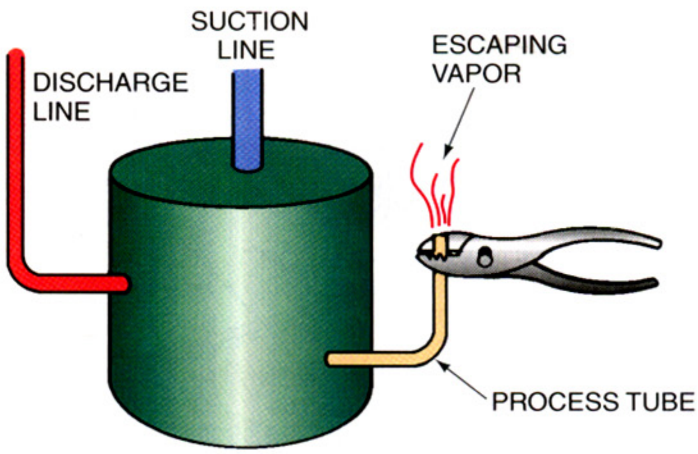


Figure 45–91 SAFETY PRECAUTION: You cannot use pliers to pinch off a line.

45.22 LOW REFRIGERANT CHARGE

If a refrigeration unit had the correct charge when it left the factory, it will maintain that charge until a leak develops. If a unit does have a low refrigerant charge, every effort should be made to determine the cause.

One service technique that many experienced service technicians use to determine whether the charge is approximately correct in a system (before connecting gages) requires only that the unit be stopped and restarted. The unit is shut off and the pressures allowed to equalize, which takes about 5 min. Before the compressor is restarted, the technician places a hand on the suction line, where it leaves the evaporator and before any heat exchanger, in such a manner that the line temperature may be sensed by touch, **Figure 45–92.** The compressor is started. If this line gets cold for a short period of time, the chances are the refrigerant charge is correct, **Figure 45–93.** This test assumes that when the

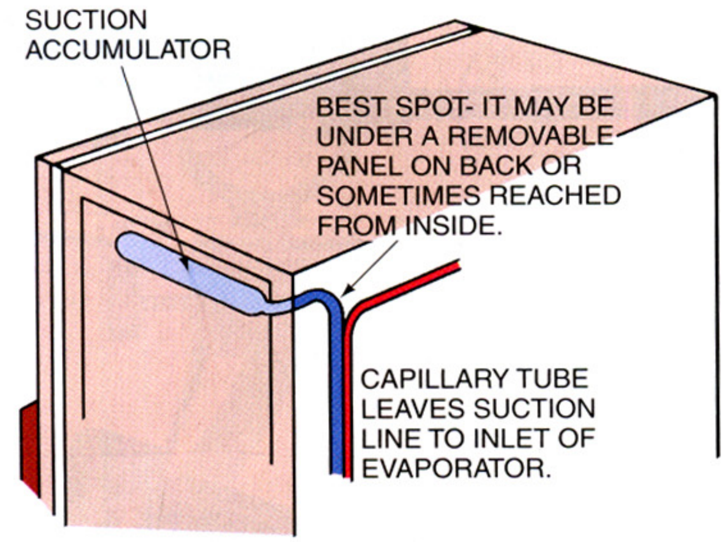


Figure 45–92 Location of the cold spot on the suction line for checking for refrigerant charge.

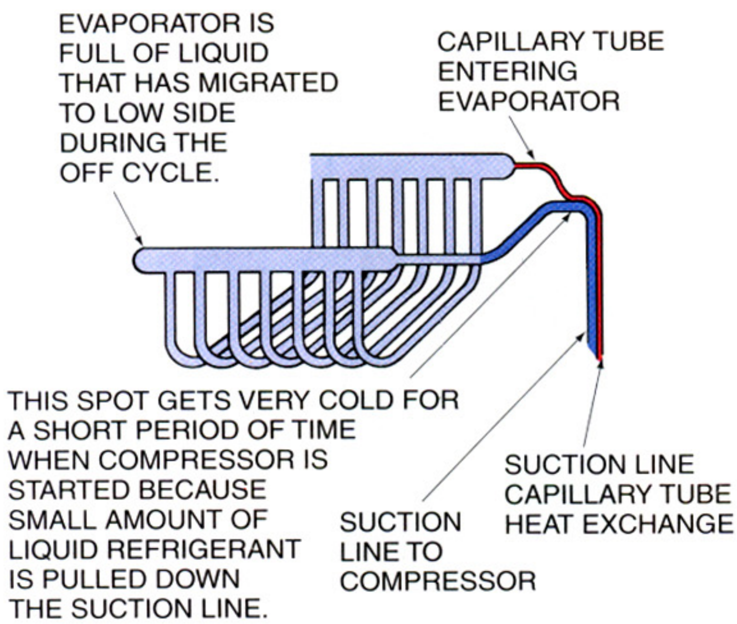


Figure 45–93 Performing the suction touch test for correct refrigerant charge.

pressures equalize, much of the refrigerant in the condenser moves to the evaporator during pressure equalization. When the low-side pressure in the suction line is reduced by the compressor starting, a small amount of liquid refrigerant will move into the suction line just at the time of start-up and cause the line to become very cold for just a moment. Such a small amount of refrigerant is in a domestic refrigerator that if the charge were short, there would not be enough liquid refrigerant to leave the evaporator. This simple test has helped many experienced refrigeration technicians keep the gages in the tool bin and look for other problems. The evaporator may have ice buildup due to lack of defrost, **Figure 45–94,** or the evaporator fan may not be functioning.

When a technician suspects a low charge, the unit should be shut off and the pressures allowed to equalize. R-12 has been the most popular refrigerant for household refrigerators in the past. All refrigerators currently being manufactured in

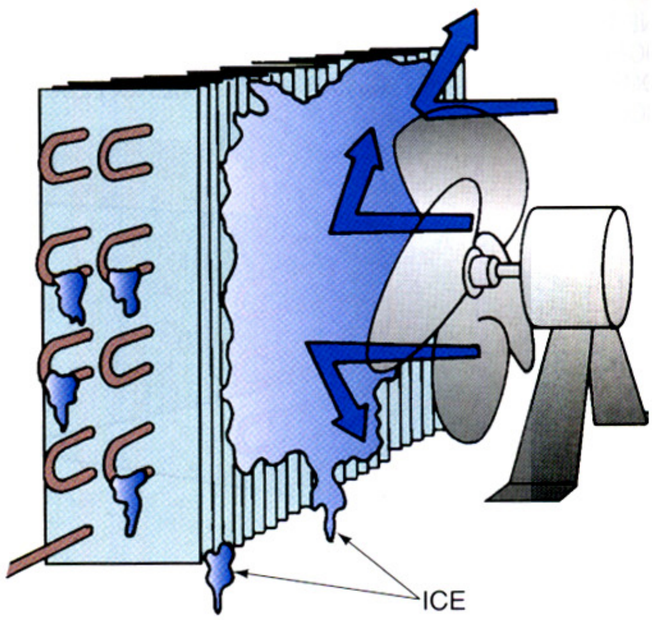


Figure 45–94 Ice buildup on the evaporator.

the United States are using R-134a. The pressures for R-134a and those of R-12 are similar. SAFETY PRECAUTION: These refrigerants must not be mixed. The low-pressure side may be operating in a vacuum as long as the compressor is running. The compressor should be stopped and uncontaminated gages applied to the system. The compressor may then be restarted. If the system low-pressure gage reads in a vacuum (below atmosphere) for a period of time, about 15 min, the unit is probably low on refrigerant, or the capillary tube may be restricted. It is not uncommon for a refrigerator to operate in a vacuum for a short period of time after start-up. A small amount of refrigerant may be added to the system and the pressures observed. SAFETY PRECAUTION: High-pressure readings should be taken when adding refrigerant because a restricted capillary tube will cause high head pressure readings if refrigerant is added. You will not be able to determine this from a low-pressure reading only. If a high-pressure reading is not possible, attach a clamp-on ammeter to the compressor common wire and do not allow the compressor amperage to rise above the run-load amperage (RLA) rating of the compressor. If it does, shut it off, **Figure 45–95.**

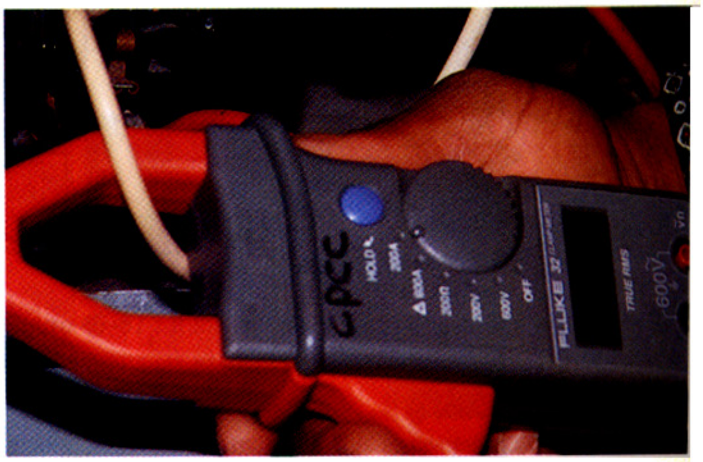


Figure 45–95 Taking a current reading at the compressor. *Photo by Bill Johnson*

The technician then removes the wires from the motor terminal box and starts to disconnect the compressor from the motor. When the motor is free to move, the hoist is set up and the motor is set on a rolling dolly to transport it to the truck. The motor is then rolled onto the lift gate, lifted to the back of the truck, and secured. The helper takes the motor to the motor shop for rebuild. This will take about 48 h. It is now 2:30 on Tuesday.

The technician goes back to the equipment room and prepares the equipment for when the motor is returned. A sample of the refrigerant and a sample of the refrigerant oil from the compressor sump are pulled and shipped by next day carrier to a chemical analysis firm. They will be analyzed and the report can be called in by Wednesday afternoon to determine what must be done about the refrigerant. The refrigerant and oil sample do not smell as though they have very much acid, but the analysis will reveal the facts.

The technician checks the contacts in the starter. There must have been quite a surge of current when the motor grounded. The contacts are good and do not require replacement.

The oil heater is turned off, locked, and tagged, and the oil is removed. The technician then cleans all gasket sealant from all compressor flanges and is now ready for the motor to be returned. Time has been saved by doing all of this before the motor is brought back.

Thursday morning the technician checks with the rebuild shop and is told the motor will be ready by 11:30 AM. The technician arranges for the helper to pick up the motor and a compressor gasket kit. They meet at the building at 1:00 PM and proceed to install the motor. The motor is moved to the equipment room and lifted back into place. All gaskets are installed and everything is tightened. This system has a history of being very tight so the only leak checking that needs to be performed is on the fittings, including the gasketed flanges that were removed and in the area where the work was done.

When all is ready, the machine is pressured with nitrogen to 10 psig with a trace of R-22 refrigerant that is used to detect leaks. The machine is leak checked and found to be good. The nitrogen and refrigerant are exhausted, and it is time to pull the vacuum. The motor leads are connected to the motor terminals.

The vacuum pump is installed and started. It will take about 5 h to pull the vacuum down to 0 in. Hg on a mercury manometer and it is 5:30 PM. The technician leaves the job and decides to come back at 10:30 PM to check the vacuum. If the vacuum can be verified this evening and the vacuum pump shut off for 8 h, the machine can be started in the morning if all is well. The technician checks the vacuum at about 11:00 PM, and the manometer reads 0 in. Hg vacuum. The vacuum pump is valved off, and the technician leaves to return in the morning.

When the technician arrives at 7:30 AM, the mercury manometer is still reading 0 in. Hg vacuum so the machine is leak-free, and it is time to charge the system. The refrigerant and oil report came back "OK" so no extra precautions need to be taken with the refrigerant. The technician starts the chilled water pump and the condenser water pump in preparation to start-up. A drum of refrigerant is connected to the machine at the drum vapor valve. The valve is slowly opened to the machine and vapor is allowed to enter the machine until the pressure is above that corresponding to freezing. This is important because if liquid refrigerant is allowed to enter the machine at such a low pressure, the tubes may freeze. The chilled water is circulating, but if there is one tube that does not have circulation, this tube may freeze. The pressure in the machine must be above 17 in. Hg vacuum to prevent freezing while charging liquid.

When the machine pressure reaches 17 in. Hg vacuum, the technician then starts charging liquid refrigerant. While the technician is charging refrigerant, the helper pulls the oil in the oil sump using the machine vacuum. When the oil is charged, the oil heater is turned on to bring the oil up to temperature.

The technician is not able to charge all of the refrigerant into the machine using the vacuum because the chilled water circuit warms the refrigerant, and pressure is soon raised. The technician then changes over and pushes the remainder of the refrigerant into the machine by pressuring the drum with nitrogen on top of the liquid and drawing liquid from the bottom of the drum, **Figure 50–20.**

The technician starts the purge pump to remove any nitrogen that may have entered the system while charging, even though the technician was careful and could see no nitrogen in the clear charging hose while charging. The purge pressure does not rise, so the machine should be free of nitrogen. The technician has closed the main

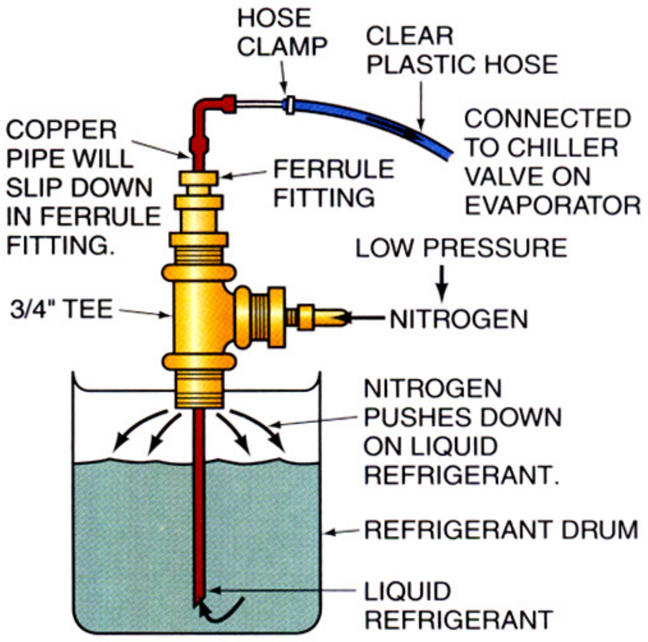


Figure 50–20 Using nitrogen to charge refrigerant into a low-pressure chiller.

Manufacturers recommend that when a low charge is found, find the leak, remove and recover the charge, and repair the leak. A measured charge may then be transferred into the system.

Some experienced service technicians may successfully add a partial charge by the frost-line method. This method is used to add refrigerant while the unit is operating and works as follows. A point on the suction line leaving the refrigerated box is located where the frost line may be observed, possibly where the suction line leaves the back of the box, **Figure 45–96.** Refrigerant is added very slowly by opening and closing the gage manifold low-side valve until frost appears at this point. Then add no more. The suction pressure may be 10 to 20 psig at this time and should reduce to about 2 to 5 psig just before the refrigerator thermostat shuts the compressor off. Using the frost-line method of charging a domestic refrigerator is a slow, tedious process that is not recommended unless just topping off a charge. The recommended method is to start from a deep vacuum and measure the charge into the system using either a charging cylinder or accurate scales, because the charge is critical to about 1/4 ounce. If the frost line creeps toward the compressor as the box temperature reduces, refrigerant may be recovered slowly through the low side until the frost line is correct, **Figure 45–97.**

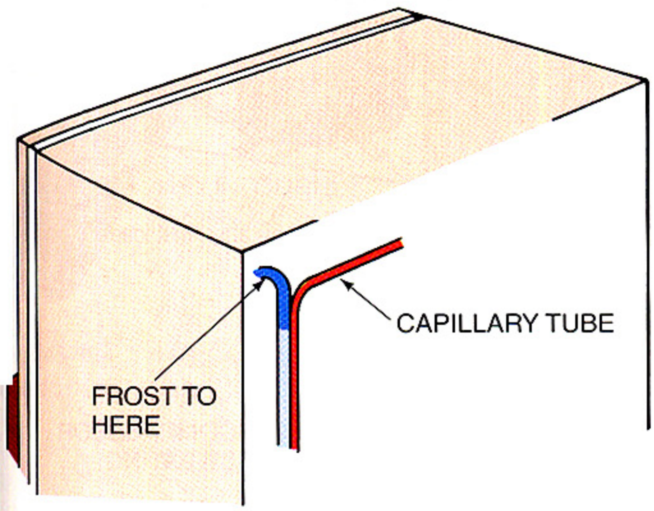


Figure 45–96 Checking the refrigerator charge using the frost-line method.

The typical operating conditions for the low-pressure side are fairly straightforward. The conditions are based on the coldest coil, the freezer coil. The typical low temperature for the freezer is 0°F. The refrigerant in the evaporator would typically be 16°F colder than the food temperature, so the refrigerant would boil at about −16°F. The corresponding pressures would be about 2 psig for R-12 and 0.7 in. Hg for R-134a at the point where the thermostat is ready to shut the compressor off. If the box temperature were to be set to a lower point, the pressures would move downward. When it is time for the compressor to start, the pressures would be higher. Typically, the temperatures may fluctuate between −5°F and +5°F with corresponding pressures.

NOTE: Many units will operate in a vacuum for a long period of time after start-up. This will occur until the refrigerant

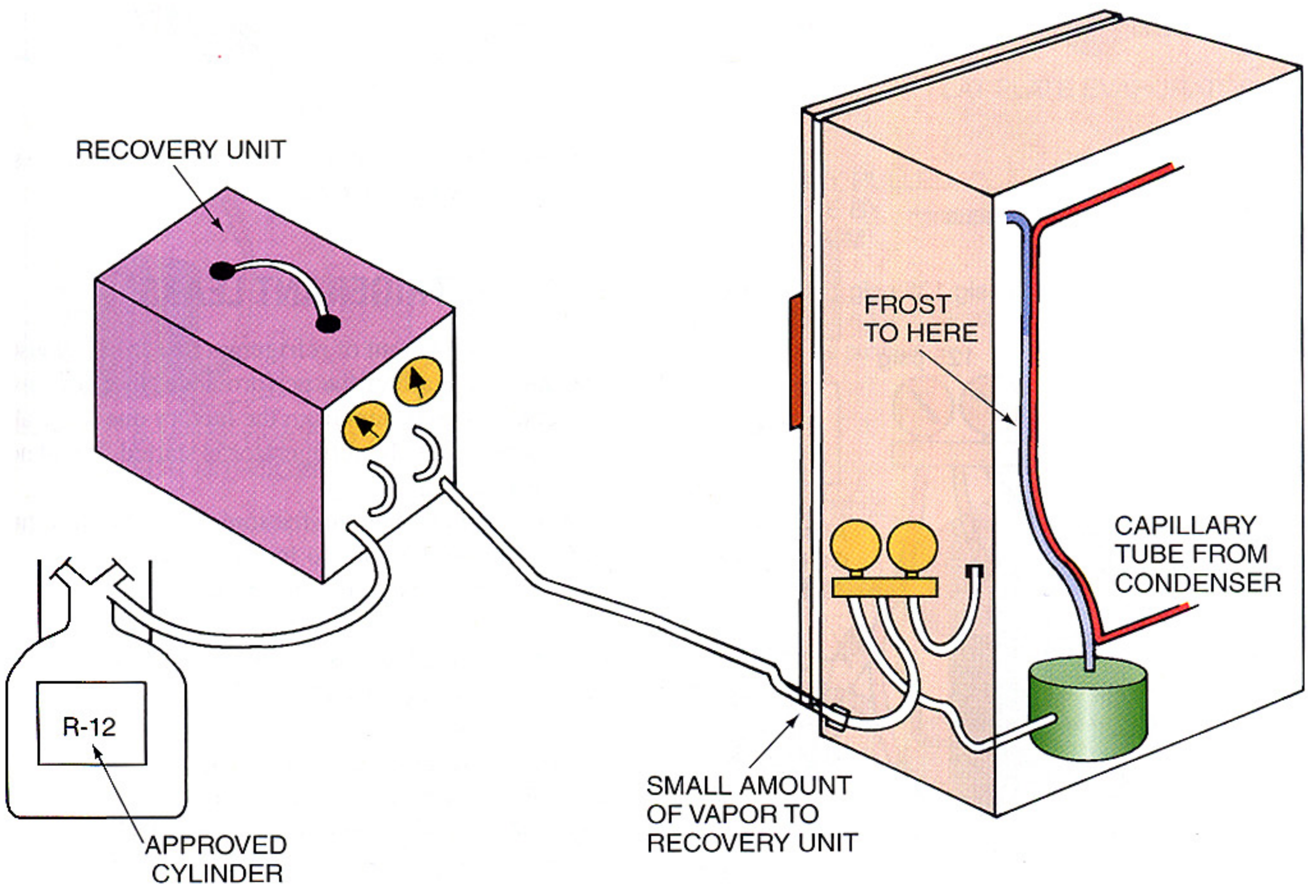


Figure 45–97 The frost line has moved toward the compressor; a small amount of vapor is recovered through the low-side gage.

feeds through the capillary tube from the condenser and the system charge is in balance. This is particularly true if a unit is charged on the high-pressure side after evacuation.

45.23 REFRIGERANT OVERCHARGE

The refrigerator condenser may be either natural draft or forced draft. The forced-draft condensers are more efficient and the head pressure will typically be lower than with the natural-draft condenser. If too much refrigerant is added to a refrigerator, the head pressure will be too high. Typical head pressures should correspond to a condensing temperature 25°F to 35°F higher than room temperature at design operating conditions. Refrigerators that use forced-draft condensers typically would condense at 25°F higher than room temperature, and those that have natural-draft (static) condensers would be 35°F. For example, if the room temperature at the floor is 70°F, the head pressure should be between 108.2 and 126.6 psig for R-12 or 114 and 135 for R-134a, **Figure 45–98.** Refer to the pressure/temperature chart in Unit 3, **Figure 3–38.** If the head pressure is higher than 136 psig, it is too high. NOTE: Be sure to check the load on the refrigerated space before drawing any final conclusions. These head pressures will be higher during a hot pull down of the refrigerated space, **Figure 45–99.** If the compressor is sweating around the suction line, there is too much refrigerant, **Figure 45–100.** The suction pressure will also be too high with an overcharge of refrigerant.

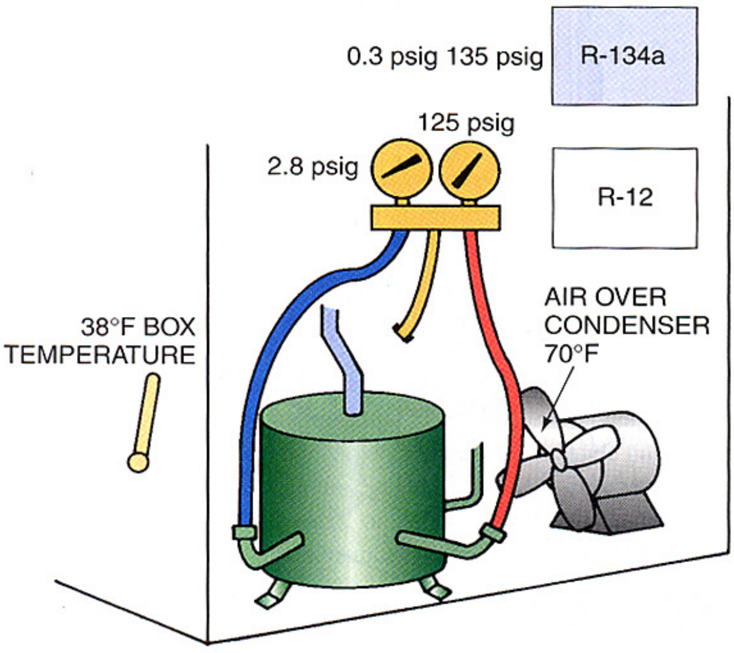


Figure 45–98 A typical head pressure.

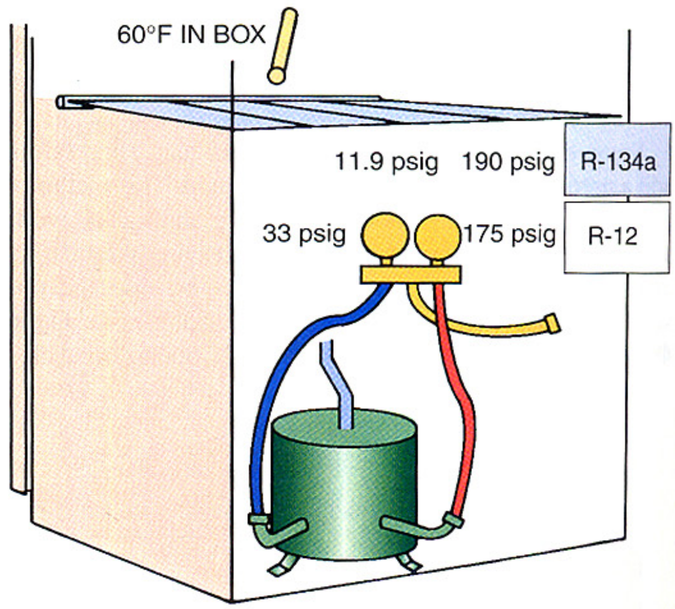


Figure 45–99 Head pressure under an abnormal load.

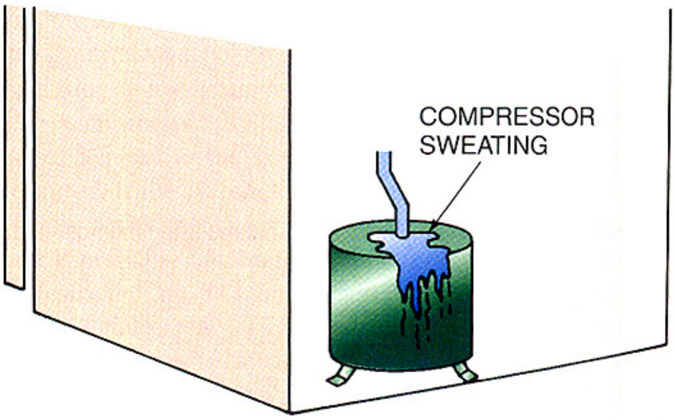


Figure 45–100 If the compressor is sweating around the suction line, there is too much refrigerant.

45.24 REFRIGERANT LEAKS

A very small amount of refrigerant lost from a household refrigerator will affect the performance. In a few instances a low charge that occurs from the factory due to a leak may be discovered when the refrigerator is started. It will not refrigerate from the start.

When the box has run for some period of time and a leak occurs, it may be hard to locate in the field. Many technicians prefer to move the unit to the shop and loan the customer a box. They can then repair the defective unit at their own pace when there is no food in it. In any case, the best place to perform difficult service on a refrigerator is in a shop, not a residence.

Very small leaks may be found only with the best leak-detection equipment, such as electronic leak detectors, **Figure 45–101.** The pressure may be increased in the refrigerator by using nitrogen, **Figure 45–102.** SAFETY PRECAUTION: Do not raise the pressure above the manufacturer's specified low-side working pressures. This is usually 150 psig.

Figure 45–101 An electronic leak detector. *Courtesy Robinair SPX Corporation*

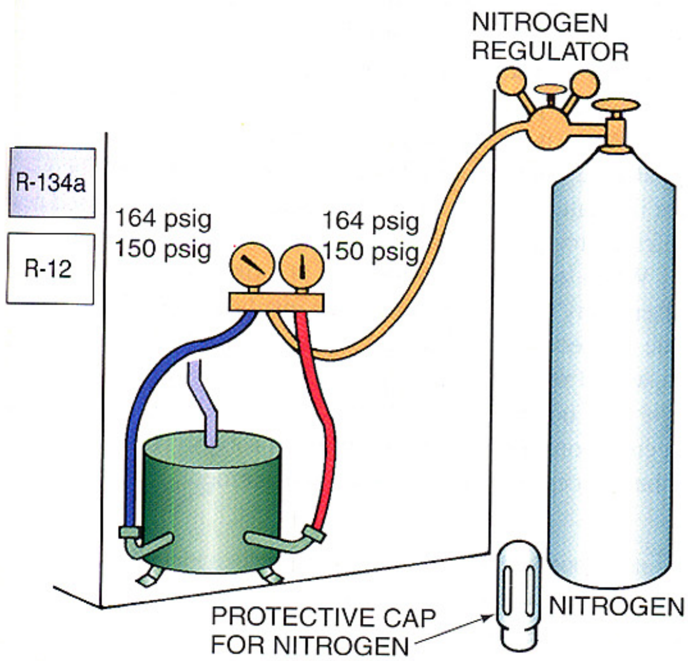


Figure 45–102 Nitrogen may be used to create more pressure for leak checking.

45.25 EVAPORATOR LEAKS

Leaks may occur in the evaporator due to abuse from the use of a sharp tool when the unit is being defrosted manually. When this occurs in an aluminum evaporator, the evaporator may be repaired. Soldering the leak from a puncture may be difficult because of location and the contraction and expansion of the evaporator. Leaks may be repaired with the proper epoxy. Special epoxy products are available that are compatible with refrigerants.

One method is to clean the surface according to the epoxy manufacturer's directions. Apply the epoxy to the hole while the unit is in a slight vacuum, about 5 in. Hg. This will pull a small amount of epoxy into the hole and form a mushroom-shaped mound on the inside of the pipe, **Figure 45–103.** This mound will prevent the patch from being pushed out when the refrigerator is unplugged and the low-side pressure rises to the pressure corresponding to the room temperature. If the refrigerated box is located outside where it may reach 100°F, the pressure inside may rise to 117 psig for R-12. This may be enough to push a plain patch off the hole, **Figure 45–104.** Care should be taken not to allow too much epoxy to be drawn into the hole or a restriction may occur.

Another method may be to use a short sheet metal (self-tapping) screw and epoxy in the hole. The vessel must have enough room for the screw inside for this to work. The puncture and the screw are cleaned according to the epoxy manufacturer's recommendations. The epoxy is applied to the hole, and the screw is tightened so that the head is snug against the hole to hold the epoxy when high pressure occurs, **Figure 45–105.**

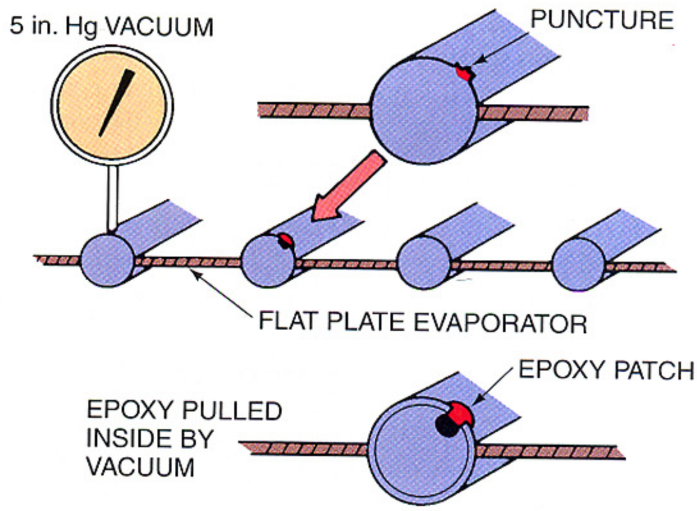


Figure 45–103 A slight vacuum may be used to pull a small amount of epoxy into the puncture.

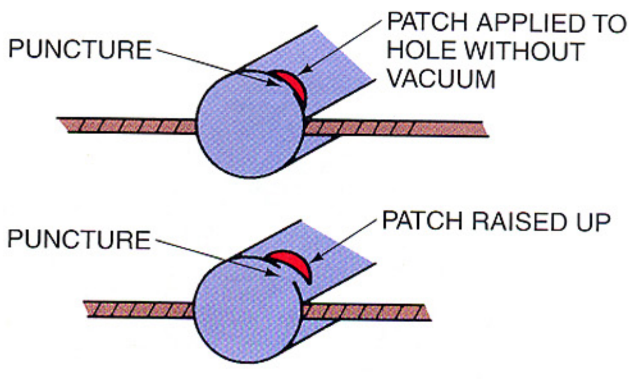


Figure 45–104 The pressure inside may push the patch off the puncture under some circumstances. This may occur during storage when the low-side pressure is high.

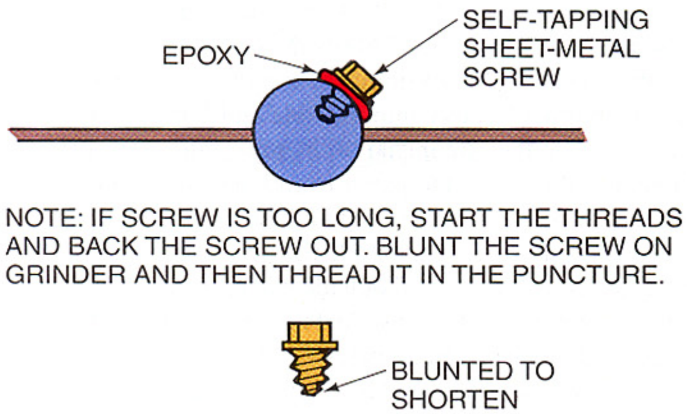


Figure 45–105 A screw may be used in some cases to hold the epoxy in the puncture hole.

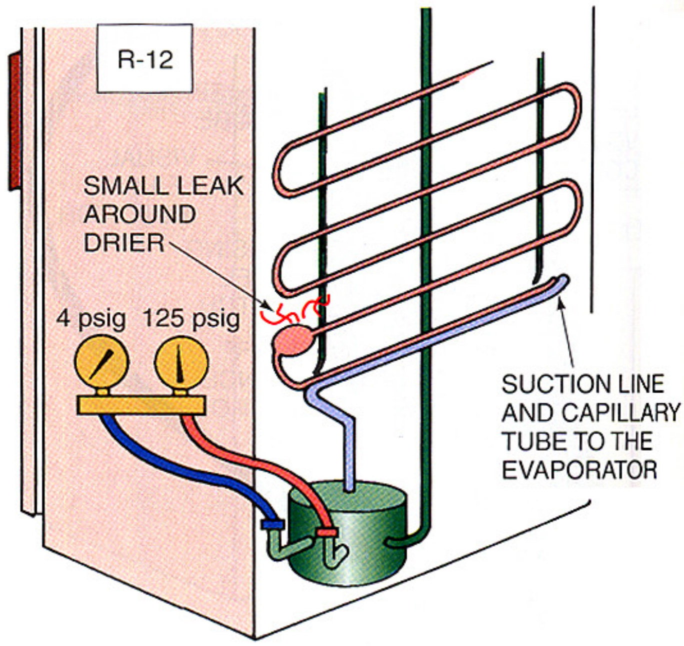


Figure 45–106 A small leak in the high-pressure side of the system will cause a greater refrigerant loss than a leak on the low-pressure side.

45.26 CONDENSER LEAKS

Condensers in refrigerators are usually made of steel. Leaks usually do not occur in the middle of the tube, but at the end where connections are made or where a tube vibrated against the cabinet, causing a hole. This part of the system operates at the high-pressure condition, and a small leak will lose refrigerant faster than the same size leak in the low-pressure side, **Figure 45–106.** Wherever the leak occurs in steel tubing, the best repair is solder. The correct solder must be used, one compatible with steel. Usually it has a high silver content. When flux is used, be sure to clean it away from the connection after the repair is made. Always leak check after the repair is made.

When the condenser is located under the refrigerator, it is often hard to gain access for leak repair. The box may be tilted to the side or back for this repair, **Figure 45–107.**

45.27 REFRIGERANT PIPING LEAKS

Leaks in the interconnecting piping may occur in the walls of the box. Fortunately this does not occur often because it can be difficult to make the repair and may not be economical. The evaporator may have to be removed to repair a leak in the adjacent evaporator piping, **Figure 45–108.** Each box has a different method for removal. The manufacturer's literature may be used. If it is not available, you may have to determine the procedure on your own. When a box has foam insulation, it is possible that it may not be disassembled. Leaks are often repairable in older boxes that used fiberglass for insulation, but it may be less expensive to purchase a new refrigerator.

When leaks occur in the wall of a fiberglass insulated box after many years, moisture in the insulation may be the cause due to electrolysis. This is caused by mild acid and current flow and usually occurs with aluminum or steel tubing. If one leak occurs due to electrolysis, more leaks will usually occur soon because the tubing is probably thin in several other places. The best repair is replacement of the box.

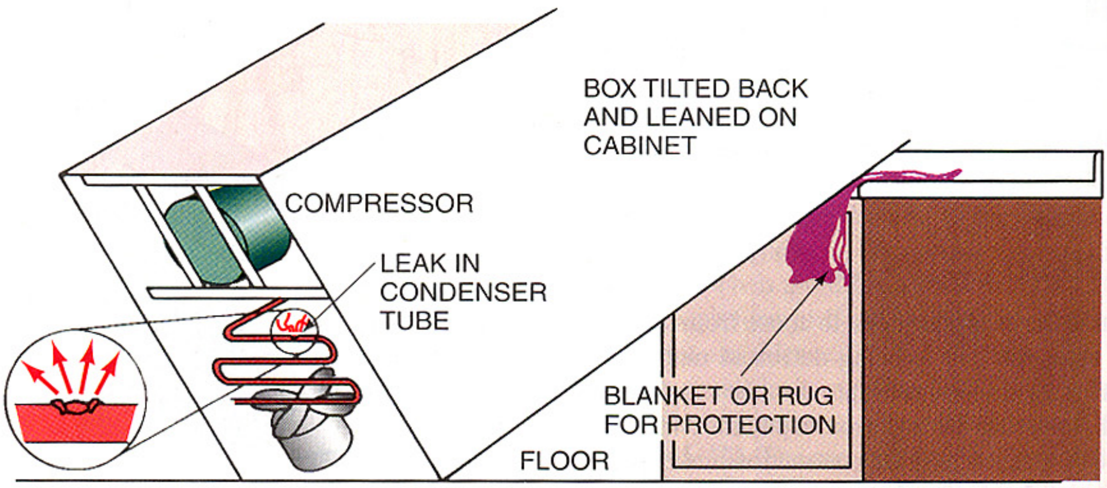


Figure 45–107 A refrigerator may be tilted to one side or to the back to service the condenser under the box.

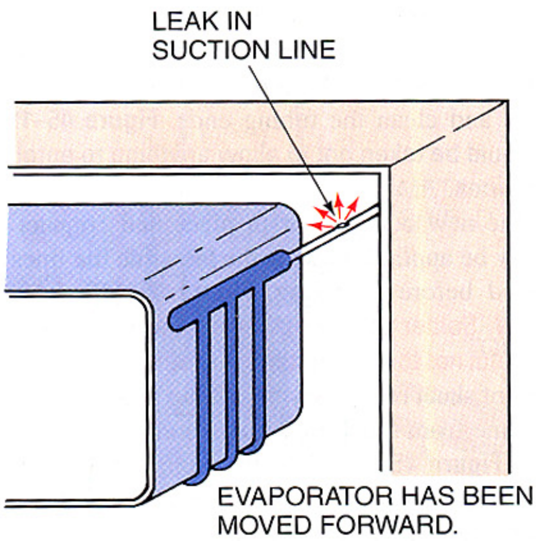


Figure 45–108 A piping leak on the suction line inside the box.

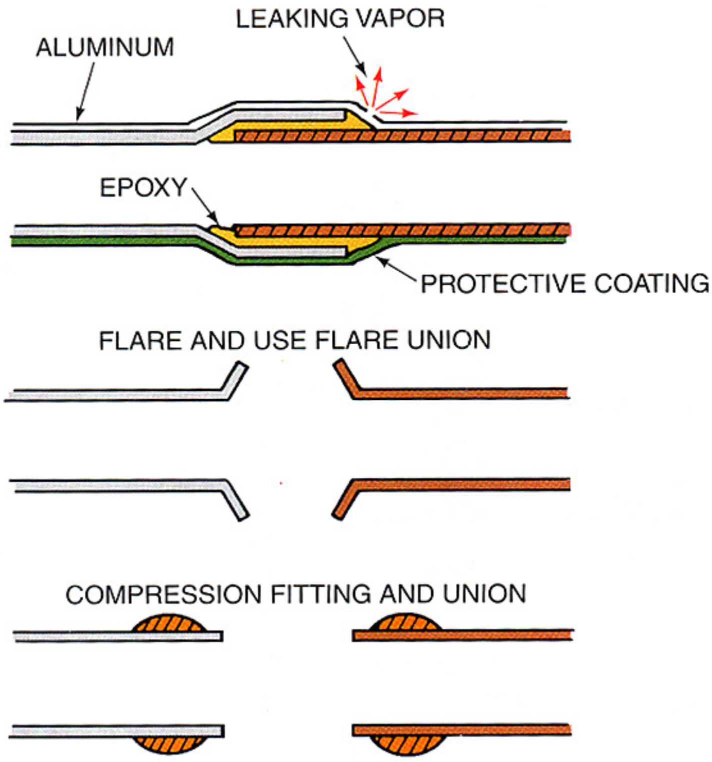


Figure 45–109 Procedures for repairing a leak in the connection between the copper suction line and the aluminum tubing leaving the evaporator.

Leaks may occur in the connection where the copper suction line is attached to the aluminum tubing leaving the evaporator, **Figure 45–109.** This is a hard place for a repair particularly because of the dissimilar metals. A flare union is sometimes used in this location. Some manufacturers may have repair kits for this connection.

45.28 COMPRESSOR CHANGEOUT

Compressors may be changed in a refrigerator by recovering the refrigerant charge and removing the old compressor. A new compressor should be ready for replacement before the old one is removed. An exact replacement is the best choice but may not be available. A diagram of the tube connections and the mounting should be available to help you connect it correctly. Remember, there may be several lines, including suction, discharge, suction access, discharge access, and two oil cooler lines that may all be the same size, **Figure 45–110.**

The best way to remove the lines from the old compressor is to recover the charge and pinch the lines off close to the compressor, **Figure 45–111,** or cut them using a very small tubing cutter. If the old tubing is removed with a torch, the tubing ends should be cleaned using a file to remove excess solder, being careful not to allow filings to enter the system. SAFETY PRECAUTION: Some of the lines may contain oil, which may flame up when separated with a torch. A fire extinguisher should always be present. The old tubes should be filed until they are clean and will slide inside the compressor fittings, **Figure 45–112.** Approved sand tape (sand tape with nonconducting abrasive) should be used to further clean the tubing ends. They must be perfectly clean with no dirty pits, **Figure 45–113.** Dirt trapped in pits will expand into the solder connection when heated, **Figure 45–114,** and cause leaks.

The new compressor should then be set in place in the compressor compartment to compare the connections on the

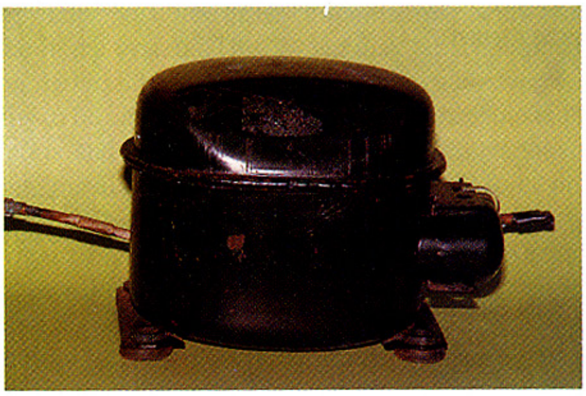


Figure 45–110 A compressor may have many lines from the shell.
Photo by Bill Johnson

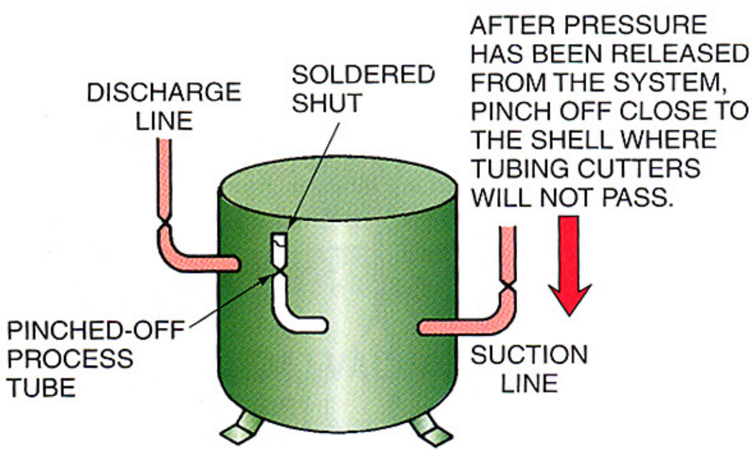


Figure 45–111 Pinch the old lines close to the compressor shell using side-cutting pliers.

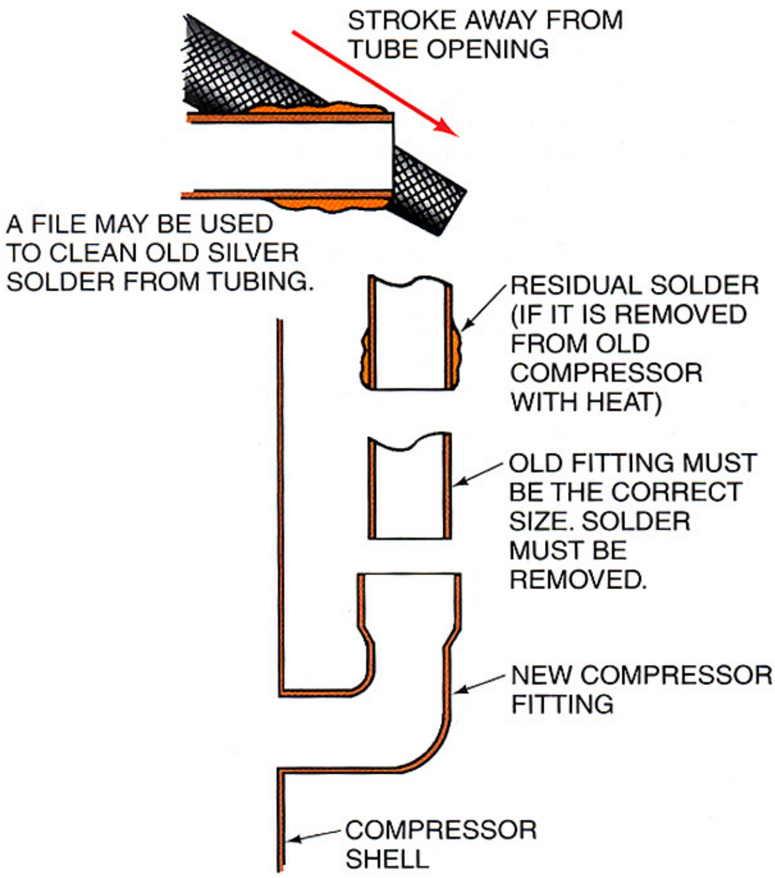


Figure 45–112 The old tubing must be cleaned of all old solder; a file may be needed.

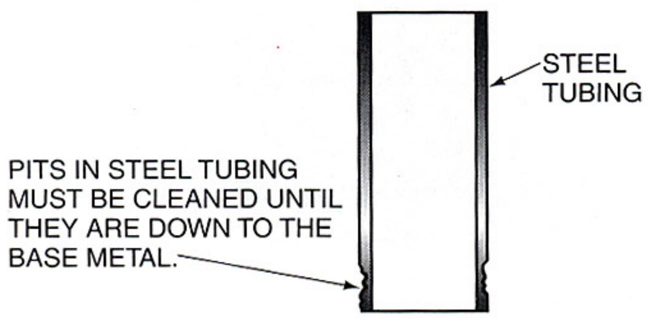


Figure 45–113 All pits in steel tubing must be cleaned.

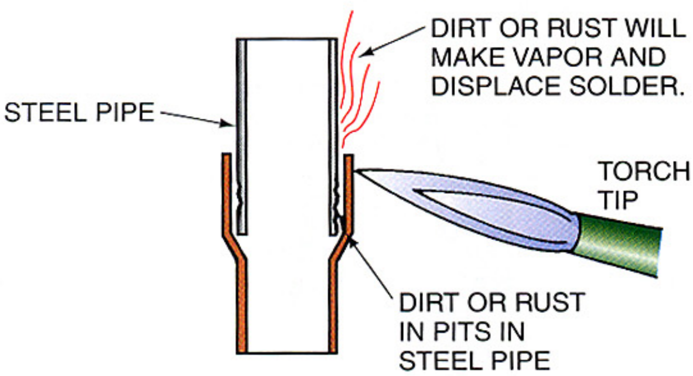


Figure 45–114 Dirt trapped in pits will expand when heated and cause leaks.

box with those on the compressor. When it is certain that the connections line up correctly, remove the new compressor from the compartment. Remove the plugs from the compressor lines and clean the tubing ends, **Figure 45–115**. NOTE: Care should be taken not to allow anything to enter the compressor lines.

Set the new compressor in place and connect all lines. Flux may be applied if this is the last time the lines are to be connected before soldering, **Figure 45–116.** SAFETY PRECAUTION: Solder the connections carefully, being particularly careful not to overheat the surrounding parts or cabinet. A shield of sheet metal may be used to prevent the heat of the torch flame from touching the surrounding components and cabinet, **Figure 45–117.** Use the minimum of heat recommended for the type of connection you are making.

While the compressor is being soldered to the lines, it is a good time to solder process tubes to the compressor. Sometimes a "tee" fitting is soldered into the suction and discharge lines with a Schrader fitting, **Figure 45–118.**

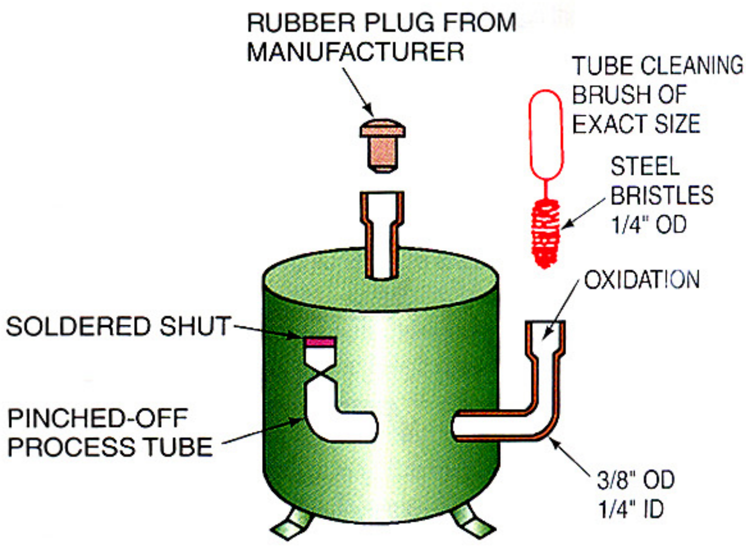


Figure 45–115 Remove the plugs from the compressor lines and clean the tubing ends.

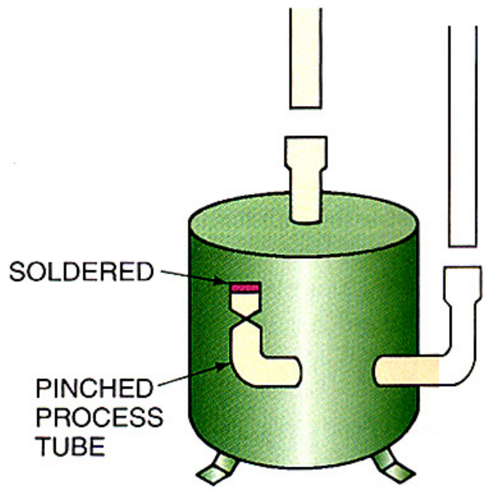


Figure 45–116 Do not apply flux until the lines are being fastened together for the last time before soldering.

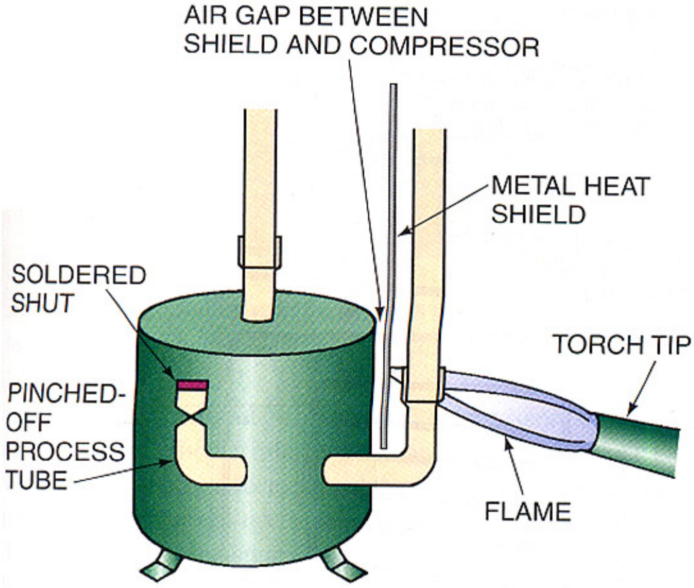


Figure 45–117 SAFETY PRECAUTION: A shield may be used to protect the surrounding components and cabinet from heat while soldering.

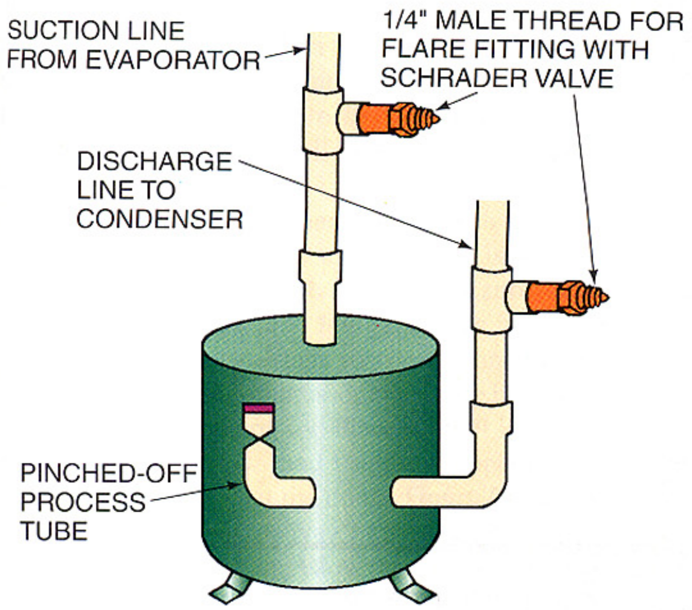


Figure 45–118 A "tee" fitting may be soldered in the suction and discharge lines for service connection while the system is open.

A filter drier should be added if the system has been open long enough to change the compressor. The refrigerator manufacturer may recommend using a liquid-line drier of the correct size. If an oversized liquid-line drier is used, additional refrigerant charge must be added. Many technicians use a suction-line drier in this case because it is in the suction line with vapor at low pressure and will not require added charge, **Figure 45–119.** The suction-line drier does not protect the capillary tube from particles or moisture, but the capillary tube will have its own strainer for particle protection, and there should not be any moisture with a correct evacuation.

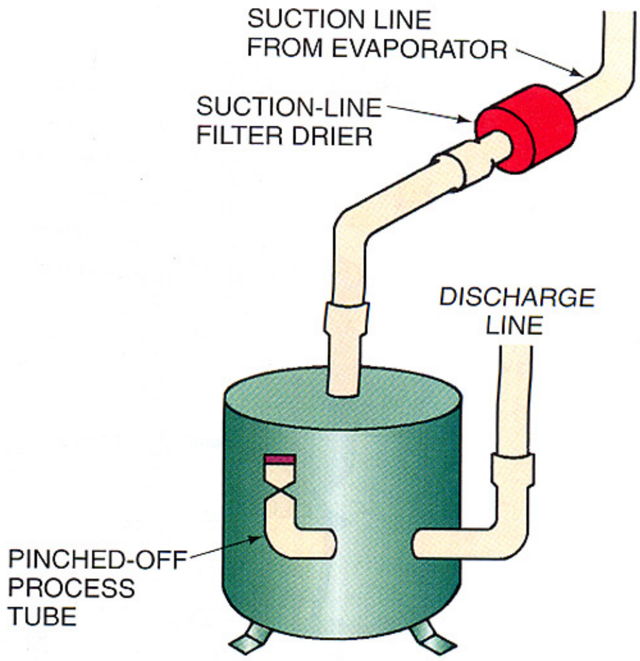


Figure 45–119 A suction-line drier added to the low side will not require extra charge because the refrigerant is in the vapor state.

It is recommended that after the compressor is installed, the system be swept with nitrogen and then the drier installed. This prevents drier contamination with whatever may be in the system. This sweep may be accomplished by cutting the liquid line or the suction line, wherever the drier is going to be installed. Connect the gage manifold to the service ports and a cylinder of nitrogen. Allow vapor to flow first into the high side of the system. This will force pressure into the high side, then through the capillary tube, through the evaporator, and out the loose suction line (this example is for suction-line installation), **Figure 45–120.** The vapor flowing from the suction line will be very slow because it is moving through the capillary tube, but it will sweep the entire system, except the compressor, which is new.

Now connect the drier by opening the whole system to the atmosphere by leaving gage valves open, so there will be no pressure buildup, **Figure 45–121.** You may want to use a drier with a flare fitting instead of a solder type, **Figure 45–122.** Close the gage manifold valves immediately after completing the solder connection so that when the vapor in the system cools it will not shrink and draw air inside.

When the new compressor is in place with process tubes, leak check the whole assembly at maximum low-side working pressure. Again the low-side working pressure may be used as the upper limit for pressure testing. If a unit holds 150 psig of nitrogen pressure overnight, it is leak-free.

45.29 SYSTEM EVACUATION

When the system is proved leak-free, a vacuum may be pulled on the entire system with confidence. Unit 8, "System Evacuation," covers evacuation procedures. Briefly, the Schrader valve stem may be removed from the service stems,

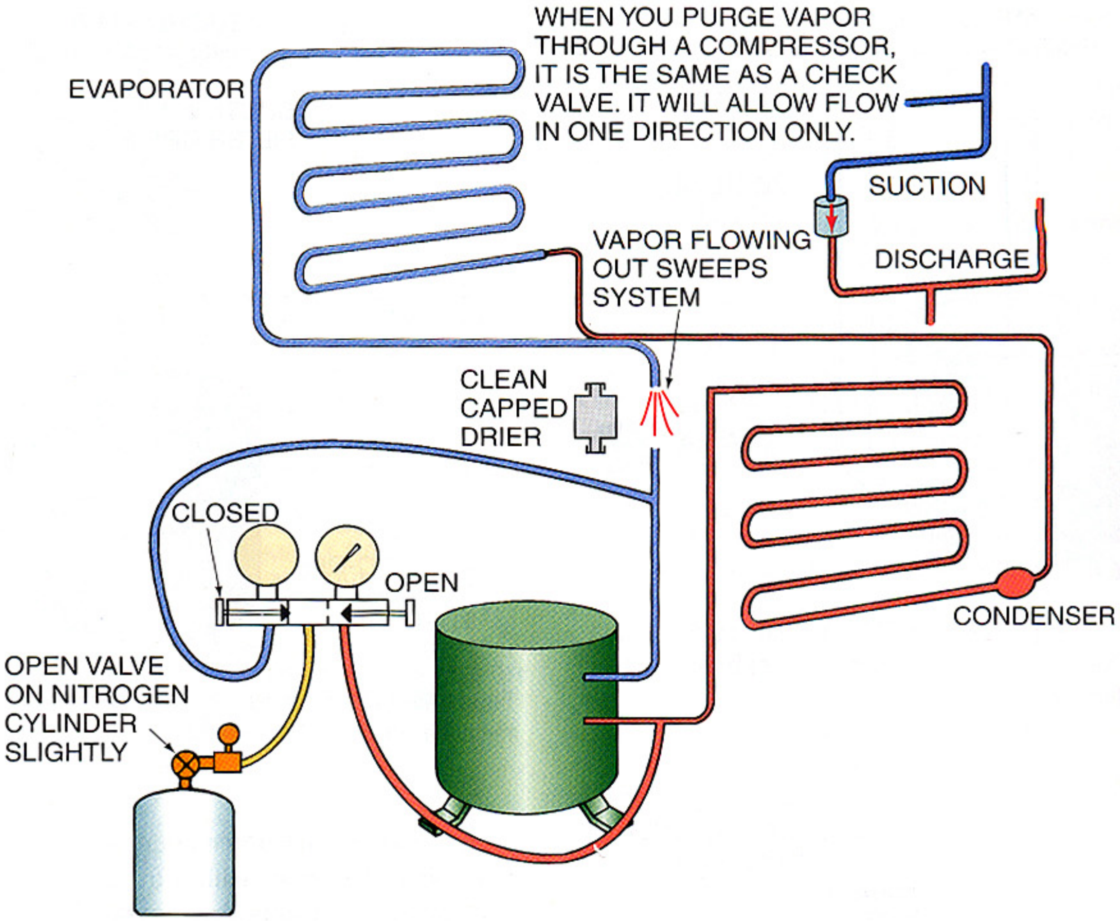


Figure 45–120 Purging or sweeping a system.

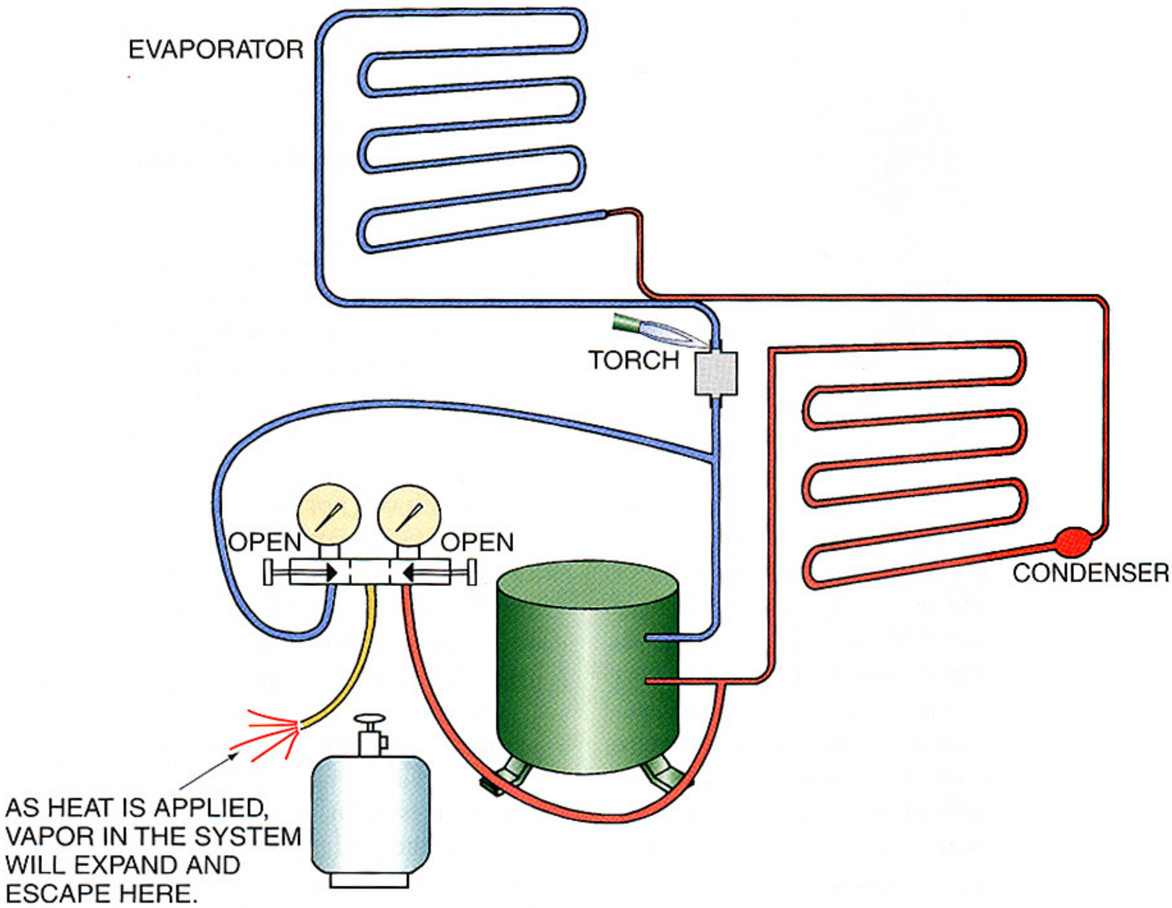


Figure 45–121 Be sure to open gages before attempting to solder the drier in the suction line.

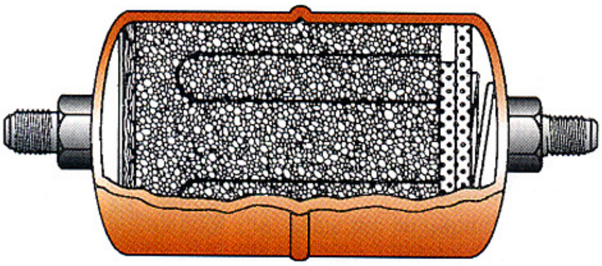


Figure 45–122 A drier with flare fittings may be a better choice to avoid soldering. *Courtesy Mueller Brass Co.*

and gage lines without Schrader valve depressors will speed the vacuum. When triple evacuation is used, the first two vacuums may be performed and then the pressure in the system may be brought up to about 5 psig above atmospheric. The Schrader valve stems may then be installed along with Schrader valve depressors and a final evacuation performed. When a deep vacuum is achieved, the charging cylinder or accurate electronic scales may be attached and the measured charge allowed into the system.

When a system has had moisture pulled inside, special evacuation procedures will be required. If moisture entered the system through a puncture during defrost by moving from the evaporator through the suction line to the compressor crankcase when the compressor was restarted, it may be trapped under the oil, **Figure 45–123.** Most experienced service technicians use the following procedure for removing moisture.

Install full-size gage connections, such as "tees" in the suction and discharge lines so evacuation is from both sides of the system, **Figure 45–124.** NOTE: Make sure that there are no Schrader depressors in the gage lines or fittings on the compressor. Use a two-stage rotary vacuum pump and start it. Apply heat to the compressor crankcase by placing a light bulb next to the compressor. Place a small light bulb (about 60 W) in both the low- and medium-temperature compartments and partially shut the doors, **Figure 45–125.** NOTE: Do not shut the doors all the way, or the heat will melt the plastic inside the refrigerator. Allow the vacuum pump to run for at least 8 h. Break the vacuum using nitrogen and pull another vacuum. This time monitor it with a manometer or electronic vacuum gage; see Unit 8. When a deep vacuum

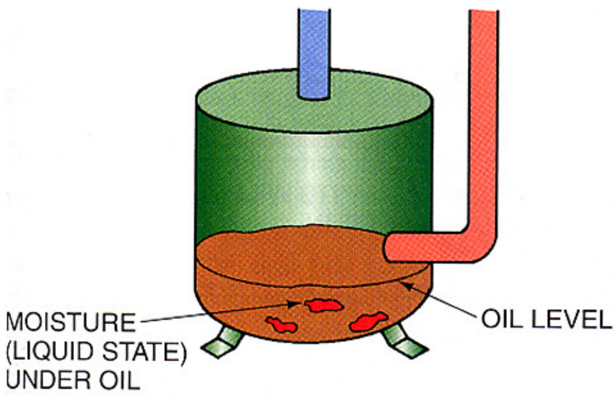
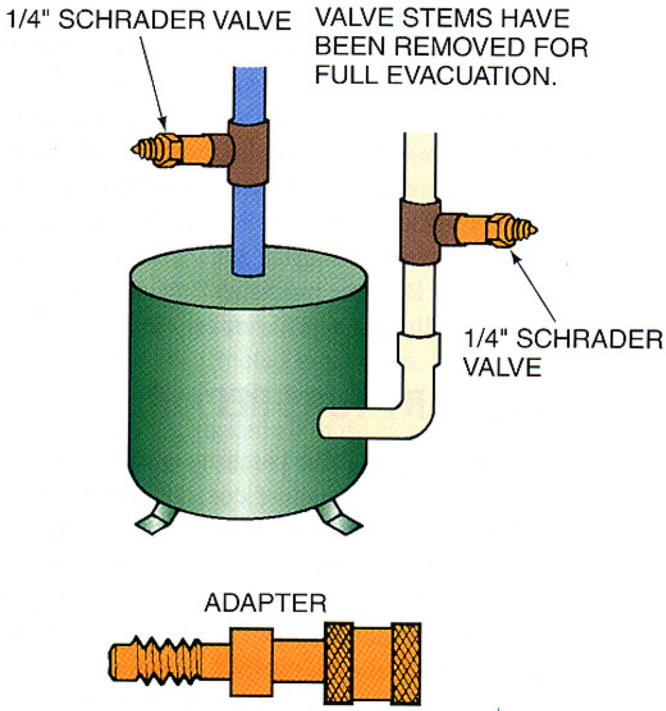


Figure 45–123 Moisture may be trapped under the oil in the compressor.



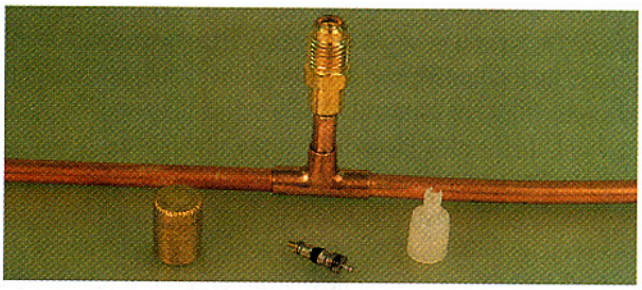


Figure 45–124 Full-size gage connections must be installed to remove moisture. *Photo by Bill Johnson*

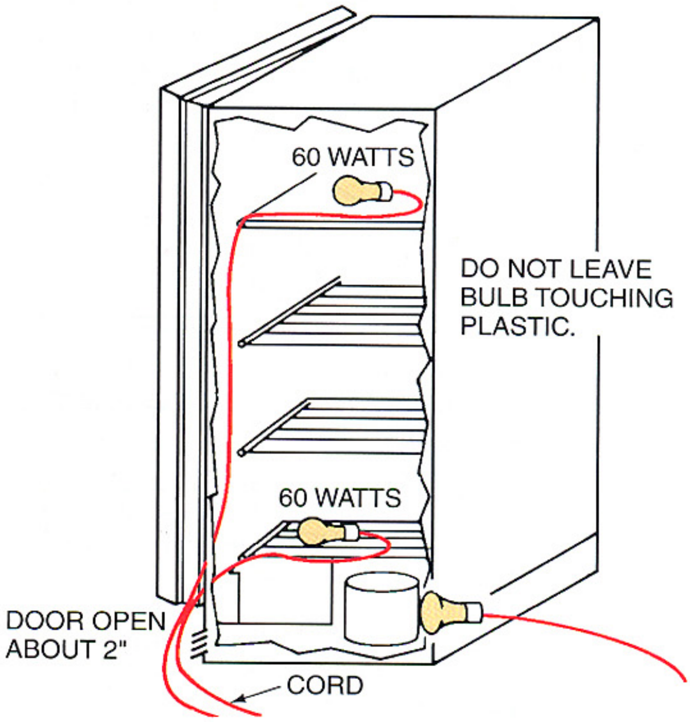


Figure 45–125 Placing light bulbs in a refrigerator to heat the refrigerant circuit and not overheat the plastic.

has been achieved, such as 1 mm Hg or 500 microns, break the vacuum with nitrogen to atmospheric pressure and remove the heat. Cut the suction line and install a suction-line filter drier. The liquid-line drier may also be replaced if the manufacturer recommends it. It may be more trouble than it is worth because the previous evacuation procedure will remove some of the moisture from this drier giving it some capacity. The new suction-line drier will give the system enough drier capacity. Pull one more vacuum and charge the unit with a measured charge of refrigerant.

45.30 CAPILLARY TUBE REPAIR

Capillary tube repair may involve patching a leak in the tube because it rubbed against some other component or the cabinet. You may need to change the drier strainer at the tube inlet. Repair may consist of clearing from the tube a partial restriction or even replacing a capillary tube. Whatever the repair, the capillary tube must be handled with care because it is small and delicate. It can be pinched easily.

When a capillary tube must be cut for any reason, the following is recommended. Use a fine file and file the tube nearly in two; then break it the rest of the way, **Figure 45–126.** Examine the end and clean any particles from the end. A very small drill bit may be used to clean the tube end to the full bore. NOTE: The tube must have the full dimension of the inside diameter or it will cause a restriction. Proper care at this time cannot be overemphasized.

When it is necessary to solder a capillary tube into a fitting, such as in the end of a new strainer, do *not* apply flux or clean the tube all the way to the end. Allow the outside of the end of the tube to remain dirty because the solder will not flow over the end of the tube if it is not cleaned, **Figure 45–127.**

A capillary tube that is broken in two may usually be repaired by cleaning both ends so the inside dimension is maintained and then pieced together with a size larger tubing, **Figure 45–128.** When a capillary tube has a rub hole in it, it is recommended that the tube be cut in two at this point and repaired as a broken tube.

Capillary tube cleanout may sometimes be accomplished with a capillary tube pump. Usually the restriction is wax or a small particle is lodged in the capillary tube, **Figure 45–129.** A capillary tube pump may pump an approved solvent or oil through the tube at a great pressure until the tube is clear, **Figure 45–130.** The only way that you will know for sure that the tube is clear is to charge the system, start it, and observe the pressures. Of course this means putting the system back to normal working order with a leak check and evacuation.

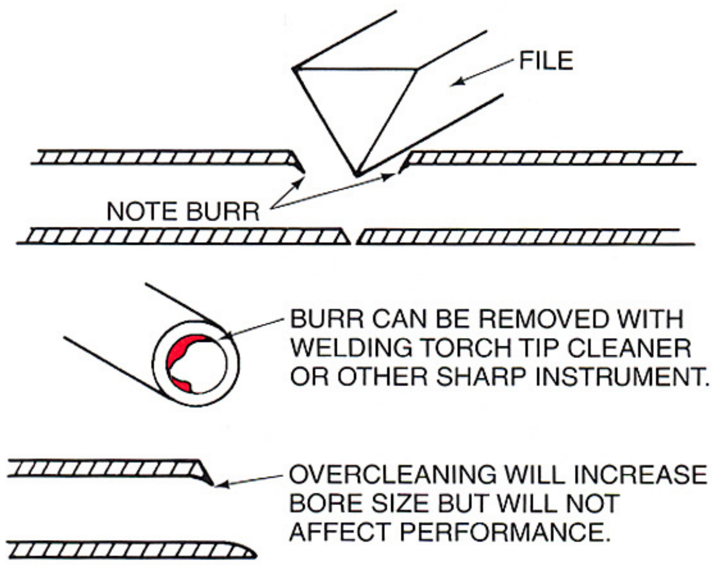


Figure 45–126 Use a file to cut a capillary tube to the correct length.

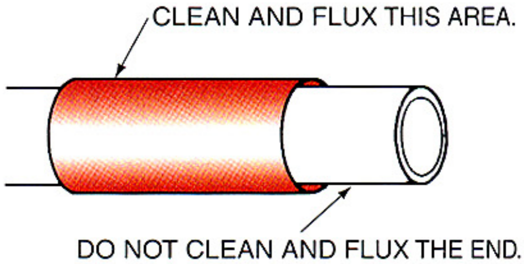


Figure 45–127 Application of flux to a capillary tube to prevent solder from entering the tube.

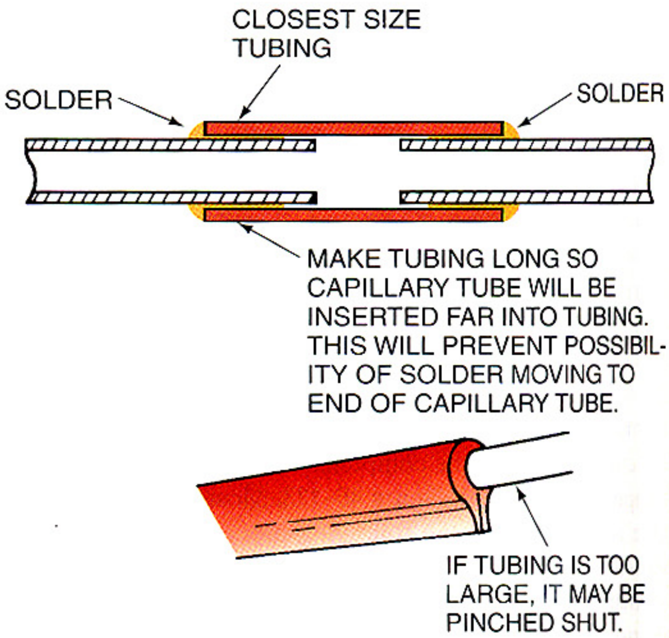


Figure 45–128 Repairing a broken capillary tube.

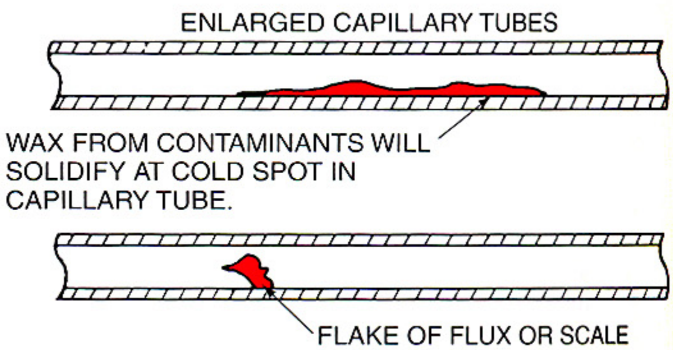


Figure 45–129 Wax or a small particle may enter and lodge in the capillary tube.

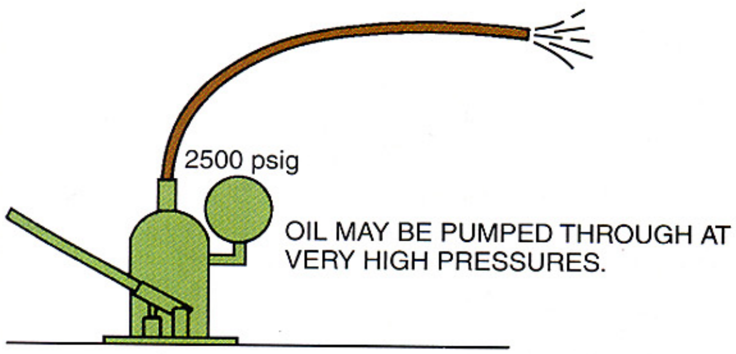


Figure 45–130 A capillary tube-cleaning pump may be used.

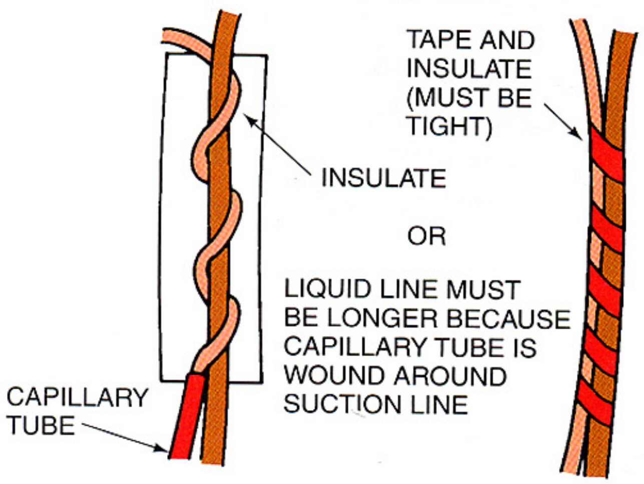


Figure 45–131 You may pass the capillary tube close to the suction line under insulation and get some heat exchange.

This can be a lot of trouble only to find that the tube is still partially blocked.

The capillary tube may be changed in some instances, but usually it is not economical because it is fastened to the suction line for a capillary tube-to-suction line heat exchange. You can never duplicate this connection exactly. You may insulate the suction line with the capillary tube under the insulation and come very close, **Figure 45–131.**

45.31 COMPRESSOR CAPACITY CHECK

One of the most difficult problems to diagnose is a compressor that is pumping to partial capacity. The customer may complain that the unit is running all the time. It may still have enough capacity to maintain the food compartments at reasonable temperatures. One of the first signs that the compartment temperature is not being maintained is that the ice cream will be slightly soft, when it has not been previously. Liquids such as water or milk served from the fresh-food compartment may not seem as cool. When the above complaint of running all the time and not holding conditions is noticed, either the refrigerator has a false load, or the compressor is not operating to capacity. You may have to decide which.

The first thing to check is to make sure that all door gaskets are in good condition and that the doors shut tight. Then check to make sure that there is no extra load such as hot food being put in the refrigerator too often, **Figure 45–132.** The defrost hot gas solenoid may be leaking hot gas through to the low side of the system, **Figure 45–133.** The light bulb may be on all the time in one of the compartments. Make sure that the condenser has the proper airflow, with all baffles in place for forced draft, **Figure 45–134,** and that it is not under a cabinet if natural draft. Make sure that the unit is not in a location that is too hot for its capacity. Usually any temperature greater than 100°F will cause the unit to run all the time, but it should maintain conditions. A unit located outside, particularly where it is affected by the sun, will always be a problem because the unit is not designed to be an outside unit. When you have checked all of this and everything proves satisfactory, then suspect the compressor.

The manufacturer's literature is invaluable for the test. A thermometer lead should be placed in both the fresh- and frozen-food compartment, **Figure 45–135.** A wattmeter can be placed in the compressor common electrical line, and the wattage of the compressor can be verified. If the compressor wattage for the conditions is low, the compressor is not doing all of its work, **Figure 45–136.** Perform the low-charge test mentioned earlier in this unit.

Loss of compressor pumping capacity can be caused by poor operating conditions for the refrigerator. For example, if the box had been operated with an extremely high head pressure due to a dirty condenser or an inoperable condenser fan motor, or if it had been operated in a very hot location for a long time span, the compressor valves could be leaking due

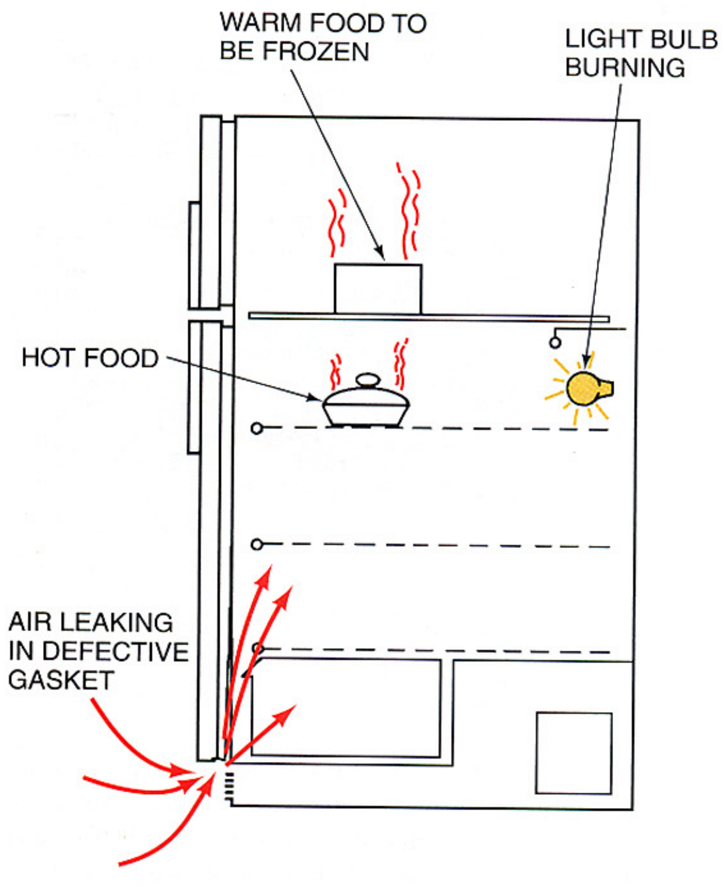


Figure 45–132 Extra load on a refrigerator may be caused by defective gaskets, hot food placed in the box, or a light bulb burning all the time.

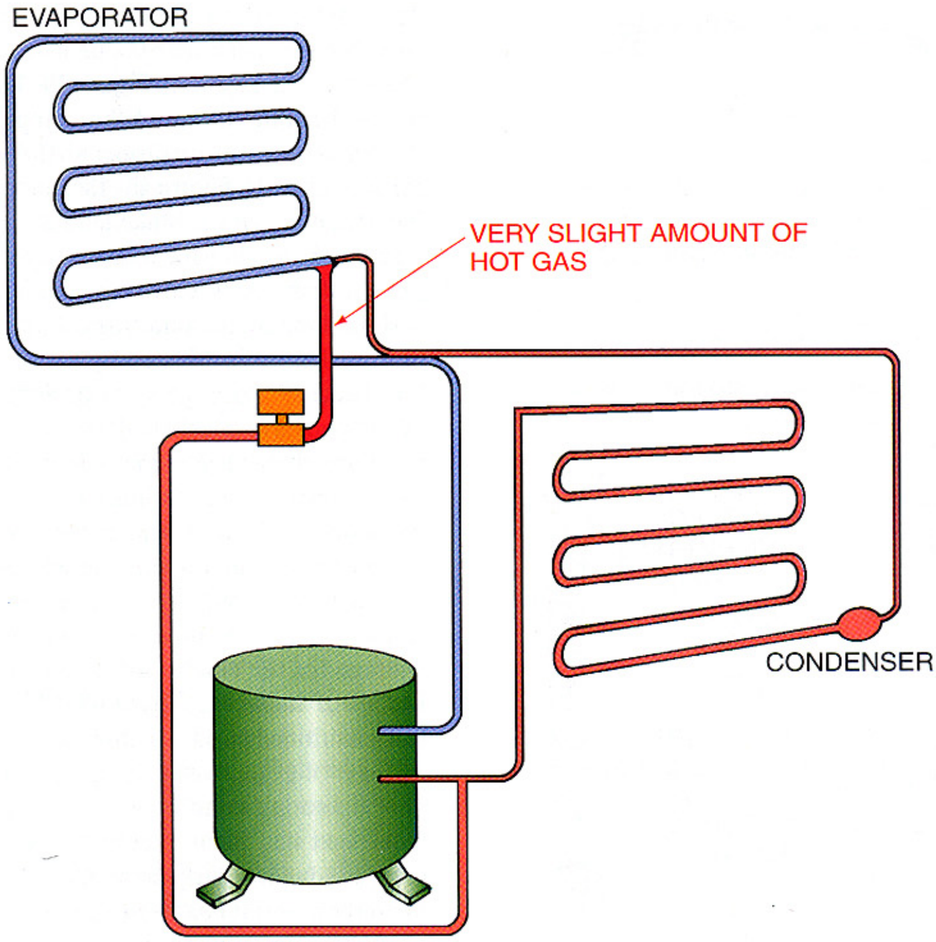


Figure 45–133 A leaking hot gas solenoid will cause a false load on a refrigerator.

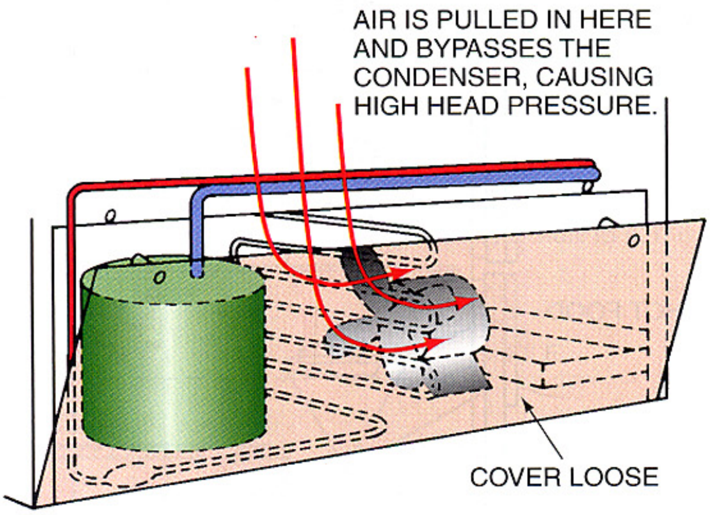


Figure 45–134 Make sure that all baffles are in place in the condenser area for correct airflow.

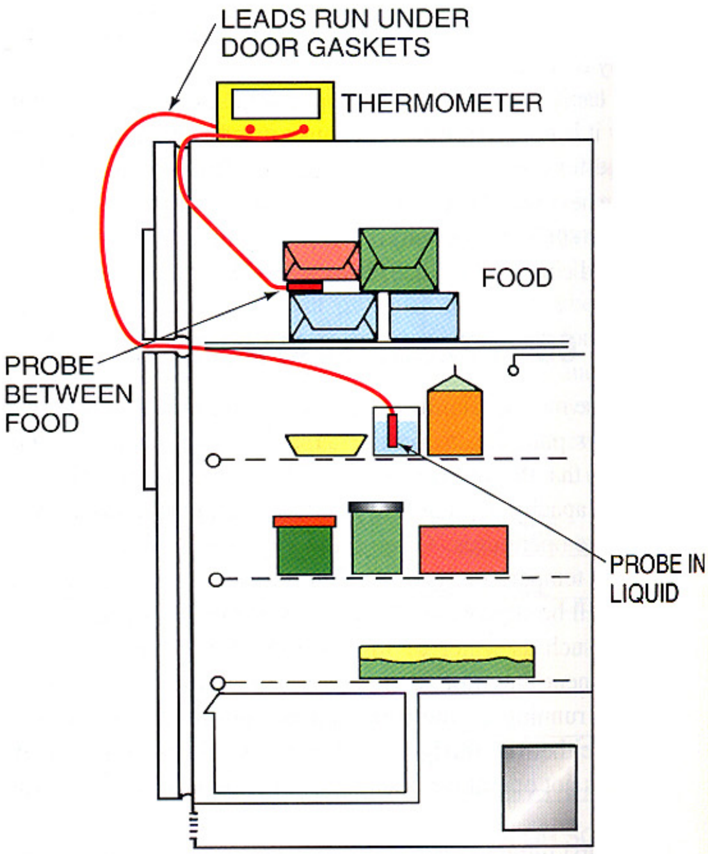


Figure 45–135 A thermometer with leads may be used to check the compartment temperatures.

to valve wear. When this happens, the compressor does not pump the correct quantity of refrigerant gas, and a loss of capacity occurs. Always make sure that the condenser is clean and that it has unobstructed airflow for both types of condensers before even thinking about compressor capacity loss. The condenser must be able to dissipate the heat, or capacity loss is ensured. Forced-draft condensers must have all

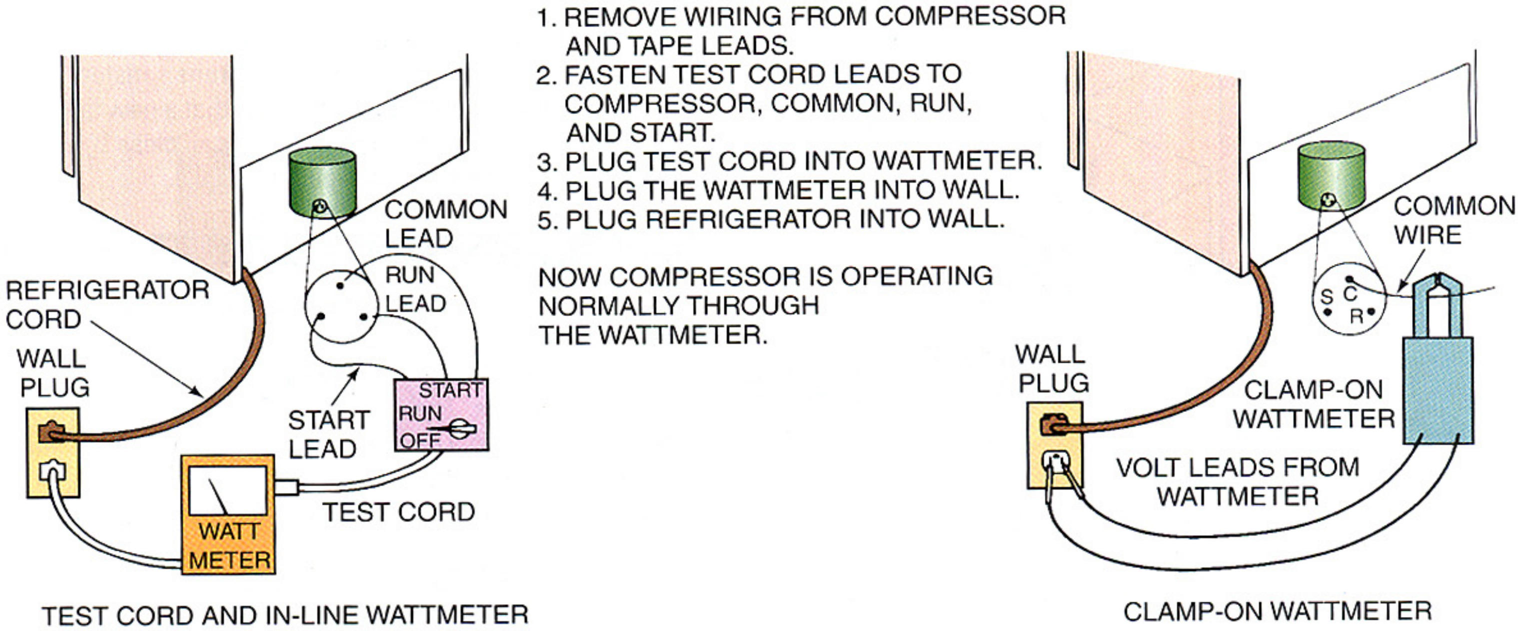


Figure 45–136 A wattmeter may be used to check the compressor to make sure that it is working to capacity. The correct wattage must be known for this procedure. The two common types of wattmeters are plug-in and clamp-on. The plug-in type requires that the compressor be isolated. A test cord is used to start the compressor.

cardboard partitions in place, or air may recirculate across the condenser causing overheating. Now the gages should be fastened to the system to check the suction and discharge pressures. Do not forget to let the pressures equalize before attaching gages. Use the manufacturer's literature to check the performance. If it is not available, you may call the distributor of the product, or you may call another technician who may have had considerable experience with this type of appliance. Declaring a compressor defective is a big decision, especially for a new technician. It may often be best to get a second opinion from an experienced technician until you are sure of yourself.

HVAC GOLDEN RULES

When making a service call to a residence:

- Make and keep firm appointments. Call ahead if you are delayed. The customer's time is valuable also.
- Keep customers informed if you must leave the job for parts or other reasons. Customers should not be upset if you inform them of your return schedule if it is reasonable.

Added Value to the Customer

Here are some simple, inexpensive procedures that may be included in the basic service call.

- Clean the condenser.
- Make sure that the condenser fan is turning freely, where applicable.
- Check the refrigerator light and replace if needed.
- Make sure the evaporator coil has no ice buildup.
- Make sure the box is level.

45.32 SERVICE TECHNICIAN CALLS

SERVICE CALL 1

A customer calls and describes to the dispatcher that a new refrigerator is sweating on the outside of the cabinet between the side-by-side doors. *The problem is a defective connection at the back of the refrigerator in a mullion heater circuit.*

The technician arrives and can see from the beginning that a mullion heater is not heating. The house temperature and humidity are normal because the house has central air conditioning. The technician dreads pulling the panels off to get to the heater between the doors if it is defective because this is a difficult time-consuming job. A look at the diagram on the back of the box reveals a junction box at the back corner of the unit where the mullion heater wires are connected before running to the front. The refrigerator is unplugged, and the junction box is located. The correct wires are located, and the connection is checked. It seems loose, but the technician wants to be sure so the connection is taken apart. An ohm check of the heater circuit proves the heater has a complete circuit. The connection is made back in a secure manner, and the refrigerator is plugged in and started. Power is checked at the connection. Power is available from the neutral wire to the hot wire going to the heater. To make sure, the technician applies the ammeter to the circuit only to find that it seems to be passing no current. A lower scale is used; the heater has a very low current draw. The wire is wrapped around the ammeter jaws to obtain a reading, **Figure 45–137.** When this is done it is determined that current is flowing, and

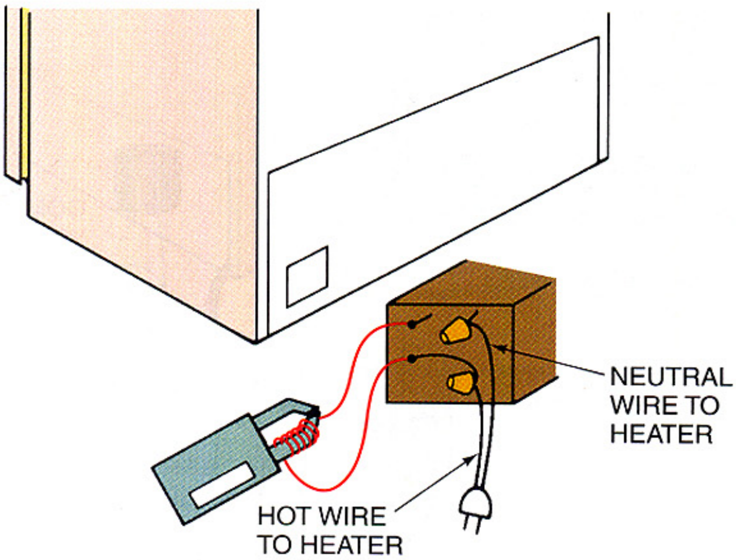


Figure 45–137 Wrapping the heater wire around the ammeter jaws to amplify the reading.

the technician feels confident the problem has been corrected.

SERVICE CALL 2

A customer reports that the refrigerator is running all the time and not keeping ice cream hard. The milk does not seem cool enough. *The problem is the condenser fan is not running; the unit is old; and the bearings are seized.*

The technician observes the inside of the freezer and can tell the unit is not cold enough because of the ice cream. When the technician leans over to listen for the condenser fan, it is noticed that it is not operating. The refrigerator is pulled out from the wall. The fan can be observed from the back, and it is not running. The motor is hot, so it is getting power but not turning. This is an impedance-protected motor with no overload protection. It can set with power to the leads and not turn, and it will not burn out. The technician unplugs the box and checks the fan to see whether it will turn. It is very tight. To make a temporary repair, a small hole is drilled in the bearing housing and penetrating oil is forced into the hole, **Figure 45–138.** The fan blade is worked back and forth until it is free and will turn over easily. Motor bearing oil is applied after the penetrating oil. Aluminum foil is formed under the motor to catch any excess oil that may drip, and the motor is plugged in. The fan motor starts and runs satisfactorily.

The technician explains to the owner that a new fan motor will be ordered and the next time a call close by is received the motor will be changed.

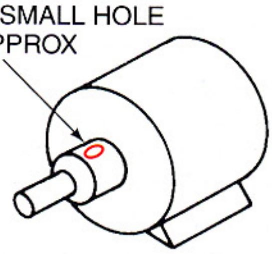


Figure 45–138 The motor housing may be drilled and penetrating oil forced into the bearings for a temporary repair. **The only permanent repair is to replace the motor.**

SERVICE CALL 3

A customer calls to report that a refrigerator is not running. A clicking sound can be heard from time to time. The owner is advised to turn the unit off or unplug it until the technician arrives. *The problem is that the compressor is stuck. The electrical circuit to the motor windings is shutting off because of the overload.*

The technician pulls the box from the wall and clamps an ammeter to the compressor common terminal before starting the compressor. When the unit is turned on, the compressor amperage rises to 20 A and before the technician can shut it off, it clicks and shuts off because of the overload.

The technician must now determine whether the compressor will not start because of electrical problems or internal mechanical problems. A compressor starting test cord is brought in from the truck. The unit is unplugged. The three wires are removed from the motor terminals and the test cord attached to common, run, and start, **Figure 45–139.** The cord is plugged in and an ammeter clamped around the common wire. A voltmeter is attached to the common and run leads to ensure correct voltage is present. The test cord switch is rotated to start and the compressor hums; the amperage is still 20 A indicating a stuck compressor. The voltage is 112 V, well within the correct voltage limits, **Figure 45–140.** The technician places a start capacitor in the start circuit of the

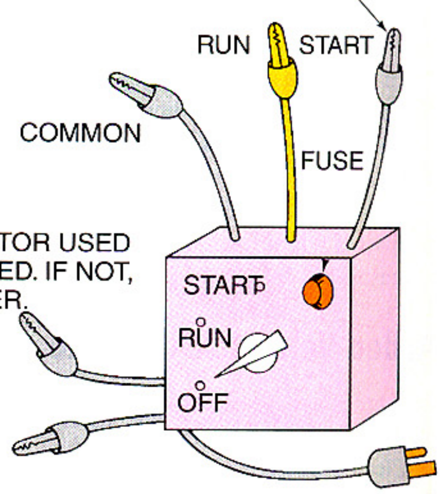


Figure 45–139 A hermetic starting test cord.

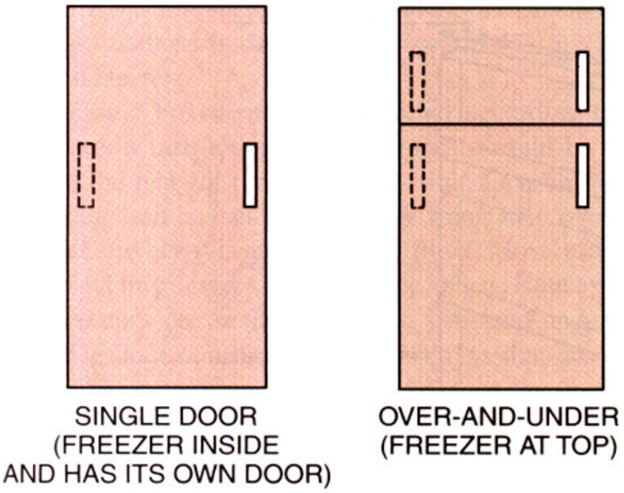


Figure 45–47 Single and over-and-under door arrangements.

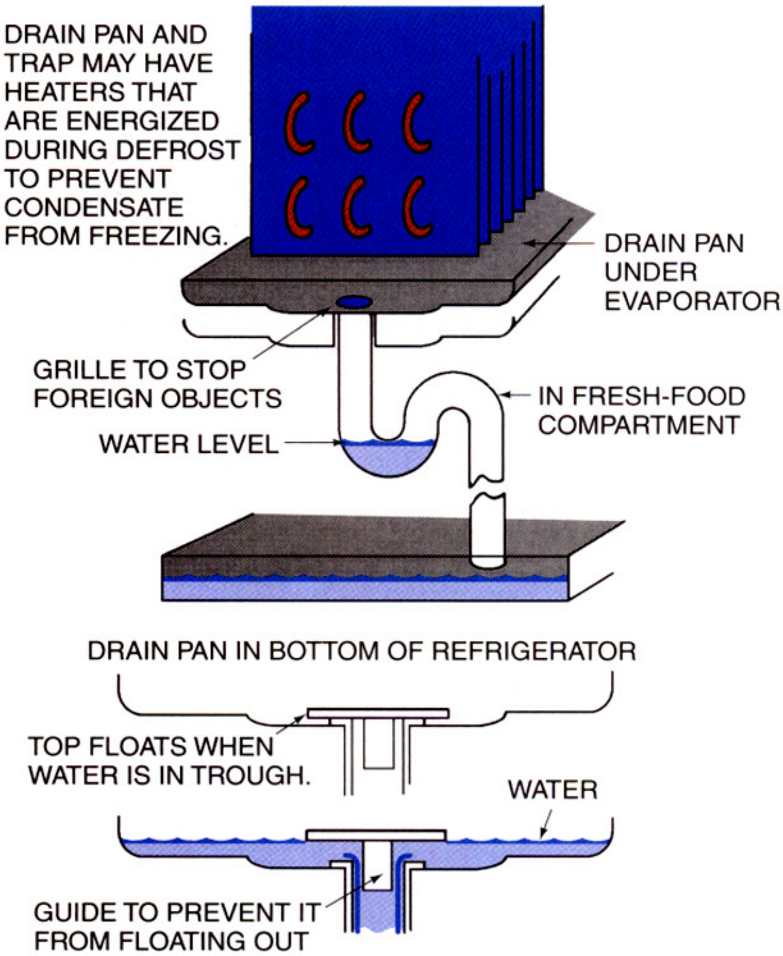


Figure 45–49 Two types of traps to allow condensate to drain and prevent air from entering.

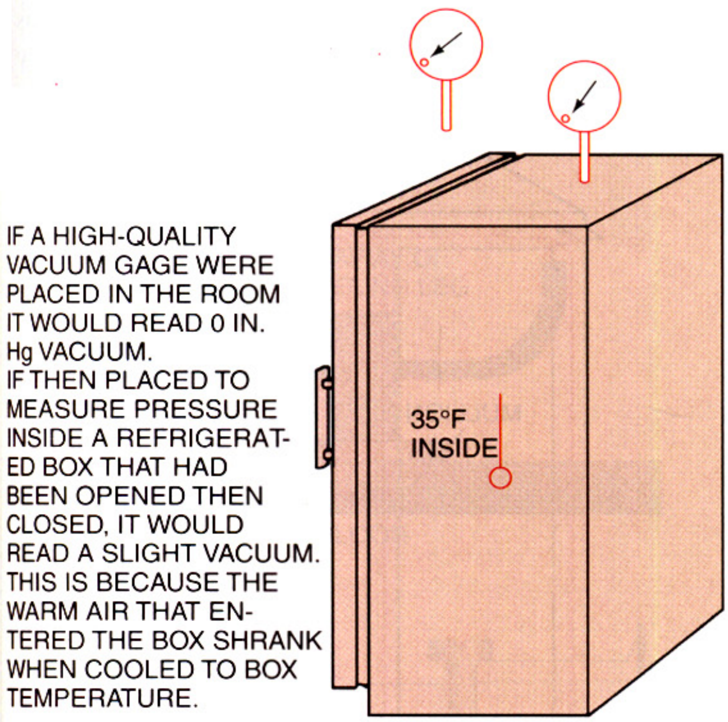


Figure 45–48 Cooled air inside the box may make it hard to open the door immediately after closing.

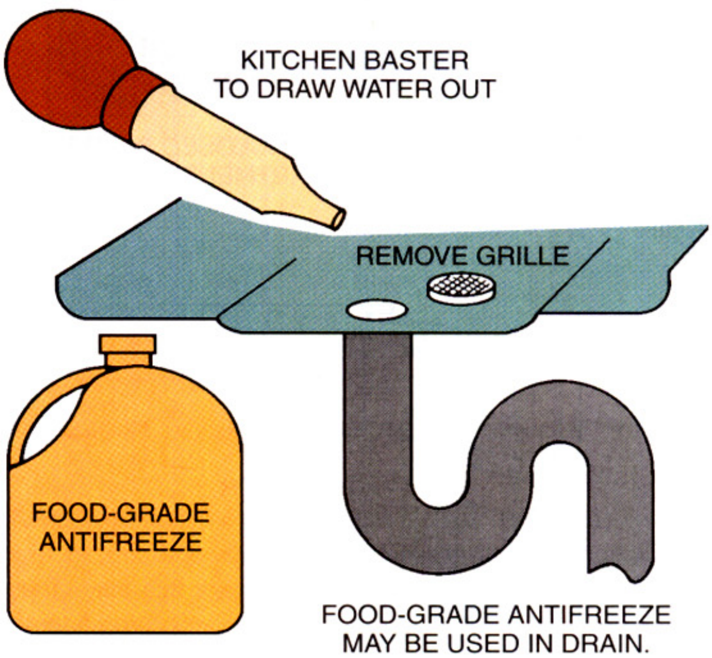


Figure 45–50 Service the drain trap for winter storage, or it may freeze.

air from traveling into the box through this opening, **Figure 45–49.** If a refrigerator is located outside in the winter for storage or use, the water in the drain tap may freeze, **Figure 45–50.**

The refrigerator may have provision for an ice maker in the frozen-food compartment. This is accomplished by furnishing a place for water to be piped to the frozen-food compartment and a bracket to which the ice maker can be

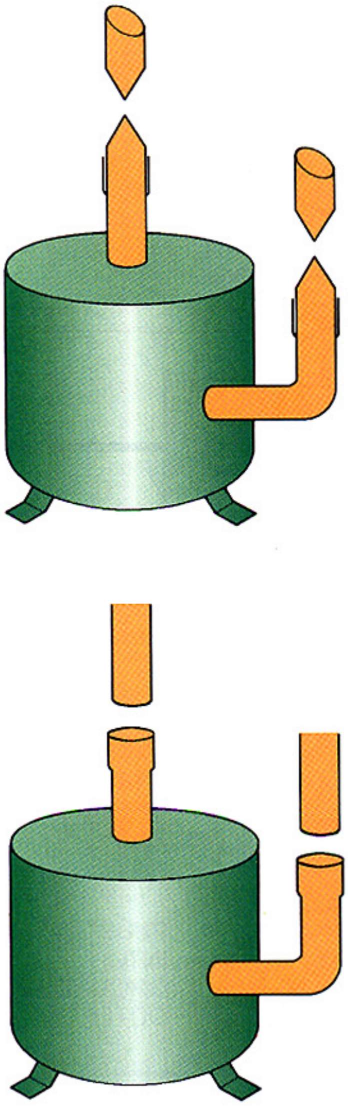


Figure 45–143 The pinched lines of the compressor must be cut off before inserting the new compressor connections.

fitted to the compressor. A process tube is attached to the high and low side of the compressor with Schrader valves in them. The valve stems are removed for soldering and are left out for a quick evacuation.

The compressor and all lines are soldered with the system open to the atmosphere. When this is finished, the technician attaches gages to the gage ports. The suction line is cut to allow for the suction-line filter drier. The system is swept with nitrogen and the gage lines removed again in preparation for soldering the suction-line filter drier, **Figure 45–144**. The filter drier is soldered into the line. The gage lines are attached as soon as possible to prevent air from being drawn into the system. The system is practically clean at this time, but you cannot be too careful with low-temperature refrigeration.

The system is now ready for the leak check. When the technician removed the plugs from the compressor, it was noticed that a vapor holding charge was still in the compressor, so all factory connections are leak-free. The system is pressurized by adding a small amount of R-22 (to 5 psig); then the pressure is increased to 150 psig using nitrogen. All connections are checked with an electronic leak detector. The technician is satisfied that the connections completed during the repair are not leaking. The refrigerator had its original charge, so it does not leak. The pressure is released from the system.

The vacuum pump is attached to the system and started. Remember, the valve stems are not in the Schrader valves. The technician's vacuum gage is in the shop for repair, so sound will be used to determine the correct vacuum. After the pump has run for about 20 min, it is not making any pumping noises; see Unit 8, "System Evacuation," for information on how to determine this. The vacuum is broken by adding nitrogen to about 20 in. Hg, and the vacuum pump is started again. When another vacuum is obtained, the pump is stopped and nitrogen pressure is allowed into the system to 5 psig.

The Schrader valve stems are installed, and Schrader adapters are fastened to the ends of the gage lines. The gages are fastened to the system again, and a third vacuum is performed. While it is pulling down, the technician reads the correct charge from the unit nameplate and gets set up to charge the system. The electrical connections are made to the compressor. A good technician knows how to manage time and uses the vacuum pump time for cleanup of details. When the vacuum is reached, the measured charge is allowed to enter the refrigerator. The high-side line is removed because the unit is about to run, and the technician does not want refrigerant to condense in this line.

An ammeter is placed on the common wire to the compressor so the technician will know whether the compressor starts correctly. The refrigerator is plugged in and started. It seems to run, and the low-side pressure starts down. The last bit of charge is pulled into the low-pressure side of the system. The unit is shut off and trucked back into place and restarted. The technician leaves the job and calls back later in the day to learn that the refrigerator is performing correctly.

SERVICE CALL 4

A customer calls and reports the refrigerator in the lunchroom is not cooling correctly. It is running all the time and the box does not seem cool enough. *The problem is that the defrost timer motor is burned out and will not advance the timer into defrost. The evaporator is frozen solid.*

The technician arrives and opens the freezing compartment inside the top door. The evaporator fan can be heard to run, but no air can be felt coming out the vents. A package of ice cream is soft, indicating the compartment is not cold enough. The technician removes the cover to the evaporator and finds it frozen, a sure sign of lack of defrost.

The compartment door is shut, and the box pulled from the wall. The timer is in the back and has a small window to observe rotation of the timer motor, **Figure 45–145**. The

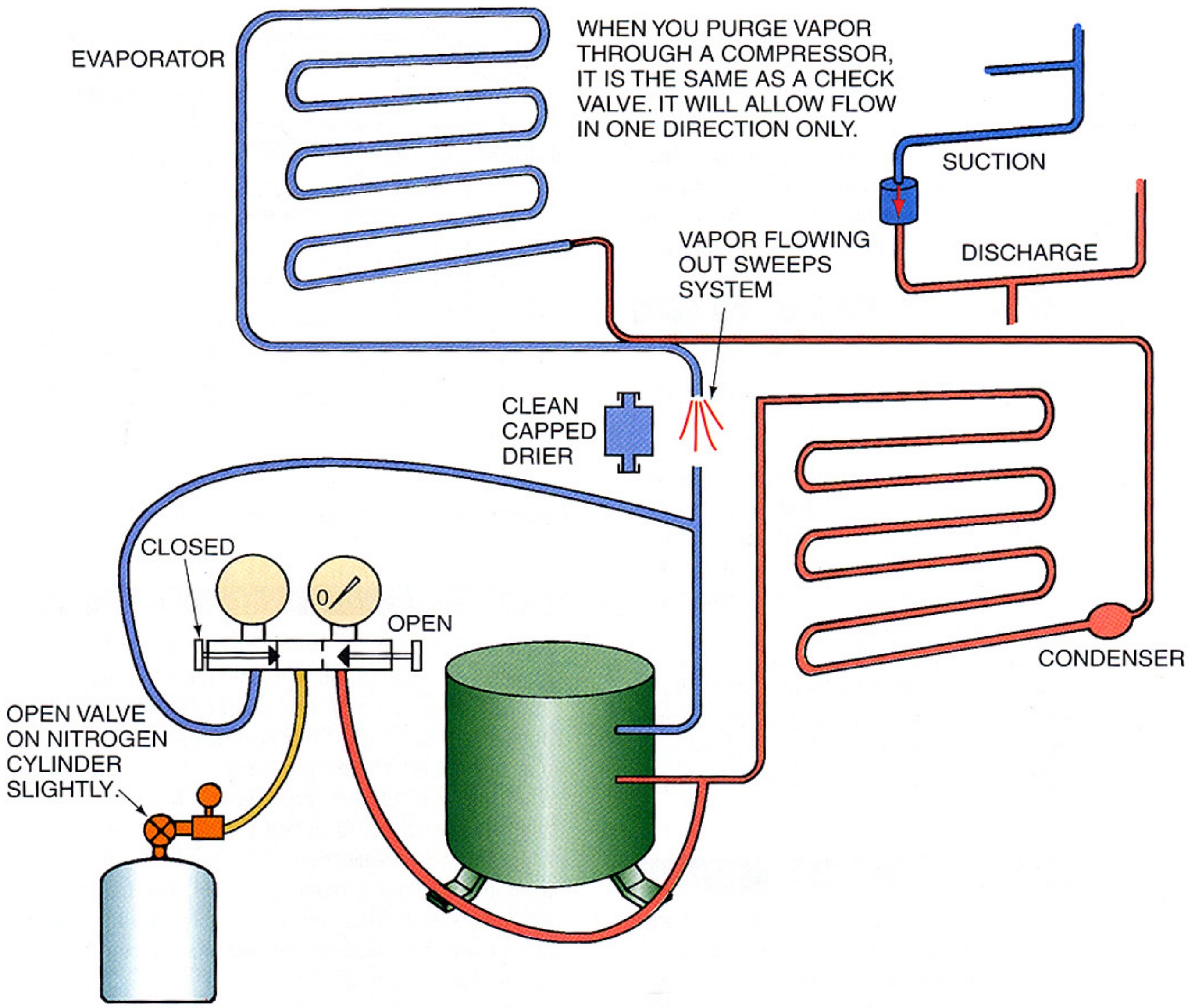


Figure 45–144 Sweeping or purging the system before soldering the drier in the line.

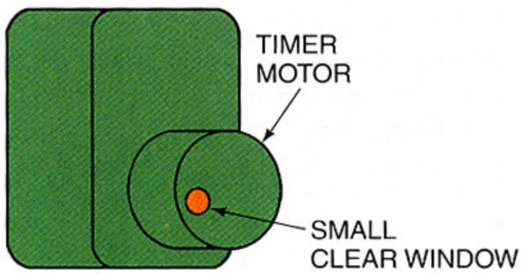


Figure 45–145 A small window may be provided to check a timer for rotation.

timer is not turning. A voltage check of the timer terminals shows voltage to the timer motor. The winding is checked for continuity; it is open and defective.

The technician opens the refrigerator door and removes the food. A small fan is placed in such a manner as to blow room air into the box for rapid defrost, **Figure 45–146**. The customer is told to watch for water on the floor as the frost

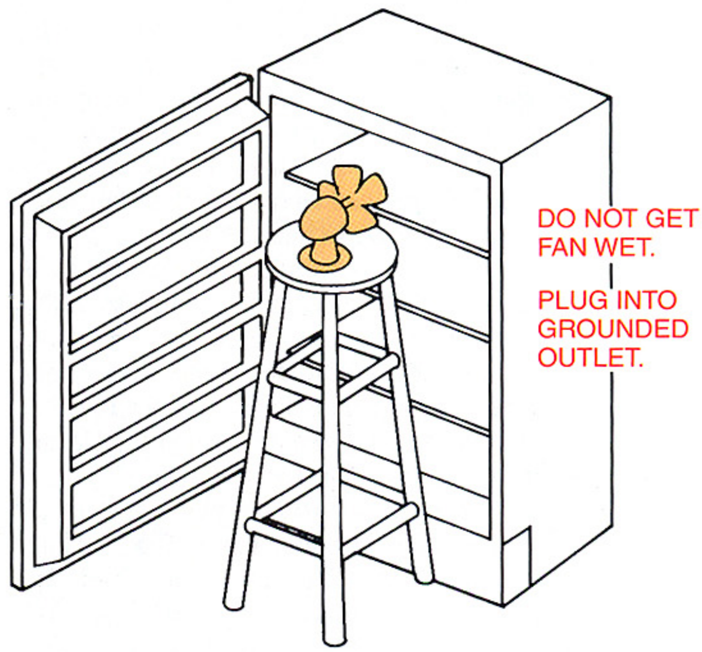


Figure 45–146 A room fan may be used for rapid defrost.

begins to melt. The technician is going to make another service call on the way to the supply house for a defrost timer.

On returning, the defrost timer is replaced. The evaporator is thawed, but the pan underneath the unit is full and must be emptied. When emptied, the pan is cleaned and sanitized. The pan is replaced, the cover to the evaporator is replaced, and the unit is started. The coil begins to cool, so the food is replaced, and the technician leaves.

SERVICE CALL 5

A homeowner reports that the refrigerator is running all the time and not shutting off. *The problem is the door gaskets are defective and the door is out of alignment.* The customer has four children.

The technician arrives and can see the problem easily when the refrigerator door is opened. The gaskets are worn badly and daylight may be seen under the door when looking from the side. The model number of the refrigerator is written down, and the technician tells the owner that a trip to the supply house is necessary.

When the gaskets are obtained, the technician returns to the job and replaces them following the manufacturer's recommendations. The door is not closing tightly at the bottom, so the technician removes the internal shelving and adjusts the brackets in the door so that it hangs straight.

SERVICE CALL 6

A customer reports that the refrigerator is running all the time. It is cool, but never shuts off. This refrigerator is in warranty. *The problem is that a piece of frozen food has fallen and knocked the door light switch plunger off, and the light in the freezer is staying on all the time. This is enough increased load to keep the compressor on all the time.*

The technician arrives and looks the refrigerator over. There does not seem to be any frost buildup on the evaporator. The owner is questioned about placing hot food in the refrigerator or leaving the door open. This does not seem to be the problem. The customer says the refrigerator is always running. It should be cycling off in the morning, no matter how much load it has.

This sounds like the compressor is not pumping, or maybe there is an additional load on the compressor. The unit has electric defrost, and the evaporator coil seems to be clean of frost. The technician opens the freezer door and notices that the light switch in the freezer does not have the plunger that touches the door when it is closed, **Figure 45–147.** The light is staying on all the time.

The technician informs the customer that a switch will have to be obtained from the manufacturer. The light bulb in the freezer is removed until a switch is obtained. The technician returns the next day with a switch and replaces it. The owner tells the technician that the refrigerator was shut off at breakfast, so the diagnosis was good.

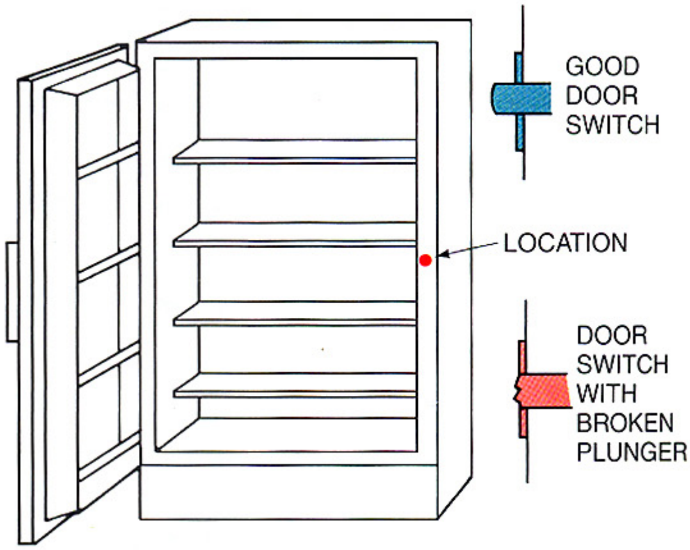


Figure 45–147 The plunger is missing from the door switch.

SERVICE CALL 7

An apartment house tenant has an old refrigerator that must be defrosted manually. The ice was not melting fast enough so an ice pick was used and the evaporator was punctured. She heard the hiss of the refrigerant leaking out, but decided to try it anyway. *The problem is the refrigerant leaked out, and when the refrigerator was restarted, water was pulled into the system.* Without refrigerant the low-pressure side of the system will pull into a vacuum. When it would not cool, she called the management office. This would normally be a throwaway situation, but the apartment house has 200 refrigerators like this and a repair shop.

The technician takes a replacement refrigerator along after reading the service ticket. This has happened many times, so many that a definite procedure has been established. The food is transferred to the replacement box and the other one is trucked to the shop in the basement.

The technician solders two process tubes into the system, one in the suction line and the other in the discharge line, **Figure 45–148.** Pressure is added to the circuit using nitrogen, and the leak is located. It is in the evaporator

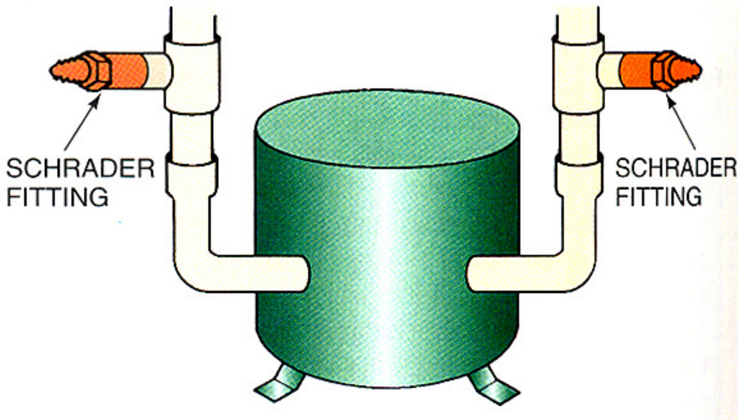


Figure 45–148 Process tubes soldered in the suction and discharge lines offer the best service access.

plate, so a patch of epoxy is going to be the repair procedure. The nitrogen pressure is allowed to escape the system, and the puncture is cleaned with a nonconductive sand tape. A solvent that is recommended by the epoxy manufacturer is used to remove all dirt and grease from the puncture area. A vacuum pump is connected to the service ports. NOTE: The service ports have no Schrader valve plungers in them and the gage lines have no Schrader valve depressors in them; they have been removed for the time being.

The vacuum pump is started and allowed to run until 5 in. Hg is registered on the suction compound gage and the gages are valved off. Epoxy is mixed. Remember, this is a two-part mixture, and it must be used very fast or it will harden, usually within 5 min. Some epoxy is spread over the puncture hole. The vacuum pulls a small amount into the hole to form the mushroom formation mentioned in the text, **Figure 45–149.** The vacuum causes a hole to be pulled through the center of the epoxy patch, so some more is spread over the hole. It is now becoming solid. The gages are opened to the atmosphere to equalize the pressure on each side of the patch, and the epoxy is allowed to dry.

The epoxy is allowed several hours to dry while other service tasks are performed. A small amount of R-22 is used to pressure the system to 5 psig, and nitrogen is then used to pressure the system to 100 psig. The epoxy patch is checked for a leak using soap bubbles. The service stems are also checked for a leak. There are no leaks. The tricky part of the service procedure comes next. This technician knows the procedure well and knows from experience that a step must not be skipped.

The pressure is allowed to escape the system, and the vacuum pump is started with no stems or depressors in the Schrader fittings. This allows full bore of the gage hose. A 60-W bulb is placed in the freezer compartment and one in the fresh-food compartment. SAFETY PRECAUTION: The doors are partially shut. A 150-W bulb is placed touching the compressor crankcase, **Figure 45–150.** None of these bulbs should ever be placed in contact with plastic or it will melt. The vacuum pump is started and allowed to run until the next day. It is not making any pumping sounds, so a good vacuum has been achieved. The technician breaks the vacuum to about 2 psig pressure using nitrogen and disconnects the vacuum pump.

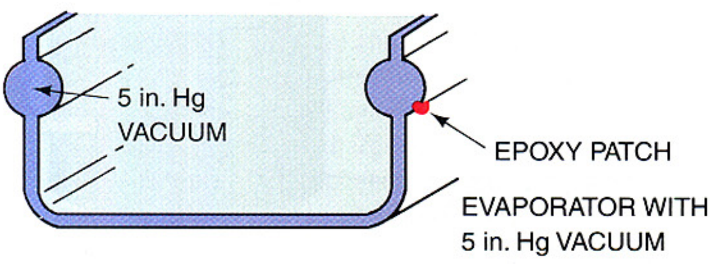


Figure 45–149 The vacuum is used to pull a small amount of epoxy into the evaporator puncture.

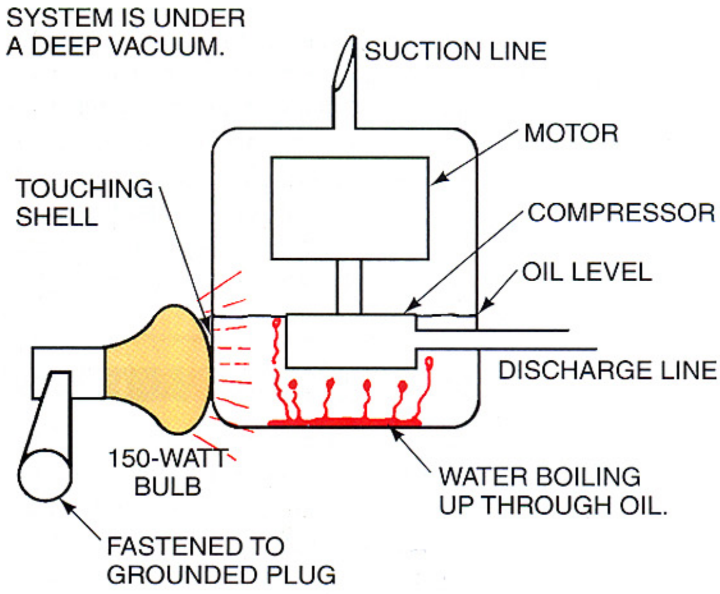


Figure 45–150 Heat is applied to the compressor to boil any moisture from under the oil.

The vacuum pump is placed on the work bench and the oil is drained. There is quite a bit of moisture in the oil. The oil is replaced with special vacuum pump oil and the opening to the vacuum pump is capped to prevent atmosphere from being pumped and the pump is started. It is allowed to run for about 15 min, long enough to allow the oil to get warm. It is shut off, the oil is drained again, and the special vacuum pump oil is added back to the pump. The drained oil looks good, so the pump is connected to the system.

Before turning the vacuum pump on, the technician starts the refrigerator compressor for about 30 sec. If there is any moisture trapped in the cylinder of the compressor, this will move it through the system and the next vacuum will remove it. The vacuum pump is now started and allowed to run for about 2 h; then the vacuum is again broken to about 5 psig using nitrogen. The gage lines are removed one at a time, and the Schrader valve stems and depressors are added back to the gage hoses.

A suction-line filter drier is installed in the suction line and the system is pressured back to 100 psig using nitrogen to leak check the drier connection. This may seem like a long procedure, but the service technician has tried shortcuts, and they do not work. The most obvious one would be to cut the drier into the circuit at the beginning. It would become contaminated before the refrigerator is started if cut into a wet system. The liquid-line drier should be changed at this time as it has become saturated. It has been partially reactivated with the evacuation, but changing it will ensure that all moisture is removed.

The vacuum pump is started for the third and final evacuation. It is allowed to run for about 2 h. During these waiting periods, the technician may have other service duties to perform.

The refrigerant for the refrigerator is prepared on the scales when the vacuum is complete. The high-side line is pinched off and soldered shut; the refrigerant is charged into the system, see Unit 10. The refrigerator is started to pull the last of the charge into the system. The suction line is disconnected and a cap is placed on the Schrader valve. The discharge line port is soldered shut so the next time a gage reading is needed, a suction-line port is available, but no discharge port. This is common; there is less chance of a leak under the low-side pressure than under the high-side pressure.

SERVICE CALL 8

A customer calls and reports that the refrigerator is off; it tripped a breaker. He tried to reset it, and it tripped again. The dispatcher advised the customer to unplug the refrigerator and reset the breaker because there may be something else on this breaker that he may need. *The problem is the compressor motor is grounded and tripping the breaker.*

The technician takes a helper, a refrigerator to loan the customer, and a refrigerator hand truck and goes to the customer's house. A bad electrical problem is suspected. This unit is in warranty and will be moved to the shop if the problem is complicated.

The technician uses an ohmmeter at the power cord to check for a ground. The meter is set to R × 1 and reads 0 when touching one meter lead to the power cord plug and the other to the cabinet indicating a ground. SAFETY PRECAUTION: The white or black lead must be used for this test because the green lead is grounded to the cabinet. The white or black lead will be one of the flat prongs on the plug, **Figure 45–151.**

The refrigerator is moved from the wall to see whether the ground can be located. It could be in the power cord and repaired on the spot. The leads are removed from the compressor and the compressor terminals are checked with one lead on a compressor terminal and the other on the cabinet or one of the refrigerant lines. The compressor shows 0 Ω to ground, **Figure 45–152**. It has internal problems and must be changed.

The technician and the helper move the refrigerator to the middle of the kitchen floor and put the spare refrigerator in place. The food is transferred to the spare refrigerator. It is cold because it was plugged in at the shop. It is plugged in and starts to run. The faulty refrigerator is trucked to the shop and unloaded.

The technician knows that the refrigerant in the box may be badly contaminated. ♻ The refrigerant is then removed to a recovery cylinder used for contaminated refrigerants. ♻ The service technician decides on a plan. Change the compressor and the liquid-line drier and add a suction-line drier.

The refrigerator is set up on a work bench to make it easy to access. The compressor is changed and process tubes soldered in place with 1/4 in. fittings on the end. **No Schrader fittings will be used on this one to demonstrate**

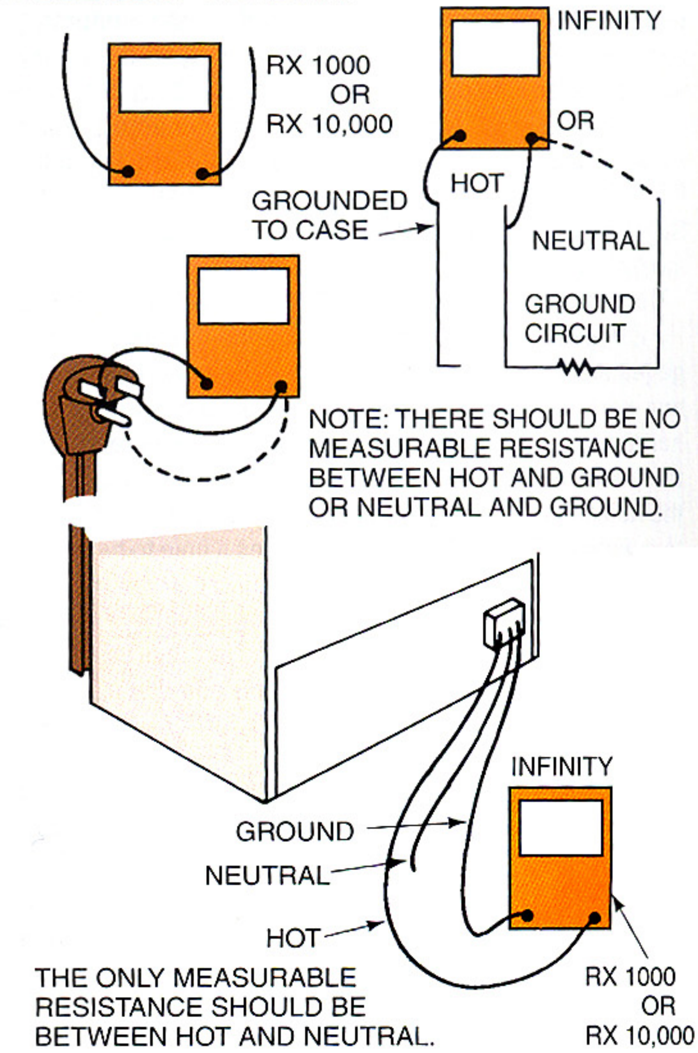


Figure 45–151 Checking the unit for a grounded circuit using the appliance plug.

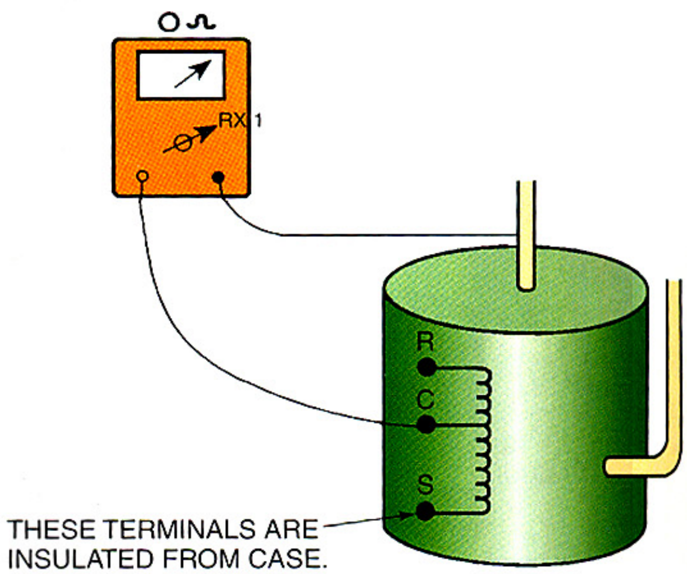


Figure 45–152 Using the compressor frame or lines to check for an electrical ground circuit.

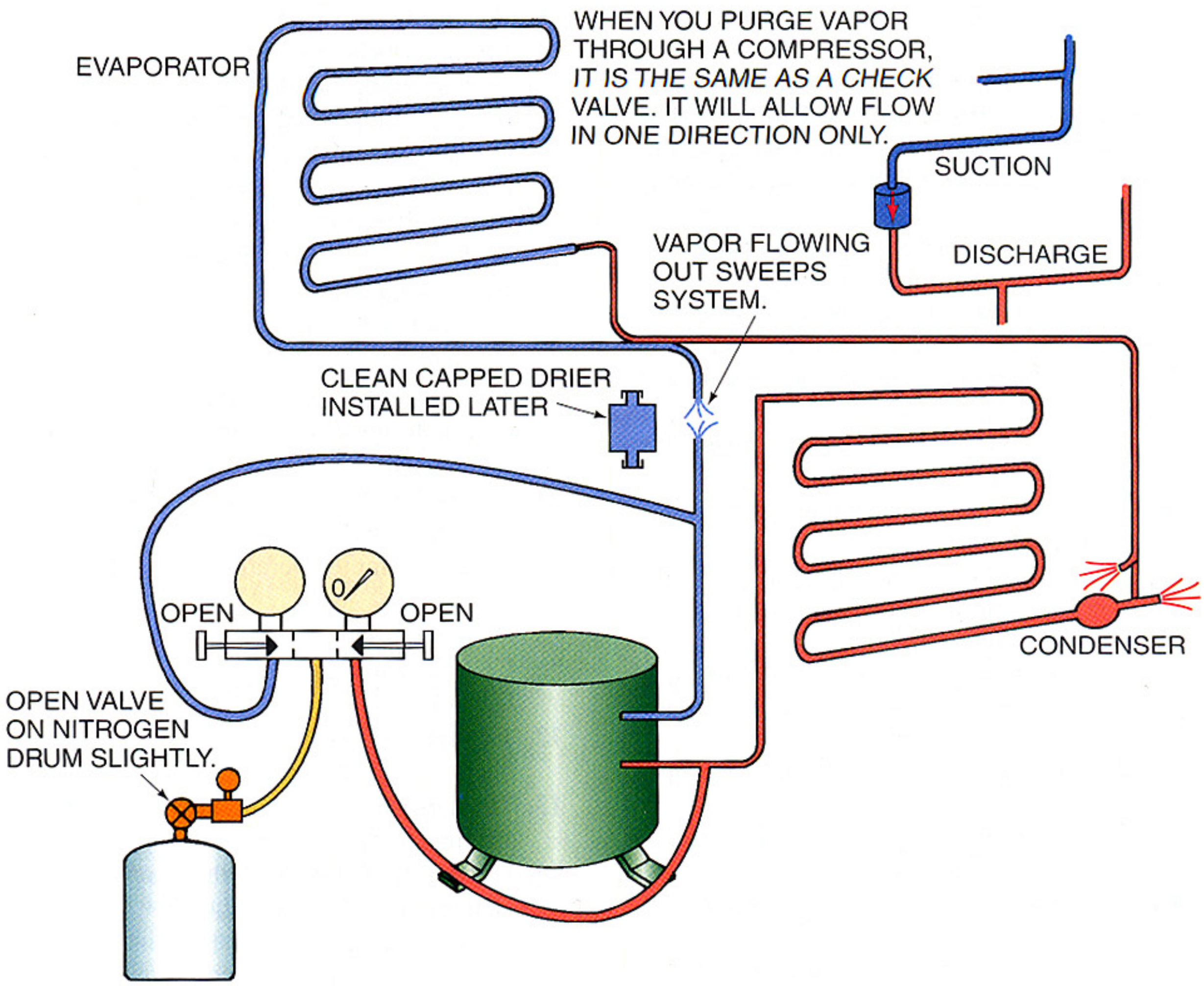


Figure 45–153 Purging the system at the suction-line drier connection before soldering the drier in the line.

how a system is totally sealed after an evacuation. The liquid line is cut and the old drier is removed. The technician then fastens the gage lines to the process tubes. There are no Schrader stems or depressors. Nitrogen is purged through the system from the suction line back through the evaporator and capillary tube, which is loose at the drier. Nitrogen under pressure is purged through the high side and out the liquid line that is attached to the liquid-line drier, **Figure 45–153.** The liquid-line drier and then the suction-line drier are soldered in place.

The difference in the purge method in this system is that there is no moisture present, just contaminated refrigerant and oil, and possibly smoke from the motor ground in the system. It can be purged to remove the large particles, and the driers will remove the rest.

The system is leak checked and triple evacuated. At the end of the third evacuation, the discharge service tube is pinched off using a special pinch-off tool. The system is charged with a measured charge and started.

The low-side pressure is observed to be correct during the pull down of the box, **Figure 45–154.** The box is allowed to stay plugged in for 24 h to operate on its own and then is transported back to the customer.

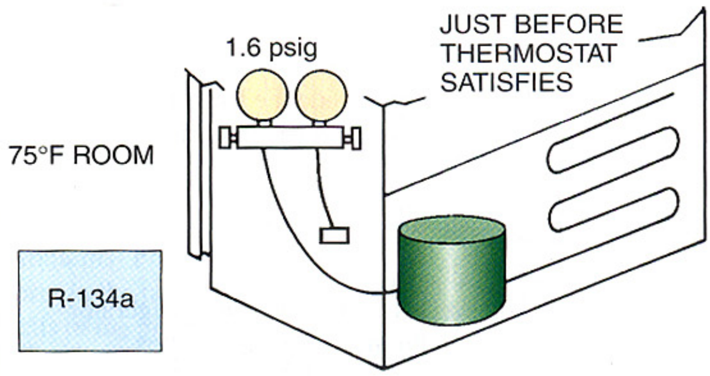


Figure 45–154 Typical pressure while the box is pulling down.

SUMMARY

- Heat enters the refrigerator through the walls of the box by conduction, by convection, and by warm food placed in the box.
- Evaporator compartments can be natural draft or forced draft.
- The evaporator in the household refrigerator operates at the low-temperature condition, yet maintains food in the fresh-food compartment.
- Sharp objects should never be used when manually defrosting the evaporator.
- Evaporators may be flat-plate type or fan-coil type.

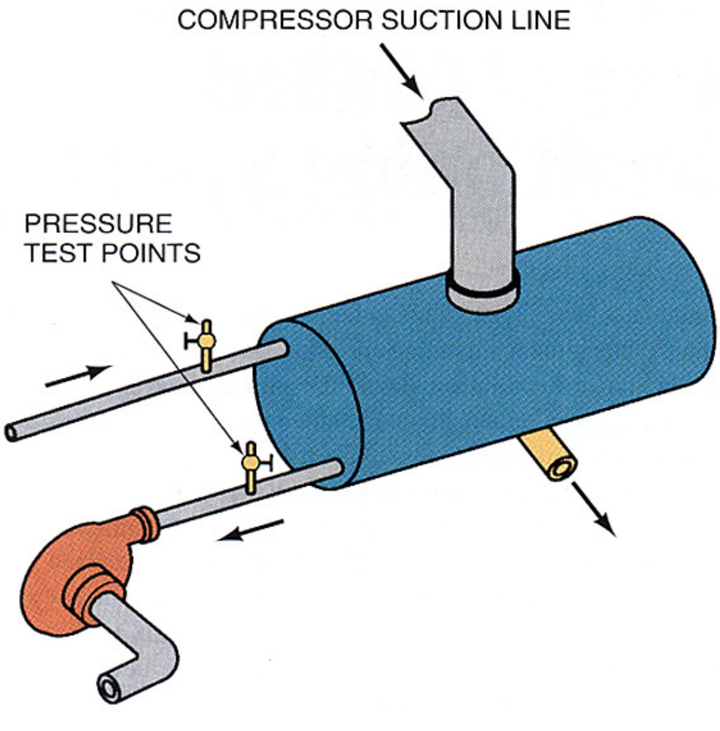


Figure 50–1 Pressure test points at the inlet and outlet of a heat exchanger.

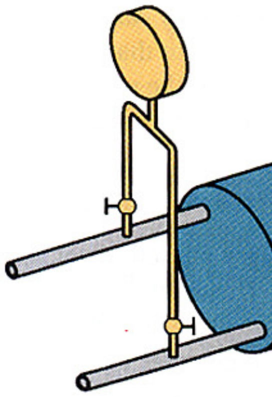


Figure 50–2 Using one gage and two ports for checking the pressure drop through a heat exchanger.

pressure connections, **Figure 50–2.** If two gages are used and they are at different heights, an error is automatically built in. For example, if one gage is 2.31 ft lower than the other, there is an error of 1 psig because of the difference in height. A standing column of water that is 2.31 ft high will have a pressure of 1 psig at the bottom, **Figure 50–3.** If the gages have a built-in error because they are not calibrated, they cannot be expected to give correct readings. If one gage reads 1 psig when open to the atmosphere while the other gage reads 0, there is an error of 1 psig in the pressure difference. Actually, all you want to know is the pressure difference at the two points. Using one gage that is not accurate at 0 may still yield the correct pressure difference.

The technician needs to know from the pressure readings that there is a pressure drop across the heat exchanger. As water flows through the heat exchanger, the pressure drops a specific amount. The heat exchanger is a calibrated pressure drop monitoring device that may be used to determine water flow. A pressure drop chart for the heat exchanger will tell you the gallons per minute (gpm) of water flow, **Figure 50–4.**

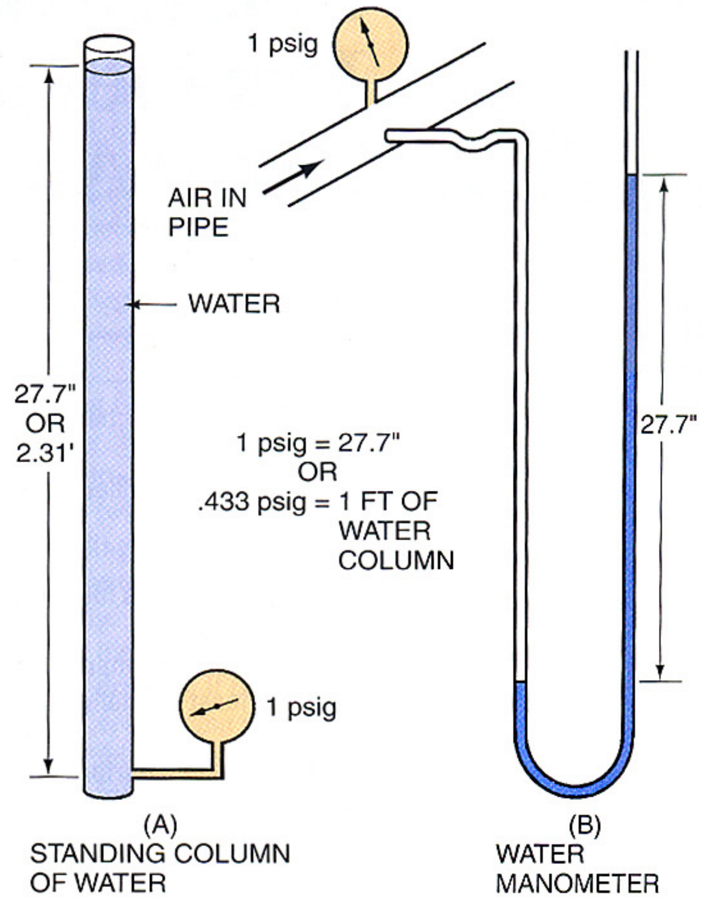


Figure 50–3 (A) Pressure at the bottom of a standing column of water, and (B) as it would be measured with a water manometer.

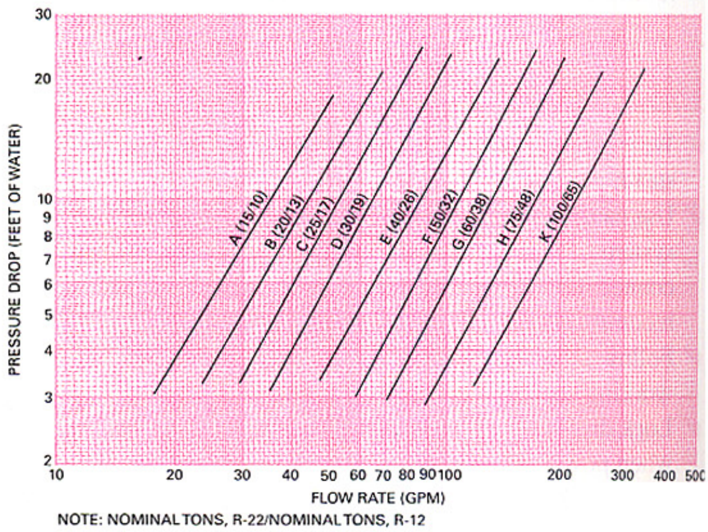


Figure 50–4 A pressure drop chart for a heat exchanger. *Courtesy Trane Company*

The original operating log sheet for the installation will show the pressure drops at start-up. This is very good information for future use. If the original log cannot be found, the manufacturer may be contacted for a copy of the log sheet or a pressure drop chart for the chiller.

The technician should also be aware of the interlock circuit through the contactors that must be satisfied before start-up. The starting sequence for most chiller systems is to start the chilled water pump first. A set of auxiliary contacts in the chilled water starter then starts the condenser water pump.

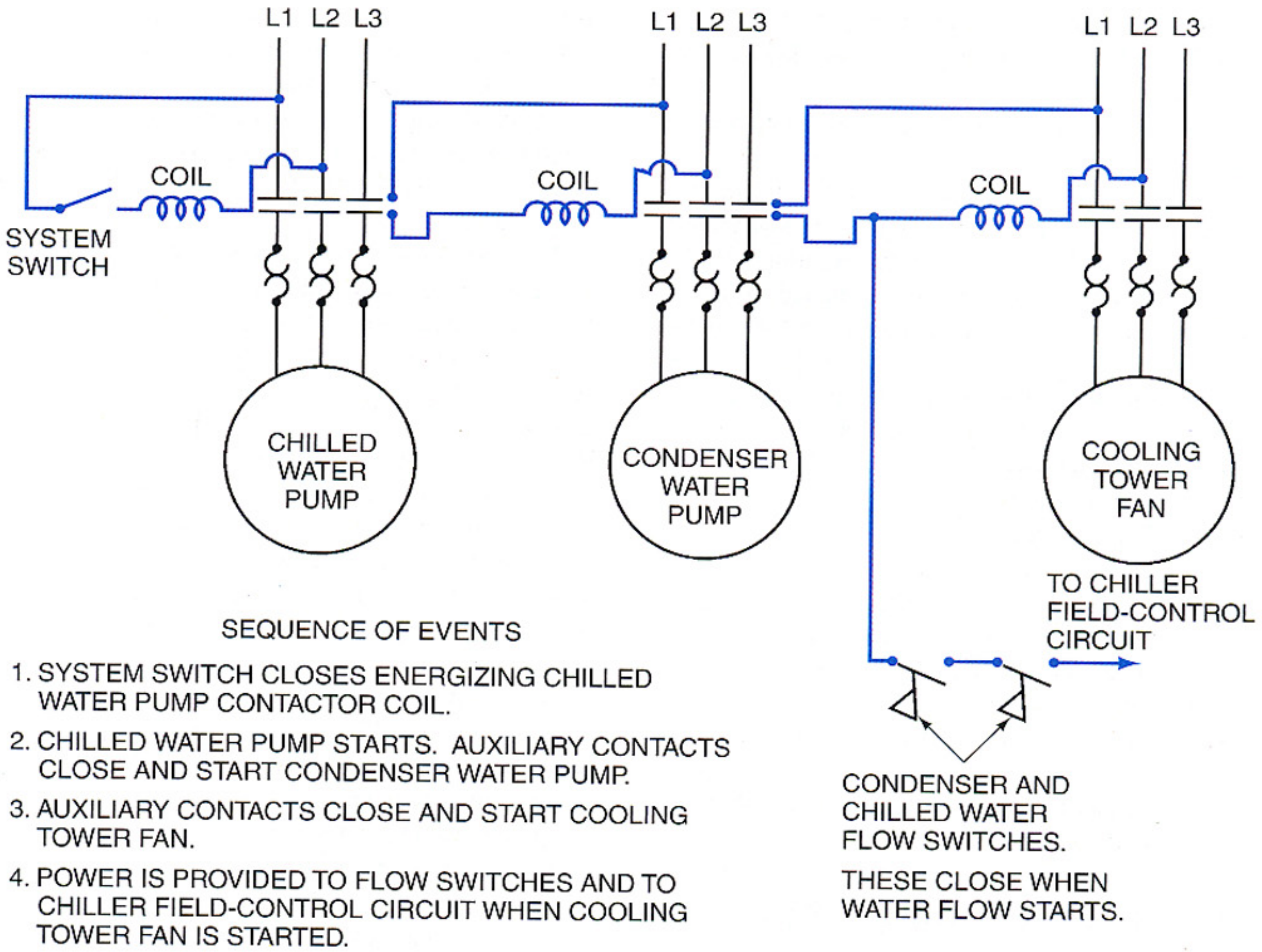


Figure 50–5 The control circuit for a typical chiller.

When the condenser water pump starts, a set of auxiliary contacts make and pass power to the cooling tower fan and the chiller circuit, **Figure 50–5.** When the signal is received at the chiller control circuit, the compressor should start. This signal is often called the field control circuit because it is the circuit furnished by the contractor to the manufacturer's control circuit. If a chiller should not start, the first thing the technician should do is check the field circuit to see if it is satisfied. A technician should know where the field circuit is wired to the chiller circuit for each chiller on the job where there are several chillers. A quick check at this point will tell whether there is a field circuit problem (flow switches, pump interlock circuit, outdoor thermostat, and often the main controller) or a chiller problem. If there is no field control circuit power, there is no need to look at the chiller until there is power. Many chillers have a ready light that shows that the field control circuit is energized.

Different chillers have different starting sequences, usually depending on the type of lubrication the compressor has. When the chiller has a positive displacement compressor (scroll, reciprocating, or rotary screw), the compressor will start soon after the field control circuits are satisfied. Some manufacturers may have a time delay before the compressor starts after the field circuit is satisfied, but the compressor should start soon. Look for a time-delay circuit and make note of it and what the time delay is for any system, so you will not be waiting and wondering what the problem is. The technician may think there is a problem only to have the chiller start up unexpectedly after a planned time delay. The reciprocating, scroll, and rotary screw compressors are lubricated from within and do not have a separate oil pump that must be started first. The reciprocating and the rotary screw compressors will start up unloaded and will begin to load when oil pressure is developed. The scroll compressor does not have compressor unloading capabilities and starts up under load.

50.2 SCROLL CHILLER START-UP

Scroll chillers are either air or water cooled. Regardless of the type, before attempting to start the chiller make sure the water for the chilled water circuit is at the correct level. The system must be full. Then operate the chilled water pump and verify the water flow using pressure drop across the chiller. Make sure that all valves in the refrigerant circuit are in the correct position, usually back seated. Visually check the system for leaks. Oil on the external portion of a fitting or valve is a sure sign of a leak as oil is entrained in the refrigerant. The compressor will have crankcase heat and it must be energized for the length of time the manufacturer requires, usually 24 h. Do not start the compressor without adequate crankcase heat, or compressor damage may occur.

When the chiller is air cooled, it will be located outside. The chiller barrel will have a heater to prevent it from freezing in the winter. Be sure this heater is wired and operable. If you do not do this at start-up, you may forget it when winter arrives. This heat strip is thermostatically controlled and will shut off when not needed.

When air cooled, make sure that the condenser fans are free to turn.

When the chiller is water cooled, the water-cooled condenser portion must be in operation. The cooling tower must be full of fresh water and the condenser water pump must be started. Make sure that water flow is established. You can look at the tower and verify this or you can check the pressure drop across the condenser.

Check to see that the field control circuit is calling for cooling. If all of the preceding requirements are met, the chiller should be ready to start.

When the chiller is started:

1. Observe suction pressure.
2. Observe discharge pressure.
3. Check the compressor for liquid floodback.
4. Check the entering- and leaving-water temperature on the chiller and the condenser entering- and leaving-water temperature for water-cooled units.

When the chiller is operating normally, it can usually be left unattended except for the water tower when the unit is water cooled. The water tower should have regular observation and maintenance.

50.3 RECIPROCATING CHILLER START-UP

The reciprocating chiller may be either air or water cooled. When air cooled, it may be located outside and a heat strip will be applied to the chiller barrel to prevent freezing in the cold. The heat strip is thermostatically controlled and only operates when needed.

Before starting a reciprocating chiller, make sure that the oil level in the sight glass is correct, usually from 1/4 to 1/2 level at the sight glass. Follow the manufacturer's instruction on oil level. When the level is high, refrigerant may be in the oil; check for crankcase heat. Reciprocating chillers will have crankcase heaters to prevent refrigerant migration to the crankcase during the off cycle. When the crankcase heat is on, the compressor will be warm to the touch, **Figure 50–6.** This crankcase heat must be energized for the prescribed length of time before start-up to prevent damage to the compressor. Refrigerant in the oil will dilute the lubrication quality of the oil and can easily cause bearing damage that does not show up immediately. The safe time for crankcase heat to be energized is 24 h unless the manufacturer states otherwise. It is not good practice to ever turn the crankcase heat off, even during winter shutdown because refrigerant will migrate to the crankcase, and it is not easy to boil it out to the extent that the oil is at the correct consistency for proper lubrication.

When the compressor is started, the pressures can be observed when there are panel gages. Typically, chillers over 25 tons have gages permanently installed by the manufacturer. These gages may be isolated by means of a service valve to prevent damage to the gages during long periods of running time so these valves will need to be opened for reading the gages. It is not good practice to leave the gage valves open all the time because the gage mechanism will experience considerable wear during normal operation from reciprocating compressor gas pulsations. These gages are for intermittent checking purposes. The technician should check these gages for accuracy from time to time because they cannot be relied on during the entire life of the chiller.

Many chillers that are manufactured today have light emitting diode (LED) readouts that show the pressures and temperatures. These pressures are registered with transducers and changed to an electrical or electronic signal for use in the electronic control system. The control system may use these signals for trouble and analysis and may have a history of operating conditions stored in memory. This can be valuable for troubleshooting as it can show any trends, such as pressure drop changes or suction and discharge pressure changes.

If a chiller has been secured for winter, the technician may have pumped the refrigerant into the receiver and the valves may need to be repositioned to the running position, which is back seated for any valve that does not have a control operating from the back seat. **Figure 50–7** shows an example of a valve in which the low-pressure control is fastened to the gage port on the back seat of the valve. If the valve is back seated, the low-pressure control will not be functional because it is isolated.

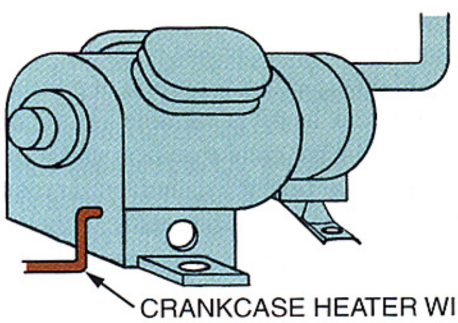


Figure 50–6 Heat from a crankcase heater.

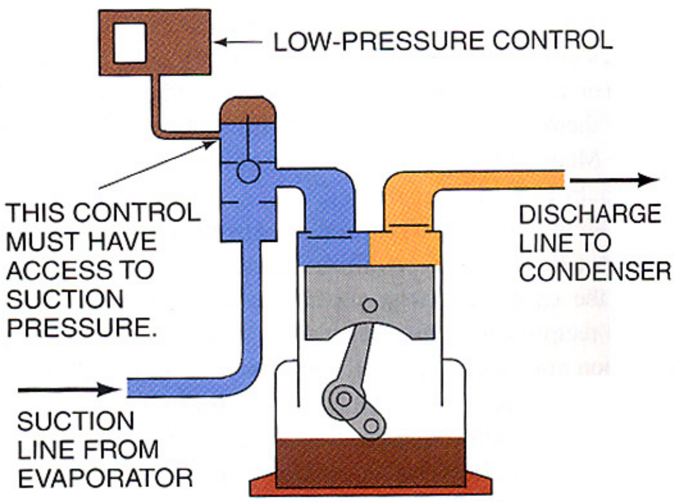


Figure 50–7 Service valve positions.

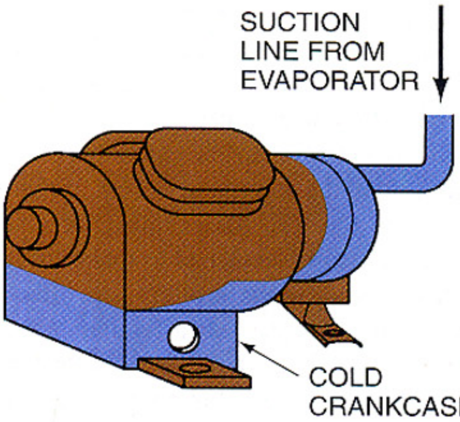


Figure 50–8 A compressor crankcase that is cold because of liquid refrigerant returning to the compressor.

When the compressor is started, it will start up unloaded until the oil pressure builds up and loads the compressor. An ammeter can be applied to the motor leads to determine what the level of load is on the compressor. When it is fully loaded, the amperage should be close to full load.

As the system temperature begins to pull down, the technician may notice that the oil level in the compressor rises and foams. This is normal for many systems, but the oil level should reach normal level after a short period of operation, normally within 15 min. The compressor is suction cooled and the technician should ensure that liquid refrigerant is not flooding back into the compressor during the running cycle. This can be determined by feeling the compressor housing; the compressor motor should be cold where the suction line enters, then it should gradually become warm where the motor housing reaches the compressor housing. The compressor crankcase should never be cool to the touch after 30 min of running time or liquid refrigerant should be suspected to be flooding back, **Figure 50–8.**

50.4 ROTARY SCREW CHILLER START-UP

The rotary screw chiller may be either air or water cooled. If it is air cooled, it will be located outdoors and the heat for the chiller barrel should be verified. Again, it is thermostatically controlled and will only operate when needed.

The compressor must have crankcase heat before start-up. Again, most manufacturers require that this heat be energized for 24 h before start-up. Start-up without crankcase heat can cause compressor damage.

The water flow must be verified through the chiller and the condenser if water cooled. The best way to verify this is to use pressure gages.

All valves must be in the correct position before start-up. Check the manufacturer's literature for valve positions. If the chiller was pumped down for winter, the correct procedures must be followed to let the refrigerant back into the evaporator before start-up.

Check the field control circuit to make sure that it is calling for cooling.

When all of the preceding is complete, the chiller is ready to start.

Start the compressor and watch for it to load up and start cooling the water. Observe the following:

1. Suction pressure
2. Discharge pressure
3. Water temperature, both chiller and condenser when water cooled
4. Liquid flooding back to the compressor

When the chiller is operating normally, it can usually be left unattended except for the water tower when the unit is water cooled. The water tower should be observed and maintained regularly.

50.5 CENTRIFUGAL CHILLER START-UP

Centrifugal chillers often need to be started and watched for the first few minutes because of the separate oil sump system. When the chiller is centrifugal, the oil sump should be checked before a start-up is tried. You should look for the following:

1. Correct oil sump temperature, from 135°F to 165°F, depending on the machine manufacturer. NOTE: Do not attempt to start a compressor unless the oil sump temperature is within the range the compressor manufacturer recommends or serious problems may occur. After the machine has been operating for some time, check the bearing oil temperature to be sure that it is not overheating. If overheating occurs, check the oil cooling medium, usually water.
2. Correct level of oil in the oil sump. If the oil level is above the glass, it may be full of liquid refrigerant. Ensure that it is the correct temperature. You may start the oil pump in manual and observe what happens. If in doubt, call the manufacturer for recommendations. Unless you have experience as to what to do, do not try to start the compressor; marginal oil pressure may cause bearing damage.
3. Start the oil pump in manual and verify the oil pressure before starting the compressor, then turn it to automatic before starting the compressor.

When the chiller is started, the compressor oil pump will start and build oil pressure first. When satisfactory oil pressure is established, the compressor will start and run up to speed then change over to the run-winding configuration. This could be autotransformer or wye-delta. The centrifugal compressor starts unloaded and only begins to load up after the motor is up to speed. This is accomplished with the prerotation guide vanes mentioned earlier. When the chiller is up to speed, the prerotation vanes begin to open and will open to full load unless the machine demand limit control stops the vanes at a lower percent of full load.

When the chiller compressor starts to work, pull full- or part-load current, the technician should observe the pressure gages. The technician should look for problems such as:

1. The suction pressure, operating too low or too high. The technician should mark on the gage front or on a notepad the expected operating suction pressure for normal operation, which would be at design water temperature. Typically this would be 45°F leaving water.

occurring problems can be plotted. For example, if the cooling tower water treatment has not been working and the condenser water tubes are beginning to have a mineral buildup, the condenser water approach will begin to spread. An alert operator will notice this and take corrective action. This action may be to change the water treatment and certainly to clean the water tubes because the heat exchange has been reduced.

50.9 AIR-COOLED CHILLER MAINTENANCE

Air-cooled chillers require little maintenance, which is one reason why they are so popular. The fan section of these chillers may require lubrication of the fan motors, or the motors may have permanently lubricated bearings. It is typical for these chillers to have multiple fans and motors. The motor horsepower can be reduced in this manner and the fans can be direct drive. This eliminates belts and the need for routine lubrication in many cases. If one fan fails, the chiller can continue to operate.

The following electrical maintenance should be performed annually for a typical system:

1. Inspect the complete power wiring circuit because this is where the most current is drawn. Look for places where hot spots have occurred. For example, the wires on the compressor contactor should show no signs of heat. The insulation should not appear to have been hot. If so, this must be repaired. This can be done by cutting the wire back to clean copper. If the lead is not long enough, a splice of new wire may be needed or the wire may need to be replaced back to the next junction.
2. Inspect the motor terminal connections at the compressor. These should not show any discoloration or a repair should be made. A hot terminal block can cause refrigerant leaks so the wiring should be inspected carefully.
3. The contacts in all contactors should be inspected and replaced if pitting is excessive. If excess pitting begins to occur, it is likely that the contacts will weld shut in the future and the motor cannot be stopped using the contactor. This can lead to single phasing of a wye-wound motor if any two contacts weld shut. Motor burn will then occur because there is nothing to shut the motor off except the breaker, **Figure 50–9.**

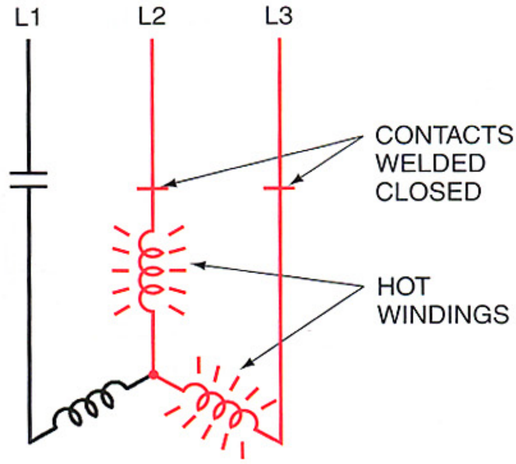


Figure 50–9 Welded contacts on a wye-wound motor.

4. The compressor motor should be checked for internal ground using an ohmmeter that can check ohm readings in the millions of ohms. This meter is called a megohmmeter. **Figure 50–10** shows an example of a basic megohmmeter. This instrument uses about 50 to 500 V DC to check for leaking circuits; others may use much higher voltages and have a crank-type generator to achieve the high voltage. The correct motor manufacturer's recommendations should be used for the allowable leakage of the circuit. Typically, a motor should not have less than a 100-megohm circuit to ground or to another winding in the case of a delta-type motor or dual-voltage motor, **Figure 50–11.** The required reading depends on the motor temperature because the temperature changes the requirements. You should consult the manufacturer if proper guidelines are not known. A reliable local motor shop can also give you guidelines to use. It is important to start a process of megging a motor when it is new and keep good records. If the motor megohm value begins to reduce, it is a sign that moisture or some other foreign matter may be getting in the system.

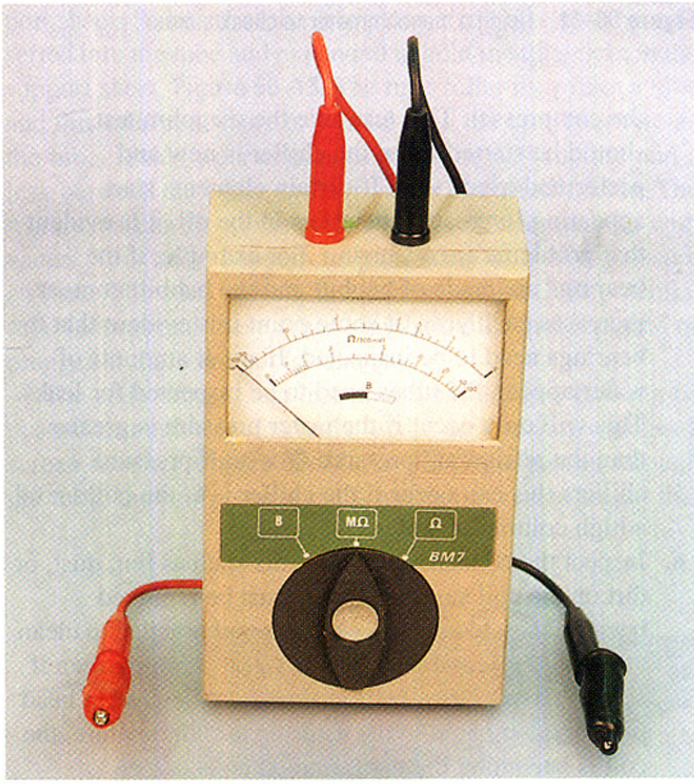


Figure 50–10 A megohmmeter for checking ground circuits in motors. *Photo by Bill Johnson*

5. An oil sample from the compressor crankcase can be sent to an oil laboratory to determine the condition of

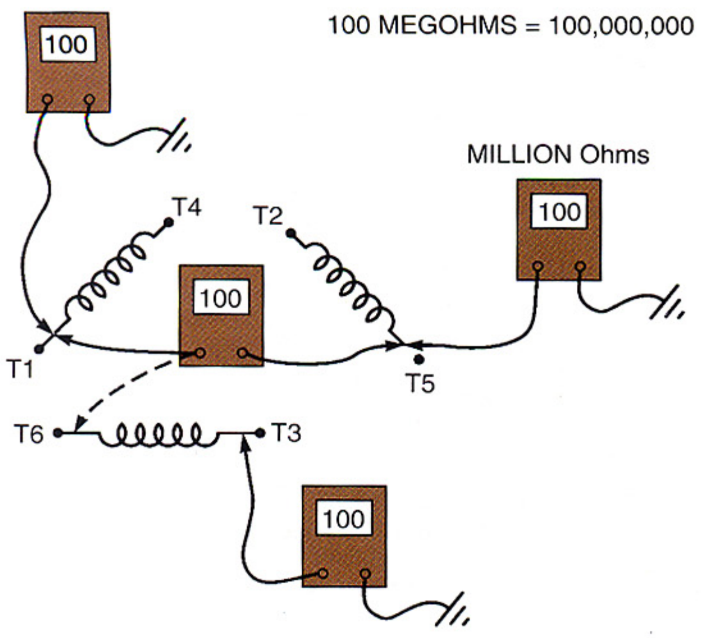


Figure 50–11 Using a megohmmeter to check a motor.

the compressor. This test, like the megohm test, should be started when the chiller is new and performed every year. If certain elements start appearing in greater quantities in the oil, it is evident that problems are occurring. For example, if the bearings are made of babbitt and the babbitt content increases each year, at some point it is evident that the bearings need to be inspected. If small amounts of water appear, the tubes need to be inspected for leaks. This will only occur if the water pressure is greater than the refrigerant pressure. For high-pressure chillers this can occur if the chiller is at the bottom of a high column of water.

6. Inspect the condenser for deposits such as lint, dust, or dirt on the coil surface. These must be removed because they block airflow. It is good practice to clean all air-cooled condensers once a year or more often if needed. If the operating log shows an increase in head pressure compared to the entering air temperature, the coil is becoming dirty. Air-cooled coils can be deceiving in that they can be dirty and you may not notice it because the dirt may be imbedded in the interior of the coil. This cannot be seen until the coil is cleaned. A coil should be cleaned by saturating the coil with an approved detergent and then washing the coil backward, in reverse to the direction of the airflow, called backwashing. An apparently clean coil may yield a large volume of dirt from the interior of the coil.

50.10 WATER-COOLED CHILLER MAINTENANCE

Routine maintenance may involve cleaning the equipment room and keeping all pipes and pumps in good working order. The technician should ensure that the room and equipment are kept clean and in good order. It is always easier to keep a room clean than to have to clean it when the chiller breaks down and needs to be disassembled. The cooling tower should be checked to be sure the strainer is not restricted. Look at the water for signs of rust, dirt, and floating debris and clean if necessary. The water treatment should be checked on a regular basis. Some systems call for the operating technician to perform water analysis on a daily basis to check for mineral content. When the water treatment gets out of balance, the technician should either make adjustments or call the water treatment company. Someone must be in charge of keeping the water chemicals at the correct level for best performance.

Annual maintenance should involve checking the complete system and chiller to prepare it for a season of routine maintenance. Some chillers operate year round and are only shut down for annual maintenance. During this maintenance, it is often wise to bring in the factory maintenance representatives. These technicians are privileged to know what is happening across the nation or around the world with regard to any service or failure problems with their equipment. They will provide the best technical knowledge for your equipment. Often, these technicians will perform the complete start-up procedure for your equipment just as though it is for the first time. All controls may be checked at this time to be sure they will perform up to standard. It is not uncommon for a system to operate for years without having a control checkup and the system then fail only to discover that a control has failed and should have saved the system but did not. A control checkup once a year can be good insurance against many failures.

During annual maintenance, all electrical connections should be checked; refer to the electrical maintenance for air-cooled systems stated previously. Water-cooled equipment has the same electrical symptoms.

The water-cooled condenser should be inspected on the inside every year by draining the water from the condenser and removing the heads. The tubes should be clean. You can tell when a tube is clean when you take a light and shine inside the tube, and all you see is copper tube with a dull copper finish. A penlight is very good for this. The penlight can be inserted inside the tube. Any film on the inside of the tube must be removed for proper heat exchange. Many technicians believe that if the tube is open enough to allow a good water flow it is clean. This is not true; the tube must be clean down to bare copper for proper efficiency.

When it is discovered that the tubes are dirty, several approaches may be used. The tubes may be brushed with a nylon brush that is the size of the inside of the tube. This is customarily done with a machine that turns the brush while flushing the tube with water. Some manufacturers recommend using a brush with fine brass bristles if the nylon will not remove the scale from the tubes. Check with the manufacturer because some do not recommend this practice. Always keep the tubes wet until it is time to brush them or the scale will become more hardened. It is good practice to be prepared to brush the tubes before removing the heads so the tubes will stay wet until they are brushed.

If brushing the tubes will not work, the tubes may be chemically cleaned using the recommended acid for the application, **Figure 50–12.**

NOTE: This is a very delicate process because the tubes may be damaged. Consult the chemical and chiller manufacturer for this procedure.

It may be good practice to let the chemical manufacturer clean the tubes; then if damage occurs, they are responsible. However the process is accomplished, make sure that the chemicals are neutralized or damage to the tubes may occur. The damage that may occur would be severe because the chemicals may eat the tube material, and leaks between the water and refrigerant may occur.

After the tubes have been chemically treated, they may be clean, or the chemicals may just soften the scale and the tubes may need brushing to remove the scale.

The water pump should be checked to make sure the coupling is in good condition. SAFETY PRECAUTION: This can be done by turning off the power, locking and tagging the disconnect, and removing the cover to the pump coupling. If materials such as filings are found inside the coupling housing, deterioration of the coupling should be suspected. Some couplings are made of rubber and some are steel. Look for the flexible material that takes up the slack to see whether it is wearing.

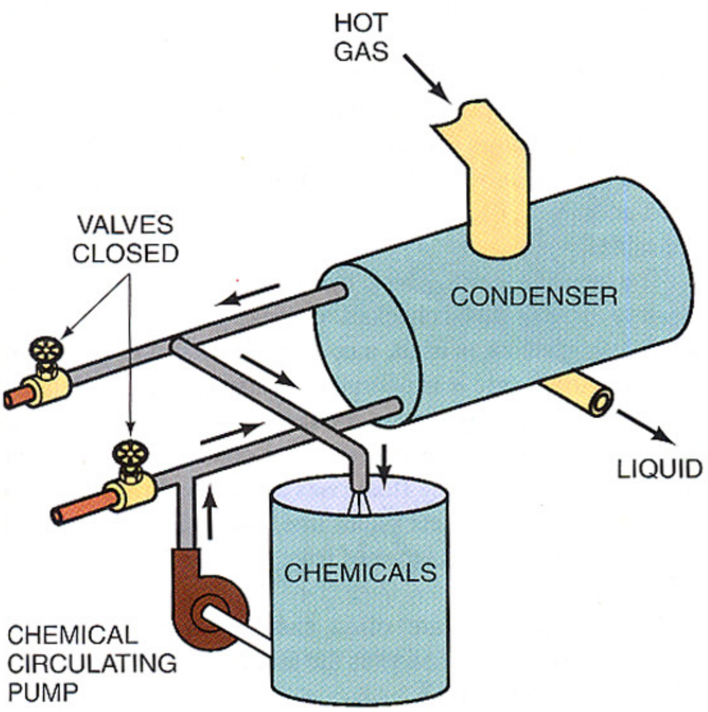


Figure 50–12 Chemically cleaning condenser tubes.

After the condenser has been cleaned, the condenser tubes may be checked for defects such as stress cracks, erosion, corrosion, and wear on the outside by means of an eddy current check. This test should be performed on the evaporator tubes as well. This check determines if there are irregularities in the tube. One common problem is wear on the tube's outer surface where it is supported by the tube support sheets. Each set of tubes has a different type of stress applied to the outside. In the condenser, the hot discharge gas is pulsating as it enters the condenser and has a tendency to shake the tubes. In the evaporator, the boiling refrigerant shakes the tubes. The tube support sheets are sheets of steel that the tubes pass through to help prevent this action and are evenly spaced between the end sheets. They are located in the condenser and the evaporator. When the evaporator or condenser shell is tubed, the tubes are guided in place through the support sheets. When the tube is in place, a roll mechanism is inserted into the tube and expanded to hold the tube tight in the support sheet, **Figure 50–13.** The tube roller may miss a tube and this tube can shake or vibrate until the tube sheet wears the tube. If this wear continues, the tube will rupture and a leak between the water and refrigerant circuit will occur. The worst case can flood the chiller on the refrigerant side with water. This may happen in particular with low-pressure chillers. The eddy current test can be used to find potential tube failures and these tubes may be pulled and replaced or plugged if there are not too many.

The eddy current test instrument has a probe that can be pushed through the clean tube while an operator watches a screen monitor, **Figure 50–14.** As the probe passes through the tube, the probe sends out a magnetic current signal that

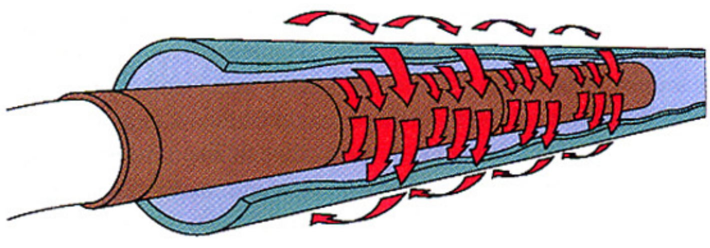


Figure 50–14 A probe for checking tubes using an eddy current tester can determine irregularities in the tubes.

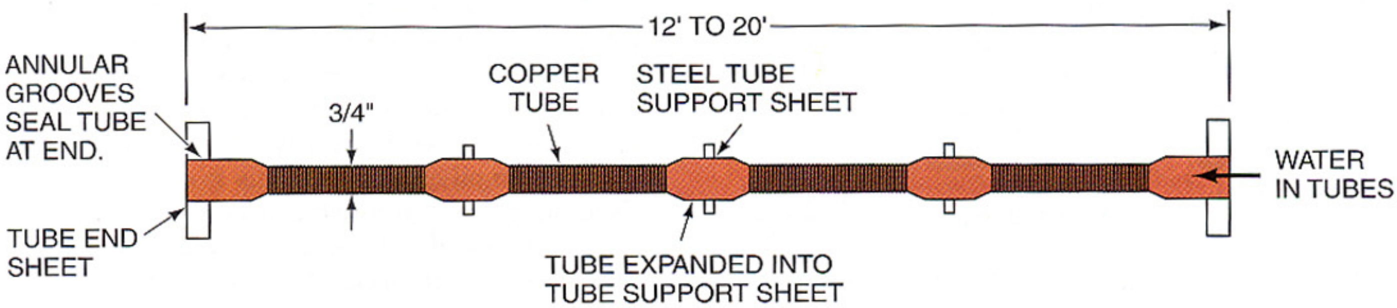


Figure 50–13 The tube assembly for a heat exchanger.

reacts with the tube and shows a profile on the screen monitor. When unusual profiles are noticed, the tube is marked for further study, which may involve comparing the profile to that of a known good tube. A decision may need to be made to pull or plug the tube. A tube failure in the middle of the cooling season can take days to repair, and it is good practice to find these problems in advance.

Remove and clean any strainers that may be in the piping. Some systems have a strainer before or after the pump. This should be checked and cleaned.

The cooling tower should be cleaned and scrubbed out, removing any residue that may have accumulated in the basin.

If the chiller and water pumps are to stand idle during the winter months, all precautions should be taken to prevent freezing of any components such as piping, sumps, pumps, or chiller if it is located where it may freeze. Even if a chiller is in a building, it is good practice to drain it during winter because if the building loses power and the interior freezes, it would be expensive if the chiller tubes were to freeze. It is easier to just drain it and not take a chance.

50.11 ABSORPTION CHILLED WATER SYSTEM START-UP

The absorption start-up is similar to any chiller; chilled water flow and condenser water flow must be established before the chiller is started. Ensure that the cooling tower water temperature is within the range of the chiller manufacturer's recommendations. If the absorption machine is started with the cooling tower water too cold, the lithium-bromide (Li-Br) may crystallize, causing a serious problem. In addition to this, the heat source must be verified whether it be steam, hot water, natural gas, or oil. Most absorption chillers are steam operated so the steam pressure must be available. If the chiller is operated from a boiler dedicated to it, the boiler must be started and operated until it is up to pressure.

The purge discharge may be monitored by placing the vacuum pump exhaust into a glass of water and looking for bubbles, **Figure 50–15.** If there are bubbles, it is a sure sign that noncondensables are in the chiller. It is pointless to start the chiller until the bubbles stop. Let the vacuum pump run even when the chiller is started (unless the manufacturer recommends not to) because often noncondensables will migrate to the purge pickup point after start-up.

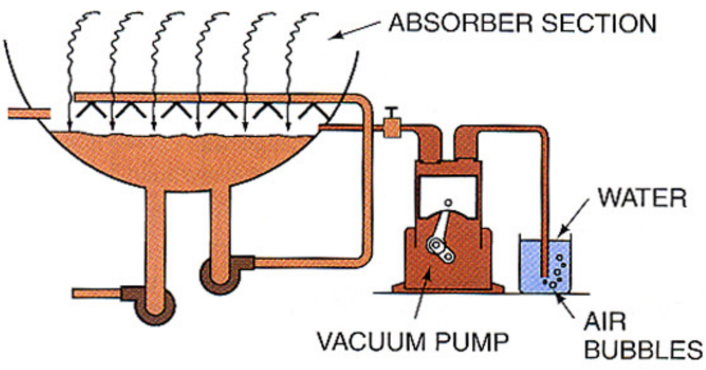


Figure 50–15 The vacuum pump exhaust is placed in a glass of water. When bubbles are observed, the vacuum pump is exhausting noncondensables.

When all systems are ready, the chiller may be started. The fluid pumps will start to circulate the Li-Br and the refrigerant and the heat source will start. The chiller will begin to cool in a very few minutes and this can be verified by the temperature drop across the chilled water circuit. When absorption chillers are refrigerating, they make a sound like ice cracking. When this sound begins to come from the machine, the chilled water temperature should begin to drop.

50.12 ABSORPTION CHILLER OPERATION AND MAINTENANCE

Absorption chillers must be observed for proper operation on a more regular basis than compression cycle chillers because they can be more intricate. Chiller manufacturers have different checkpoints to determine the chiller operation. The refrigerant temperature and the absorption fluid temperatures measured against the leaving chilled water temperatures are among a few. The manufacturer's literature must be consulted for the checkpoints and procedures. The maintenance of an operating log is highly recommended for absorption installations.

When the chiller is operating, it is good practice to pay close attention to the purge operation. If the chiller is requiring excessive purge operation, the machine may have leaks or it may be manufacturing excess hydrogen internally and need additives. The machine must be kept free of noncondensables.

The heat source may need maintenance. If it is steam, the steam valve should be checked for leaks and operating problems. When steam is used, a condensate trap will also need checking to be sure it is operating properly. The condensate trap ensures that only water (condensed steam) returns to the boiler. A typical condensate trap may contain a float. When the water level rises, the float rises and only allows water to move into the condensate return line, **Figure 50–16.** There are several other different types of trap; this one is shown as an example.

Condensate traps are often checked with an infrared checking device that measures the temperature on both sides of the trap, **Figure 50–17.**

When the chiller is operated using hot water, the hot water valve should be observed for proper operation and to ensure that there are no leaks.

Gas- or oil-operated machines will need the typical maintenance for these fuels. Oil in particular requires maintenance of the filter systems and nozzles.

The purge system may require the most maintenance with the absorption chiller. If there is a vacuum pump with the chiller, regular oil changes will help to make it last longer. Li-Br is salt and will corrode the vacuum pump on the inside. It is not recommended that a vacuum pump used for a compression cycle system be used on an absorption system because of the corrosion problem, but if one is used, extra care should be taken to change the oil immediately after use.

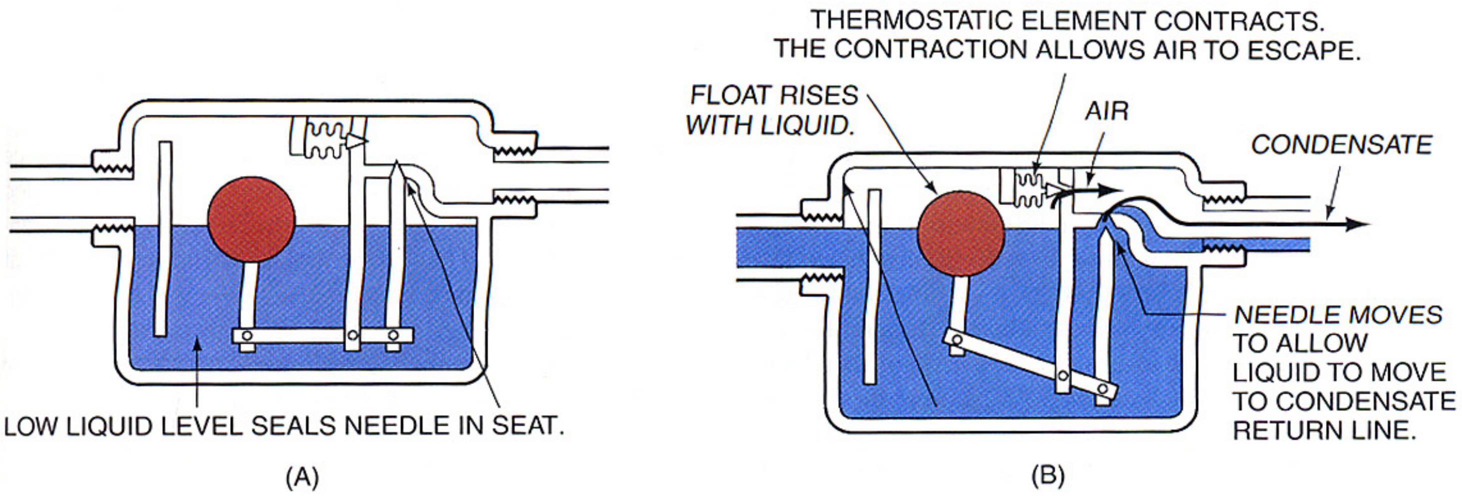


Figure 50–16 The condensate float trap for a steam coil.

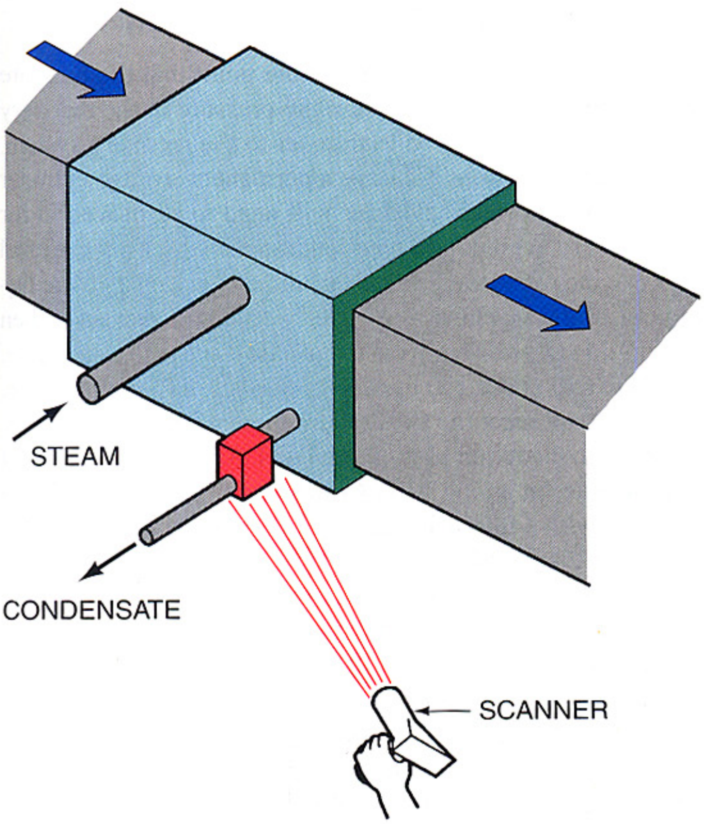


Figure 50–17 Checking a condensate trap using an infrared scanner.

Any Li-Br that is spilled in the equipment room will rust any metal it is in contact with. It is good practice to keep the area where it is handled washed with fresh water to prevent this. The machine and other equipment may need to be painted periodically for additional protection in these areas.

The system solution pump or pumps may require periodic maintenance. A check with the manufacturer will detail the type and frequency of this maintenance.

The machine room must be kept above freezing or the refrigerant (water) inside the machine will freeze and cause tube rupture problems. Unlike the other chillers, this water cannot be drained and must be protected.

The water pumps need regular maintenance as with any other system.

The steam or hot water valve and condensate trap should be inspected for any needed maintenance. A strainer will be located in the vicinity of the condensate trap and should be cleaned during the off season.

The cooling water must be maintained by cleaning and water treatment. Do not forget blowdown water. Absorption chillers operate at higher temperature than compression cycle chillers and good water treatment maintenance is vital because the tubes will become fouled much quicker.

Absorption chillers may need the tubes probed with an eddy current probe on a more regular basis than compression cycle chillers because of the higher temperatures in the condenser section. The tubes are stressed when the heat source is applied to these tubes and they expand and then contract when cooled during the off cycle. Checking with the manufacturer is a good idea.

50.13 GENERAL MAINTENANCE FOR ALL CHILLERS

Technicians who maintain chillers must be well qualified and should stay in contact with the manufacturers for the latest training schools and advice. Manufacturers receive feedback from all over the world on their equipment and know what is happening, such as with premature failures. They should share any potential problems with you to prevent future problems with your equipment. Technicians should attend factory seminars and schools and make friends with the factory technicians. The technician who works on or observes work on large equipment should learn what to do during all service procedures. Because factory technicians perform much of the service on large system chillers, the operating technician will be present to observe the service procedures and assist the factory technician. These procedures may be anything from routine checking of the controls to major overhaul of the equipment. The operating technician should be able to recognize the procedures. When the factory technician leaves, the operating technician must operate the equipment.

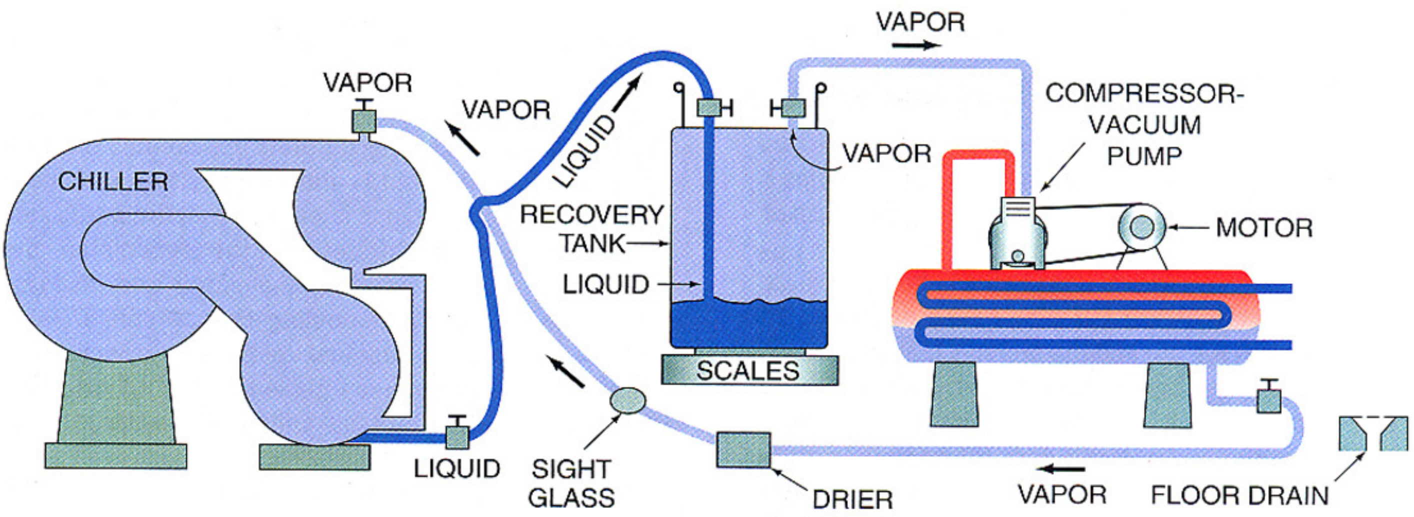


Figure 50–18 The recovery machine pulls vapor from the top of the recovery cylinder and puts it back into the chiller. This creates a low pressure in the recovery cylinder in relation to the chiller, and liquid moves into the recovery cylinder.

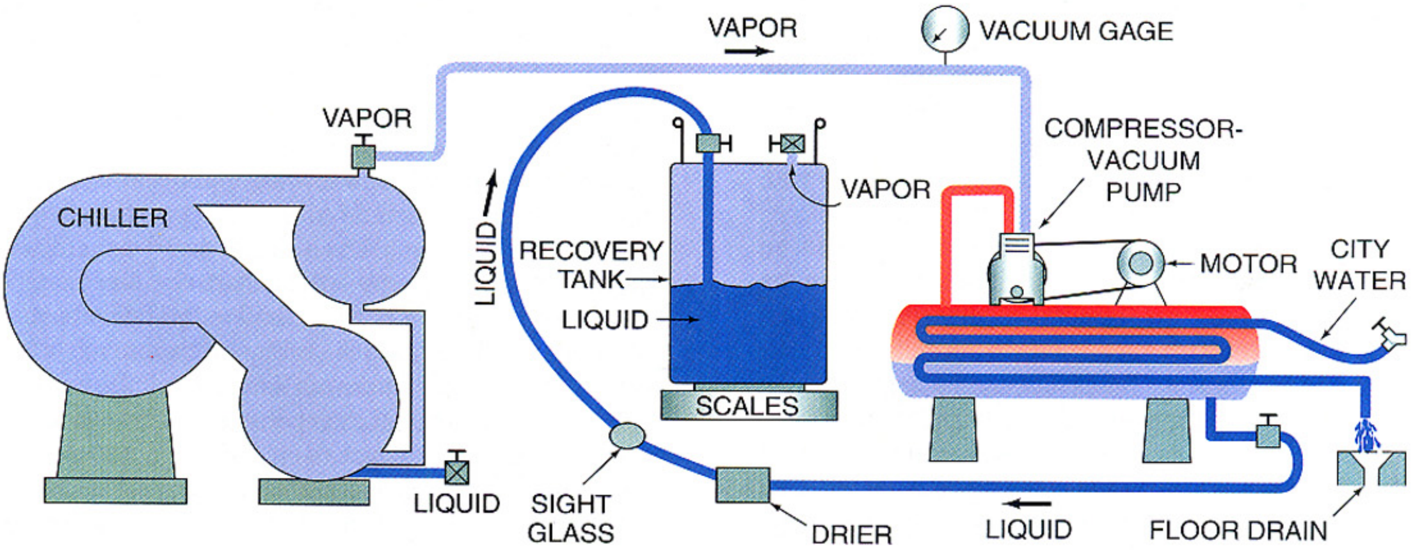


Figure 50–19 The flexible hoses are reconnected only to remove vapor from the chiller. It is condensed using water and moves to the recovery cylinder. The scales tell the technician when to stop adding refrigerant to the cylinder.

the drain. This is not a procedure that is used except for service, so a permanent water connection is not needed.

SAFETY PRECAUTION: When charging, vapor should be added only until the pressure inside the chiller is well above the pressure that corresponds to freezing. The freezing pressure is 17 in. Hg for R-11 and 20.3 in. Hg for R-123. The pressure in the machine must be above these two values before liquid refrigerant is introduced. Some technicians will circulate water through the evaporator water tubes and allow liquid to enter from the very beginning. This is taking a chance. If there is one tube in the shell that does not have water flowing, it is likely to freeze and split. Water will enter the shell when it thaws if it is split.

50.16 HIGH-PRESSURE CHILLERS

High-pressure chillers must be watched closely for leaks. A visual inspection is something that you can do any time you are at the machine. Where refrigerant leaks out, oil will leak out also. Any time a fresh oil spot appears, you should suspect a leak. You can use an electronic leak detector or soap bubbles to check the place out. Be sure to clean the soap bubbles off with water, or dust will collect on the spot, giving the impression that oil has leaked and dust has collected on the oil. Some systems are designed so the refrigerant may be pumped into the condenser for repairs on the low-pressure side of the system. Otherwise, the refrigerant may have to be recovered for major repairs. A recovery system and procedures similar to the push-pull system described above is used.

The recovery of high-pressure refrigerants is much like recovering low-pressure refrigerant by means of a push-pull system that will handle high-pressure refrigerants. The same rules apply for charging refrigerant into a high-pressure machine. Make sure the pressure in the machine is above the freezing point of the refrigerant before allowing liquid to enter the machine, or a chiller tube may be frozen and broken.