What is Refrigeration?

Refrigeration is the process of removing heat from one substance and transferring it to another substance. Or Refrigeration may be defined as the process of achieving and maintaining a temperature below that of the surroundings, the aim being to cool some product or space to the required temperature.

1. Natural Refrigeration

In olden days refrigeration was achieved by natural means such as the use of ice or evaporative cooling. In earlier times, ice was either:

1. Transported from colder regions,

2. Harvested in winter and stored in ice houses for summer use or,

3. Made during night by cooling of water by radiation to stratosphere.

2. Artificial Refrigeration

Refrigeration as it is known these days is produced by artificial means.

2.1 Vapour Compression Refrigeration Systems:

The basis of modern refrigeration is the ability of liquids to absorb enormous quantities of heat as they boil and evaporate. Professor William Cullen of the University of Edinburgh demonstrated this in 1755 by placing some water in thermal contact with ether under a receiver of a vacuum pump. The evaporation rate of ether increased due to the vacuum pump and water could be frozen. This process involves two thermodynamic concepts, the vapour pressure and the latent heat. A liquid is in thermal equilibrium with its own vapor at a pressure called the saturation pressure, which depends on the temperature alone. If the pressure is increased for example in a pressure cooker, the water boils at higher temperature. The second concept is that the evaporation of liquid requires latent heat during evaporation. If latent heat is extracted from the liquid, the liquid gets cooled. The temperature of ether will remain constant as long as the vacuum pump maintains a pressure equal to saturation pressure at the desired temperature. This requires the removal of all the vapors formed due to vaporization. If a lower temperature is desired, then a lower saturation pressure will have to be maintained by the vacuum pump. The component of the modern day refrigeration system where cooling is produced by this method is called *evaporator.*

If this process of cooling is to be made continuous the vapors have to be recycled by condensation to the liquid state. The condensation process requires heat rejection to the surroundings. It can be condensed at atmospheric temperature by increasing its pressure. The process of condensation was learned in the second half of eighteenth century. U.F. Clouet and G. Monge liquefied SO_2 in 1780 while van Marum and Van Troostwijk liquefied NH_3 in 1787. Hence, a compressor is required to maintain a high pressure so that the evaporating vapours can condense at a temperature greater than that of the surroundings.

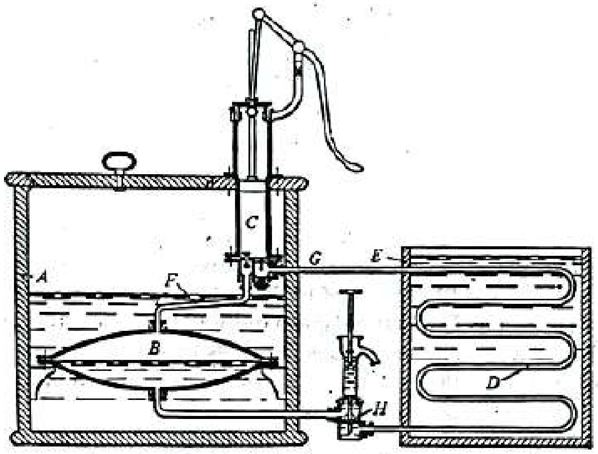


Fig. 1.1. Apparatus described by Jacob Perkins in his patent specification of 1834. The refrigerant (ether or other volatile fluid) boils in evaporator B taking heat from surrounding water in container A. The pump C draws vapour away and compresses it to higher pressure at which it can condense to liquids in tubes D, giving out heat to water in vessel E. Condensed liquid flows through the weight loaded valve H, which maintains the difference of pressure between the condenser and evaporator. The small pump above H is used for charging the apparatus with refrigerant.

Examples:

Domestic refrigeration systems

Air conditioning systems

2.2 Vapour Absorption Refrigeration Systems

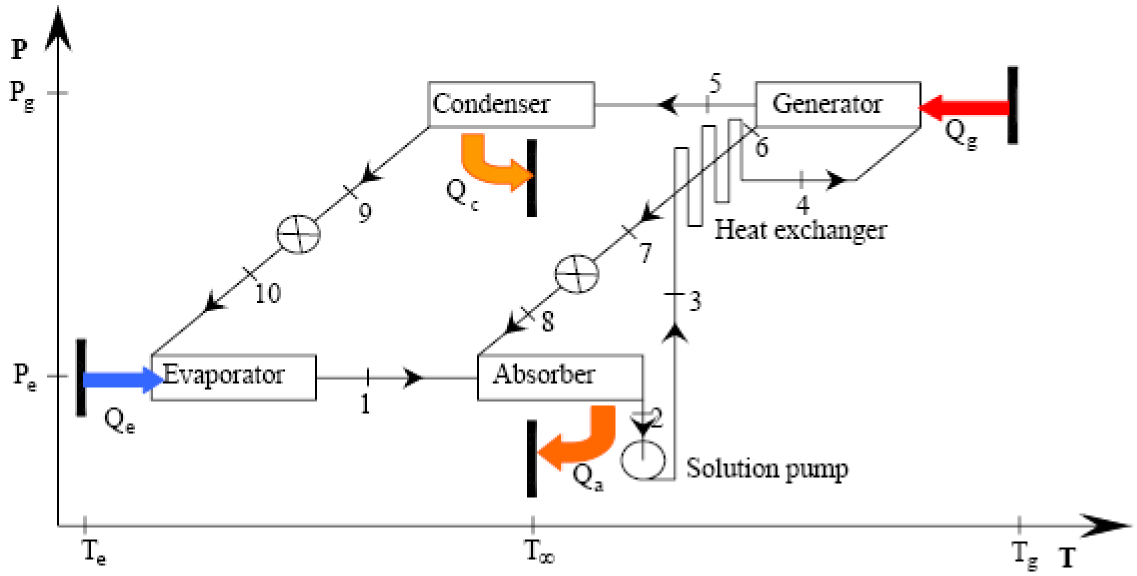
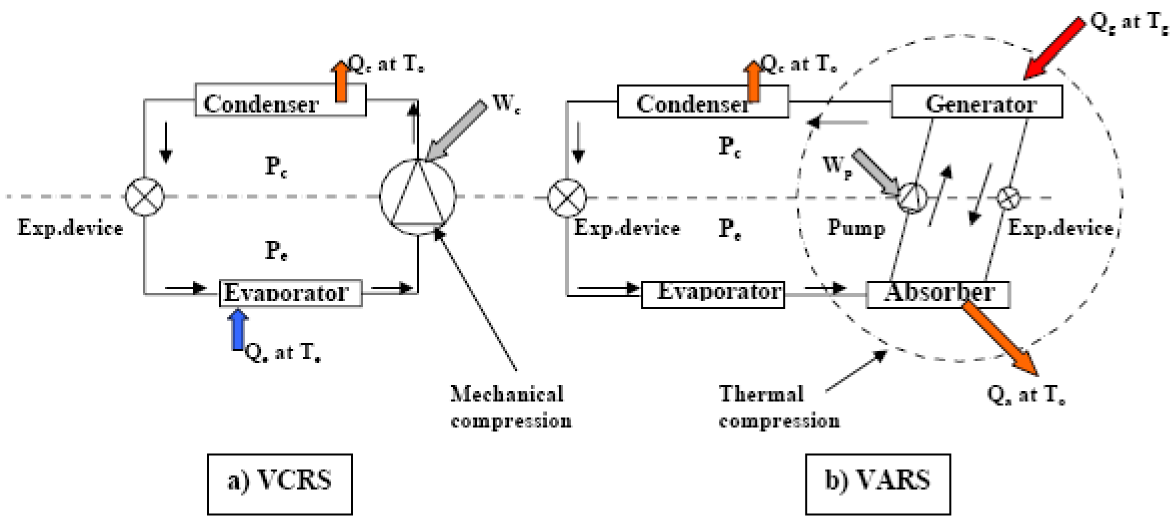
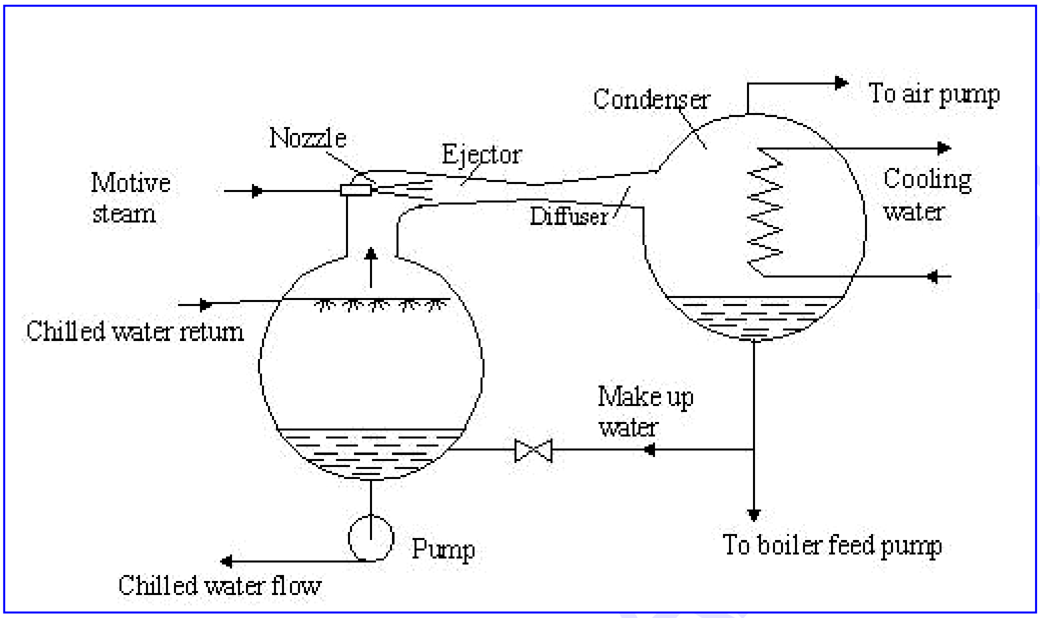


Fig.14.7: Basic vapour absorption refrigeration system with a solution heat exchanger on a pressure vs temperature diagram



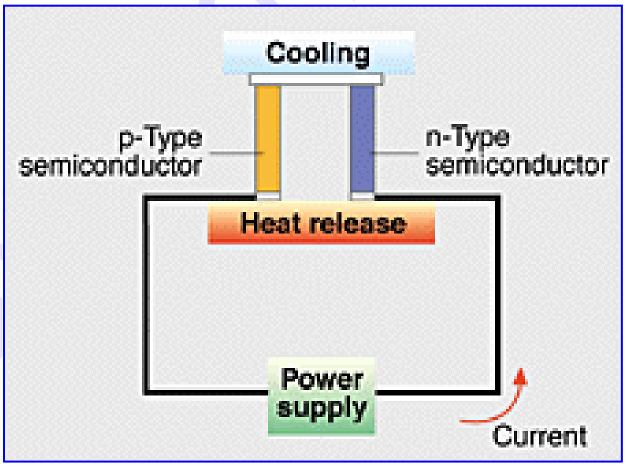
Figs.14.2: a) Vapour compression refrigeration system (VCRS)
b) Vapour Absorption Refrigeration System (VARS)

2.3 Steam Jet Refrigeration System:



Schematic of a steam jet refrigeration system

Thermoelectric Refrigeration Systems



Schematic of a thermoelectric refrigeration system

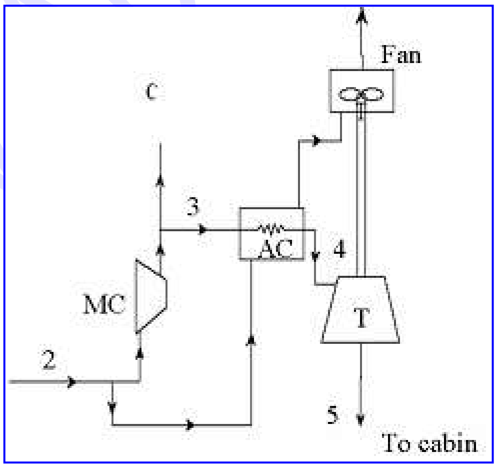
2.5. **Air Standard Cycle analysis**

Air cycle refrigeration systems belong to the general class of gas cycle refrigeration systems, in which a gas is used as the working fluid. The gas does not undergo any phase change during the cycle; consequently, all the internal heat transfer processes are sensible heat transfer processes. Gas cycle refrigeration systems find applications in air craft cabin cooling and also in the liquefaction of various gases. In the present graph gas cycle refrigeration systems based on air are discussed.

Air cycle refrigeration system analysis is considerably simplified if one makes the following assumptions:

i. The working fluid is a fixed mass of air that behaves as an ideal gas
ii. The cycle is assumed to be a closed loop cycle with all inlets and exhaust processes of open loop cycles being replaced by heat transfer processes to or from the environment
iii. All the processes within the cycle are reversible, i.e., the cycle is internally reversible
iv. The specific heat of air remains constant throughout the cycle

An analysis with the above assumptions is called as cold Air Standard Cycle (ASC) analysis. This analysis yields reasonably accurate results for most of the cycles and processes encountered in air cycle refrigeration systems. However, the analysis fails when one considers a cycle consisting of a throttling process, as the temperature drop during throttling is zero for an ideal gas, whereas the actual cycles depend exclusively on



the real gas behavior to produce refrigeration during throttling.

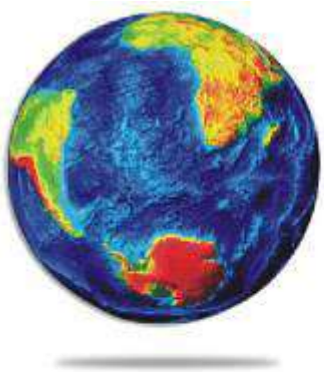
Schematic of a simple aircraft refrigeration cycle

What is Heat?

Heat is a form of energy

What is Heat?

Heat is a form of energy. Every object on earth contains heat energy in both quantity and intensity.



Quantity and Intensity

Heat intensity is measured by its temperature, commonly in either degrees **Fahrenheit** (°F) or degrees **Celsius** (°C). If all heat were removed from an object, the temperature of the object would decrease to -459.6°F [-273.2°C].

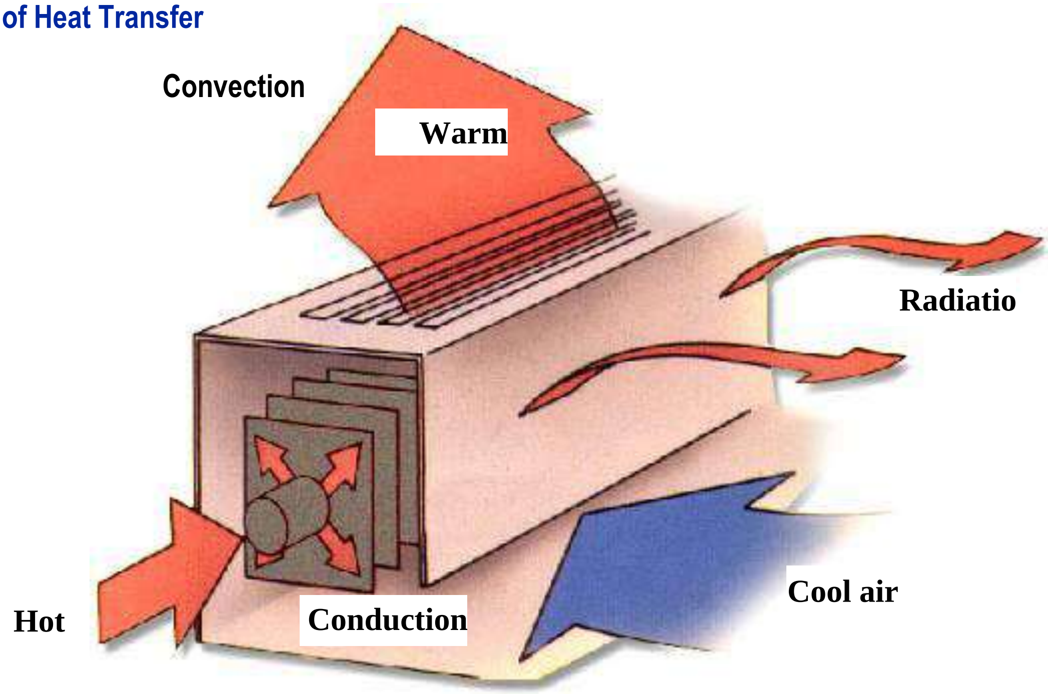
This temperature is referred to as “absolute zero” and is the temperature at which all-molecular activity stops. The quantity of heat contained in an object or substance is not the same as its intensity of heat. For example, the hot sands of the desert contain a large quantity of heat, but a single burning candle has a higher intensity of heat.

These two different masses of water contain the same quantity of heat, yet the temperature of the water on the left is higher. Why? The water on the left contains more heat per unit of mass than the water on the right. In other words, the heat energy within the water on the left is more concentrated, or intense, resulting in the higher temperature. Note that the temperature of a substance does not reveal the quantity of heat that it contains.

In the English system of units, the quantity of heat is measured in terms of the **British Thermal Unit** (Btu). The Btu is defined as the quantity of heat energy required to raise the temperature of 1 lb of water by 1°F. Similarly, in the metric system of units, the quantity of heat is measured in terms of the **kilocalorie** (kilogram-calorie or kcal). The kcal is defined as the amount of heat energy required to raise the temperature of 1 kg of water 1°C. Alternatively, in the System International (SI) metric system, heat quantity can be expressed using the unit **kiloJoule** (kJ). One kcal is equal to 4.19 kJ.

Principles of Heat Transfer

Methods of Heat Transfer



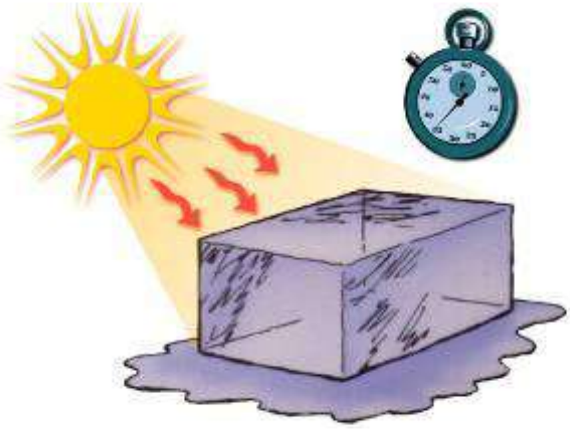
The third principle is that heat is transferred from one substance to another by one of three basic processes: conduction, convection, and radiation. The device shown is a baseboard convector that is commonly used for heating a space. It can be used to demonstrate all three processes of transferring heat. Hot water flows through a tube inside the convector, warming the inside surface of the tube. Heat is transferred, by conduction, through the tube wall to the slightly cooler fins that are attached to outside surface of the tube.

Conduction is the process of transferring heat through a solid. The heat is then transferred to the cool air that comes into contact with the fins. As the air is warmed and becomes less dense, it rises, carrying the heat away from the fins and out of the convector. This air movement is known as convection current.

Convection is the process of transferring heat as the result of the movement of a fluid. Convection often occurs as the result of the natural movement of air caused by temperature (density) differences. Additionally, heat is radiated from the warm cabinet of the convector and contacts cooler objects within the space.

Radiation is the process of transferring heat by means of electromagnetic waves, emitted due to the temperature difference between two objects. An interesting thing about radiated heat is that it does not heat the air between the source and the object it contacts; it only heats the object itself.

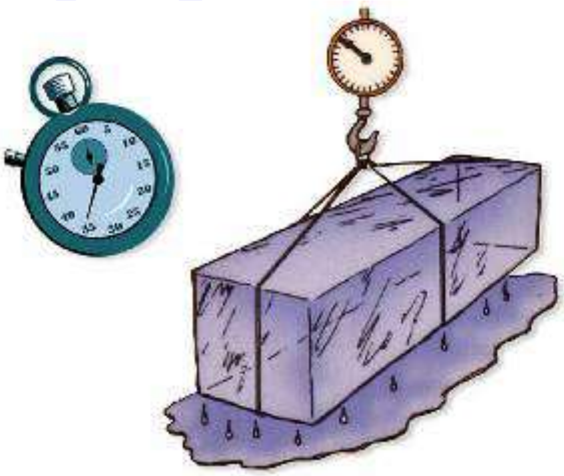
Rate of Heat Flow



In refrigeration, as in heating, emphasis is placed on the rate of heat transfer, that is, the quantity of heat that flows from one substance to another within a given period of time. This rate of heat flow is commonly expressed in terms of Btu/hr—the quantity of heat, in Btus, that flows from one substance to another over a period of 1 hour.

Similarly, in the SI metric system of units, the rate of heat flow is expressed in terms of kilowatts (kW), which are equivalent to kJ/sec. Kilowatts describe the quantity of heat, in kJ, that flows from one substance to another over a period of 1 second.

Ton of Refrigeration



12,000 Btu/hr
[3.517 kW]

In the English system of units, there is a larger and more convenient measure of the rate of heat flow. It is called a **ton of refrigeration**. One ton of refrigeration produces the same cooling effect as the melting of 2000 lb of ice over a 24-hour period.

When 1 lb of ice melts, it absorbs 144 Btu. Therefore, when 1 ton (2000 lb) of ice melts, it absorbs 288,000 Btu (2000 x 144). Consequently, 1 ton of refrigeration absorbs 288,000 Btu within a 24-hour period or 12,000 Btu/hr (288,000/24). So, 1 ton of refrigeration is defined as the transfer of heat at the rate of 12,000 Btu/hr [3.517 kW].

Enthalpy (h): Energy due to both heat and pressure.

Saturated Liquid: Adding heat to (or dropping the pressure of) a saturated liquid will cause it to boil (begin changing to a vapor)

Saturated Vapor: Removing any heat from a saturated vapor will cause it to begin to condense (change to a liquid)

Latent Heat

The quantity of heat that must be added to the water in order for it to evaporate cannot be sensed by an ordinary thermometer. This is because both the water and steam remain at the same temperature during this phase change.

This kind of heat is called latent heat, which is dormant or concealed heat energy. **Latent heat** is the energy involved in changing the phase of a substance—from a liquid to a vapor in this example. Or Heat absorbed (or released) when a liquid changes phase without any temperature change.

Sensible Heat

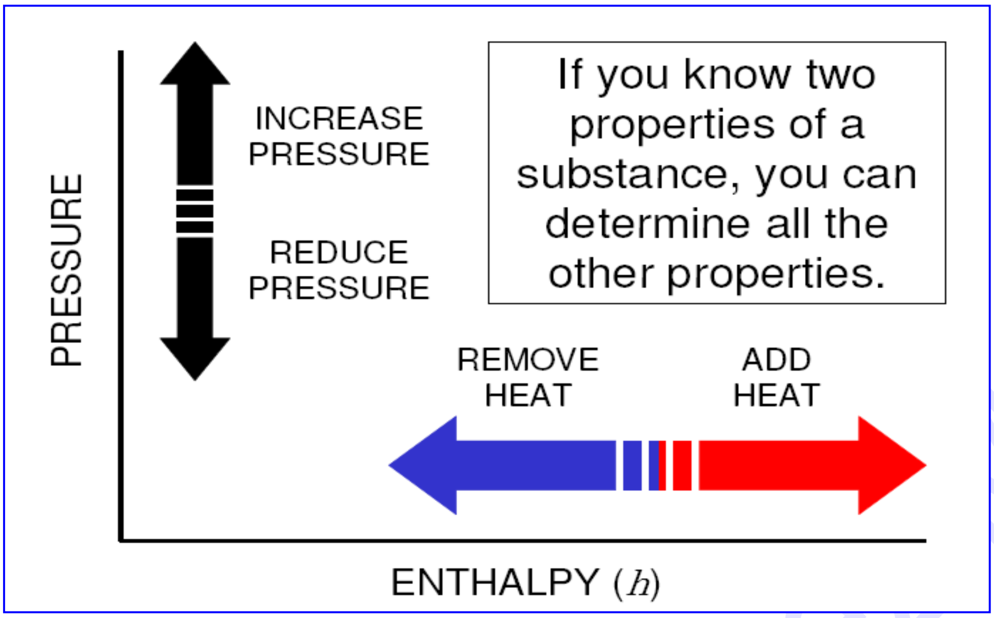
In contrast, **sensible heat** is heat energy that, when added to or removed from a substance, results in a measurable change in temperature. Refrigerants can absorb a significant amount of heat when they change phase; much more than if they just change temperature. Different substances have different specific temperatures at which these phase changes occur, and different quantities of heat are required for this change to take place. They also have different capacities for absorbing heat. This capacity is a property of the substance called specific heat.

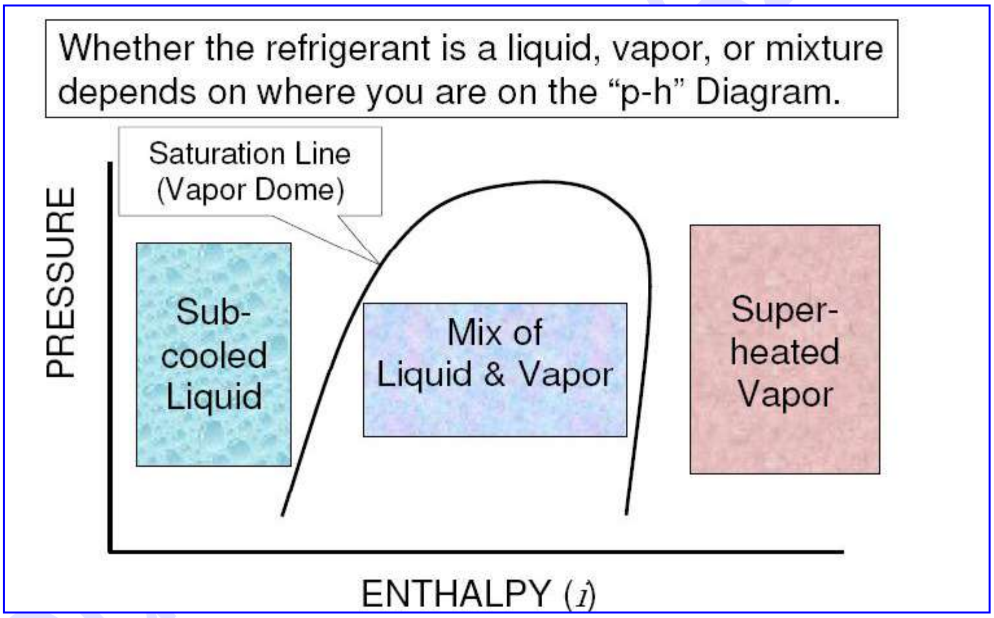
Specific Heat

Suppose equal quantities of two different liquids, **A** and **B**, both at room temperature, are heated. The gas burners are lighted and adjusted so that each is burning exactly the same quantity of gas over the same time period, ensuring that each container of liquid receives the same quantity of heat. After a period of time, the thermometer in the container of liquid **A** indicates 140°F [60°C], while the thermometer in the container of liquid **B** indicates 200°F [93.3°C]. Even though equal quantities of the two liquids were supplied with exactly the same quantity of heat, why does liquid **B** reach a higher temperature than liquid **A**?

The reason is that liquid **B** has less capacity for absorbing heat than liquid **A.** This capacity for absorbing heat is called **specific heat**. The specific heat of a substance is defined as the quantity of heat, in Btus, required to raise the temperature of 1 lb of that substance 1°F.

Similarly, in metric units, specific heat is defined as the quantity of heat, in kJs, required to raise the temperature of 1 kg of that substance 1°C.

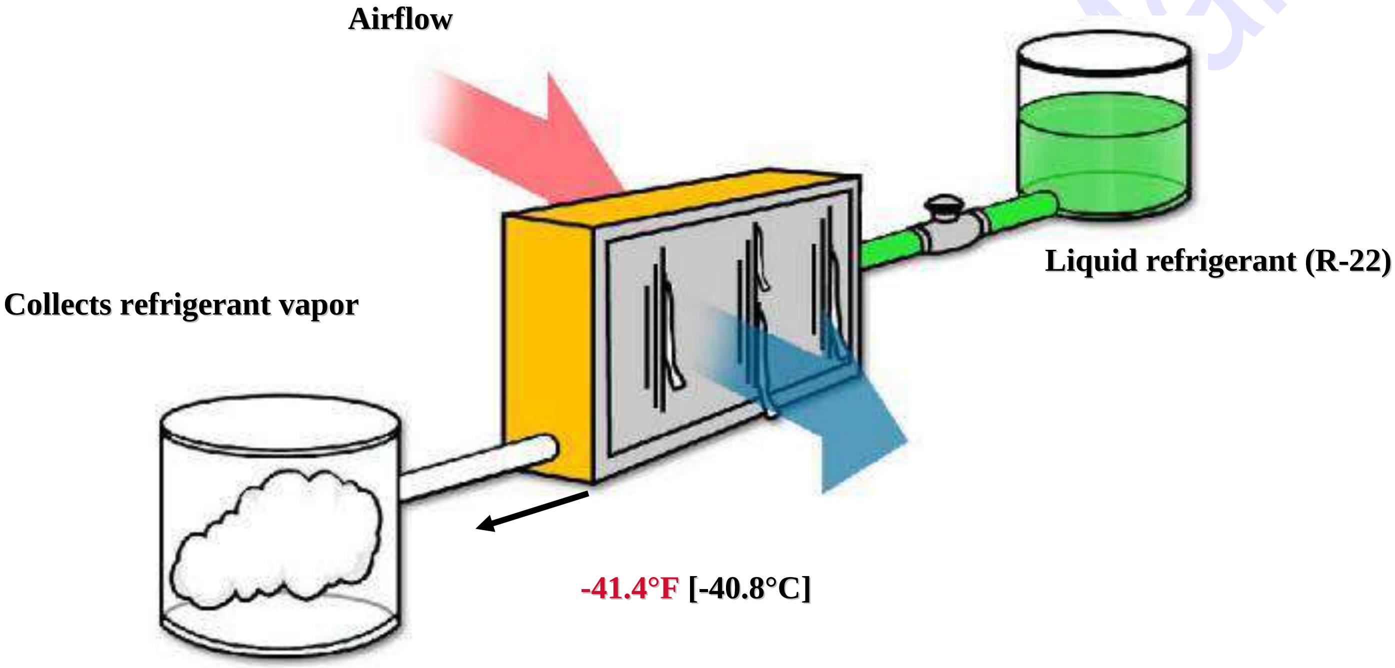

PRESSURE
INCREASE PRESSURE
REDUCE PRESSURE
If you know two properties of a substance, you can determine all the other properties.
REMOVE HEAT
ADD HEAT
ENTHALPY (h)


Whether the refrigerant is a liquid, vapor, or mixture depends on where you are on the "p-h" Diagram.
Saturation Line (Vapor Dome)
PRESSURE
Sub-cooled Liquid
Mix of Liquid & Vapor
Super-heated Vapor
ENTHALPY (i)

Refrigeration System

The frozen display case example used in the last period demonstrates that, at a given pressure, refrigerants absorb heat and change phase at a fixed temperature. It also shows how these refrigerants are "consumed" in the

cooling process, either melting into a liquid or evaporating into a vapor. This period discusses how the refrigerant can be recovered and reused to continue the refrigeration cycle.

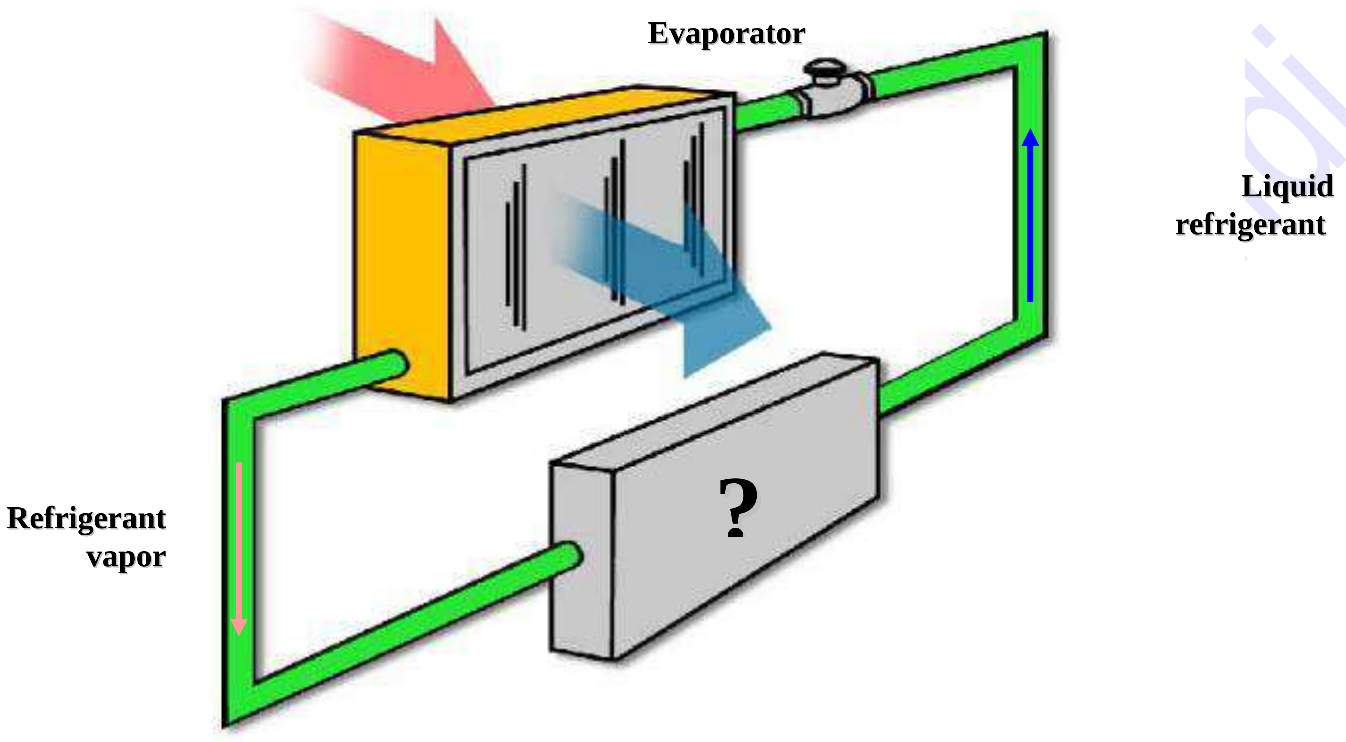


A rudimentary refrigeration system could hypothetically be constructed using a drum of liquid refrigerant at atmospheric pressure, a coil, a collecting drum, and a valve to regulate the flow of refrigerant into the coil. Opening the valve allows the liquid refrigerant to flow into the coil by gravity. As warm air is blown over the surface of the coil, the liquid refrigerant inside the coil will absorb heat from the air, eventually causing the refrigerant to boil while the air is cooled. Adjustment of the valve makes it possible to supply just enough liquid refrigerants to the coil so that all the refrigerant evaporates before it reaches the end of the coil. One disadvantage of this system is that after the liquid refrigerant passes through the coil and collects in the drum as a vapor, it cannot be reused. The

cost and environmental impacts of chemical refrigerants require the refrigeration process to continue without loss of refrigerant.

Additionally, the boiling temperature of R-22 at atmospheric pressure is -41.4°F [-40.8°C]. At this unnecessarily low temperature, the moisture contained in the air passing through the coil freezes on the coil surface, ultimately blocking it completely.

Refrigeration System

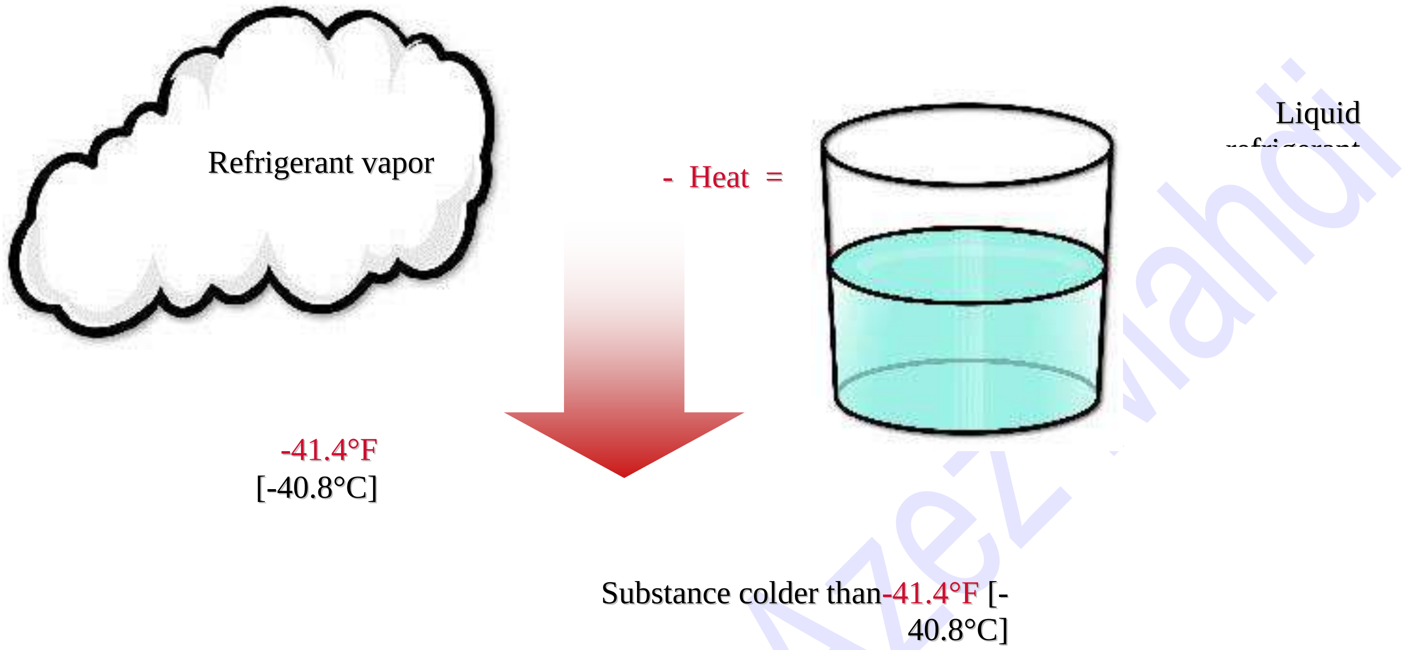


Closing the Cycle

To solve the first problem, a system is needed to collect this used refrigerant and return it to the liquid phase. Then the refrigerant can be passed through the coil again.

This is exactly what happens in a typical mechanical refrigeration system. Liquid refrigerant absorbs heat and evaporates within a device called an evaporator. In this example system, air is cooled when it passes through the evaporator, while the heat is transferred to the refrigerant, causing it to boil and change into a vapor. As discussed in the previous period, a refrigerant can absorb a large amount of heat when it changes phase. Because of the refrigerant changing phase, the system requires far less refrigerant than if the refrigerant was just increasing in temperature. The refrigerant vapor must then be transformed back into a liquid in order to return to the evaporator and repeat the process.

Refrigeration System



The liquid refrigerant absorbed heat from the air while it was inside the evaporator, and was transformed into a vapor in the process of doing useful cooling. Earlier in this clinic, we demonstrated that if the heat is then removed from this vapor, it will transform (condense) back to its original liquid phase. Heat flows from a higher temperature substance to a lower temperature substance. In order to remove heat from the refrigerant vapor, it must transfer this heat to a substance that is at a lower temperature. Assume that the refrigerant evaporated at -41.4°F [-40.8°C]. To condense back into liquid, the refrigerant vapor must transfer heat to a substance that has a temperature less than -41.4°F [-40.8°C]. If a substance were readily available at this cooler temperature, however, the refrigerant would not be required in the first place. The cooler substance could accomplish the cooling by itself. How can heat be removed from this cool refrigerant vapor, to condense it, using a readily available substance that is already too warm for use as the cooling medium? What if we could change the temperature at which the refrigerant vapor condenses back into liquid?

Vapor-Compression Cycle

IDEAL CYCLE

An ideal reversible cycle based on the two temperatures of the system , can be drawn on a temperature–entropy basis

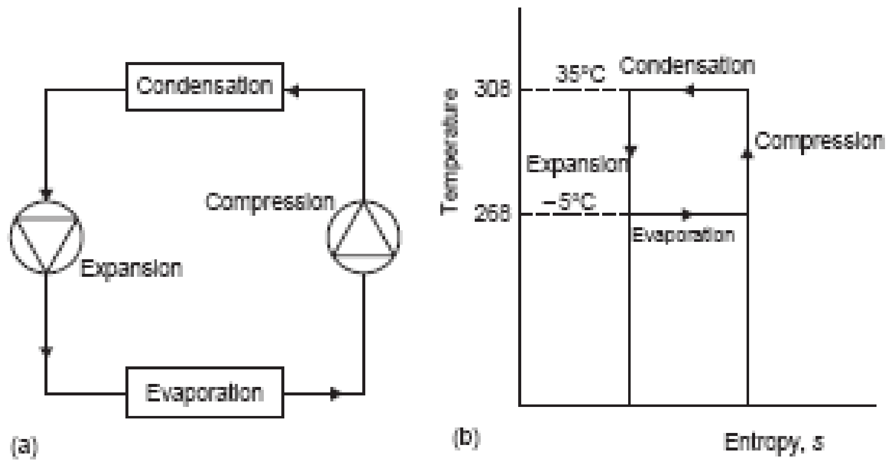
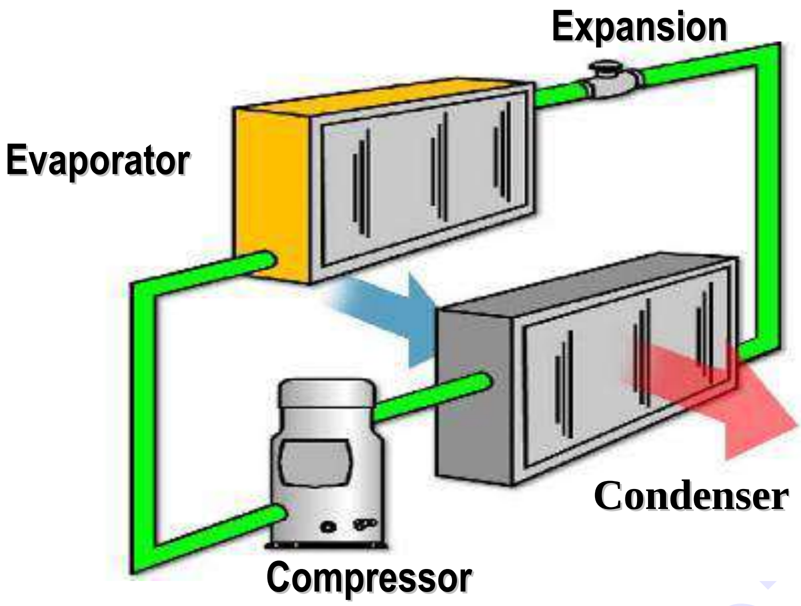


Figure 2.1 The ideal reversed Carnot cycle: (a) circuit and (b) temperature–entropy diagram



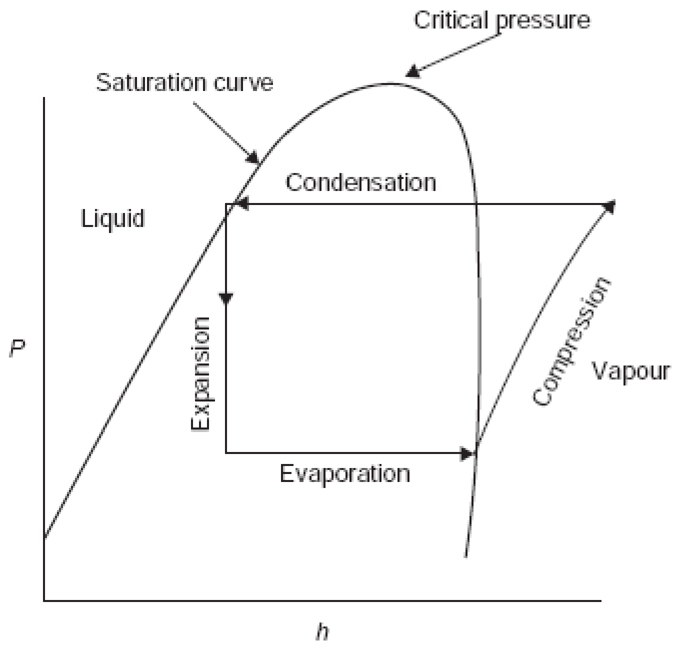


Figure 2.4 Pressure–enthalpy, *P–h* diagram, showing vapour compression cycle

A compressor, condenser, and expansion device form the rest of the system that returns the refrigerant vapor to a low-temperature liquid, which can again be used to produce useful cooling. This cycle is called the **vapor-compression refrigeration cycle**.

In this cycle, a **compressor** is used to pump the low-pressure refrigerant vapor from the evaporator and compress it to a higher pressure. This hot, high-pressure refrigerant vapor is then discharged into a **condenser**. Because heat flows from a substance at a higher temperature to a substance at a lower temperature, heat is transferred from the hot refrigerant vapor to a cooler condensing media, which, in this example, is ambient air. As heat is

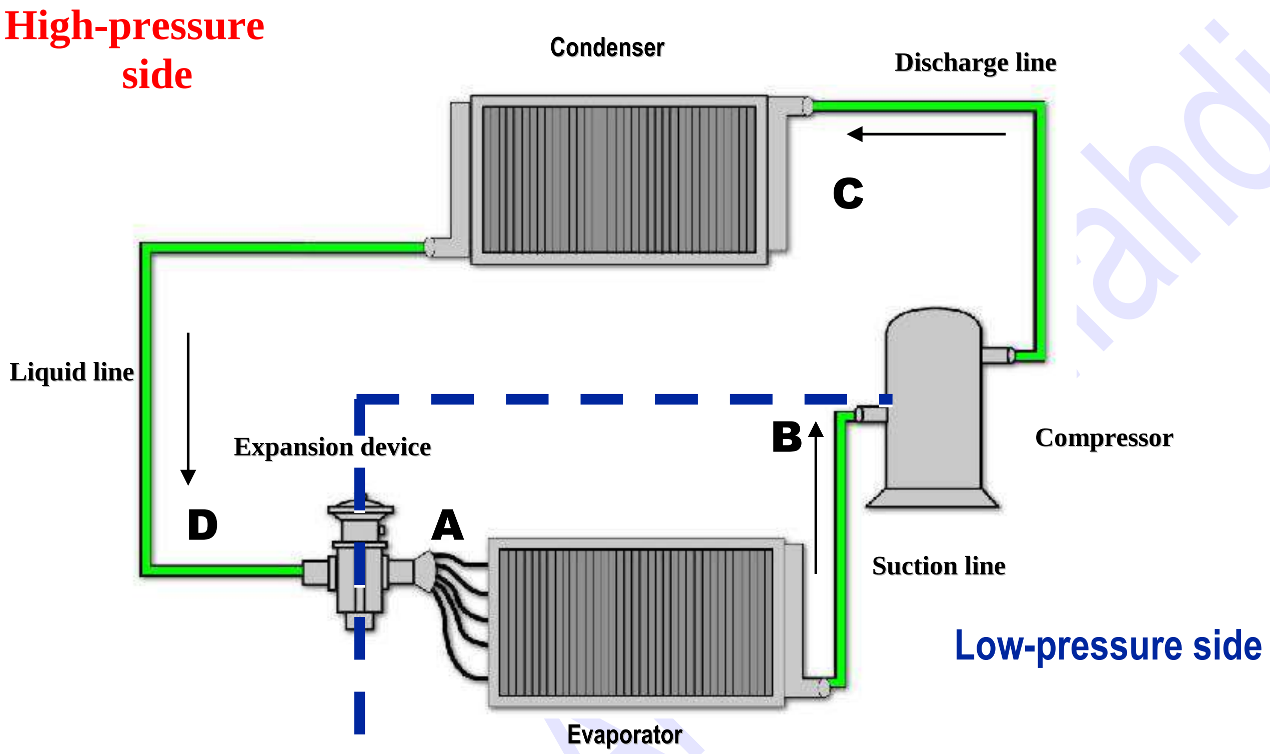
removed from the refrigerant, it condenses, returning to the liquid phase. This liquid refrigerant is, however, still at a high temperature. Finally, an **expansion device** is used to create a large pressure drop that lowers the pressure, and correspondingly the temperature, of the liquid refrigerant. The temperature is lowered to a point where it is again cool enough to absorb heat in the evaporator.

Basic Refrigeration System

Basic Refrigeration System

This diagram illustrates a basic vapor-compression refrigeration system that contains the described components. First, notice that this is a closed system. Refrigerant piping connects the individual components. The **suction line** connects the evaporator to the compressor, the **discharge line** connects the compressor to the condenser, and the **liquid line** connects the condenser to the evaporator. The expansion device is located in the liquid line. Recall that the temperature at which refrigerant evaporates and condenses is related to its pressure. Therefore, regulating the pressures throughout this closed system can control the temperatures at which the refrigerant evaporates and then condenses. These pressures are obtained by selecting system components that will produce the desired balance. For example, select a compressor with a pumping rate that matches the rate at which refrigerant vapor is boiled off in the evaporator. Similarly, select a condenser that will condense this volume of refrigerant vapor at the desired temperature and pressure.

Basic Refrigeration System



Placing each component in its proper sequence within the system, the compressor and expansion device maintain a pressure difference between the high-pressure side of the system (condenser) and the low-pressure side of the system (evaporator).

This pressure difference allows two things to happen simultaneously. The evaporator can be at a pressure and temperature low enough to absorb heat from the air or water to be cooled, and the condenser can be at a temperature high enough to permit heat rejection to ambient air or water that is at normally available temperatures.

THE COMPRESSOR

is one of the four essential components of the compression refrigeration system; the others include the condenser, evaporator, and expansion device. The compressor circulates refrigerant through the system in a continuous cycle. There are two basic types of compressors: positive displacement and dynamic.

Positive-displacement compressors

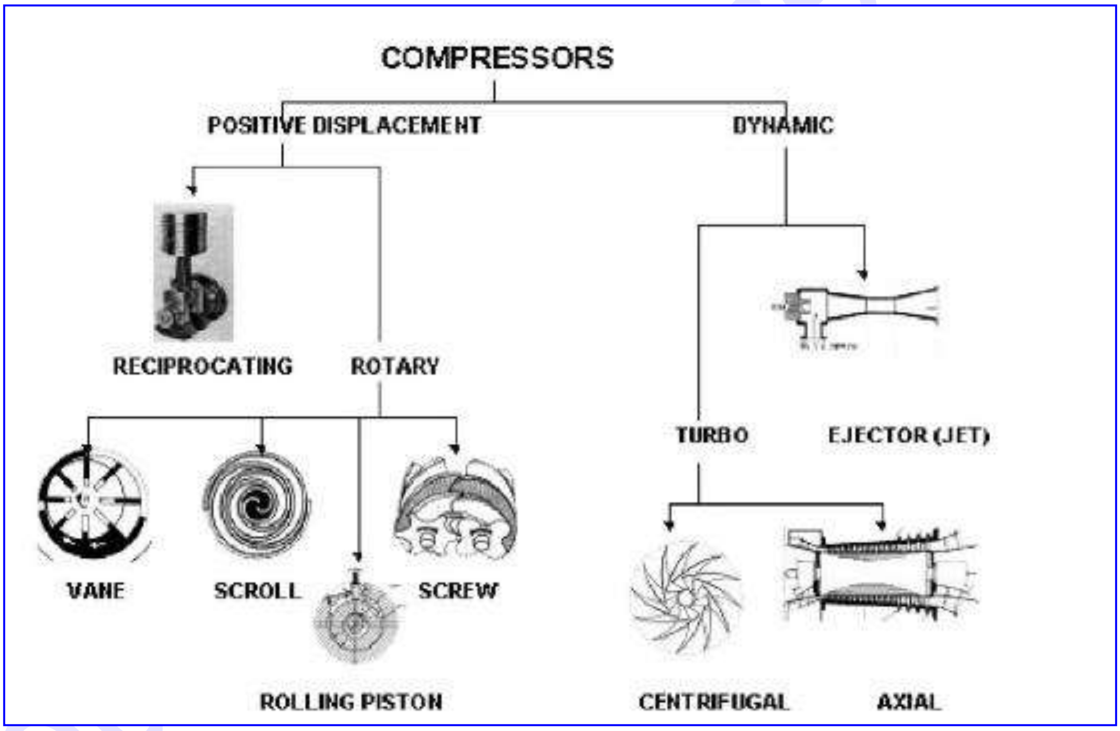
Increase the pressure of refrigerant vapor by reducing the volume of the compression chamber through work applied to the compressor's mechanism: reciprocating, rotary (rolling piston, rotary vane, single screw, and twin-screw), scroll. These compressors have the following features:

1. The pressure ratio is high.
2. the capacities are limited

Dynamic compressors

Increase the pressure of refrigerant vapor by a continuous transfer of angular momentum from the rotating member to the vapor followed by the conversion of this momentum into a pressure rise. Centrifugal compressors function based on these principles. These compressors have the following features:

1. The pressure ratio is lower or medium.
2. The capacities are high.



Figure(2.1) types of compressors

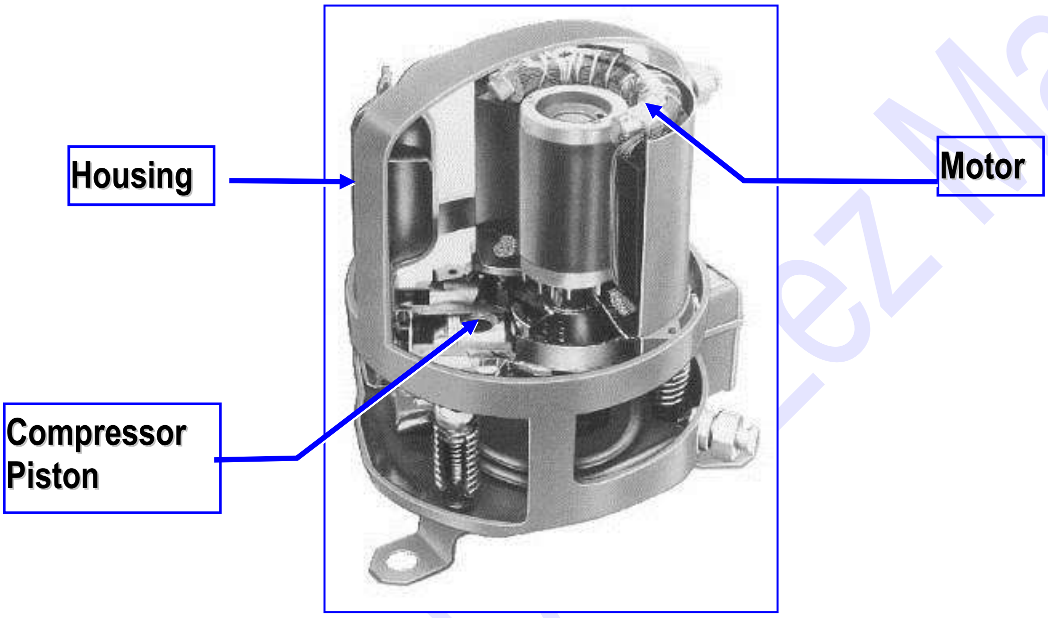
Table (2.1) types and capacity of compressors

	Compressor type	Rating T.R
1	Rolling piston	0.25 - 12
2	scroll	2.5 - 16
3	Reciprocating	0.10 - 100
4	Screw	75 - 450
5	Centrifugal	325 - 1500

Compressor has two parts:

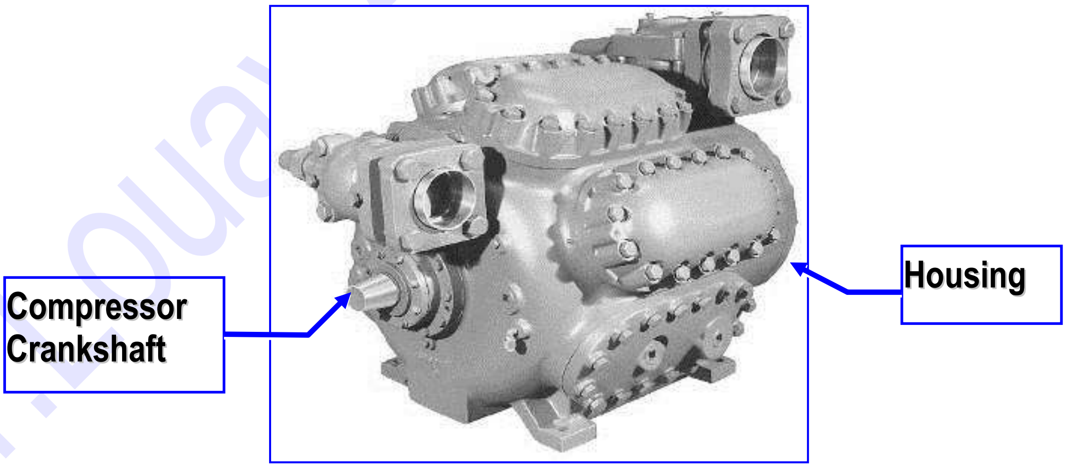
1. **The motor**: stator and rotor, AC or DC current, the stator consists of start winding and running winding must take care for the type of wire and insulation selection with high resistant to heat and oil. and must be put over load for the high current protection.
2. **The engine**: consist of the ;crank, arms, piston, pin beam, cylinder case, valves outlet chamber, inlet chamber, housing, supporting, bearing, oil lubrication, high pressure safety valve**.**

When the motor and engine be in one container we called it ***hermetic*** or ***closed type***: no maintenance can be done.

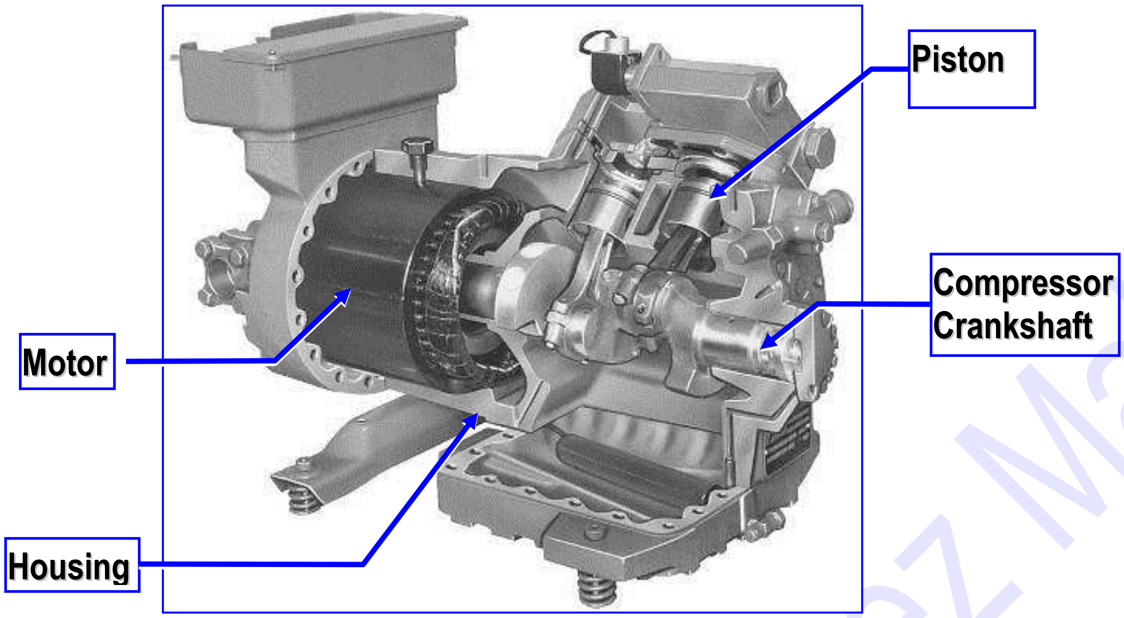


Figure(2.2) hermetic compressor

And when the motor and engine be in separated container we called it ***open type or sime-hermetic:*** can do the maintenance.



Figure(2.3) open type or sime-hermetic compressor



Figure(2.4) sime-hermetic compressor

Another kind of classification:

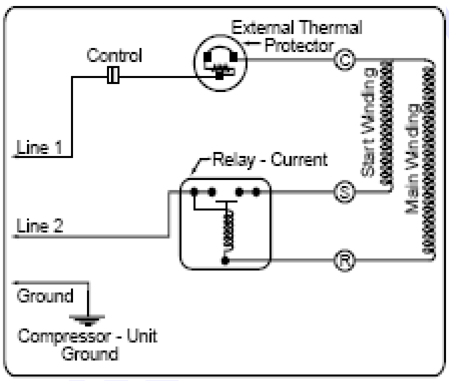
i. Low Back Pressure.
ii. High Back Pressure.

We must study:

1. **The parts**
2. **Type of operation**
3. **The lubrication method**
4. **The losses type**
5. **Control**

Single Phase Compressor
Motor Types
Tecumseh hermetic compressors contain motors designed for specific requirements of starting torque and running efficiency. There are four general types of single phase motors, each distinctly different from the others. Each type of motor may have two to four different configurations depending on the compressor components.

A. Resistance Start—Induction Run (RSIR)
This motor, also known as a split-phase motor, is used on many small hermetic compressors up through 1/3 HP. The motor has low starting torque and must be applied to completely self-equalizing capillary tube systems such as household refrigerators, freezers, small water coolers, and dehumidifiers.
This motor has a high resistance start winding which is not designed to remain in the circuit after the motor has come up to speed. A relay is necessary to perform the function of disconnecting the start winding as the motor comes up to design speed.
Three types of relays are used with this motor:
a current relay,
a wired-in Positive Temperature Coefficient (PTC) relay, or
a module Positive Temperature Coefficient (PTC).



Figure(2.5) RSIR motor diagram with current relay.

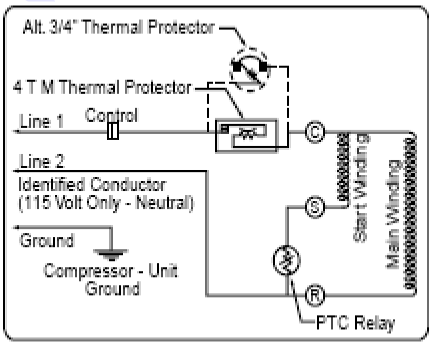
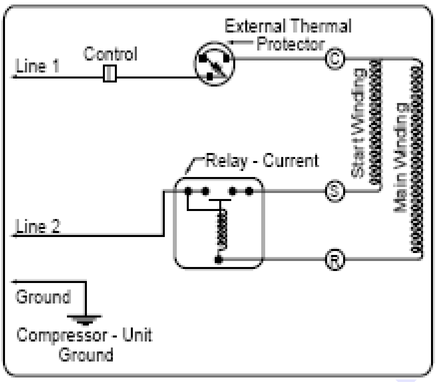


Figure (2.6) RSIR motor diagram with wired-in PTC relay.

B. Capacitor Start—Induction Run (CSIR)

The CSIR motor is similar to RSIR except a start capacitor is included in series with start winding to produce a higher starting torque. This is commonly used on commercial refrigeration systems through 3/4 HP. Two types of relays are used with this motor:

- a current relay, or
- a potential relay.



Figure(2.7) CSIR motor diagram.

C. Capacitor Start and Run (CSR)

This motor arrangement uses a start capacitor and a run capacitor in parallel with each other and in series with the motor start winding. This motor has high starting torque, runs efficiently, and is used on many refrigeration and air conditioning applications through 5 HP. A potential relay removes the start capacitor from the circuit after the motor is up to speed. This motor may use either:

- an external thermal protector, or
- an internal thermal protector.

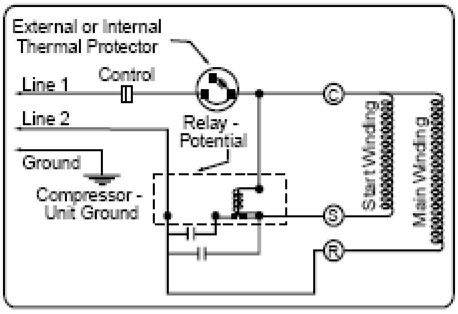


Figure (2.8) CSR motor diagram.

D. Permanent Split Capacitor (PSC)

Here a run capacitor is in series with the start winding. Both run capacitor and start winding remain in the circuit during start and after motor is up to speed. This normal starting torque motor is sufficient for capillary and other self-equalizing systems. No start capacitor or relay is necessary. For additional starting torque, a proper start assist kit may be added (see Figure 3-6). Some start assist kits may include:

- a wired-in Positive Temperature Coefficient (PTC) relay, or
- a module Positive Temperature Coefficient (PTC) relay.

This motor may use either:

- an external thermal protector, or

• an internal thermal protector.

PSC motors are basically air conditioning compressor motors and are very common up through 5 HP.

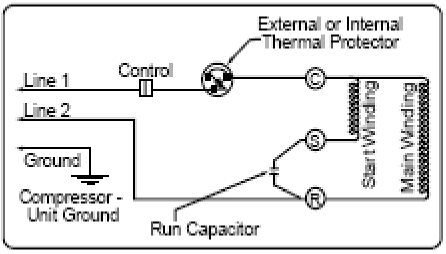


Figure (2.9) PSC motor diagram.

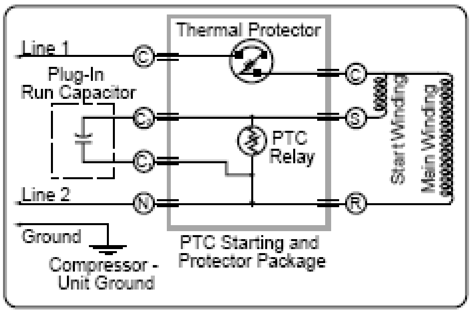


Figure (2.10) PSC motor diagram with start assist kit that includes a module PTC relay.

PSC Motor Starting

Products Company has pioneered in encouraging the development of Permanent Split Capacitor compressor motors. This type of motor eliminates the need for potentially troublesome and costly extra electrical components (start capacitors and potential motor starting relays). (See Figure 2-11.)

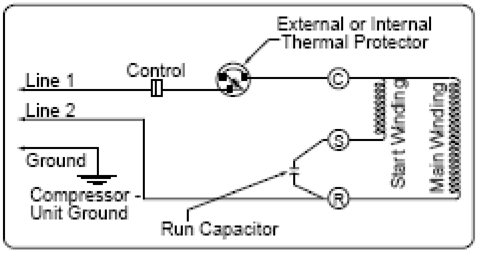


Figure (2.11) Circuit diagram for PSC compressors.

To fully realize the capabilities of this simplified type of compressor motor, it is necessary to understand its starting and operating characteristics and the field conditions which can affect it. The following conditions affect PSC motor starting:

• **Low voltage**: Reduces motor starting and running torque. A 10% voltage drop reduces a motor's starting ability by 19%. Low voltage can cause no start; hard start, light flicker, and TV screen flip flop. Minimum starting voltage for the compressor when it is attempting to start (locked rotor) is:

Table (2.2): **Minimum Starting Voltage**

Serial Label Voltage	Min. Voltage for Start
115	103
208	188
230	207
230/208	198
265	239

Equalized system pressure: Head and suction pressures must be equal and not more than 170 psig. Refrigeration metering device (cap tube or TX valve) should equalize system pressures within 3 minutes. Unequal system pressure may be caused by excessive refrigerant charge, short cycling thermostat, or system restriction.

• **Circuit breaker or fuse trips**: Branch circuit fuses or circuit breakers sized too small will cause nuisance tripping.
• **Electrical components**: A failed run capacitor will not allow the compressor to start, and it will trip the thermal protector.

Hermetic Compressor Thermal Protectors

Hermetic compressor motors are protected from overheating by thermal protectors built into or mounted in contact with the compressor motor. The thermal protector device (see Figure 2-12), when firmly attached to the compressor housing, quickly senses any unusual temperature rise or excess current draw. The bi-metal disc within the thermal protector (see Figure 2-13) reacts to either excess temperature and/or excess current draw by flexing downward, and disconnecting the compressor from the power source.

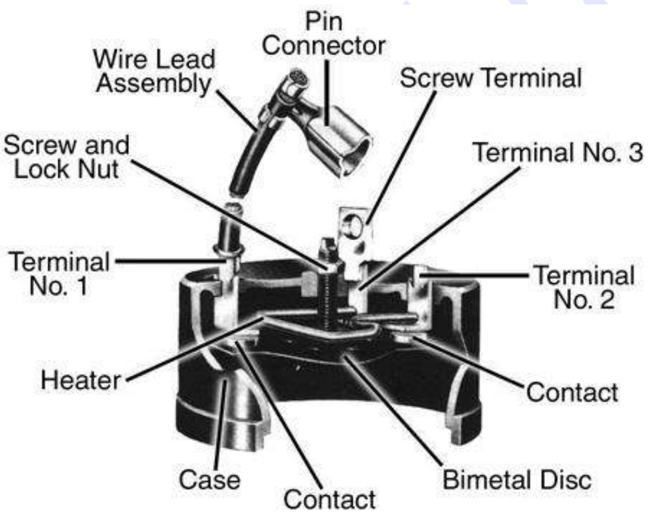


Figure (2.12) External thermal protector.

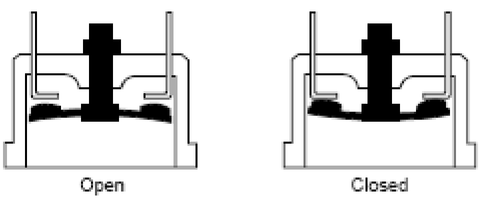
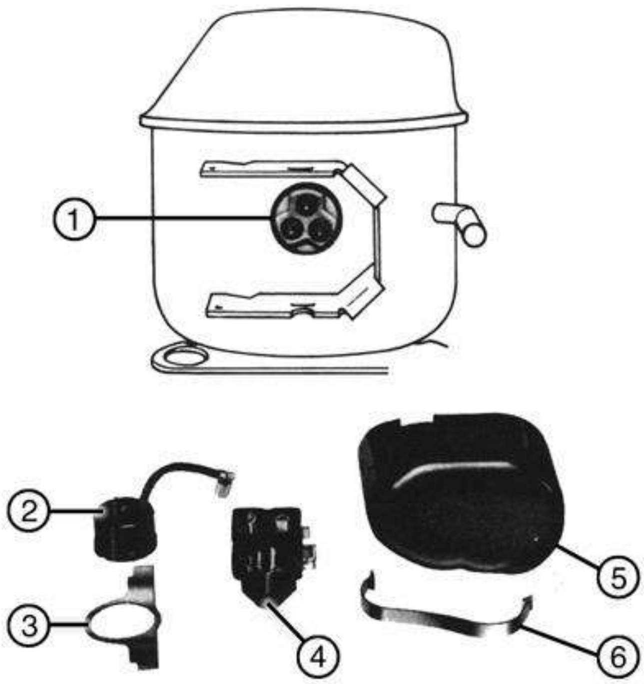


Figure (2.13) Bi-metal disc.



Figure(2.14) AE refrigeration compressor showing (1) hermetic terminal, (2) thermal protector, (3) thermal protector clip, (4) push-on relay, (5) protective terminal cover, and (6) bale strap.

Figure(2.15)Refrigeration compressor with the thermal protector and relay assembled.

Compressor Motor Starting Relays

A hermetic motor starting relay is an automatic switching device to disconnect the motor start capacitor and/or start winding after the motor has reached running speed. Never select a replacement relay solely by horsepower or other generalized rating. Select the correct relay from the Electrical Service Parts Guide Book. There are two types of motor starting relays used in refrigeration and air conditioning applications: the current responsive type and the potential (voltage) responsive type.

A. Current Type Relay

When power is applied to a compressor motor, the relay solenoid coil attracts the relay armature upward causing bridging contact and stationary contact to engage. This energizes the motor start winding. When the compressor motor attains running speed, the motor main winding current is such that the relay solenoid coil de-energizes allowing the relay contacts to drop open thereby disconnecting motor start winding.
The relay must be mounted in true vertical position so armature and bridging contact will drop free when relay solenoid is de-energized.

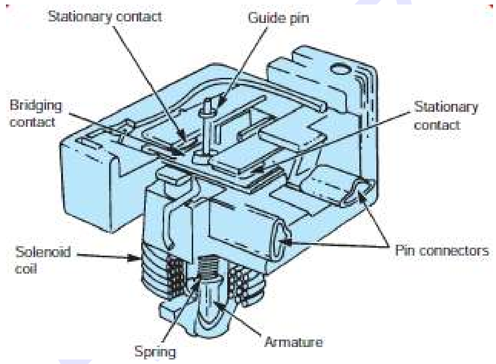


Figure (2.16) Current type relay.

B. PTC Type Relay

Solid state technology has made available another type of current sensitive relay—a PTC starting switch. Certain ceramic materials have the unique property of greatly increasing their resistance as they heat up from current passing through them. A PTC solid state starting device is placed in series with the start winding and normally has a very low resistance. Upon startup, as current starts to flow to the start winding, the resistance rapidly rises to a very high value thus reducing the start winding current to a trickle and effectively taking that winding out of operation. Usage is generally limited to domestic refrigeration and freezers. Because it takes 3 to 10 minutes to cool down between operating cycles, it is not feasible for short cycling commercial applications.

Figure (2.17) PTC type relay.

C. Potential Type Relay

Generally used with large commercial and air conditioning compressors (capacitor start, capacitor run) to 5 HP. Relay contacts are normally closed. The relay coil is wired across the start winding and senses voltage change. Starting winding voltage increases with motor speed. As the voltage increases to the specific pickup value, the armature pulls up, opening the relay contacts, de-energizing the start winding capacitor. After switching, there is still sufficient voltage induced in the start winding to keep the relay coil energized and the relay starting contacts open. When power is shut off to the motor, the voltage drops to zero, the coil is de-energized, and the start contacts reset. When changing a compressor relay, care should be taken to install the replacement in the same position as the original.

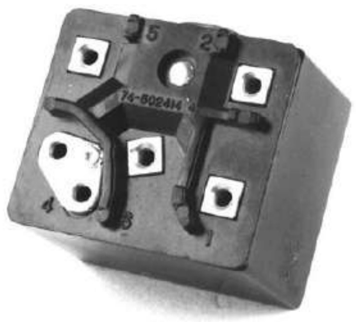


Figure (2.18) Potential type relay.

Table (2.3): **Facts about Starting Relays**

Relay Type	Compressor Motor Type	Characteristics
Current Relay	RSIR and CSIR	• Sense starting current to main (run) windings • Contacts normally open • Contacts close and then release in less than 1 second as motor starts • Must be installed vertically since contacts open by gravity
PTC Relay	RSIR and PSC	• Sense starting current to start winding • Solid state device whose resistance increases with heat from current as motor starts • Takes 3 to 10 minutes to cool down between operating cycles
Potential Relay	CSR	• Sense voltage generated by start winding • Contacts normally closed • Contacts open in less than 1 second as motor starts

Selecting Capacitors
Never use a capacitor with a lower voltage rating than that specified. A higher voltage rating than that specified is acceptable.

A. Start Capacitor Bleeder Resistors
Modern high power factor, low current single phase compressor motors which require start and run capacitors used with potential type relays can create electrical circuits which could cause starting relay damage resulting in compressor failure.

The high voltage stored in the start capacitor could discharge across the contacts of the starting relay thus welding them and preventing the relay from functioning. Capacitor failure and/or start winding failure could result. To eliminate this, start capacitors are equipped with bleeder resistors wired across the capacitor terminals. No start capacitor used in conjunction with a potential relay and run capacitor should be installed without such a bleeder resistor.

In an emergency where no bleeder resistor equipped capacitors are available, then a two watt 15,000 ohm resistor can be obtained and soldered across the capacitor terminals.

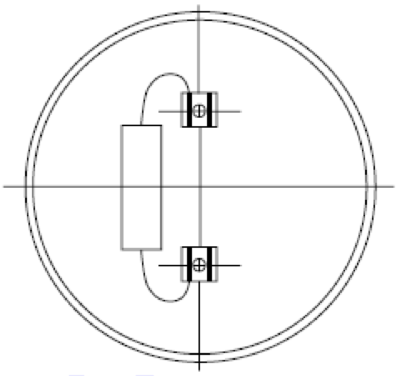


Figure (2.19) 15000 OHMS 2 WATT ± 20% bleeder resistor wired across capacitor terminals.

B. Start Capacitor Substitution
If the specified start capacitor is not available, you may use the next larger sized MFD capacitor at the same or higher voltage rating. Do not add excessive starting capacitance.

C. Run Capacitors
Since January 1979, capacitors provided have contained non-PCB oils or have been constructed using non-PCB impregnated metallized paper electrodes and polypropylene dielectric. These capacitors are protected against case rupture, if failure occurs, by a device within the capacitor can. The operation of this safety device could cause the terminal end to bulge outward 1/2”. Suitable head space and/or rubber caps should be provided when installing such capacitors.

In some instances, for reasons of both space and economics, it is advantageous to use two capacitors whose MFD values add up to the total amount specified. In these cases, the capacitors should be connected in parallel. Rated voltage for each should not be less than that specified. The tolerance on a run capacitor is ±10%, and therefore only one rating figure is given. You should not go below this figure on any application. You may exceed this figure by a small amount, and the limits are shown in this table:

Table (2.4): **Limits for Run Capacitor Ratings**

Specific Rating	Maximum Addition
10 to 20 MFD	+ 2 1/2 MFD
20 to 50 MFD	+ 5 MFD
Over 50 MFD	+ 10 MFD

Remember the voltage rating of all capacitors must be the same or greater than the original rating. If you do not know the voltage, use 370 volt capacitors on 115 volt units and 440 volt capacitors on 230 volt units.

Table (2.5): **Facts About Capacitors**

Capacitor Type	Compressor Motor Type	Characteristics
Start Capacitor	**CSIR and CSR**	Designed to operate for only a few seconds during start • Taken out of start winding circuit by relay • Excessive start capacitor MFD increases start winding current, increases start winding temperature, and may reduce start torque • Capacitors in CSR motors should have 15,000 ohm, 2 watt bleed resistor across terminals • Capacitor rated voltage must be equal to or more than that specified • Capacitor MFD should not be more than that specified
Run Capacitor	**RSIR, CSR, and PSC**	• Permanently connected in series with start winding • Excessive MFD increases running current and motor temperature • Fused capacitors not recommended for CSR and not required for PSC motors • Capacitor rated voltage must be equal to or more than that specified • Capacitor MFD should not exceed limits shown in Table 3-8

Identification of Terminal Pins:

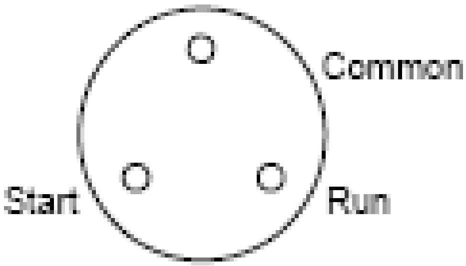
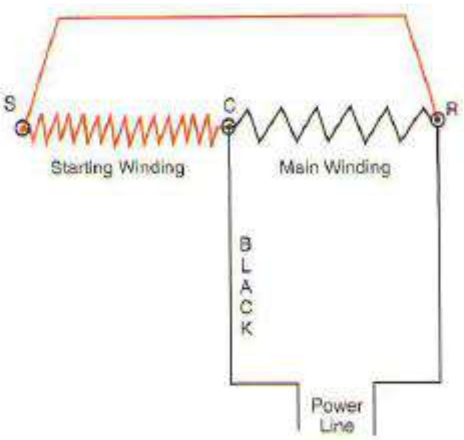
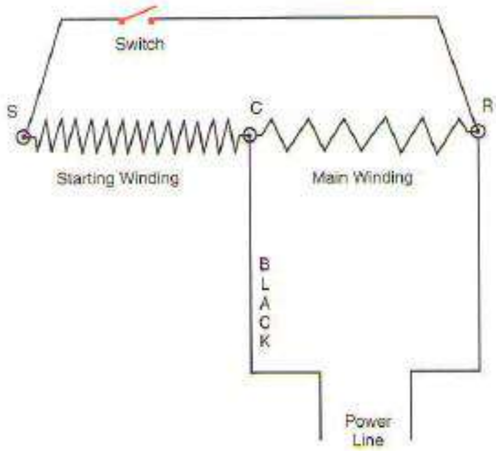
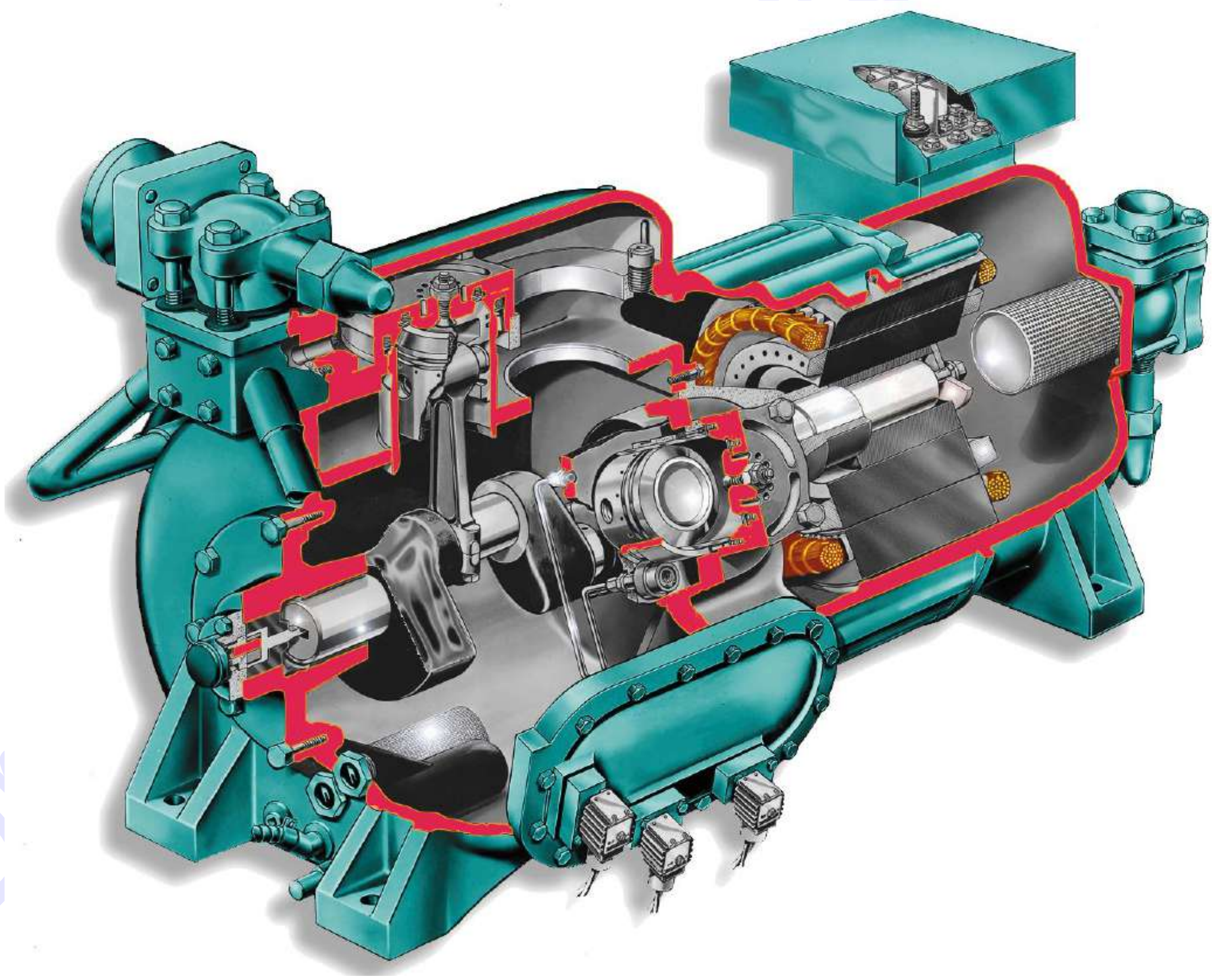


Figure (2.20) terminal pins of household compressor.

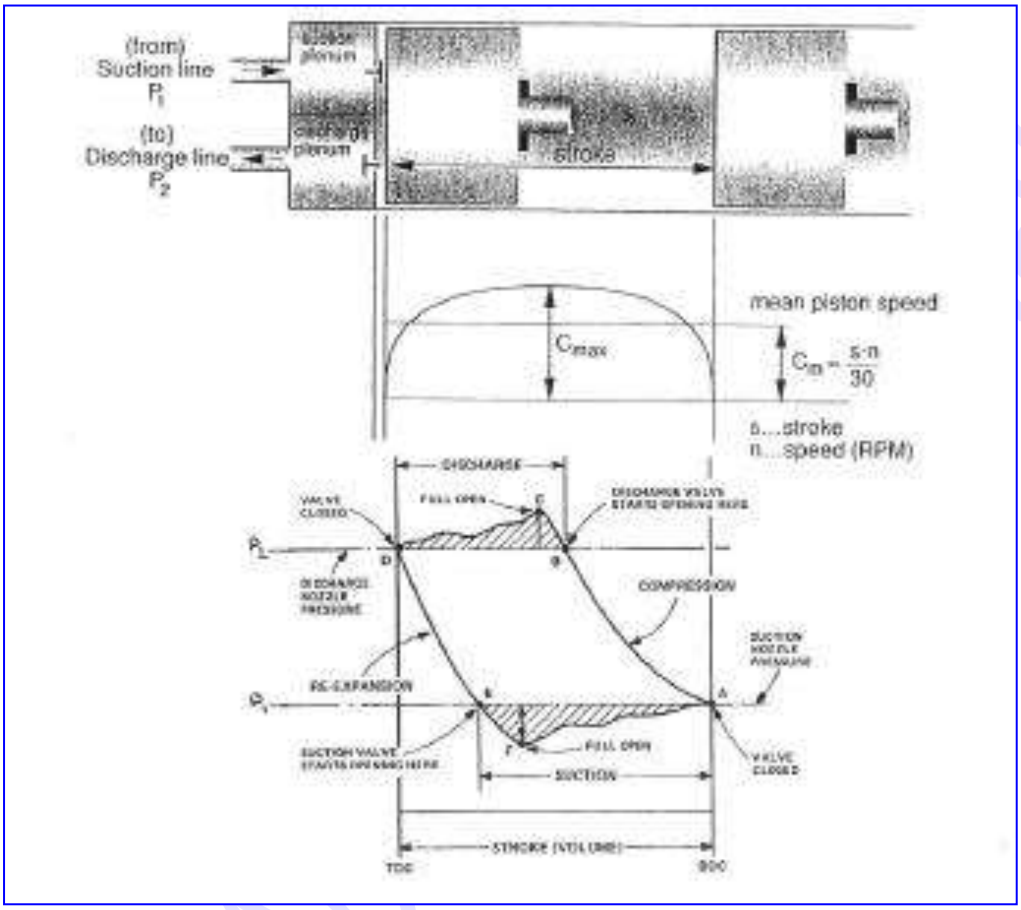




RECIPROCATING COMPRESSOR



The Perssure-volume digram of reciprocating compresor



RECIPROCATING COMPRESSORS

The traditional **reciprocating** compressor has been used in the industry for decades. It contains cylinders, pistons, rods, a crankshaft, and valves, similar to an automobile engine. Refrigerant is drawn into the cylinders on the down stroke of the piston and compressed on the upstroke.
The types of compressors (reciprocating) work on the principle of trapping the refrigerant vapor and compressing it by gradually shrinking the volume of the refrigerant. Thus, they are called **positive-displacement** compressors.
Most reciprocating compressors are single acting, using pistons that are driven directly through a pin and connecting rod from the crankshaft. Double-acting compressors that use piston rods, crossheads, stuffing boxes, and oil injection are not used extensively and, therefore, are not covered here.

Single-stage compressors are primarily used for medium temperatures (-20 to 0°C) and in air-conditioning applications but can achieve temperatures below -35°C at 35°C condensing temperatures with suitable refrigerants.

Integral two-stage compressors achieve low temperatures (−30 to −60°C), using R-22 or ammonia within the frame of a single compressor. The cylinders within the compressor are divided into respective groups so that the combination of volumetric flow and pressure ratios are balanced to achieve booster and high-stage performance effectively. Refrigerant connections between the high pressure suction and low-pressure discharge stages allow an inter stage gas cooling system to be connected to remove superheat between stages. This interconnection is similar to the methods used for individual high-stage and booster compressors. Capacity reduction is typically achieved by cylinder unloading, as in the case of single-stage compressors. Special consideration must be given to maintaining the correct relationship between high and low-pressure stages. The most widely used compressor is the halocarbon compressor, which is manufactured in three types of design: (1) open, (2) semi hermetic or bolted hermetic, and (3) welded-shell hermetic.

Ammonia compressors are manufactured only in the open design because of the incompatibility of the refrigerant and hermetic motor materials.

Features

Crankcases. in a welded hermetic compressor, the cylinder block, is usually of **cast iron.**

Crankshafts. are made of either ***forged steel*** with hardened bearing surfaces finished or ***iron castings***.

Main Bearings. Main bearings are made ***of steel-backed Babbitt***, ***steel backed*** or ***solid bronze***, or ***aluminum***.

Connecting Rods and Eccentric Straps. Connecting rods have the large end split and a bolted cap for assembly. Un split eccentric straps require the crankshaft to be passed through the big bore at assembly. Rods or straps are of ***steel, aluminum, bronze, nodular iron, or gray iron***. ***Steel or iron*** rods often require inserts of such bearing material as steel-backed Babbitt or bronze, while aluminum and bronze rods can bear directly on the crankpin and piston pin.

Piston, Piston Ring, and Piston Pin. Pistons are usually made of ***cast iron or aluminum***.

Suction and Discharge Valves. The most important components in the reciprocating compressor are the suction and discharge valves. Successful designs provide long life and low-pressure loss. The life of a properly made and correctly applied valve is determined by the motion and stress it undergoes in performing its function. Excessive pressure loss across the valve results from high gas velocities, poor mechanical action, or both.
For design purposes, gas velocity is defined as being equal to the bore area multiplied by the average piston speed and divided by the valve area. Permissible gas velocity through the restricted areas of the valve is left to the discretion of the designer and depends on the level of volumetric efficiency and performance desired. In general, designs with velocities up to 60 m/s with ammonia and up to 45 m/s with R-22 have been successful.

A valve should meet the following requirements:

- large flow areas with shortest possible path
- Straight gas flow path, minimum directional changes
- Low valve mass combined with low lift for quick action
- Symmetry of design with minimum pressure imbalance
- Minimum clearance volume
- Durability
- Low cost
- Tight sealing at ports
- Minimum valve flutter

Here are some advantages and disadvantages of reciprocating compressor.

Advantages	**Disadvantages**
Simple design, easy to install	Higher maintenance cost
Lower initial cost	Many moving parts
Large range of horsepower	Potential for vibration problems
Special machines can reach extremely high pressure	Foundation may be required depending on size
Two stages models offer the highest efficiency	Many are not designed to run at full capacity

Lubrication. Lubrication systems range from a simple splash system to the elaborate forced-feed systems with filters, vents, and equalizers. The type of lubrication required depends largely on bearing load and application. For low to medium bearing loads and factory-assembled systems where cleanliness can be controlled, the splash system gives excellent service. Bearing clearances must be larger, however; otherwise, oil does not enter the bearing readily. Thus, the splashing effect of the dippers in the oil and the freer bearings cause the compressor to operate somewhat noisily. Furthermore, the splash at high speed encourages frothing and oil pumping; this is not a problem in package equipment but may be in remote systems where gas lines are long.A **flooded system** includes disks, screws, grooves, oil-ring gears, or other devices that lift the oil to the shaft or bearing level. These devices flood the bearing and are not much better than splash systems, except that the oil is not agitated as violently, so that quieter operation results. Since little or no pressure is developed by this method, it is not considered forced feed. In **forced-feed lubrication**, a pump gear, vane, or plunger develops pressure, which forces oil into the bearing. Smaller bearing clearances can be used because adequate pressure feeds oil in sufficient quantity for proper bearing cooling. As a result, the compressor may be quieter in operation. Gear pumps are used to a large extent. Spur gears are simple but tend to promote flashing of the refrigerant dissolved in the oil because of the sudden opening of the tooth volume as two teeth disengage. This disadvantage is not apparent in internal-type eccentric gear or vane pumps where a gradual opening of the suction volume takes place. The eccentric gear pump, the vane pump, or the piston pump therefore give better performance than simple gear pumps when the pump is not submerged in the oil. Oil pumps must be made with minimum clearances to pump a mixture of gas and oil. The discharge of the pump should have provision to bleed a small quantity of oil into the crankcase. A bleed vents the pumps, prevents excess pressure, and ensures faster priming. A strainer should be inserted in the suction line to keep foreign substances from the pump and bearings. If large quantities of fine particles are present and bearing load is high, it may be necessary to add an oil filter to the discharge side of the pump. Oil must return from the suction gas into the compressor crankcase. A flow of gas from piston leakage opposes this oil flow, so the velocity of the leakage gas must be low to permit oil to separate from the gas. A separating chamber may be built as part of the compressor to help separate oil from the gas. In many designs, a check valve is inserted at the bottom of the oil return port to prevent a surge of crankcase oil from entering the suction. This check valve must have a bypass, which is always open, to permit the check valve to open wide after the oil surge has passed. When a separating chamber is used, the oil surge is trapped before it can enter the suction port, thus making a check valve less essential.

Seals. Stationary and rotary seals have been used extensively on open-type reciprocating compressors. Older stationary seals usually used metallic bellows and a hardened shaft for a wearing surface. Their use has diminished because of high cost. The rotary seal costs less and is more reliable. A synthetic seal tightly fitted to the shaft prevents leakage and seals against the back face of the stationary member of the seal. The front face of this carbon
nose seals against a stationary cover plate. This design has been used on shafts up to 100 mm in diameter.

The rotary seal should be designed so that the carbon nose is never subjected to the full thrust of the shaft; the spring should be designed for minimum cocking force; and materials should be such that a minimum of swelling and shrinking is encountered.

Special Devices

Capacity Control. An ideal capacity control system would have the following operating characteristics (not all of these benefits can occur simultaneously):

- Continuous adjustment to load
- Full-load efficiency unaffected by the control
- No loss in efficiency at part load
- Reduction of starting torque
- No reduction in compressor reliability
- No reduction of compressor operating range
- No increase in compressor vibration and sound level at part load

Capacity control may be obtained by:

(1) Controlling suction pressure by throttling;
(2) Controlling discharge pressure;
(3) Returning discharge gas to suction;
(4) Adding re expansion volume;
(5) Changing the stroke;
(6) Opening a cylinder discharge port to suction while closing the port to discharge manifold;
(7) Changing compressor speed;
(8) Closing off cylinder inlet,
(9) Holding the suction valve open.

The most commonly used methods are opening the suction valves by some external force, gas bypassing within the compressor, and gas bypassing outside the compressor. When capacity control compressors are used, system design becomes more important and the following must be considered:

- Possible increase in compressor vibration and sound level at unloaded conditions
- Minimum operating conditions as limited by discharge or motor temperatures (or both) at part-load conditions
- Good oil return at minimum operating conditions when fully unloaded
- Rapid cycling of unloaders
- Refrigerant feed device capable of controlling at minimum capacity

Crankcase Heaters. During shutdown, refrigerants tend to migrate to the coldest part of the refrigeration system. In cold weather, the compressor oil sump could be the coldest area. When the refrigerant charge is large enough to dilute the oil excessively and cause flooded starts, a crankcase heater should be used. The heater should maintain the oil at least 10 K above the rest of the system at shutdown and well below the breakdown temperature of the oil at any time.

Application

To operate through the entire range of conditions for which the compressor was designed and to obtain the desired service life, it is important that the mating components in the system be correctly designed and selected. Suction superheat must be controlled, lubricant must return to the compressor, and adequate protection must be provided against abnormal conditions.

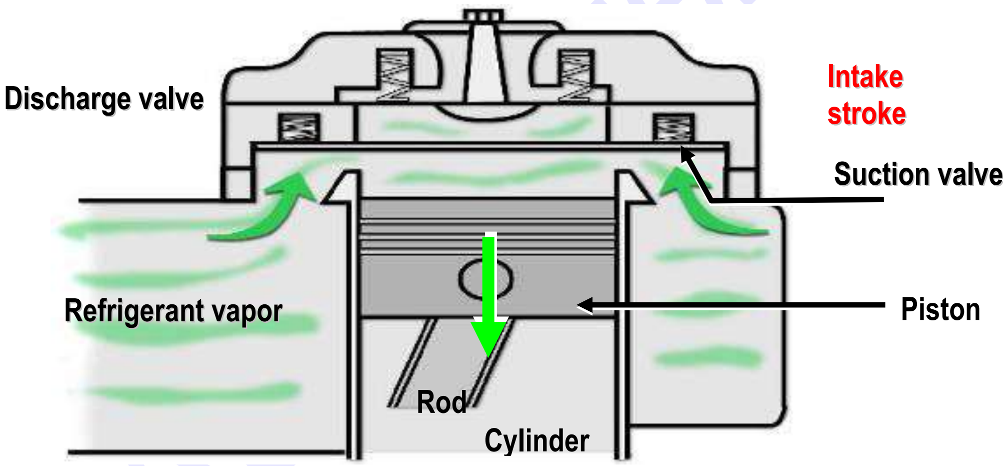
Automatic Oil Separators. Oil separators are used most often to reduce the amount of oil discharged into the system by the compressor and to return oil to the crankcase. They are recommended for all field-erected systems and on packaged equipment where lubricant contamination will have a negative effect on evaporator capacity and/or where lubricant return at reduced capacity is marginal.

Reciprocating Compressor

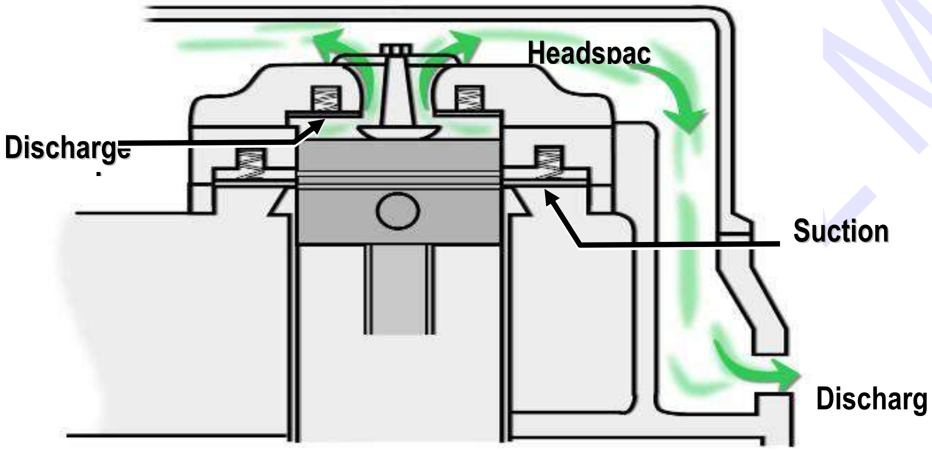
The first type of compressor to be discussed is the **reciprocating compressor**. The principles of operation for all reciprocating compressors are fundamentally the same. The refrigerant vapor is compressed by a piston that is located inside a cylinder, similar to the engine in an automobile. A fine layer of oil prevents the refrigerant vapor from escaping through the mating surfaces. The piston is connected to the crankshaft by a rod. As the crankshaft

rotates, it causes the piston to travel back and forth inside the cylinder. This motion is used to draw refrigerant vapor into the cylinder, compress it, and discharge it from the cylinder. A pair of valves, the suction valve and the discharge valve, are used to trap the refrigerant vapor within the cylinder during this process. In the example reciprocating compressor shown, the spring-actuated valves are O-shaped, allowing them to cover the valve

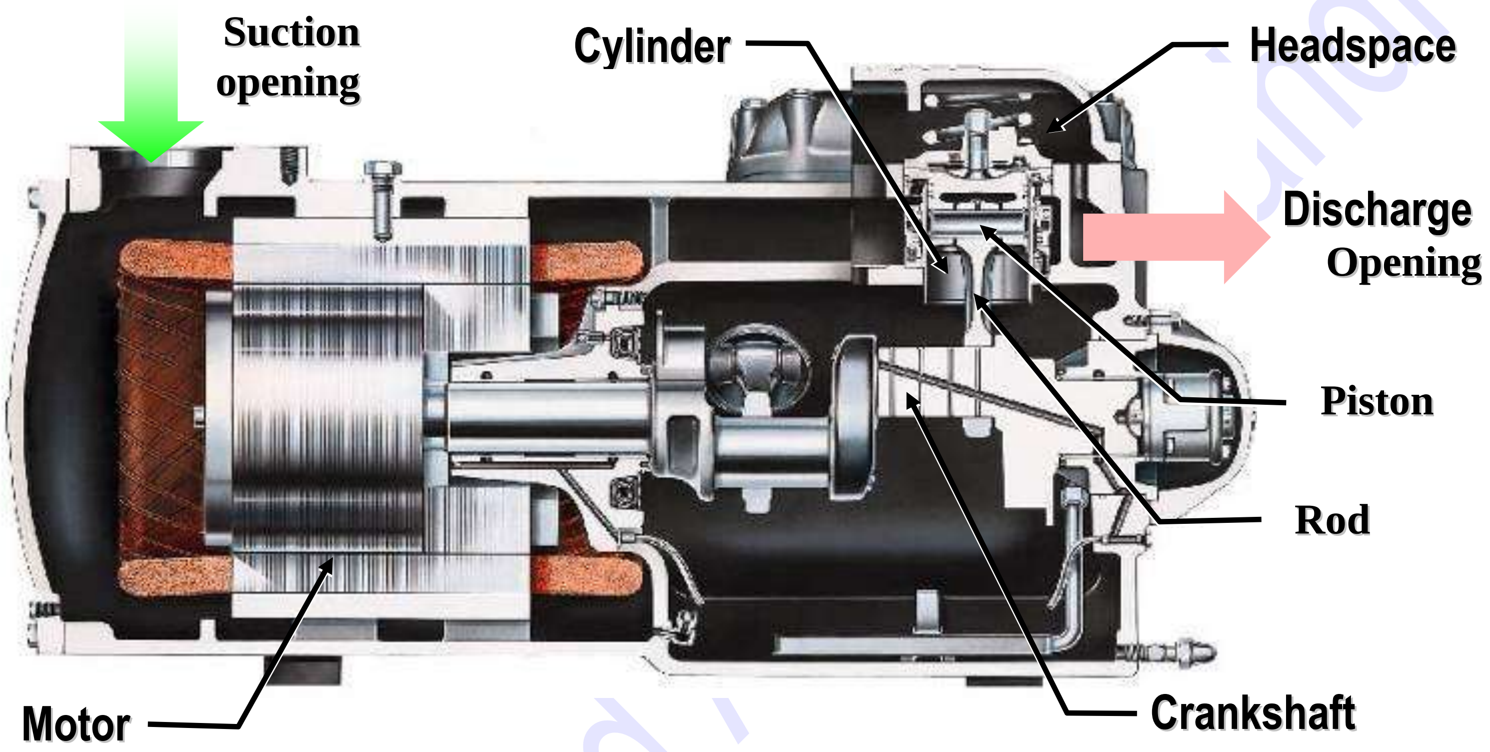
openings around the outside of the cylinder while the piston travels through the middle. During the **intake stroke** of the compressor, the piston travels away from the discharge valve and creates a vacuum effect, reducing the pressure within the cylinder to below suction pressure. Since the pressure within the cylinder is less than the pressure of the refrigerant at the suction side of the compressor, the suction valve is forced open and the refrigerant vapor is drawn into the cylinder.



During the **compression stroke**, the piston reverses its direction and travels toward the discharge valve, compressing the refrigerant vapor and increasing the pressure within the cylinder. When the pressure inside the cylinder exceeds the suction pressure, the suction valve is forced closed, trapping the refrigerant vapor inside the cylinder. As the piston continues to travel toward the discharge valve, the refrigerant vapor is compressed, increasing the pressure inside the cylinder.



When the pressure within the cylinder exceeds the discharge (or head) pressure, the discharge valve is forced open, allowing the compressed refrigerant vapor to leave the cylinder. The compressed refrigerant travels through the headspace and leaves the compressor through the discharge opening.



In the reciprocating compressor shown, the refrigerant vapor from the suction line enters the compressor through the suction opening. It then passes around and through the motor, cooling the motor, before it enters the cylinder to be compressed. The compressed refrigerant leaves the cylinder, travels through the headspace, and leaves the compressor through the discharge opening. Most reciprocating compressors have multiple pistons–cylinder pairs attached to a single crankshaft.

In the air-conditioning industry, reciprocating compressors were widely used in all types of refrigeration equipment. As mentioned earlier, however, scroll and helical-rotary compressors have become more common, replacing the
reciprocating compressor in most of these applications because of their improved reliability and efficiency.

Compressor Capacity Control

The capacity of a compressor is defined by the volume of evaporated refrigerant that can be compressed within a given time period. The compressor needs a method of capacity control in order to match the ever-changing load on the system.

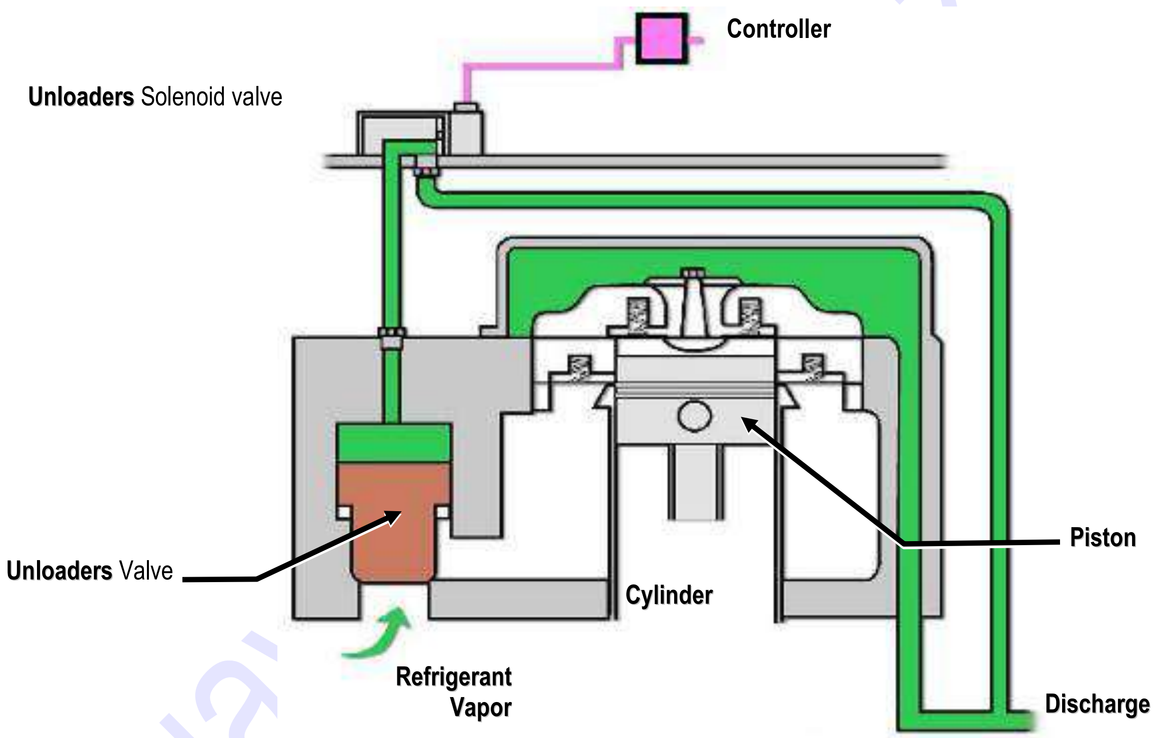
Methods of Compressor Unloading

Reciprocating Cylinder Unloaders

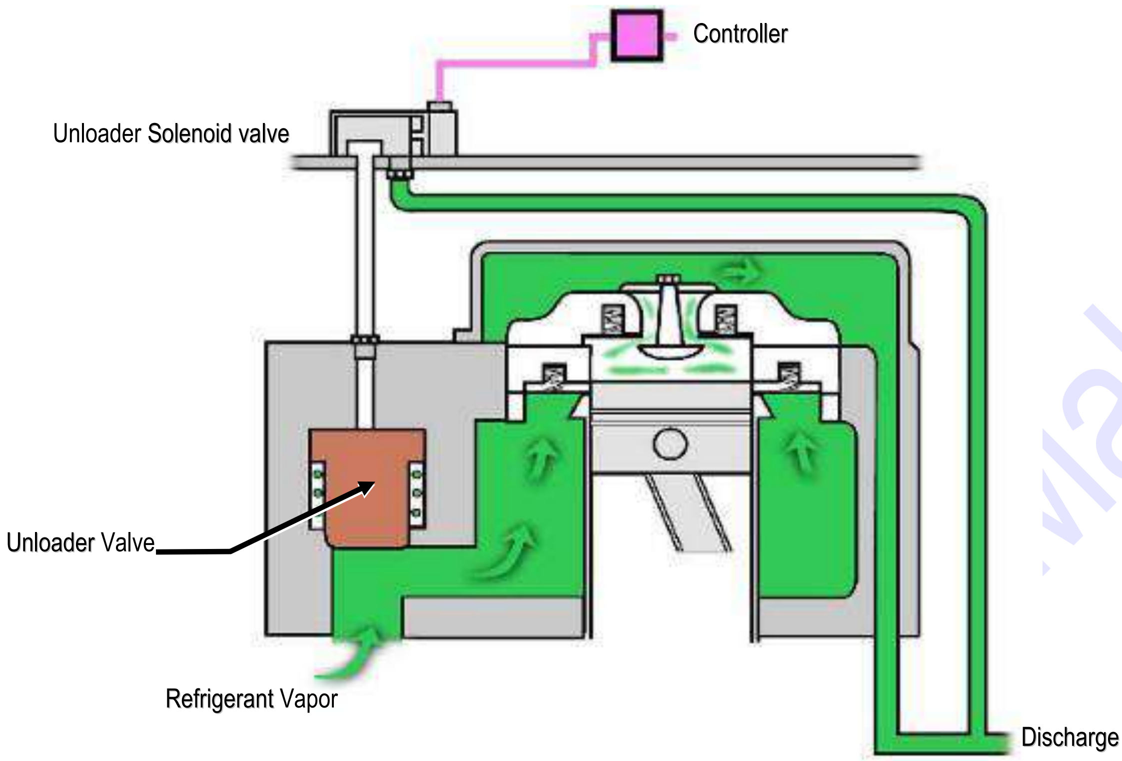
Capacity control is commonly accomplished by unloading the compressor. The method used for unloading generally depends on the type of compressor.

Many reciprocating compressors use cylinder unloaders or compressors could use variable speed to control their capacity.

Cylinder Unloaders

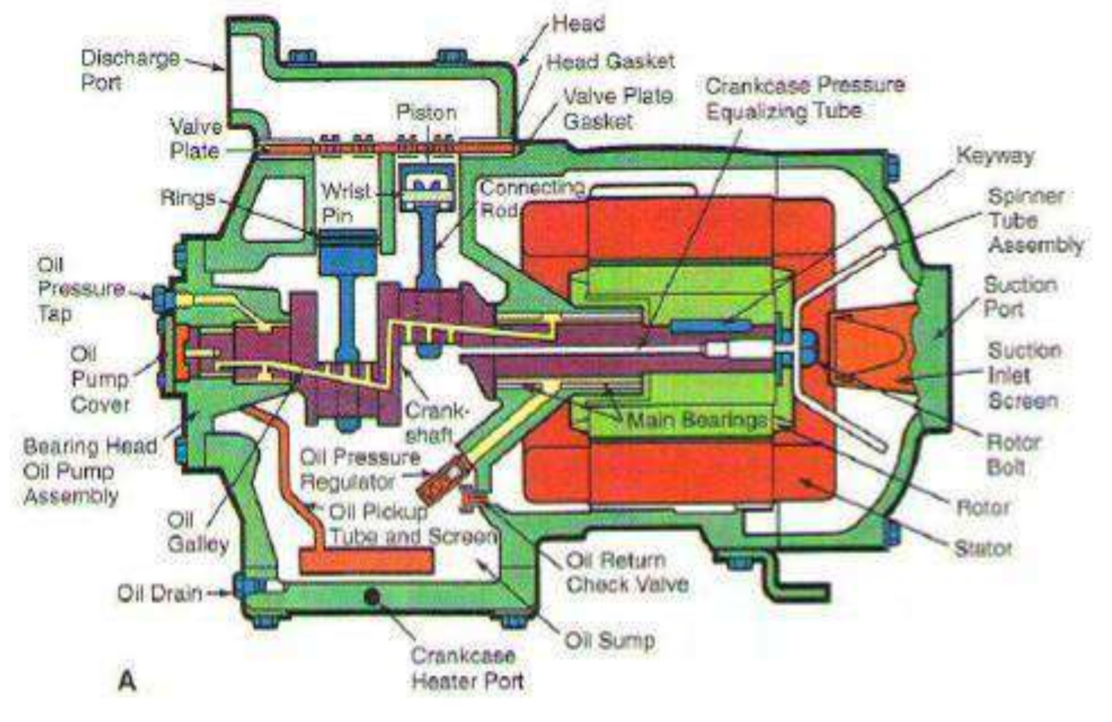


Most large reciprocating compressors (above 10 tons [35 kW]) are fitted with **cylinder unloaders** that are used to match the compressor's refrigerant pumping capacity with the falling evaporator load, by progressively deactivating piston–cylinder pairs. The cylinder unloader shown in this example reciprocating compressor uses an
electrically-actuated unloader valve to close the suction passage to the cylinder that is being unloaded. In response to a decreasing load, an electronic controller sends a signal to open a solenoid valve. This solenoid valve diverts pressurized refrigerant vapor from the compressor discharge to the top of the unloader valve,causing the unloader valve to close and shut off the flow of refrigerant vapor into the cylinder. Even though the piston continues to travel back and forth inside this cylinder, it is no longer performing compression since it cannot take in any refrigerant vapor.



In response to an increasing load, the controller sends a signal to close the solenoid valve. This closes the port that allows the pressurized refrigerant vapor to travel to the top of the unloader valve. A controlled leakage rate

around the unloader valve relieves the pressure, allowing the valve to open and refrigerant vapor to once again flow to the cylinder to be compressed. Another type of cylinder unloader uses either pressure or electrically-actuated valving mechanisms to hold open the suction valve of the piston–cylinder pair. Since the suction valve is prevented from closing, no compression occurs in that cylinder and the discharge valve does not open. Still other types of cylinder unloaders divert the compressed refrigerant vapor back to the suction side of the compressor. In contrast to the cylinder unloaders shown, these other methods expend energy in moving refrigerant vapor during both the upward and downward piston strokes within the unloaded cylinders.



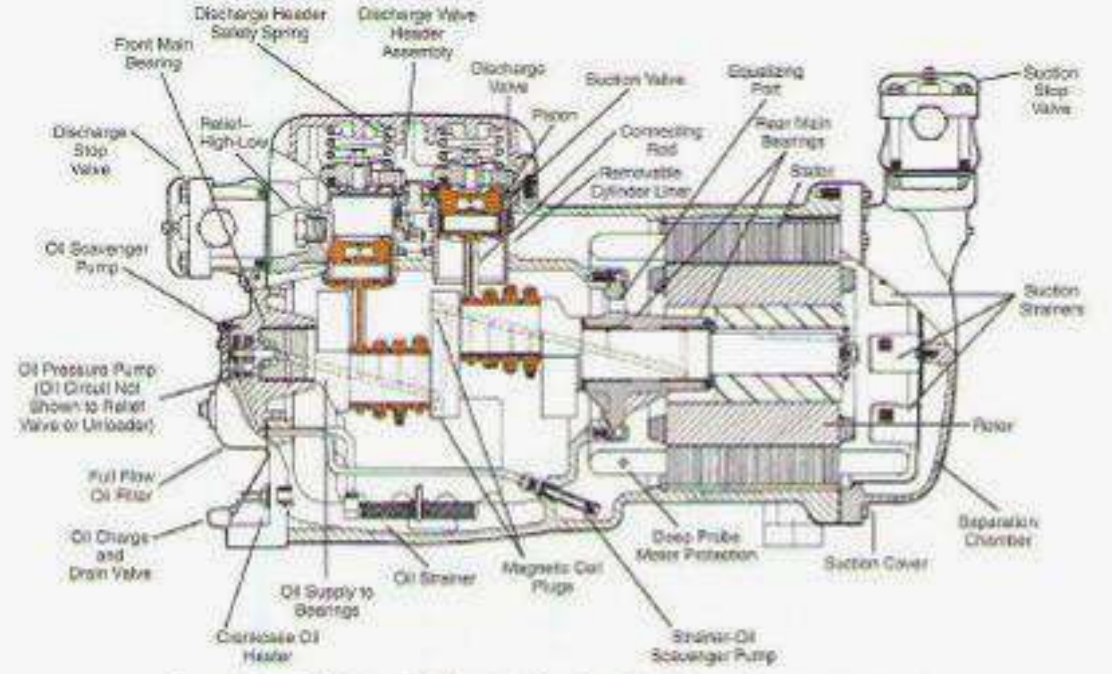
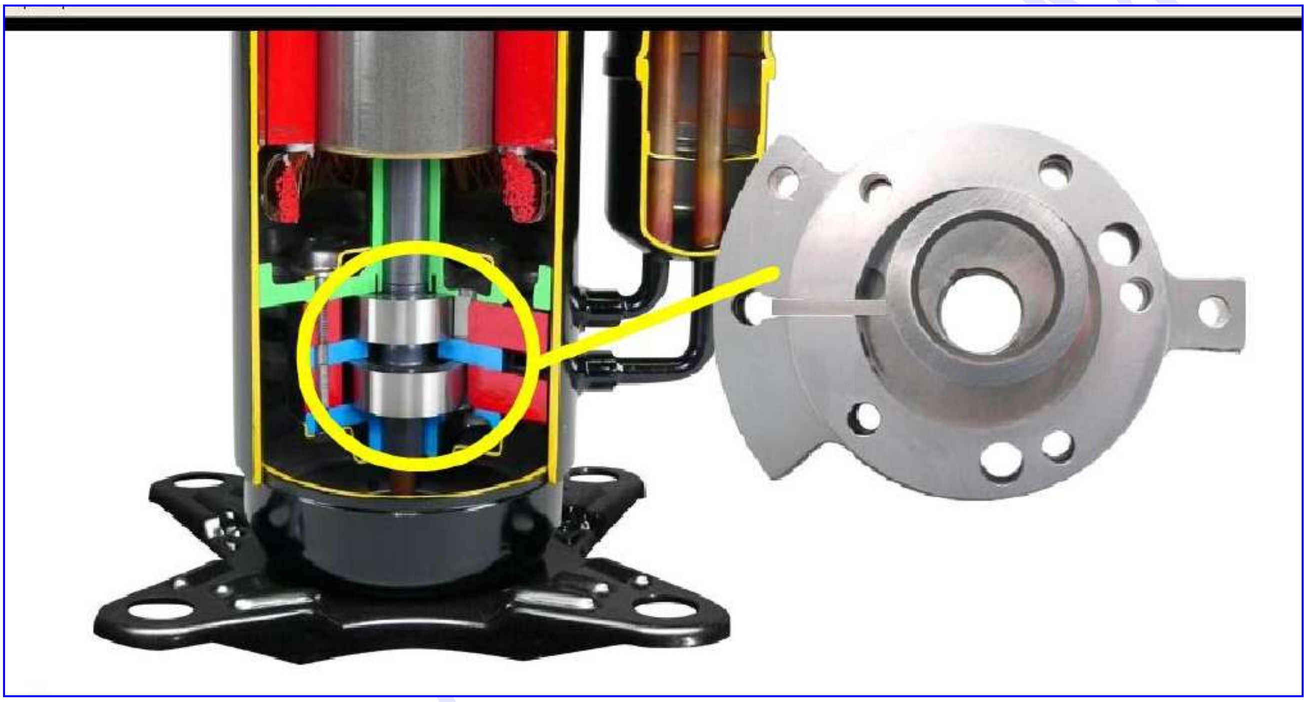
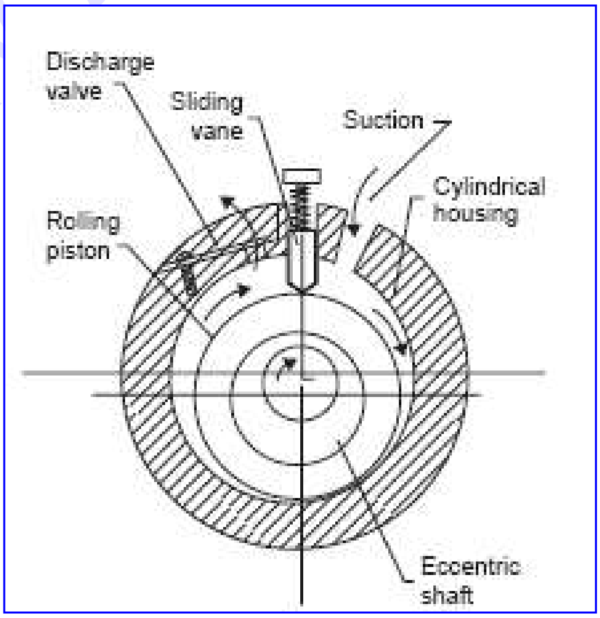


Figure 13-8. *Bolted type field serviceable eight-cylinder hermetic motor compressor.*

Rotary compressors

Rolling piston – Fixed vane





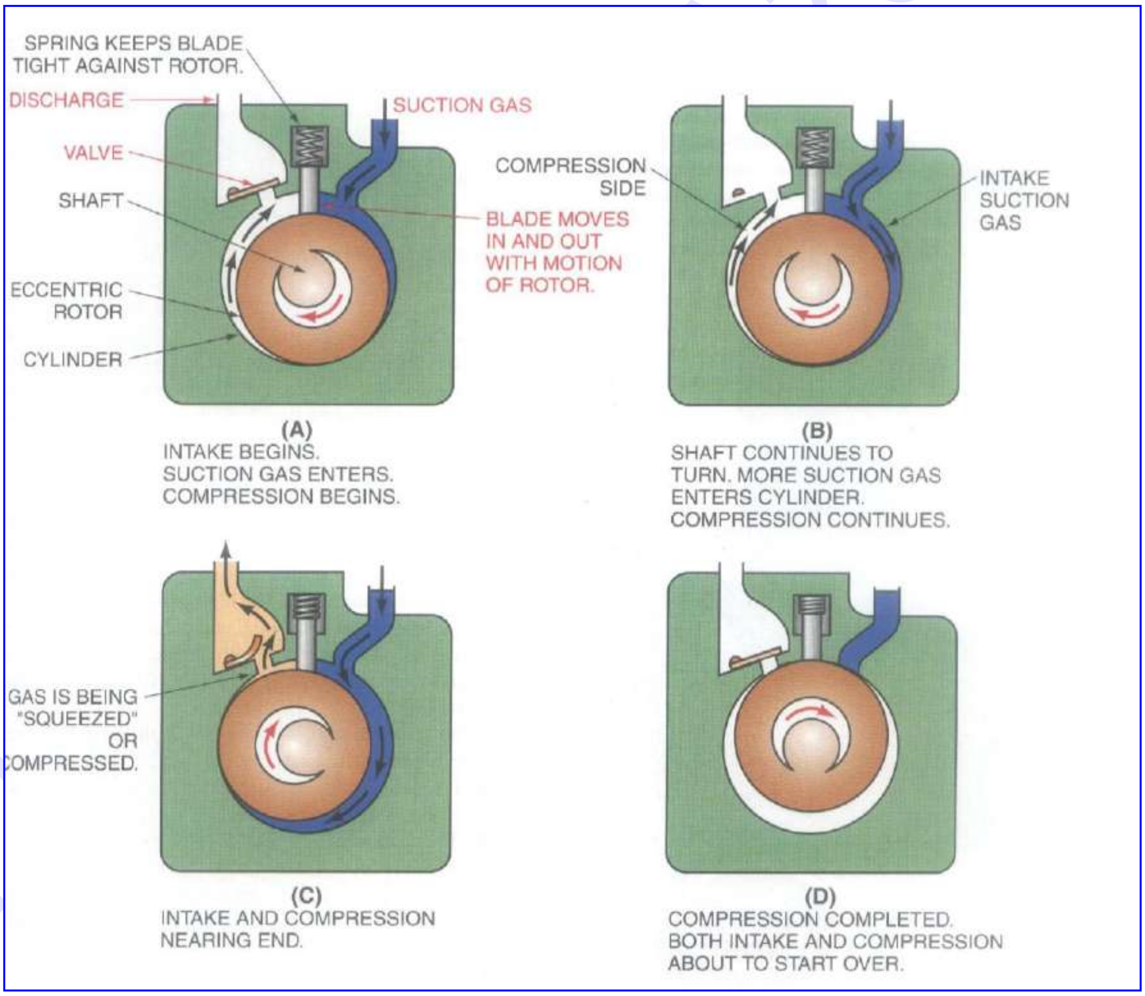
ROLLING PISTON COMPRESSORS

Rolling piston, or fixed vane, rotary compressors are used in household refrigerators and air- conditioning units . This type of compressor uses a roller mounted on the eccentric of a shaft with a single vane or blade suitably positioned in the non-rotating cylindrical housing, generally called the cylinder block. The blade reciprocates in a slot machined in the cylinder block. This reciprocating motion is caused by the eccentrically moving roller.

The drive motor stator and compressor are solidly mounted in the compressor housing. This design feature is possible due to low vibration associated with the rotary compression process, as opposed to reciprocating designs which employ spring isolation between the compressor parts and the housing.

Suction gas is directly piped into the suction port of the compressor, and the compressed gas is discharged into the compressor housing shell. This high-side shell design is used because of the simplicity of its lubrication system and the absence of oiling and compressor cooling problems.

Compressor performance is also improved because this arrangement minimizes heat transfer to the suction gas and reduces gas leakage area. Internal leakage is controlled through hydrodynamic sealing and selection of mating parts for optimum clearance. Hydrodynamic sealing depends on clearance, surface speed, surface finish, and oil viscosity. Close tolerance and low surface finish machining is necessary to support hydrodynamic sealing and to reduce gas leakage.



Performance

Rotary compressors have a high volumetric efficiency because of the small clearance volume and correspondingly low reexpansion losses inherent in their design.

An acceptable sound level is important in the design of any small compressor. Since gas flow is continuous and no suction valve is required, rotary compressors can be relatively quiet. The sound level for a rotary compressor of the same design is directly related to its power input.

Table	Typical Rolling Piston Compressor Performance
3450 rpm	Compressor speed
R-22	Refrigerant
54.4°C	Condensing temperature
46.1°C	Liquid refrigerant temperature
7.2°C	Evaporator temperature
625 kPa	Suction pressure
18.3°C	Suction gas temperature
3.5 kW	Evaporator capacity
3.22	Coefficient of performance
1090 W	Input power

FEATURES

Shafts and Journals. The shafts are generally made from **steel forging and nodular cast iron**.

Bearings. The bearing must support the rotating member under all conditions. **Powdered metal** has been extensively used for these components, due to its porous properties, which help in lubrication.

Vanes. Vanes are designed for reliability by the choice of materials and lubrication. The vanes are hardened, ground, and polished to the best finish obtainable. **Steel, powdered metal, and aluminum alloys** have been used.

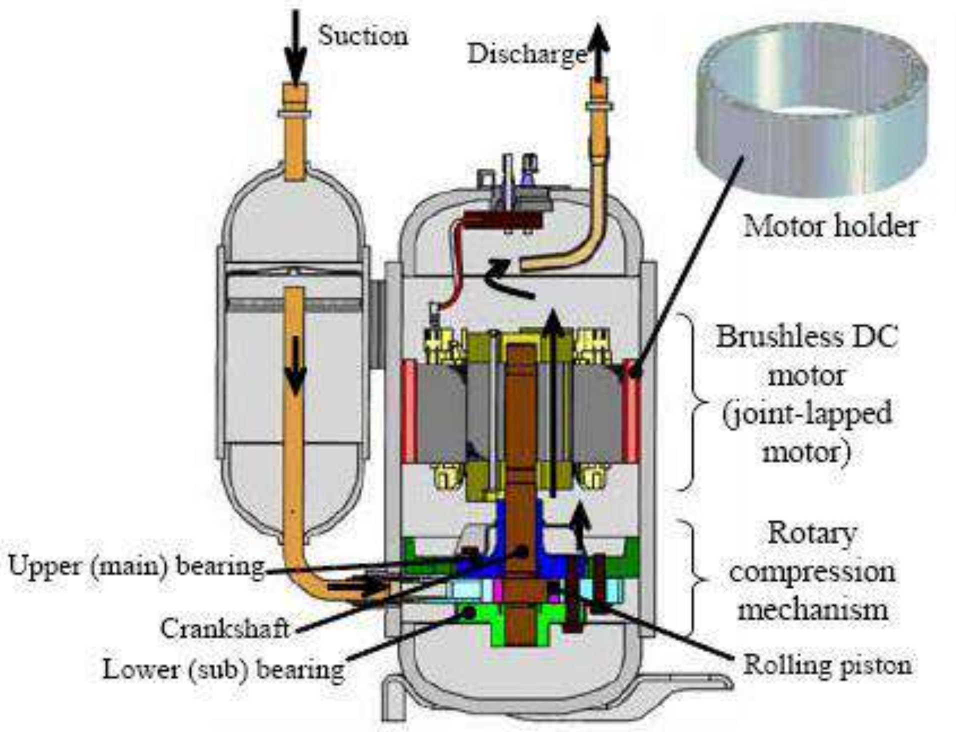
Vane Springs. Vane springs force the vane to stay in contact with the roller during start-up. The spring rate depends on the inertia of the vane.

Valves. Only discharge valves are required by rolling piston rotary compressors. They are usually simple reed valves made **of high-grade steel**.

Lubrication. A good lubrication system circulates an ample supply of clean oil to all working surfaces, bearings, blades, blade slots, and seal faces. High-side pressure in the housing shell ensures a sufficient pressure differential across the bearings; passageways distribute oil to the bearing surfaces.

Mechanical Efficiency. High mechanical efficiency depends on minimizing friction losses. Friction losses occur in the bearings and between the vane and slot wall, vane tip, and roller wall, and roller and bearing faces. The amount and distribution of these losses vary based on the geometry of the compressor.

Motor Selection. Breakdown torque requirements depend on the displacement of the compressor, the refrigerant, and the operating range. Domestic refrigerator compressors typically require a breakdown torque of about 190 to 200 N·m per liter of compressor displacement per revolution. Similarly, larger compressors using R-22 for window air conditioners require about 350 to 360 N·m breakdown torque per liter of compressor displacement per revolution. Rotary machines do not usually require complete unloading for successful starting. The starting torque of standard split-phase motors is ample for small compressors. Permanent split capacitor motors for air conditioners of various sizes provide sufficient starting and improve the power factor to the required range.



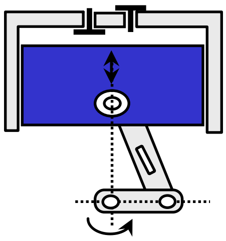
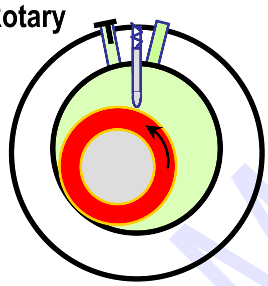
Advantages

- Simple design
- Low to medium initial and maintenance cost
- Two-stages design provide good efficiencies
- Easy to install
- Few moving parts

Disadvantages

- High rotational speed
- shorter life expectancy than any other designs
- Single-stage designs have lower efficiency
- Difficulty with dirty environment

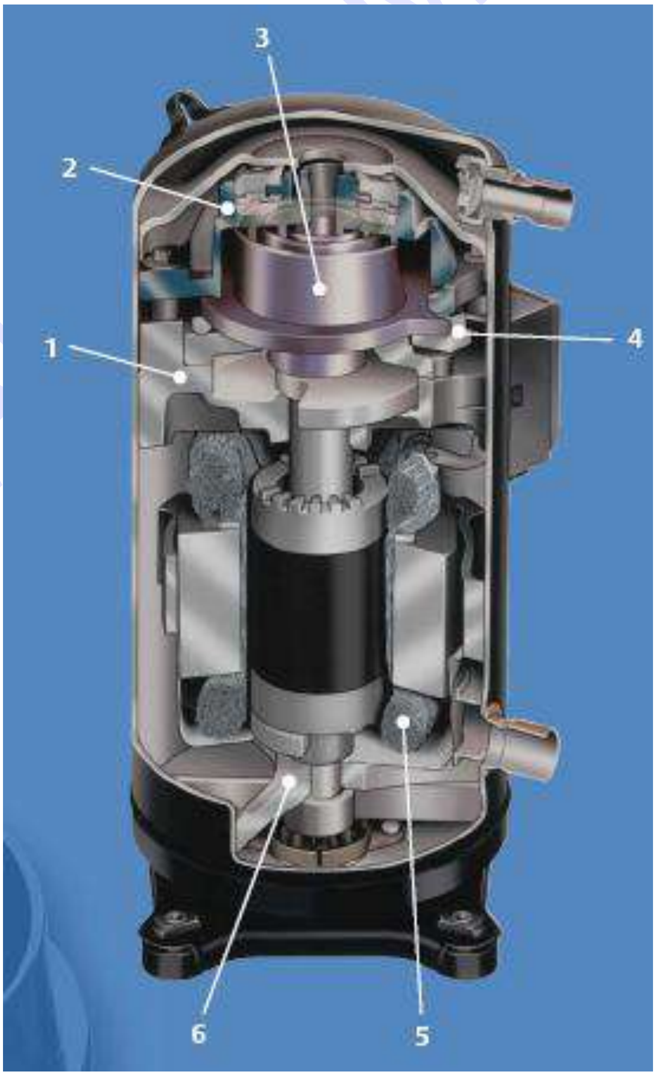
Comparison between reciprocating and rotary compressor:

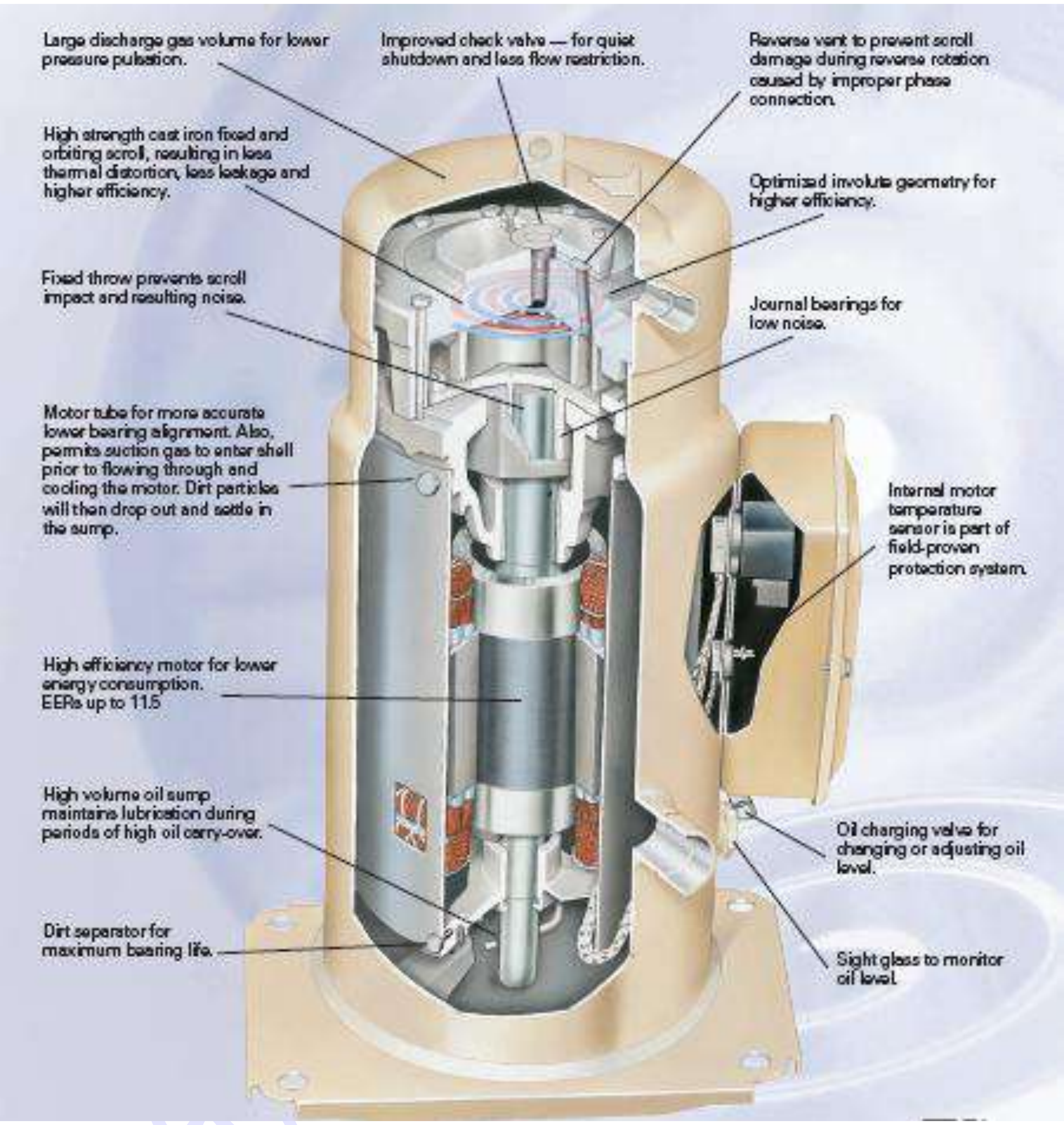
Item	Reciprocating	Rotary
		
Shell pressure	Low side	Hi side
Shell temp	Low	High
Compressor cooling	Natural air cooling Forced air cooling	Natural air cooling Forced air cooling Liquid injection cooling
Intake method of suction gas	Indirect intake to cylinder	Direct intake into cylinder
Inside supporting structure	Inner supporting or suspension	Shrink fitting
(Set Condition)Sound	55dB	52dB
R.E.E	W.h/9.1 Btu	W.h/10.6 Btu
Vibration	100	60
Weight	29kg	23.6kg
Part Numbers	So many parts	35% Fewer than Reciprocating

SCROLL COMPRESSORS

ORBITAL COMPRESSORS

	Parts name
1	main bearing
2	Axially compliant upper scroll
3	Radially compliant orbiting scroll
4	Precision Oldham coupling
5	High-performance motor
6	Precision lower bearing




Large discharge gas volume for lower pressure pulsation.
Improved check valve — for quiet shutdown and less flow restriction.
Reverse vent to prevent scroll damage during reverse rotation caused by improper phase connection.
High strength cast iron fixed and orbiting scroll, resulting in less thermal distortion, less leakage and higher efficiency.
Optimized involute geometry for higher efficiency.
Fixed throw prevents scroll impact and resulting noise.
Journal bearings for low noise.
Motor tube for more accurate lower bearing alignment. Also, permits suction gas to enter shell prior to flowing through and cooling the motor. Dirt particles will then drop out and settle in the sump.
Internal motor temperature sensor is part of field-proven protection system.
High efficiency motor for lower energy consumption. EERs up to 11.5
High volume oil sump maintains lubrication during periods of high oil carry-over.
Oil charging valve for changing or adjusting oil level.
Dirt separator for maximum bearing life.
Sight glass to monitor oil level.

Why scroll compressor

- **Few moving parts**
- **Hermetic design**
- **Direct driven - No gears**
- **Simple design with 60% less components**
- **Motor cooled by suction gases superior reliability energy efficiency improvement**

SCROLL COMPRESSORS (ORBITAL COMPRESSORS)

Description

Scroll compressors are orbital motion, positive-displacement machines that compress with two interfitting, spiral-shaped scroll members. They are currently used in residential and commercial air-conditioning, refrigeration, and heat pump applications as well as in automotive air conditioning. Capacities range from 3 to 50 kW. To function effectively, the scroll compressor requires close tolerance machining of the scroll members, which is possible due to the recent advances in manufacturing technology. This positive-displacement, rotary motion compressor includes performance features, such as high efficiency and low noise.

The two scrolls are fitted to form pockets between their respective base plate and various lines of contact between their vane walls. One scroll is held **fixed**, while the other **moves** in an orbital path with respect to the first. The flanks of the scrolls remain in contact, although the contact locations move progressively inward. Relative rotation between the pair is prevented by an interconnecting coupling.

Compression is accomplished by sealing suction gas in pockets of a given volume at the outer periphery of the scrolls and progressively reducing the size of those pockets as the scroll relative motion moves those inwards toward the discharge port. The trapped gas is at suction pressure and has just entered the compression process.

Orbiting motion moves the gas toward the center of the scroll pair, and pressure rises as pocket volumes are reduced. The gas reaches the central discharge port and begins to exit from the scrolls.

Two distinct compression paths operate simultaneously in a scroll set. The discharge process is nearly continuous, since new pockets reach the discharge stage very shortly after the previous discharge pockets have been evacuated.
Scroll compression embodies a fixed, built-in volume ratio that is defined by the geometry of the scrolls and by discharge port location. <u>This feature provides the scroll compressor with different performance characteristics than those of reciprocating or conventional rotary compressors.</u>

Features:

Scroll Members.
Gas sealing is critical to the performance advantage of scroll compressors. Sealing within the scroll set must be accomplished at the flank contact locations and between the vane tips and bases of the intermeshed scroll pair. Tip/base sealing is generally considered more critical than flank sealing. The method used to seal the scroll members tends to separate scroll compressors into compliant and noncompliant designs.

Noncompliant Designs.
In designs lacking compliance, the orbiting scroll takes a fixed orbital path. In the radial direction, sealing small irregularities between the vane flanks (due to flank machining variation) can be accomplished with oil flooding. In the axial direction, the position of both scrolls remains fixed, and flexible seals fitted into machined grooves on the tips of both scrolls accomplish tip sealing. The seals are pressure loaded to enhance uniform contact.

Radial Compliance.
This feature enhances flank sealing and allows the orbiting scroll to follow a flexible path defined by its own contact with the fixed scroll. In one type of radial compliance, a sliding “Unloaders” bushing is fitted onto the crankshaft eccentric pin in such a way that it directs the radial motion of the orbiting scroll. The orbiting scroll is mounted over this bushing through adrive bearing, and the scroll may now move radially in and out to accommodate variations in orbit radius caused by machining and assembly discrepancies. This feature tends to keep the flanks constantly in contact, and reduces impact on the flanks that can result from intermittent contact. Sufficient clearance in the pin/Unloaders assembly allows the scroll flanks to separate fully when desired. In some designs, the mass of the orbiting scroll is selected so that
Centrifugal force overcomes radial gas compression forces that would otherwise keep the flanks separated. In some other designs, the drive is designed so that the influence of centrifugal force is reduced, and the drive force overcomes the radial gas compression force. Radial compliance has the added benefit of increasing resistance to slugging and contaminants, since the orbiting scroll can “unload” to some extent as it encounters obstacles or non uniform hydraulic pressures.

Axial Compliance.
With this feature, an adjustable axial pressure maintains sealing contact between the scroll tips and bases while running. This pressure is released when the unit is shut down, allowing the compressor to start unloaded and to approach full operational speed before a significant load is encountered. This scheme obviates the use of tip seals, eliminating them as a potential source of wear and leakage. With the scroll tips bearing directly on the opposite base plates and with suitable lubrication, sealing tends to improve over time. Axial compliance can either be implemented on the orbiting scroll or the fixed scroll. The use of axial compliance requires auxiliary sealing of the discharge side with respect to the suction side of the compressor.

Antirotation Coupling. To ensure relative orbital motion, ***the orbiting scroll must not rotate in response to gas loading***. This rotation is most commonly accomplished by an Oldham coupling mechanism, which physically connects the scrolls and permits all planar motion, except relative rotation, between them.

Bearing System. The bearing system consists of a drive bearing mounted in the orbiting scroll and generally one of two main bearings. The main bearings are either of the cantilevered type (main bearings on same side of the motor as the scrolls) or consist of a main bearing on either side of the motor. All bearing load vectors rotate through a full 360° due to the nature of the drive load. The orbiting scroll is supported axially by a thrust bearing on a housing which is part of the internal frame or is mounted directly to the compressor shell.

Capacity Control

Two different capacity control mechanisms are currently being used by the scroll compressor industry.

1. Variable-Speed Scroll Compressor.

Conventional air conditioning uses a constant speed motor to drive the compressor. The variable-speed scroll compressor uses an inverter drive to convert a fixed frequency alternating current into one with adjustable voltage and frequency, which allows the variation of the rotating speed of the compressor motor. The compressor uses either an induction or a permanent magnet motor. Typical operating frequency varies between 15 and 150 Hz. The capacity provided by the machine is nearly directly proportional to its running frequency. Thus, virtually infinite capacity steps are possible for the system with a variable- speed compressor. The variable-speed scroll compressor is now widely used in Japan.

2. Variable-Displacement Scroll Compressor.

This capacity control mechanism incorporates porting holes in the fixed scroll member. The control mechanism disconnects or connects compression chambers to the suction side by respectively closing or opening the porting holes. When all porting holes are closed, the compressor runs at full capacity; opening of all porting holes to the suction side yields the smallest capacity. Thus, by opening or closing a different number of porting holes, variable cooling or heating capability is provided to the system. The number of different capacities and the extent of the capacity reduction available is governed by the locations of the ports in reference to full capacity suction seal-off.

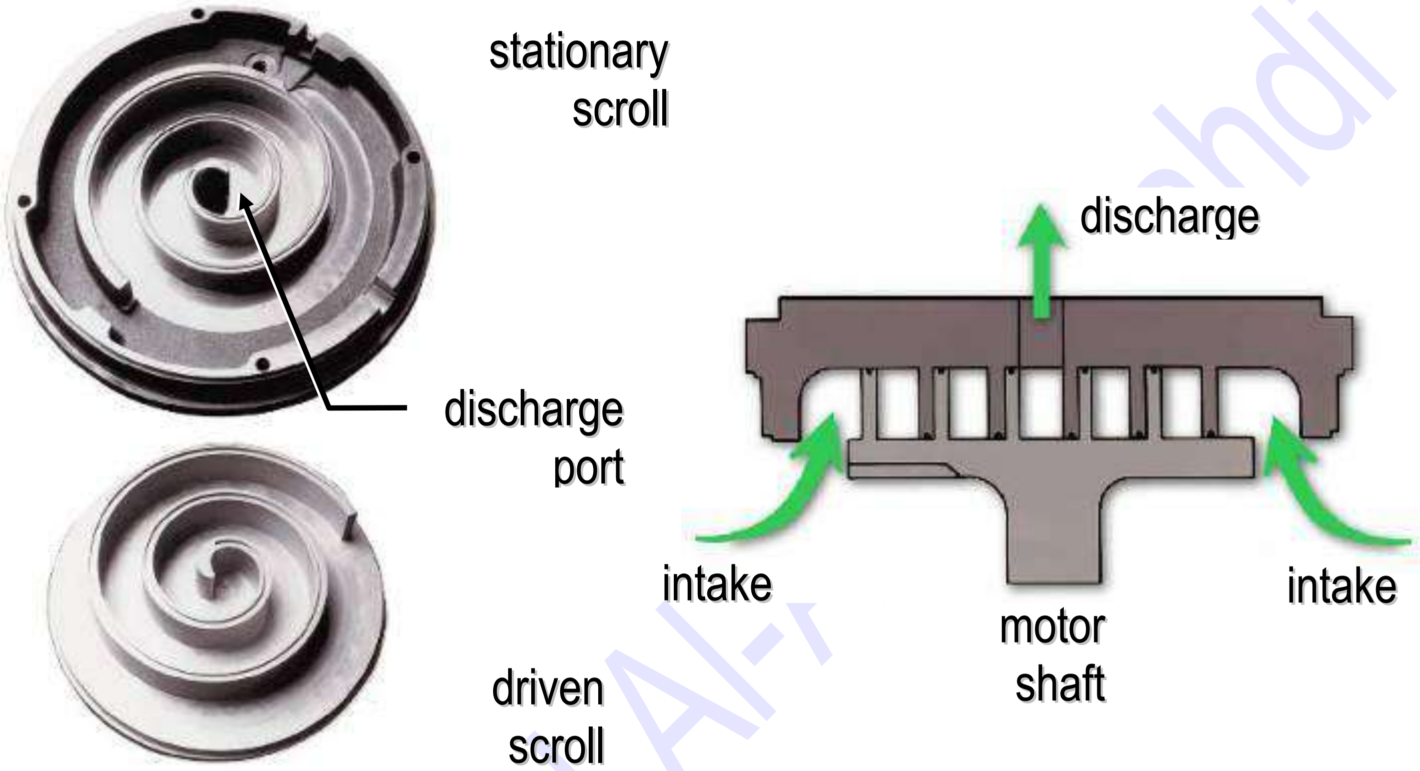
Performance

Scroll technology offers an advantage in performance for a number of reasons. Large suction and discharge ports reduce pressure losses incurred in the suction and discharge processes. Also, physical separation of these processes reduces heat transfer to the suction gas. The absence of valves and reexpansion volumes and the continuous flow process results in high volumetric efficiency over a wide range of operating conditions. Figure 36 illustrates this effect. The built-in volume ratio can be designed for lowest over- or under compression at typical demand conditions (2.5 to 3.5 pressure ratio for air conditioning). Isentropic efficiency in the range of 70% is possible at such pressure ratios, and it remains quite close to the efficiency of other compressor types at high pressure ratio. Scroll compressors offer a flatter capacity versus outdoor ambient curve than reciprocating products, which means that they can more closely approach indoor requirements at high demand conditions. As a result, the heat pump mode requires less supplemental heating; the cooling mode is more comfortable, because cycling is less as demand decreases.

Noise and Vibration

The scroll compressor inherently possesses a potential for low sound and vibration. It includes a minimal number of moving parts compared to other compressor technologies. ***Since scroll compression requires no valves, impact noise and vibration are completely eliminated.*** The presence of a continuous suction-compression-discharge process and low gas pressure pulsation help to keep vibration low. A virtually perfect dynamic balancing of the orbiting scroll inertia with counterweights eliminates possible vibration due to the rotating parts. Also, smooth surface finish and accurate machining of the vane profiles and base plates of both scroll members (requirement for small leakage) aids in minimal impact of the vanes. A typical sound spectrum of the scroll compressor is shown in Most scroll compressors used today are of the hermetic type, which require virtually no maintenance. However, the compressor manufacturer’s operation and application manual should be followed.

Structure: This compressor is constructed from one fixed and one rotating scroll in an offset spiral configuration.
Shaft rotation creates spaces of varying volume between the 2 scrolls, causing refrigerant to be sucked in and compressed.



Scroll Compressor
Similar to the reciprocating compressor, the **scroll compressor** works on the principle of trapping the refrigerant vapor and compressing it by gradually shrinking the volume of the refrigerant. The scroll compressor uses two scrolls
Configurations, mated face-to-face, to perform this compression process. The tips of the scrolls are fitted with seals that, along with a fine layer of oil, prevent the compressed refrigerant vapor from escaping through the mating surfaces.
The upper scroll, called the stationary scroll, contains a discharge port. The lower scroll, called the driven scroll, is connected to a motor by a shaft and bearing assembly. The refrigerant vapor enters through the outer edge of the
Scroll assembly and discharges through the port at the center of the stationary scroll.

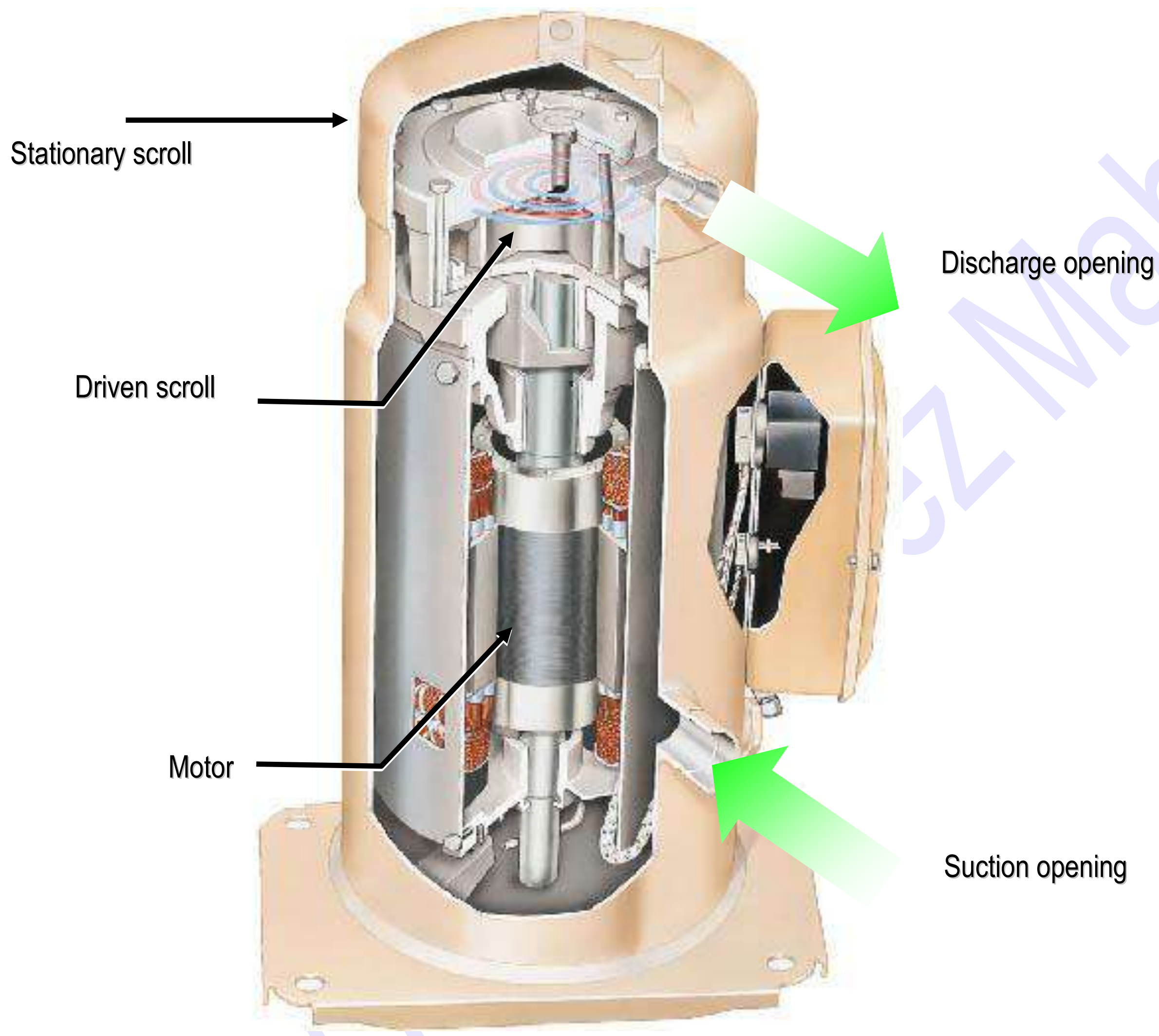
The center of the scroll journal bearing and the center of the motor shaft are offset. This offset imparts an orbiting motion to the driven scroll. Rotation of the motor shaft causes the scroll to orbit—not rotate—about the shaft center.
This orbiting motion causes the mated scrolls to form pockets of refrigerant vapor. As the orbiting motion continues, the relative movement between the orbiting scroll and the stationary scroll causes the pockets to move toward the
discharge port at the center of the assembly, gradually decreasing the refrigerant volume and increasing the pressure.
Three revolutions of the motor shaft are required to complete the compression process.
During the first full revolution of the shaft, or the **intake phase**, the edges of the scrolls separate, allowing the refrigerant vapor to enter the space between the two scrolls. By the completion of first revolution, the edges of

the scrolls meet again, forming two closed pockets of refrigerant. During the second full revolution, or the **compression phase**, the volume of each pocket is progressively reduced, increasing the pressure of the trapped refrigerant vapor. Completion of the second revolution produces near maximum compression.
During the third full revolution, or the **discharge phase**, the interior edges of the scrolls separate, releasing the compressed refrigerant through the discharge port. At the completion of the revolution, the volume of each pocket
is reduced to zero, forcing the remaining refrigerant vapor out of the scrolls. Looking at the complete cycle, notice that these three phases—intake, compression, and discharge—occur simultaneously in an ongoing sequence. While one pair of these pockets is being formed, another pair is being compressed and a third pair is being discharged.

Intake phase

Compression phase

Discharge phase

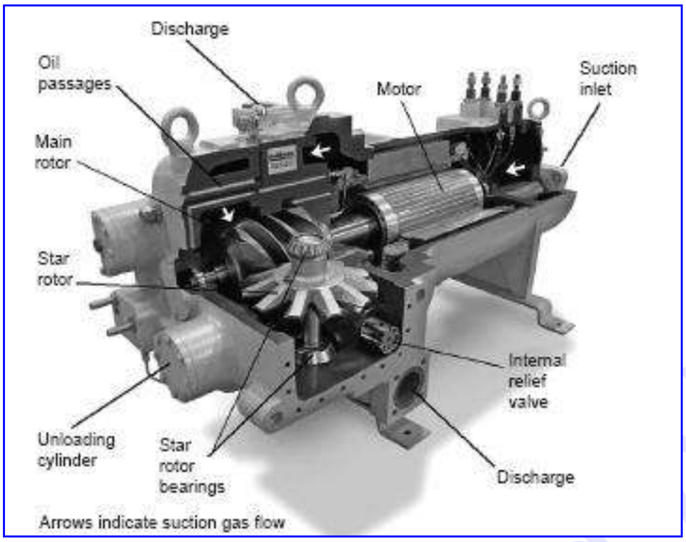


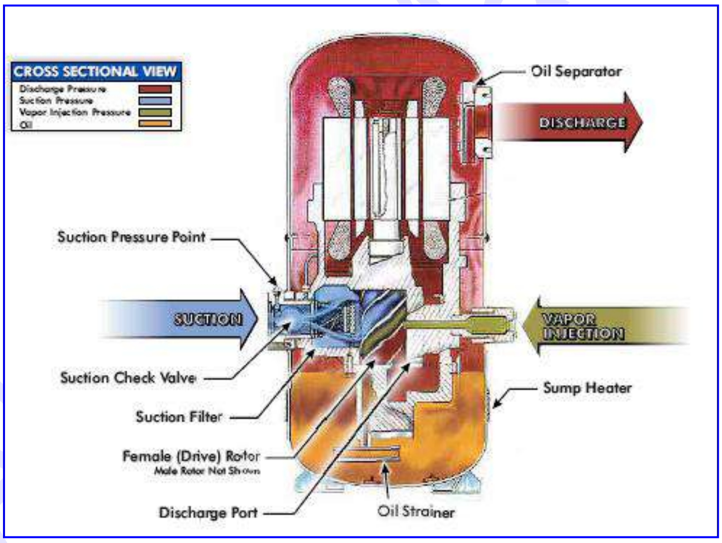
In this example scroll compressor, refrigerant vapor enters through the suction opening. The refrigerant then passes through a gap in the motor, cooling the motor, before entering the compressor housing. The refrigerant vapor is drawn

In to the scroll assembly where it is compressed, discharged into the dome, and finally discharged out of the compressor through the discharge opening. In the air-conditioning industry, scroll compressors are widely used in heat pumps, rooftop units, split systems, self-contained units, and even small water chillers.

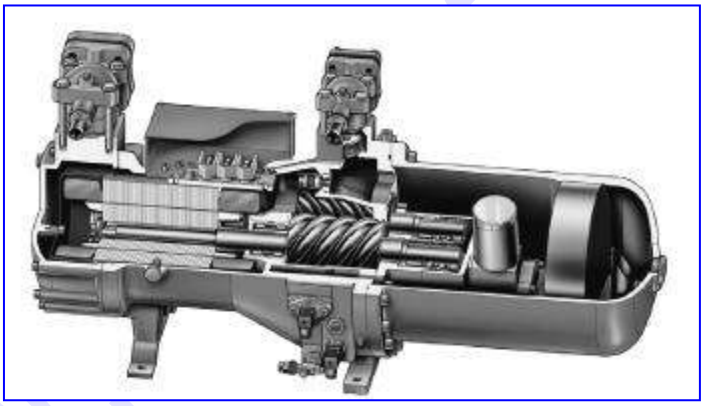
SCREW COMPRESSOR

SINGLE-SCREW

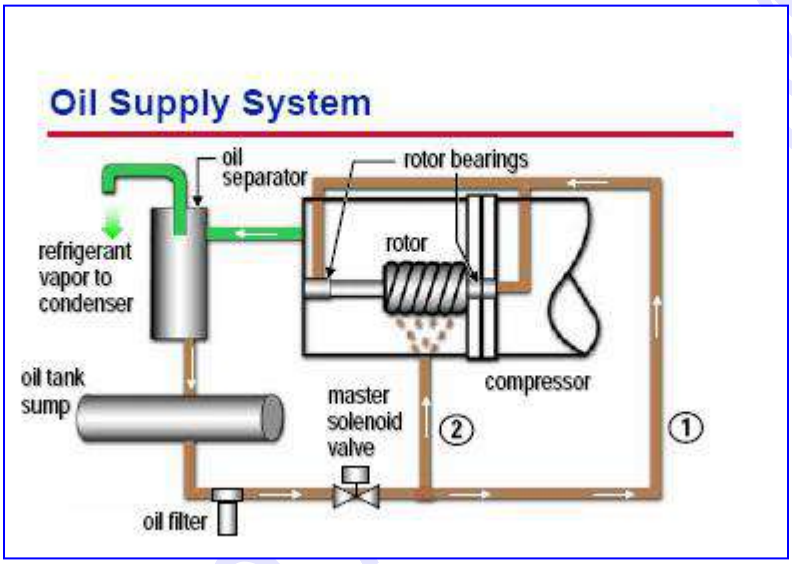




TWIN-SCREW



Lubrication:
A major function of injecting a fluid into the compression area is the removal of the heat of (compression, friction and stator heat) and reduction the wear. Oil is used to seal, cool, lubricate, and actuate capacity control. It gives a flat efficiency curve over a wide compression ratio and speed range, thus decreasing discharge temperature and reducing noise. In addition, the compressor can handle some liquid Flood back because it tolerates oil.
Oil injection requires an oil separator to remove the oil from the high-pressure refrigerant . For those applications with exacting demands for low oil carryover, separation equipment is available to leave less than 5 ppm oil in the circulated refrigerant.



With most compressors, oil can be injected automatically without a pump because of the pressure difference between the oil reservoir (discharge pressure) and the reduced pressure in a flute or bearing assembly during compression.
A continuously running oil pump is used in some compressors to generate oil pressure 30 to 45 psi over compressor discharge pressure. This pump requires 0.3 to 1.0% of the compressor's motor power.
Several methods of oil cooling include the following:

- Direct injection of liquid refrigerant into the compression process. Injection is controlled directly from the compressor discharge temperature, and loss of compressor capacity is minimized as injection takes place in a closed flute just before discharge occurs. This method requires very little power (typically less than 5% of compressor power).
- A small refrigerant pump draws liquid from the receiver and injects it directly into the compressor discharge line. The injection rate is controlled by sensing discharge temperature and modulating the pump motor speed. The power penalty in this method is the pump power (about 1 hp for compressors up to 1000 hp), which can result in energy savings over refrigerant injected into the compression chamber.
- External oil cooling between the oil reservoir and the point of injection is possible. Various heat exchangers are available to cool the oil: (1) separate water supply, (2) chiller water on a package unit, (3) condenser water on a package unit, (4) water from an evaporative condenser sump, (5) forced air cooled oil cooler, and (6) high-pressure liquid recirculation (thermo siphon).
- The heat added to the oil during compression is the amount usually removed in the oil cooler.

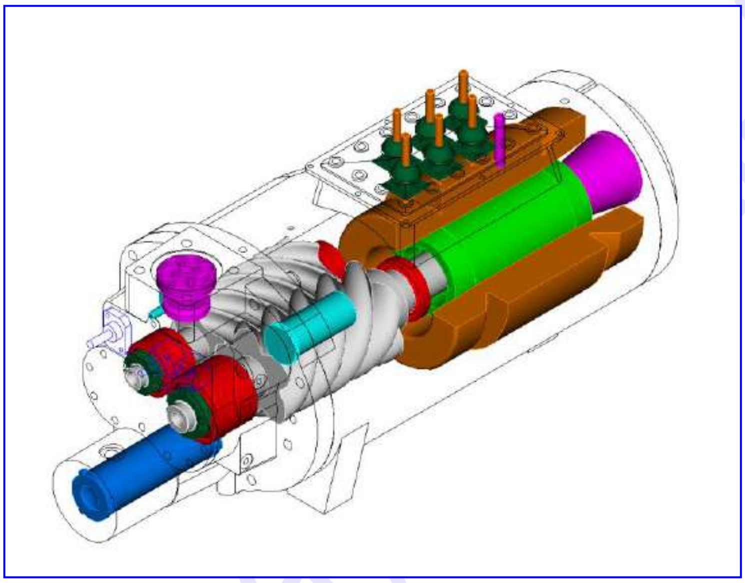
Mechanical Features

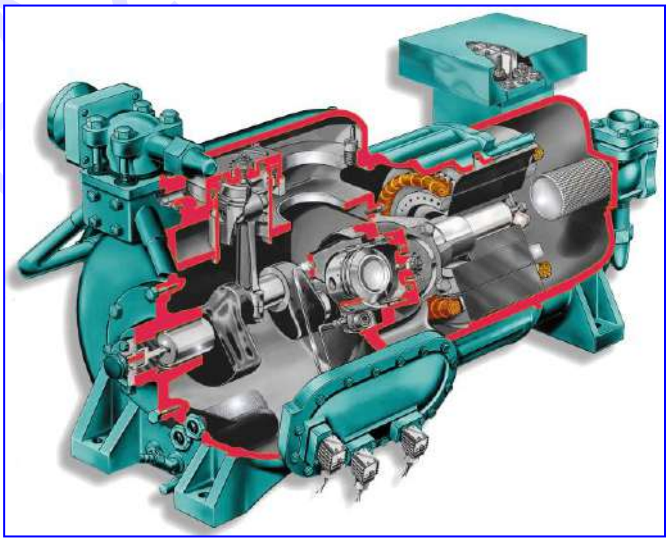
Rotors. The screw rotor is normally made of **cast iron.**

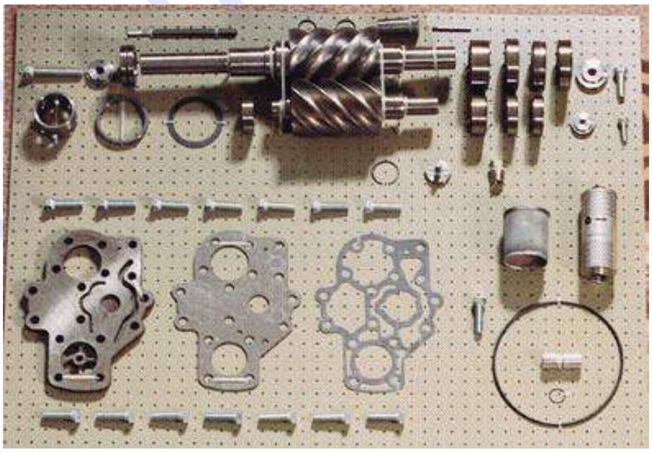
Bearings. Roller bearing is used.

Rotor Contact and Loading.
Contact between the male and female rotors is mainly rolling, primarily at a contact band on each rotor's pitch circle. Rolling at this contact band means that virtually no rotor wear occurs.

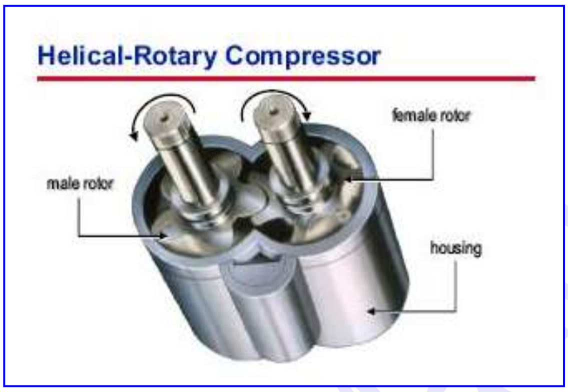
Gas Forces.
On the driven rotor, the internal gas force always creates a torque in a direction opposite to the direction of rotation. This is known as positive or braking torque. On the undriven rotor, the design can be such that the torque is positive, negative, or zero, except on female drive designs, where zero or negative torque does not occur.
Negative torque occurs when internal gas force tends to drive the rotor. If the average torque on the undriven rotor is near zero, this rotor is subjected to torque reversal as it goes through its phase angles. Under certain conditions, this can cause instability. Torque transmitted between the rotors does not create problems because the rotors are mainly in rolling contact.







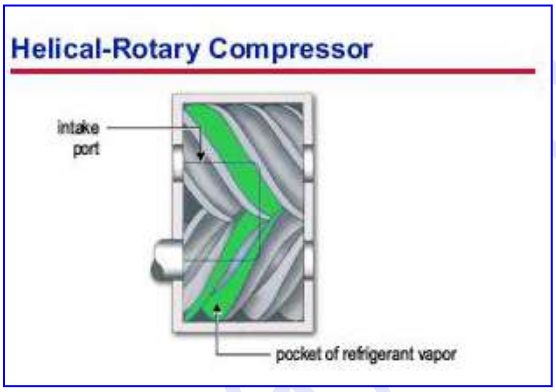
Helical – Rotary (Screw) Compressor

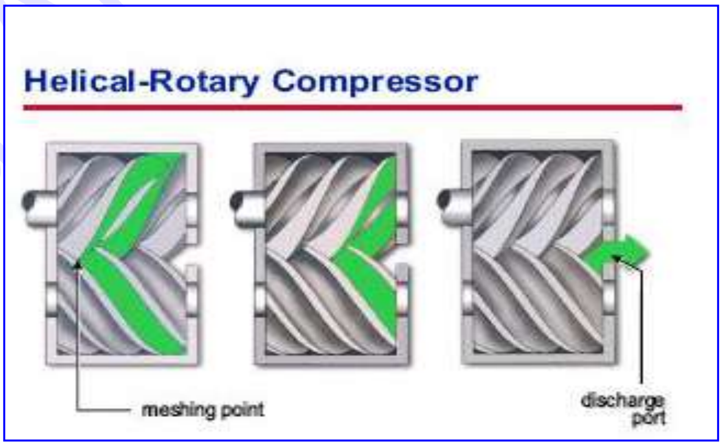


Helical-Rotary (Screw) Compressor

Similar to the scroll compressor, the **helical-rotary compressor** traps the refrigerant vapor and compresses it by gradually shrinking the volume of the refrigerant. This particular helical-rotary compressor design uses two mating screw-like **rotors** to perform the compression process.

The rotors are meshed and fit, with very close tolerances, within the compressor housing. The gap between the two rotors is sealed with oil, preventing the compressed refrigerant vapor from escaping through the mating surfaces. Only the male rotor is driven by the compressor motor. The lobes of the male rotor engage and drive the female rotor, causing the two parts to counter rotate.





Refrigerant vapor enters the compressor housing through the **intake port** and fills the pockets formed by the lobes of the rotors. As the rotors turn, they push these pockets of refrigerant toward the discharge end of the compressor.
After the pockets of refrigerant travel past the intake port area, the vapor, still at suction pressure, is confined within the pockets by the compressor housing.

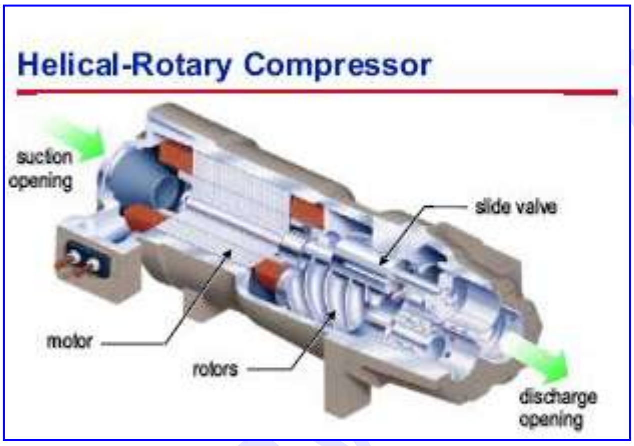
Viewing the compressor from the opposite side shows that continued rotation of the meshed rotor lobes drives the trapped refrigerant vapor (to the right), toward the discharge end of the compressor, ahead of the meshing point. This
action progressively reduces the volume of the pockets, compressing the refrigerant. Finally, when the pockets of refrigerant reach the **discharge port**, the compressed vapor are released and the rotors force the remaining refrigerant from the pockets.

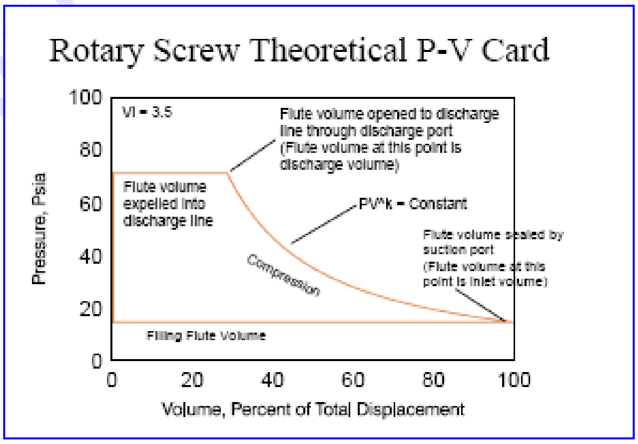
Compression Process
Compression is obtained by direct volume reduction with pure rotary motion. For clarity, the following description of the three basic compression phases is limited to one male rotor lobe and one female rotor inters lobe space.

Suction.
As the rotors begin to unmeshed, a void is created on both the male side (male thread) and the female side (female thread), and gas is drawn in through the inlet port. As the rotors continue to turn, the inter lobe space increases in size, and gas flows continuously into the compressor. Just prior to the point at which the inter lobe space leaves the inlet port, the entire length of the inter lobe space is completely filled with gas.

Compression.
Further rotation starts the meshing of another male lobe with another female inters lobe space on the suction end and progressively compresses the gas in the direction of the discharge port. Thus, the occupied volume of the trapped gas within the inter lobe space is decreased and the gas pressure consequently increased.

Discharge.
At a point determined by the designed built-in volume ratio, the discharge port is uncovered and the compressed gas is discharged by further meshing of the lobe and inters lobe space. During the remeshing period of compression and discharge, a fresh charge is drawn through the inlet on the opposite side of the meshing point. With four male lobes rotating at 3600 rpm, four inter lobe volumes are filled and give 14,400 discharges per minute. Since the intake and discharge cycles overlap effectively, a smooth continuous flow of gas results.





In this example helical-rotary compressor, refrigerant vapor is drawn into the compressor through the suction opening and passes through the motor, cooling it. The refrigerant vapor is drawn into the compressor rotors where it is
compressed and discharged out of the compressor.

Capacity Control

As with all positive-displacement compressors, both speed modulation and suction throttling can reduce the volume of gas drawn into a screw compressor. Ideal capacity modulation for any compressor would be :
(1) Continuous modulation from 100% to less than 10%.
(2) Good part-load efficiency.
(3) Unloaded starting.
(4) Unchanged reliability.
However, not all applications need ideal capacity modulation. Variable compressor displacement and variable speed are the best means for meeting these criteria. Variable compressor displacement is the most common capacity control method used. Various mechanisms achieve variable displacement, depending on the requirements of a particular application.

Capacity Slide Valve.

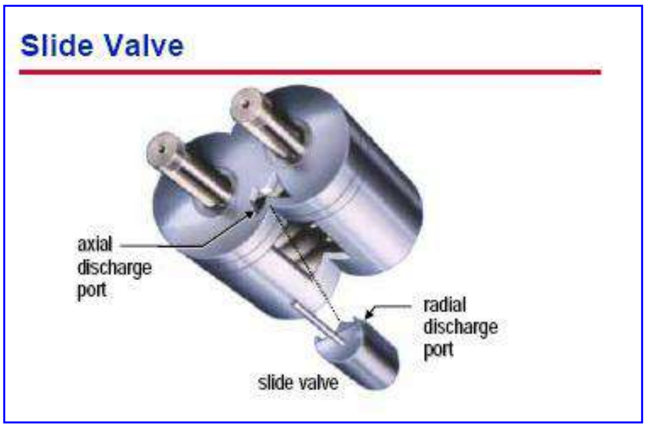
A slide valve for capacity control is a valve with sliding action parallel to the rotor bores. They are placed within or close to the high-pressure cusp region, face one or both rotor bores, and bypass a variable portion of the trapped gas charge back to suction, depending on their position. Within this definition, there are two types of capacity slide valves.
1. *Capacity slide valve regulating discharge port.* This type of slide valve is located within the high-pressure cusp region. It controls capacity as well as the location of the radial discharge port at part load. The axial discharge port is designed for a volume ratio giving good part-load performance without losing full-load performance. Figure 26 shows a schematic view of the most common arrangement.
2. *Capacity slide valve not regulating discharge port.* A slide valve outside the high-pressure cusp region controls only capacity and not the radial discharge port.
The first type is the most common arrangement. It is generally the most efficient of the available capacity reduction methods, due to its indirect correction of built-in volume ratio at part load and its ability to give large volume reductions without large movement of the slide valve.

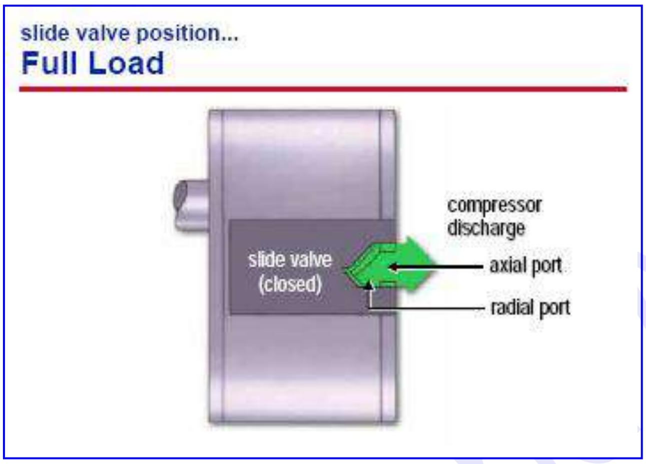
Capacity Slot Valve.

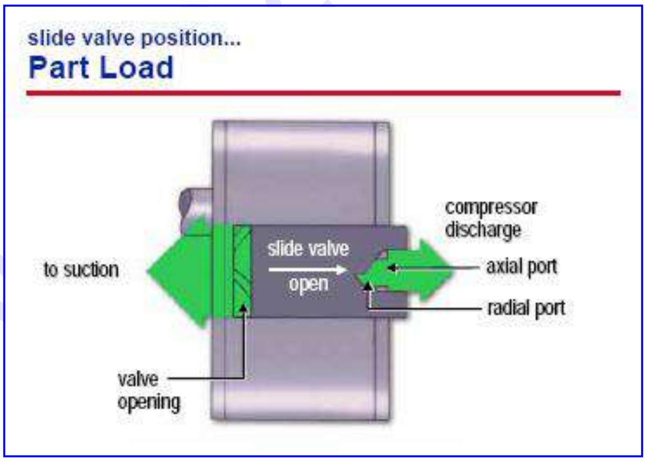
A capacity slot valve consists of a number of slots that follow the rotor helix and face one or both rotor bores. The slots are gradually opened or closed with a plunger or turn valve. These recesses in the casing wall increase the volume of the compression space and also create leakage paths over the lobe tips. The result is somewhat lower full-load performance when compared to a design without slots.

Capacity Lift Valve. Capacity lift valves or plug valves are movable plugs in one or both rotor bores (with radial or axial lifting action) that regulate the actual start of compression. These valves control capacity in a finite number of steps, rather than by the infinite control of a conventional slide valve . Neither slot valves nor lift valves offer quite as good efficiency at part load as a slide valve, because they do not relocate the radial discharge port. Thus, under compression losses at part load can be expected if the machines have the correct volume ratio for full-load operation and the compression ratio at part load does not reduce.

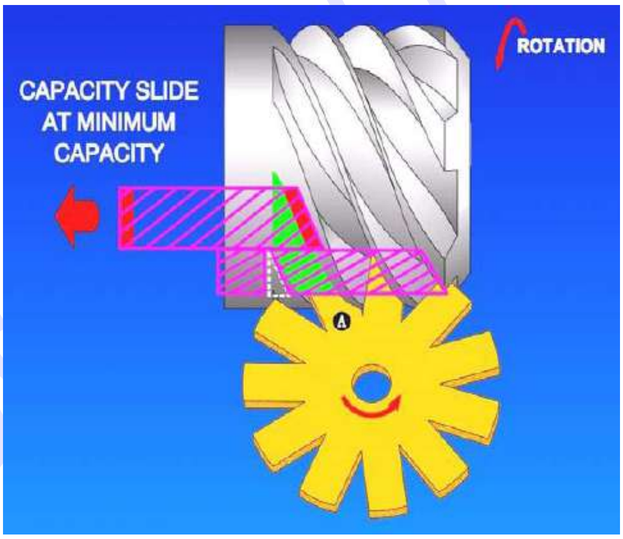
Twin type:

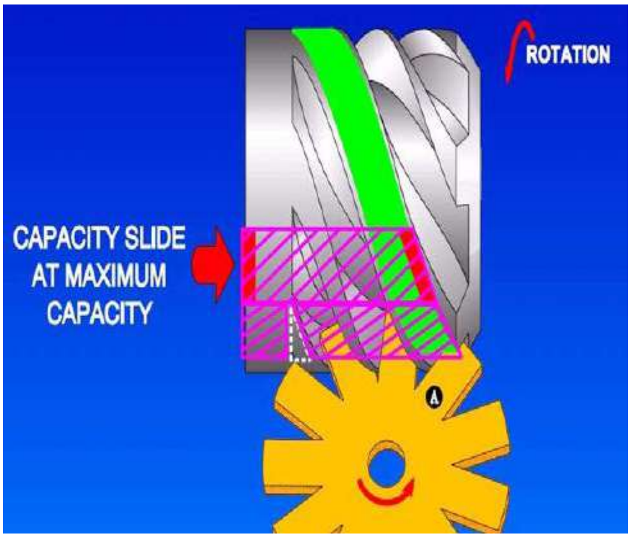






Single type:

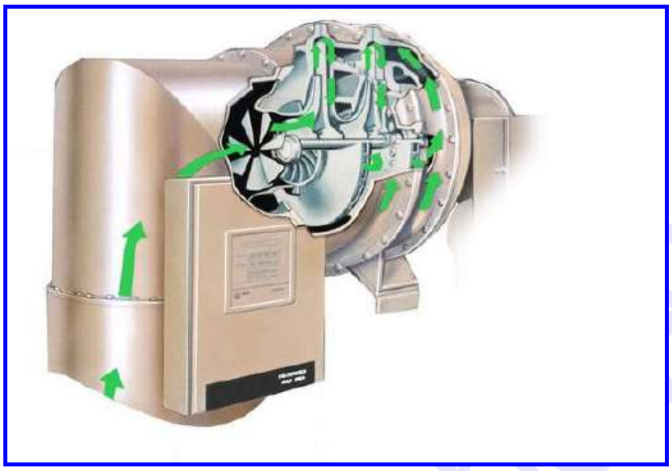


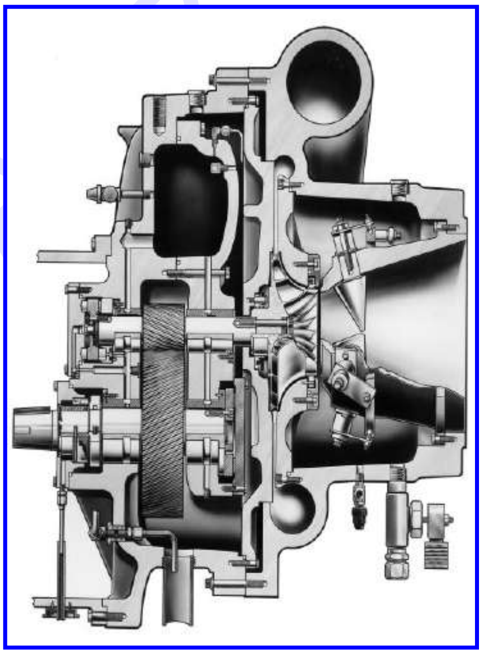


Dynamic compressors

Turbo compressors

CENTRIFUGAL COMPRESSOR





CENTRIFUGAL COMPRESSORS

Centrifugal compressors, sometimes called turbo compressors, belong to a family of turbo machines that includes fans, propellers, and turbines. These machines continuously exchange angular momentum between a rotating mechanical element and a steadily flowing fluid. **Because their flows are continuous, turbo machines have greater volumetric capacities, than do positive displacement devices**. For effective momentum exchange, their rotating speeds must be higher, but little vibration or wear results because of the steadiness of the motion and the absence of contacting parts. Centrifugal compressors are well suited for air-conditioning and refrigeration applications because of their ability to produce a high pressure ratio. The suction flow enters the rotating element, or impeller, in the axial direction and is discharged radially at a higher velocity.

The change in diameter through the impeller increases the velocity of the gas flow. This dynamic pressure is then converted to static pressure, through a diffusion process, which generally begins within the impeller and ends in a radial diffuser and outboard of the impeller.

Centrifugal compressors are used in a variety of refrigeration and air-conditioning installations. Suction flow ranges between 0.03 and 15 m3/s, with rotational speeds between 1800 and 90 000 rpm.

However, the high angular velocity associated with a low volumetric flow establishes a minimum practical capacity for most centrifugal applications. The upper capacity limit is determined by physical size, a 15 m^3/s.

Suction temperature is usually between 10 and -100°C, with a suction pressure between 14 and 700 kPa and discharge pressure up to 2 MPa. Almost any refrigerant can be used.

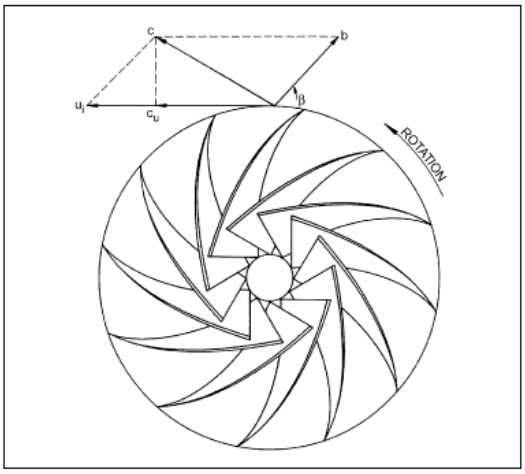
Angular Momentum

These velocities are shown in Figure 45, where refrigerant flows out from between the impeller blades with relative velocity *b* and absolute velocity *c*. The relative velocity angle b is a few degrees less than the blade angle because of a phenomenon known as slip.

If the incoming refrigerant was already swirling in the direction of rotation, the impeller's ability to impart angular momentum to the flow would be reduced. Some of the work done by the impeller increases the refrigerant pressure, while the remainder only increases its kinetic energy. The ratio of pressure-producing work to total work is known as the impeller reaction. An appreciable amount of kinetic energy leaves the impeller with magnitude $C^2 / 2$.

To convert this kinetic energy into additional pressure, a diffuser is located after the impeller. Radial vane less diffusers is most common.

In a multistage compressor, the flow leaving the first diffuser is guided to the inlet of the second impeller and so on through the machine provided that the mass flow rate is constant throughout the compressor.



Description

A centrifugal compressor can be single-stage, having only one impeller, or it can be multistage, having two or more impellers mounted in the same casing as shown in Figure. For process refrigeration applications, a compressor can have as many as ten stages.

The suction gas generally passes through a set of adjustable inlet guide vanes or an external suction damper before entering the impeller. The vanes (or suction damper) are used for capacity control as will be described later.

The high-velocity gas discharging from the impeller enters the radial diffuser which can be vaned or vaneless. Vaned diffusers are typically used in compressors designed to produce high pressure. These vanes are generally fixed, but they can be adjustable. Adjustable diffuser vanes can be used for capacity modulation either in lieu of or in conjunction with the inlet guide vanes.

For multistage compressors, the gas discharged from the first stage is directed to the inlet of the second stage through a return channel. The return channel can contain a set of fixed flow straightening vanes or an additional set of adjustable inlet guide vanes. Once the gas reaches the last stage, it is discharged in a volute or collector chamber. From there, the high-pressure gas passes through the compressor discharge connection. When multistage compressors are used, side loads can be introduced between stages so that one compressor performs several functions at several temperatures. Multiple casings can be connected in tandem to a single driver. These can be operated in series, in parallel, or even with different refrigerants.

Typical centrifugal for the single-stage design can intake gas volumes between 100 to 150,000 inlet acfm. A multi-stage centrifugal compressor is normal considered for inlet volume between 500 to 200,000 inlet acfm. It designs to discharge pressures up to 2352 psi, which the operation speeds of impeller from 3,000 rpm to higher. There is limitation for velocity of impeller due to impeller stress considerations; it is ranged from 0.8 to 0.85 Mach number at the impeller tip and eye.

Centrifugal compressors can be driven by electrical motor, steam turbine, or gas turbines.

Based on application requirement, centrifugal compressors may have different configurations. They may be classified as follows:

i. **Compressors with Horizontally-split Casings**:

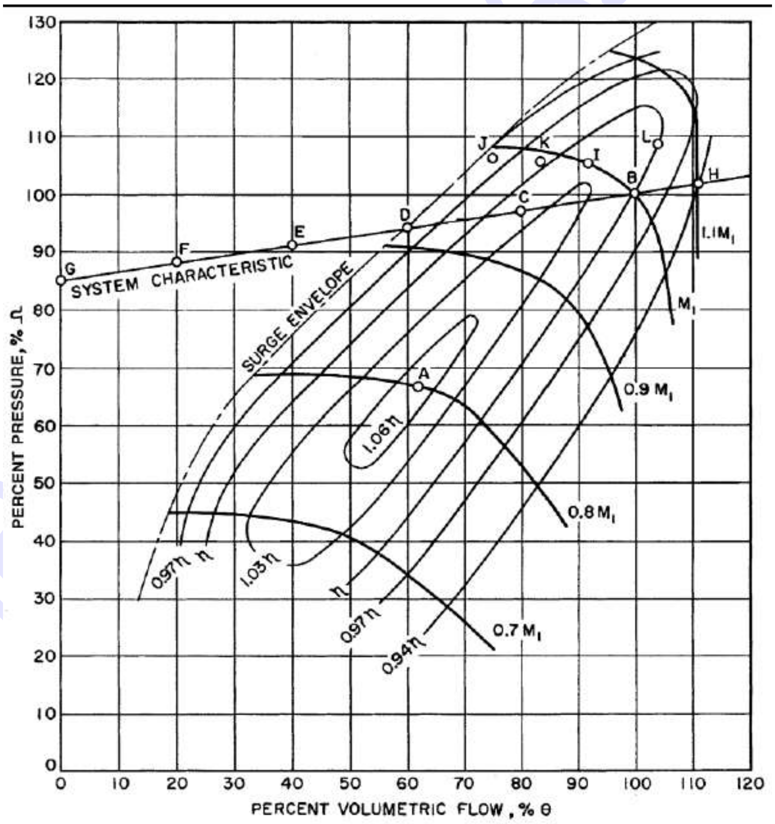
Horizontally-split casings consisting of half casings joined along the horizontal centerline are employed for operating pressures below 60 bars

ii. **Compressors with Vertically-split Casings**:

Vertically-split casings are formed by a cylinder closed by two end covers. It is generally multistage, and used for high pressure services (up to 700 kg/cm^2).

Performance

They are as general as the customary test coefficients and produce performance maps like the one in Figure 48, with speed expressed in terms of first-stage impeller Mach number *M*1. A compressor user with a particular installation in mind may prefer more explicit curves, such as pressure ratio and power versus volumetric flow at constant rotational speed. Plots of this sort may require fixed suction conditions to be entirely accurate, especially if discharge pressure and power are plotted against mass flow or refrigeration effect. A typical compressor performance map is shown in Figure 48 where percent of rated work is plotted with efficiency contours against percent of rated volumetric flow at various speeds. Point A is the design point at which the compressor operates with maximum efficiency. Point B is the selection or rating point at which the compressor is being applied to a particular system. From the application
or user's point of view, W and Q have their 100% values at Point B. To reduce first cost, refrigeration compressors are selected for pressure and capacity beyond their peak efficiency, as shown in Figure 48. The opposite selection would require a larger impeller and additional stages. Refrigerant acoustic velocity and the ability to operate at a high enough Mach number are also of concern. If the compressor shown in Figure 48 were of a multistage design, *M*1 would be about 1.2; for a single-stage compressor, it would be about 1.5.
Another acoustical effect is seen on the right of the performance map, where increasing speed does not produce a corresponding increase in capacity. The maximum flow at *M*1 and 1.1*M*1 approach a limit determined by the relative velocity of the refrigerant entering the first impeller. As this velocity approaches a sonic value, the flow becomes choked and further increases become impossible. Another commonly used term for this phenomenon is stonewalling; it represents the maximum capacity of an impeller.



Surging

Part-load range is limited (on the left side of the performance map) by a **surge envelope**. Satisfactory compressor operation to the left of this line is prevented by unstable **surging** or **hunting**, in which the refrigerant alternately flows backward and forward through the compressor, accompanied by increased noise, vibration, and heat. Prolonged operation under these conditions can damage the compressor. The flow reverses during surging about once every 2 s. Small systems surge at higher frequencies and large systems at lower. Surging can be distinguished from other kinds of noise and vibration by the fact that its flow reversals alternately unload and load the driver. Motor current varies markedly during surging, and turbines alternately speed up and slow down. Another kind of instability, **rotating stall**, may occur slightly to the right of the true surge envelope. This phenomenon involves the formation of rotating stall pockets or cells in the diffuser. It produces a roaring noise at a frequency determined by the number of cells formed and the impeller running speed. The driver load is steady during rotating stall, which is harmless to the compressor, but it may, however, vibrate components excessively.

Critical Speed

Centrifugal compressors are designed so that the first lateral critical speed is either well above or well below the operating speed. Operation at a speed between 0.8 and 1.1 times the first lateral speed is generally unacceptable from a reliability standpoint.

The second lateral critical speed should be at least 25% above the operating speed of the machine. The operating speeds of hermetic compressors are fixed, and each manufacturer has full responsibility for making sure the critical speeds are not too close to the operating speeds.

For open-drive compressors, however, operating speed depends on the required flow of the application. Thus, the designer must make sure that the critical speed is sufficiently far away from the operating speed. In applying open-drive machines, it is also necessary to consider torsional critical speed, which is a function of the designs of the compressor, the drive turbine or motor, and the coupling(s). In geared systems, the gearbox design is also involved. Manufacturers of centrifugal compressors use computer programs to calculate the torsional natural frequencies of the entire system, including the driver, the coupling(s), and the gears, if any. Responsibility for performing this calculation and ascertaining that the torsional natural frequencies are sufficiently far away from torsional exciting frequencies should be shared between the compressor manufacturer and the designer. For engine drives, it may be desirable to use a fluid coupling to isolate the compressor (and gear set) from engine torque pulsations. Depending on compressor bearing design, there may be other speed ranges that should be avoided to prevent the nonsynchronous shaft vibration commonly called oil whip or oil whirl.

MECHANICAL DESIGN

Impellers

Impellers without covers, such as the one shown in Figure 45, are known as open or unshrouded designs. Those with covered blades (Figure 46), are known as shrouded impellers. Open models must operate in close proximity to contoured stationary surfaces to avoid excessive leakage around their vanes. Shrouded designs must be fitted with labyrinth seals around their inlets for a similar purpose. Labyrinth seals behind each stage are required in multistage
compressors. Impellers must be shrunk, clamped, keyed, or bolted to their shafts to prevent loosening from thermal and centrifugal expansions. Generally, they are made of **cast or brazed aluminum** or of **cast, brazed, riveted**, or **welded steel**. **Aluminum** has a higher strength-mass ratio than steel, up to about 150°C, which permits higher rotating speeds with lighter rotors. ***Steel impellers*** retain their strength at higher temperatures and are more resistant to erosion. Lead-coated and stainless steels can be selected in corrosive applications.

Casings

Centrifugal compressor casings are about twice as large as their largest impellers, with suction and discharge connections sized for flow Mach numbers between 0.1 and 0.3. They are designed for the pressure requirements of ASHRAE *Standard* 15. A hydrostatic test pressure 50% greater than the maximum design working pressure is
customary. **Cast iron** is the most common casing material, having been used for temperatures as low as -100°C and pressures as high as 2 Mpa. Nodular **iron and cast or fabricated steel** are also used for low temperatures, high pressures, high shock, and hazardous applications. **Multistage casings** are usually *split horizontally*, although un split barrel designs can also be used.

Lubrication

Like motors and gears, the bearings and lubrication systems of centrifugal compressors can be internal or external, depending on whether or not they operate in refrigerant atmospheres. For reasons of simplicity, size, and cost, most air-conditioning and refrigeration compressors have internal bearings, as shown in Figure 46.
In addition, they often have internal oil pumps, driven either by an internal motor or the compressor shaft; the latter arrangement is typically used with an auxiliary oil pump for starting and/or backup service. Most refrigerants are soluble in lubricating oils, the extent increasing with refrigerant pressure and decreasing with oil temperature.

A compressor's oil may typically contain 20% refrigerant (by mass) during idle periods of high pressure and 5% during normal operation. Thus, refrigerant will come out of solution and foam the oil when such a compressor is started.

To prevent excessive foaming from activating the oil pump and starving the bearings, **oil heaters** minimize refrigerant solubility during idle periods. **Standby oil temperatures between 55 and 65°C are required**, depending on pressure. Once a compressor has started, its oil should be cooled to increase oil viscosity and maximize refrigerant retention during the pull-down period. A sharp reduction in pressure before starting tends to supersaturate the oil. This produces more foaming at start-up than would the same pressure reduction after the compressor has started.

Mechanical seals are commonly used in refrigeration machines because they are leak-tight during idle periods. These seals require some lubricating oil leakage when operating, however. Shaft seals leak oil out of compressors with internal bearings and into compressors with external bearings. Means for recovering seal oil leakage with a minimal loss of refrigerant must be provided in external bearing systems.

Bearings

Centrifugal compressor bearings are generally of a hydrodynamic design, with sleeve bearings (one-piece or split) being the most common for radial loads; tilting pad, tapered land, and **pocket bearings are customary for thrust**. The usual materials are Babbitt-lined, and bronze. Thrust bearings tend to be the most important in turbo machines, and centrifugal compressors are no exception. Thrust comes from the pressure behind an impeller exceeding the pressure at its inlet. In multistage designs, each impeller adds to the total, unless some are mounted backward to achieve the opposite effect. In the absence of this opposing balance, it is customary to provide a balancing piston behind the last impeller, with pressure on the piston thrusting opposite to the stages. To avoid axial rotor vibration, some net thrust must be retained in either balancing arrangement.

Accessories

The minimum accessories required by a centrifugal compressor are an **oil filter**, **oil cooler**, and **three safety controls**.

Oil filters may be built into the compressor but are more often externally mounted. Dual filters can be provided for industrial applications so that one can be serviced while the other is operating.

Single or dual oil coolers usually use condenser water, chilled water, refrigerant, or air as their cooling medium. Water- and refrigerant-cooled models may be built into the compressor, and refrigerant-cooled oil coolers may be built into a system heat exchanger. Many oil coolers are mounted externally for maximum serviceability.

Safety controls, with or without anticipatory alarms, must include a low oil pressure cutout, a high oil temperature switch, and high discharge and low suction pressure (or temperature) cutouts. A high motor temperature device is necessary in a hermetic compressor. Other common safety controls and alarms sense discharge temperature,
bearing temperature, oil filter pressure differential, oil level, low oil temperature, shaft seal pressure, balancing piston
pressure, surging, vibration, and thrust bearing wear. **Pressure gages** and **thermometers** are useful indicators of the
critical items monitored by the controls. **Suction, discharge, and oil pressure gages** are the most important, followed by suction, discharge, and oil thermometers. Suction and discharge instruments are often attached to components rather than to the compressor itself, but they should be provided. Inter stage pressures and temperatures can also be helpful, either on the compressor or on the system. Electronic components may be used for all safety and operating controls. Electronic sensors and displays may be used for pressure and temperature monitoring.

OPERATION AND MAINTENANCE

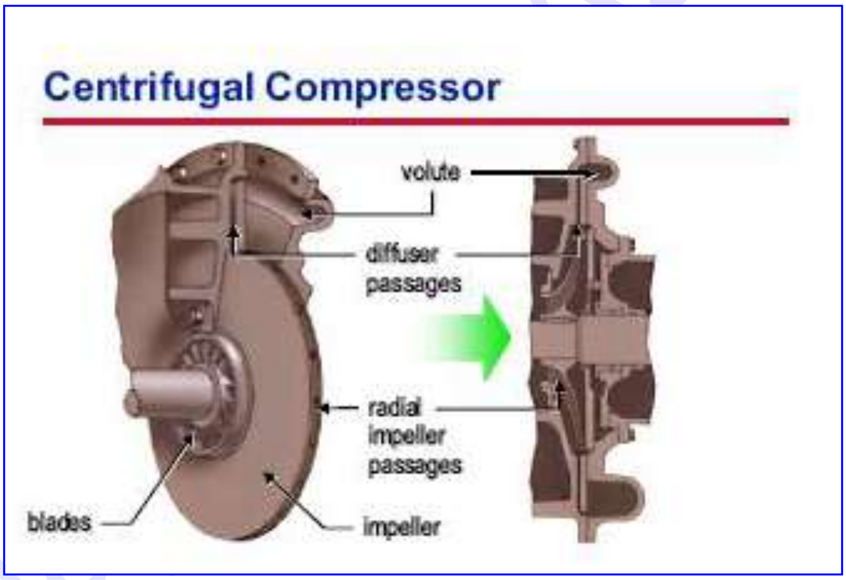
Reference should be made to the compressor manufacturer's operating and maintenance instructions for recommended procedures. A planned maintenance program should be established. As part of this program, operating documentation should be kept, tabulating pertinent unit temperatures, pressures, flows, fluid levels, electrical data, and refrigerant added. These can be compared periodically with values recorded for the new unit. Gradual changes in data can be used to signify the need for routine maintenance; abrupt changes should indicate system or component difficulty. A successful maintenance program requires the operating engineer to be able to recognize and identify the reason for these data trends. In addition, by having a knowledge of the component parts and their operational interaction, the designer will be able to use these symptoms to prescribe the proper maintenance procedures.

The following items deserve attention in establishing a planned compressor maintenance program:

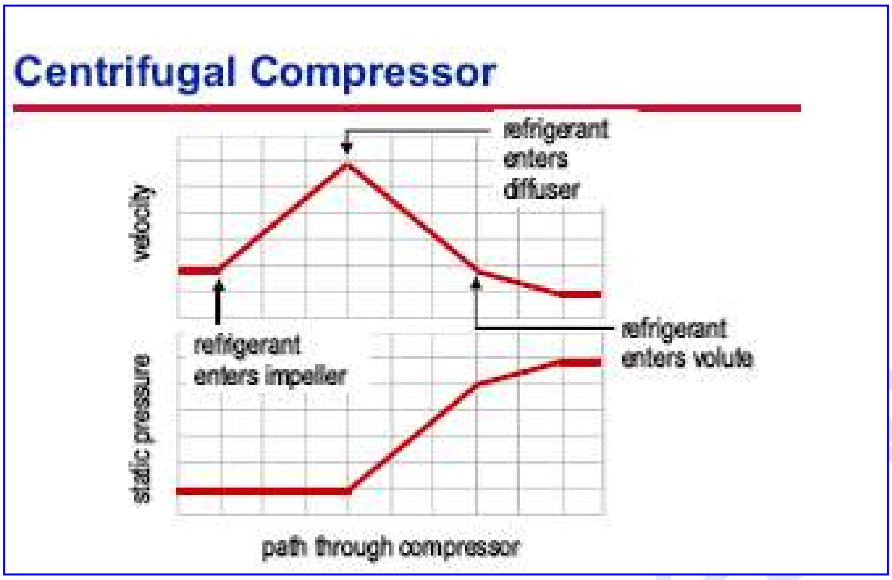
1. A tight system is important. Leaks on compressors operating at sub atmospheric pressures allow non condensable and moisture to enter the system, adversely affecting operation and component life. Leakage in higher pressure systems allows oil and refrigerant loss.
2. Compliance with the manufacturer's recommended oil filter inspection and replacement schedule allows visual indication of the condition of the compressor lubrication system. Repetitive clogging of filters can mean system contamination. Periodic oil sample analysis can monitor acid, moisture, and particulate levels to assist in problem detection.
3. Operating and safety controls should be checked periodically and calibrated to ensure reliability.
4. The electrical resistance of hermetic motor windings between phases and to ground should be checked regularly, following the manufacturer's outlined procedure. This will help detect any internal electrical insulation deterioration or the formation of electrical leakage paths before a failure occurs.
5. Water-cooled oil coolers should be systematically cleaned on the water side, and the operation of any automatic water control valves should be checked.
6. For some compressors, periodic maintenance, such as manual lubrication of couplings and other external components, and shaft seal replacement, is required.
7. Vibration analysis, when performed periodically, can locate and identify trouble. Without disassembly of the machine, such trouble can be found in its early stages before machinery failure or damage can occur.
8. The necessary steps for preparing the unit for prolonged shutdown (i.e., winter) and specified instruction for starting after this standby period, should both be part of the program.

Centrifugal Compressor

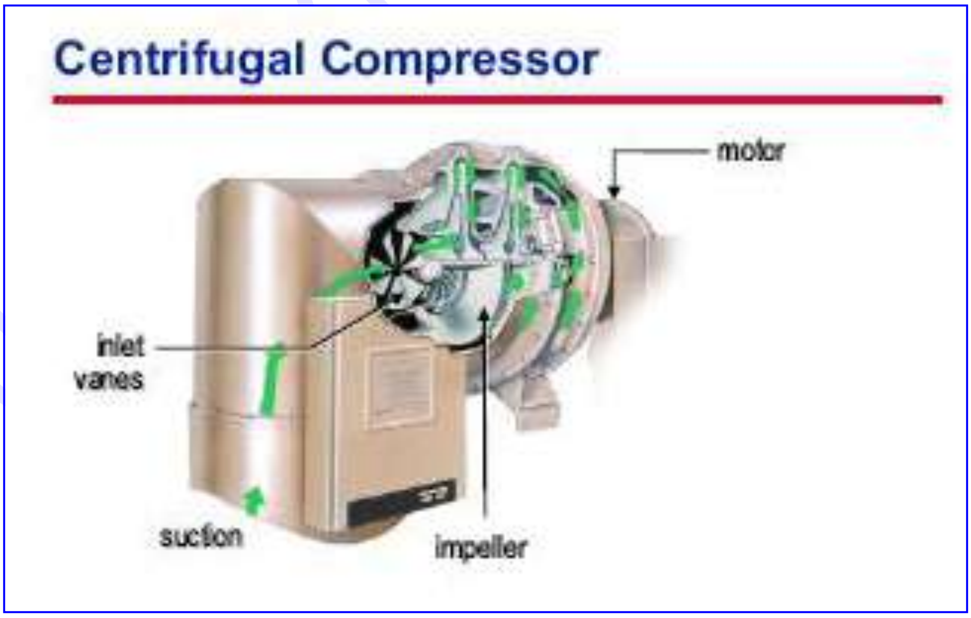
The **centrifugal compressor** uses the principle of dynamic compression, which involves converting energy from one form to another, to increase the pressure and temperature of the refrigerant. It converts kinetic energy (velocity)
to static energy (pressure). The core component of a centrifugal compressor is the rotating **impeller**.



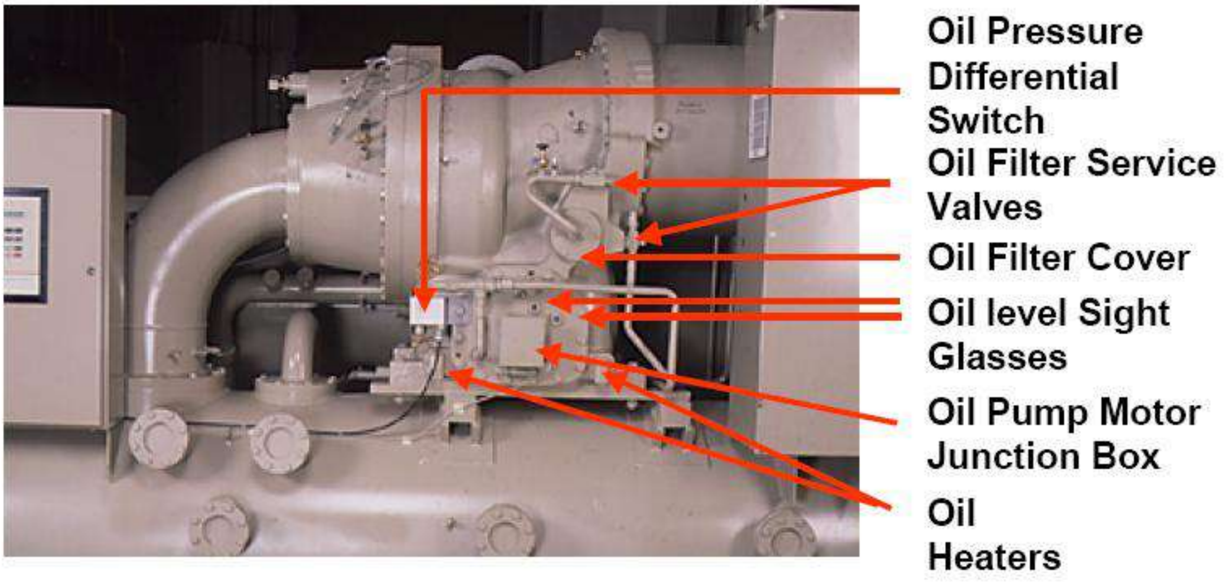
The center, or eye, of the impeller is fitted with blades that draw refrigerant vapor into **radial passages** that are internal to the impeller body. The rotation of the impeller causes the refrigerant vapor to accelerate within these passages,
increasing its velocity and kinetic energy.
The accelerated refrigerant vapor leaves the impeller and enters the **diffuser passages**. These passages start out small and become larger as the refrigerant travels through them. As the size of the diffuser passage increases, the velocity, and therefore the kinetic energy, of the refrigerant decreases. The first law of thermodynamics states that energy is not destroyed—only converted from one form to another. Thus, the refrigerant's kinetic energy (velocity) is converted to static energy (or static pressure). Refrigerant, now at a higher pressure, collects in a larger space around the perimeter of the compressor called the **volute**. The volute also becomes larger as the refrigerant travels through it. Again, as the size of the volute increases, the kinetic energy is converted to static pressure.



This chart plots the conversion of energy that takes place as the refrigerant passes through the centrifugal compressor. In the radial passages of the rotating impeller, the refrigerant vapor accelerates, increasing its velocity and
kinetic energy. As the area increases in the diffuser passages, the velocity, and therefore the kinetic energy, of the refrigerant decreases. This reduction in kinetic energy (velocity) is offset by an increase in the refrigerant's static energy or static pressure. Finally, the high-pressure refrigerant collects in the volute around the perimeter of the compressor, where further energy conversion takes place.



In this example centrifugal compressor, refrigerant vapor is drawn into the compressor and enters the center of impeller. This particular centrifugal compressor uses multiple impellers to perform the compression process in stages. The impellers rotate on a common shaft that is connected to the motor.

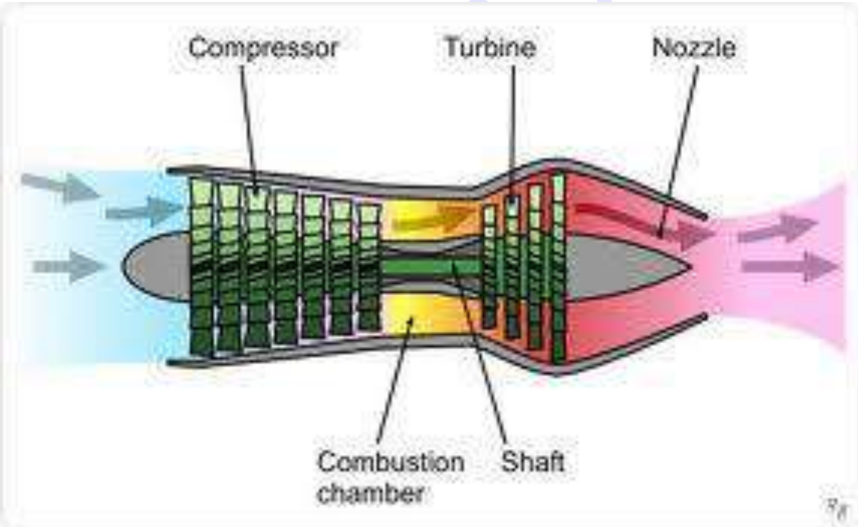


Centrifugal compressor from TRANE

The advantages and disadvantages of centrifugal compressor can be summarized into this table below.

Advantages	**Disadvantages**
High efficiency approaching two stages reciprocating compressor	High initial cost
Can reach pressure up to 1200 psi	Complicated monitoring and control systems
Completely package for plant or instrument air up through 500 hp	Limited capacity control modulation, requiring unloading for reduced capacities
Relatives first cost improves as size increase	High rotational speed require special bearings and sophisticated vibration and clearance monitoring
Designed to give lubricant free air	Specialized maintenance considerations
Does not require special foundations	

Axial compressor



Axial flow compressors are used mainly as compressors for gas turbines. They are used in the steel industry as blast furnace blowers and in the chemical industry for large nitric acid plants.

Compare to other type of compressor, axial flow compressors are mainly used for applications where the head required is low and with the high intake volume of flow. The efficiency in an axial flow compressor is higher than the centrifugal compressor. They are available in sizes producing pressures in excess of 100 psi at intake volumes between 23,500 to 588,500 acfm.

The component of axial flow compressor consist of the rotating element that construct from a single drum to which are attached several rows of decreasing-height blades having airfoil cross sections. Between each rotating blade row is a stationary blade row. All blade angles and areas are designed precisely for a given performance and high efficiency.

One additional row of fixed blades (inlet guide vanes) is frequently used at the compressor inlet to ensure that air enters the first stage rotors at the desired angle. Also, another diffuser at the exit of the compressor might be added, known as exit guide vanes, to further diffuse the fluid and control its velocity.

Axial flow compressors do not significantly change the direction of the flow stream; the fluid flow enters the compressor and exits from the gas turbine in an axial direction (parallel with the axis of rotation). It compresses the gas fluid by first accelerating the fluid and then diffusing it to increase its pressure.

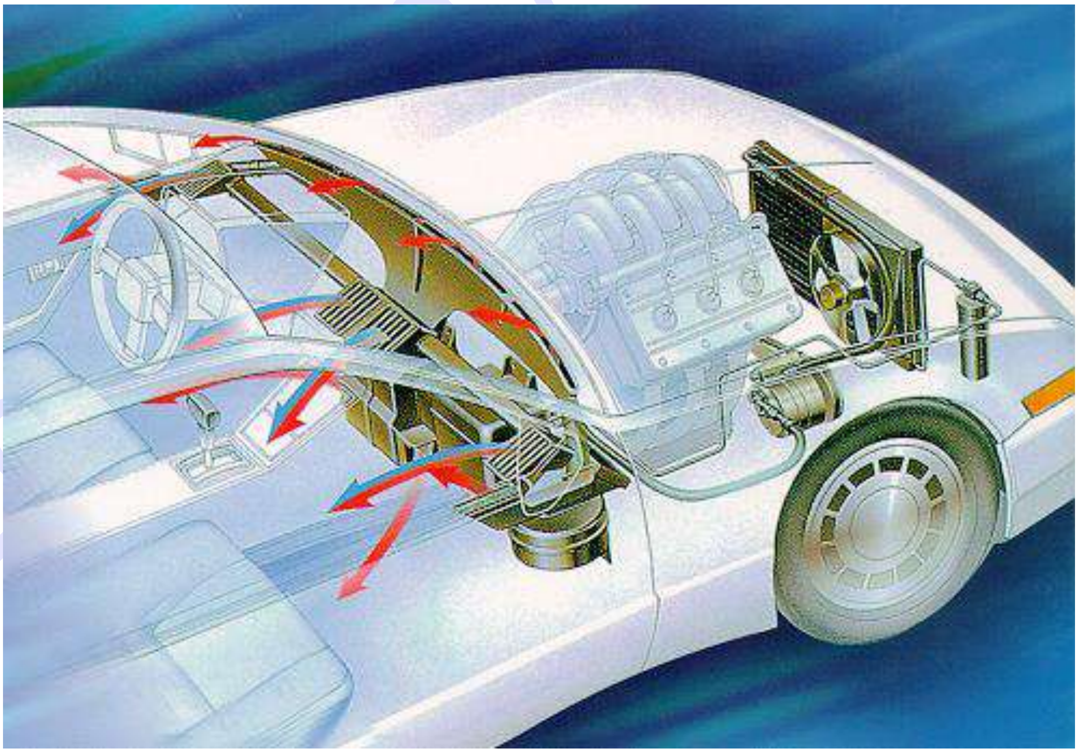
The fluid flow is accelerated by a row of rotating airfoils (blades) called the rotor, and then diffused in a row of stationary blades (the stator). Similar to the centrifugal compressor, the stator then converts the velocity energy gained in the rotor to pressure energy. One rotor and one stator make up a stage in a compressor. The axial flow compressor produces low pressure increase, thus the multiple stages are generally use to permit overall pressure increase up to 30:1 for some industrial applications.

Driver of axial flow compressor can be steam turbines or electric motors. In the case of direct electric motor drive, low speeds are unavoidable unless sophisticated variable frequency motors are employed.

Here are the advantages and disadvantages of axial flow compressor.

Advantages	**Disadvantages**
High peak efficiency	Good efficiency over narrow rotational speed range
Small frontal area for given airflow	Difficulty of manufacture and high cost.
Straight-through flow, allowing high ram efficiency	Relatively high weight
Increased pressure rise due to increased number of stages with negligible losses	High starting power requirements

Automotive Air conditioning system



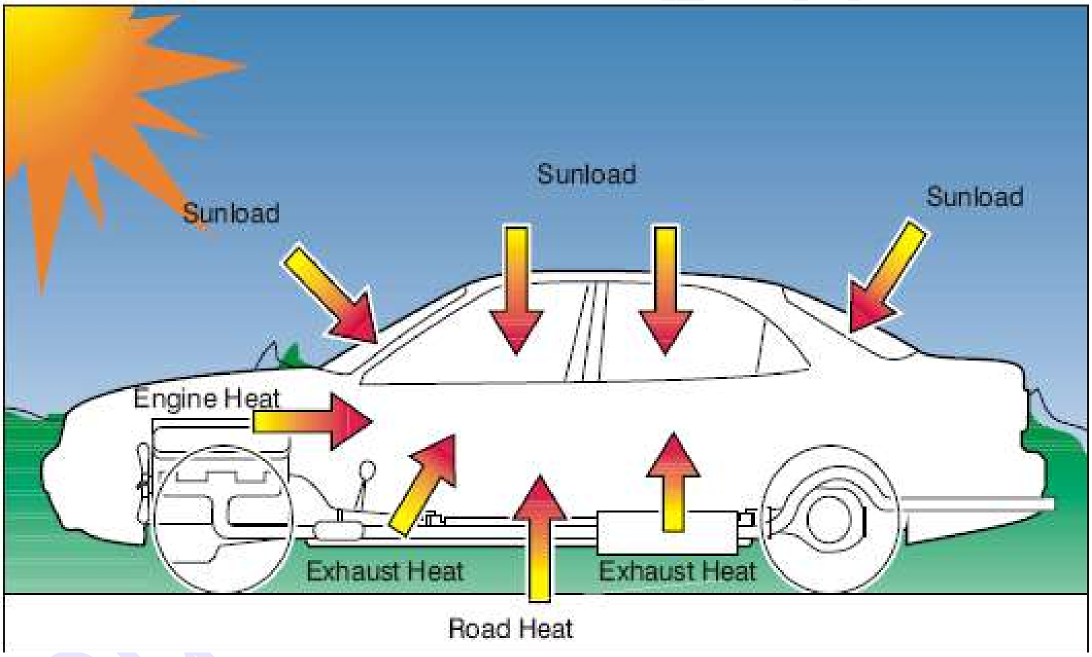
How does heat get inside a vehicle?

When a car is driven or parked in the sun, heat enters the vehicle from many sources.

These sources include:

- Ambient air
- Sunlight
- Engine heat
- Road heat
- Transmission
- Exhaust heat

All of these and other miscellaneous heat sources, increase the air temperature within the vehicle. In a high ambient temperature situation, (e.g. on a 37 C day), the interior of a vehicle left standing in the sun with windows closed could reach 65 - 70 C!



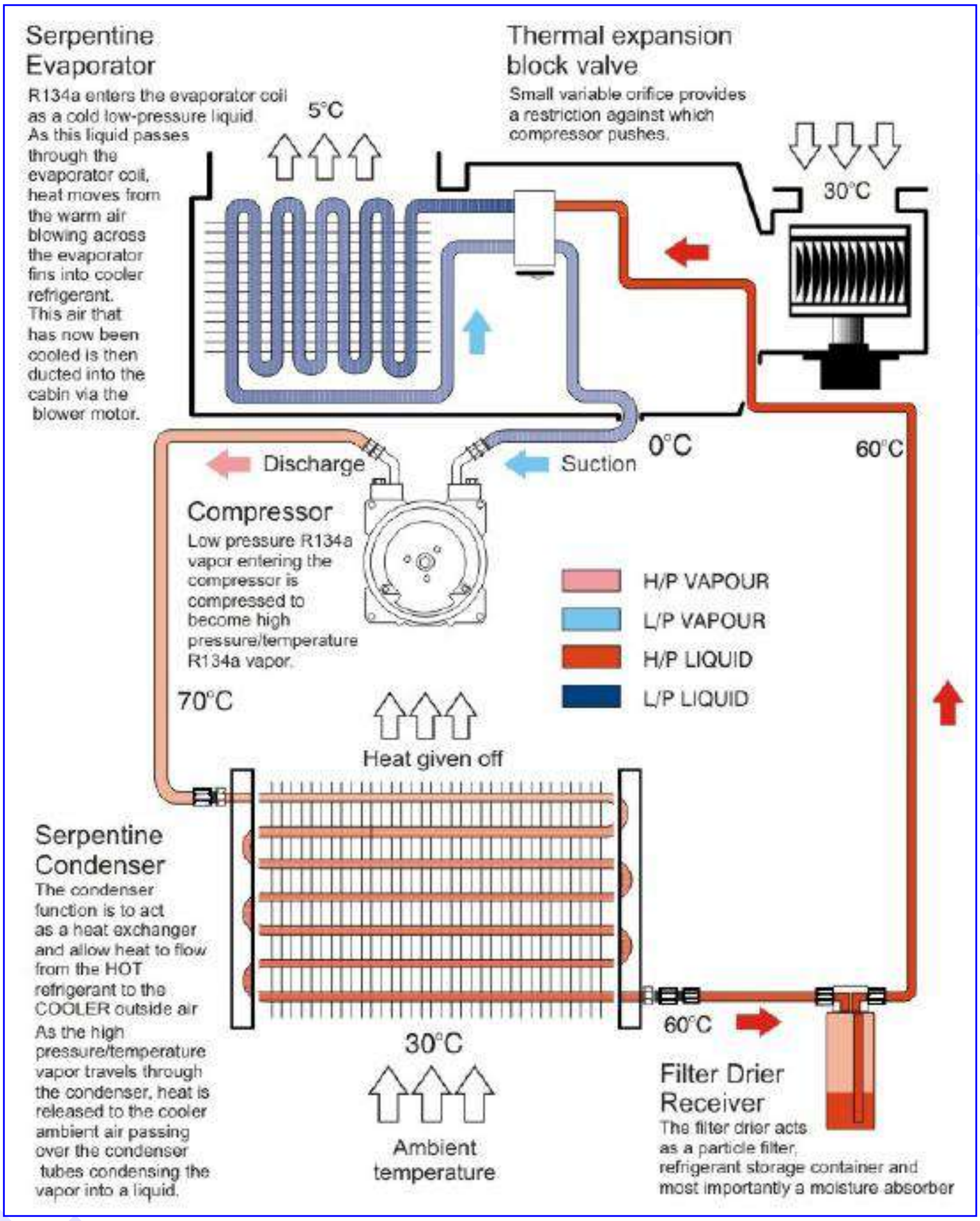
***The four major functions*:**

To be effective, the automotive air conditioner must control four (4) conditions within the vehicle interior**:**

These functions are essential if passenger comfort is to be maintained when the ambient temperature and humidity are high. By performing these functions, the air conditioner maintains the body comfort of the passengers.

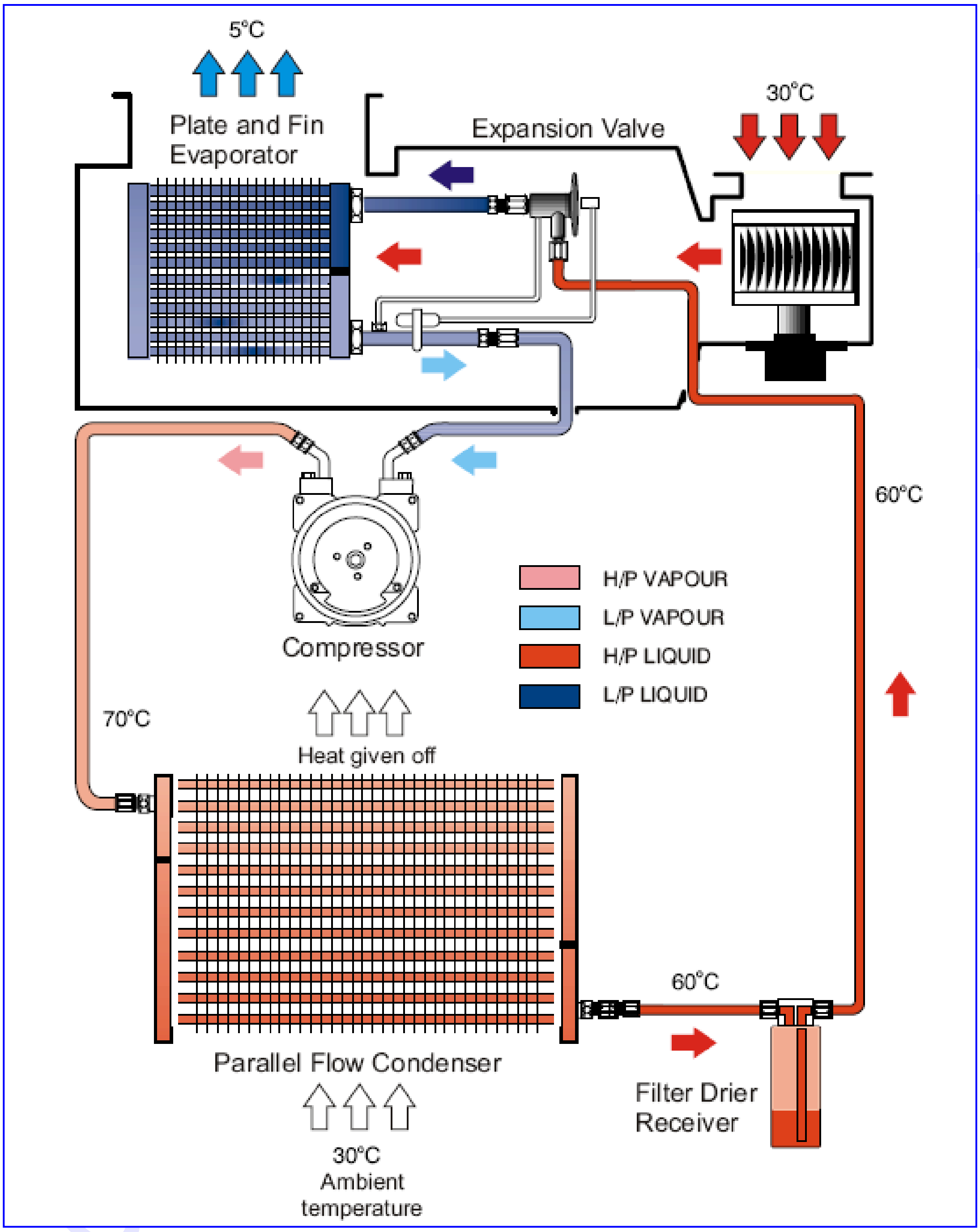
Types of automotive air conditioning systems:

1. **A/C System with: Thermal Expansion Block Valve, Serpentine Condenser, Serpentine Evaporator**:

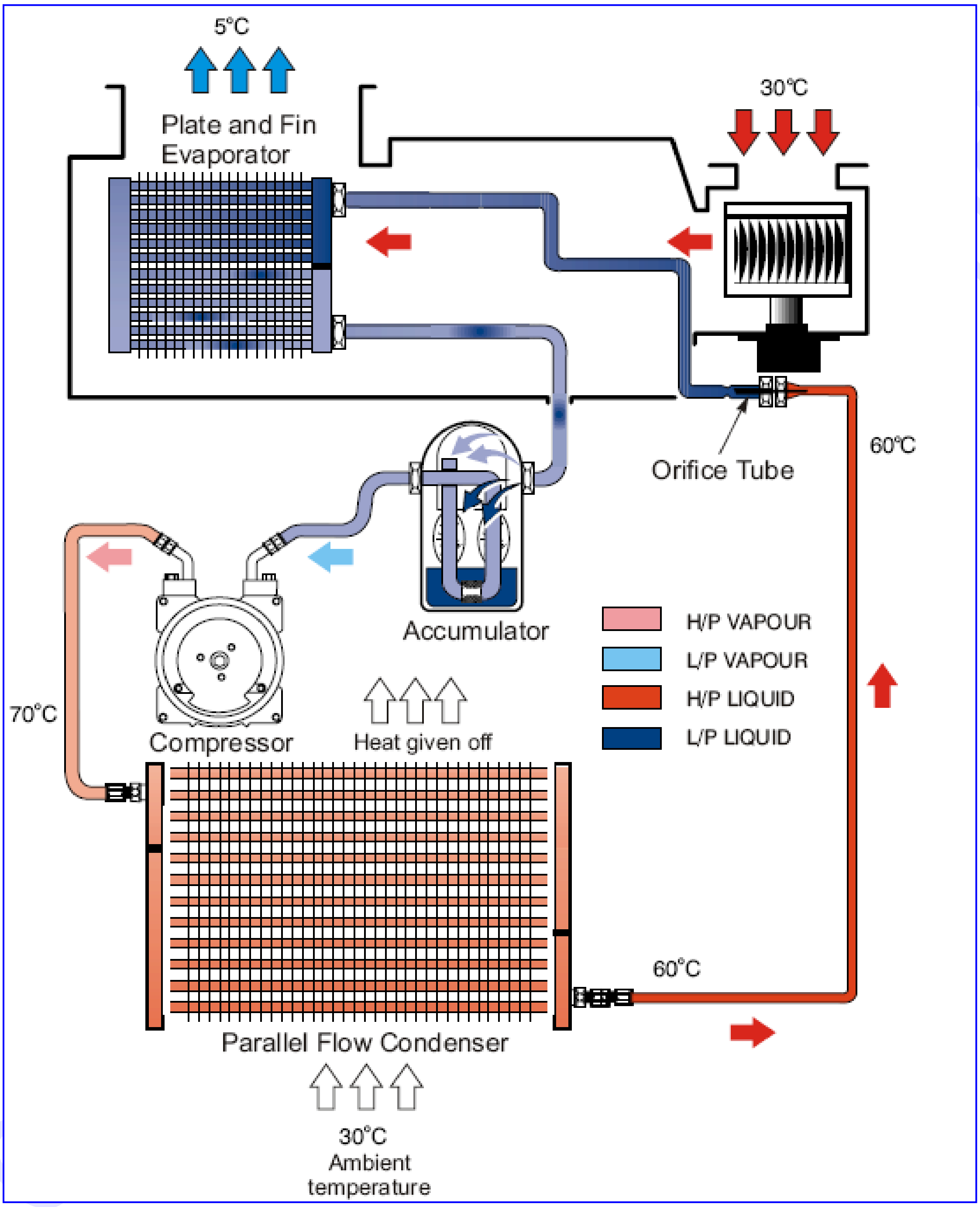


Note: Temperatures shown are examples only

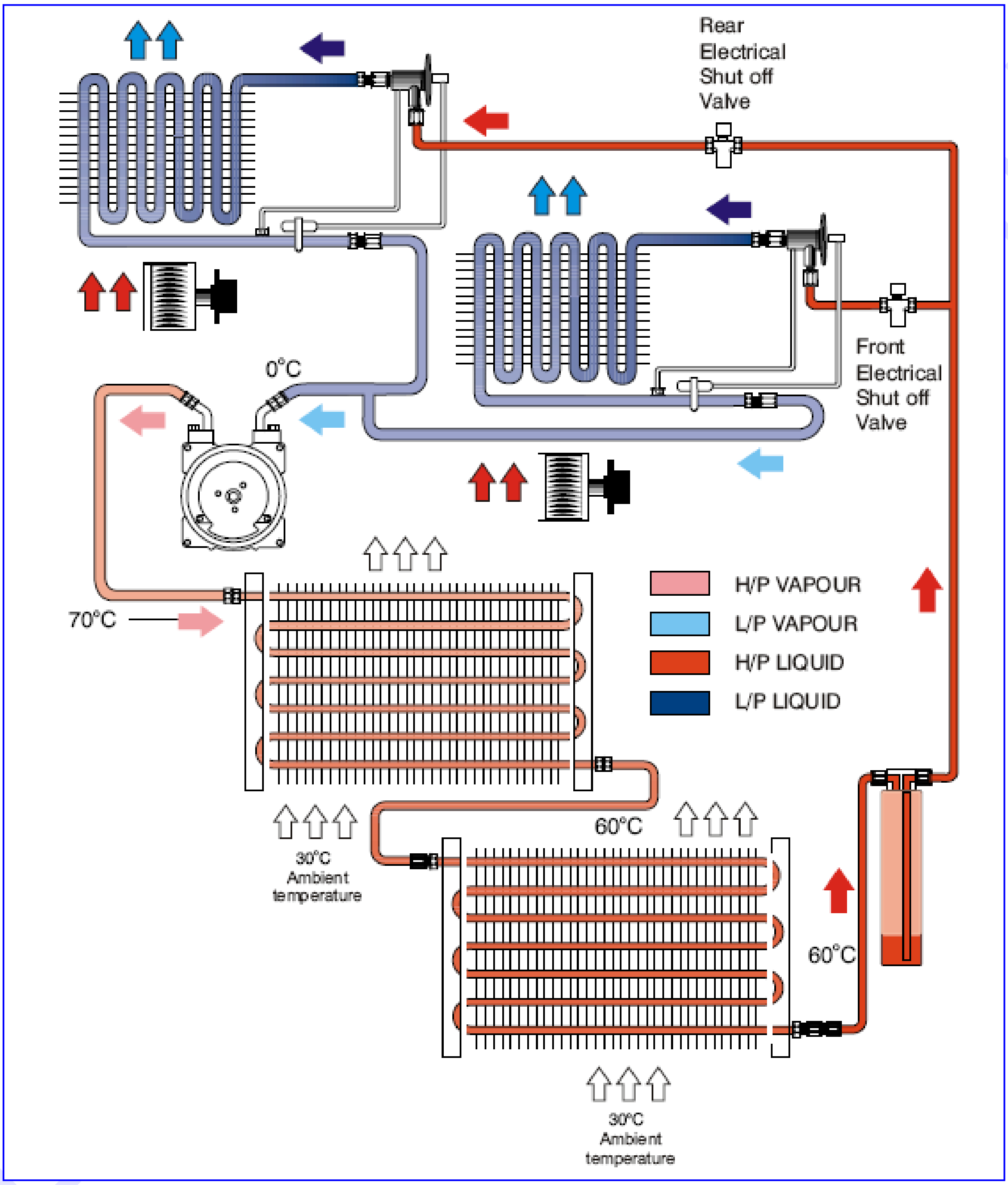
2. **A/C System with: Expansion Valve, Parallel Flow Condenser, Plate and Fin Evaporator**:



3. A/C System with: Orifice Tube, Accumulator, Parallel Flow Condenser ,Plate and Fin Evaporator:



4. **Dual A/C System with: Externally Equalized Expansion Valves (x2), Serpentine Condensers in series (x2), Serpentine Evaporator in parallel (x2), Electrical Refrigerant Flow Shut Off Valves.**



Automotive air conditioning system components:

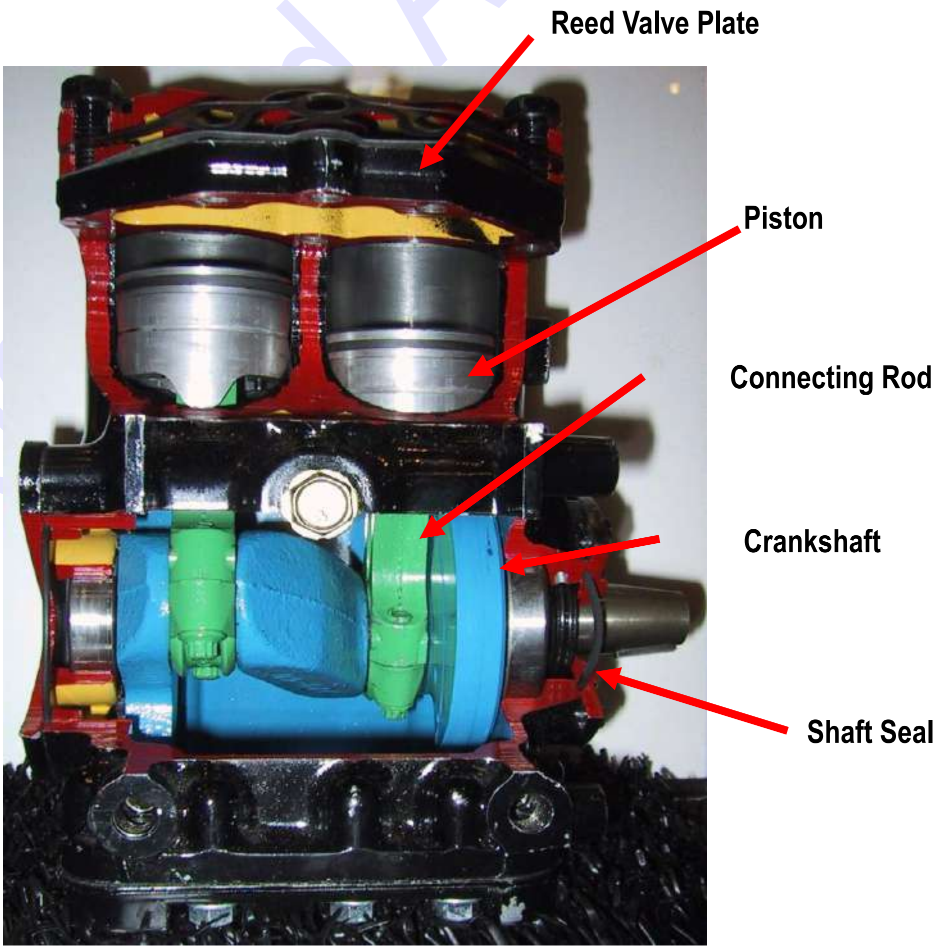
- Compressors
- Compressor Clutches
- Condensers
- Expansion Devices
- Evaporators
- Receiver-Driers/Accumulators
- Switches and Evap. Temperature Controls
- Rear AC Systems

1. **Compressors**:

There is a large variety of compressors. Some of variations are: The compressor manufacturer Piston, vane, or scroll type, the piston and cylinder arrangement. How the compressor is mounted Style and position of ports Type and number of drive belts Compressor displacement Fixed or variable displacement.

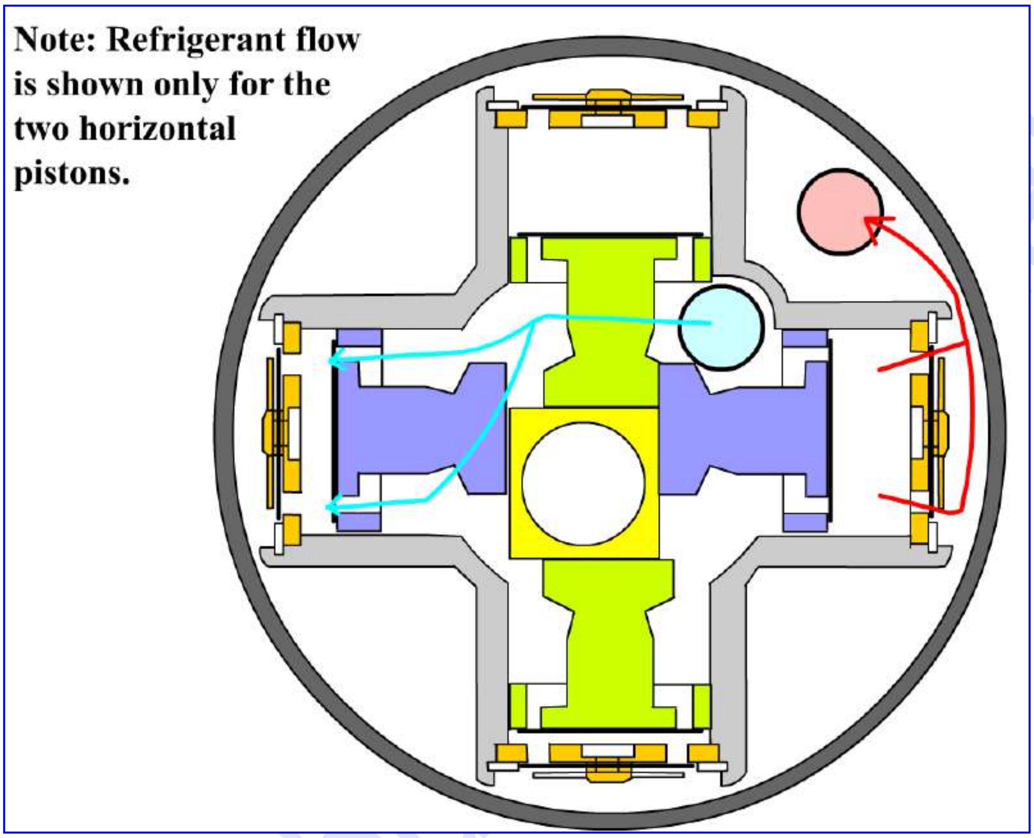
Piston Compressors:

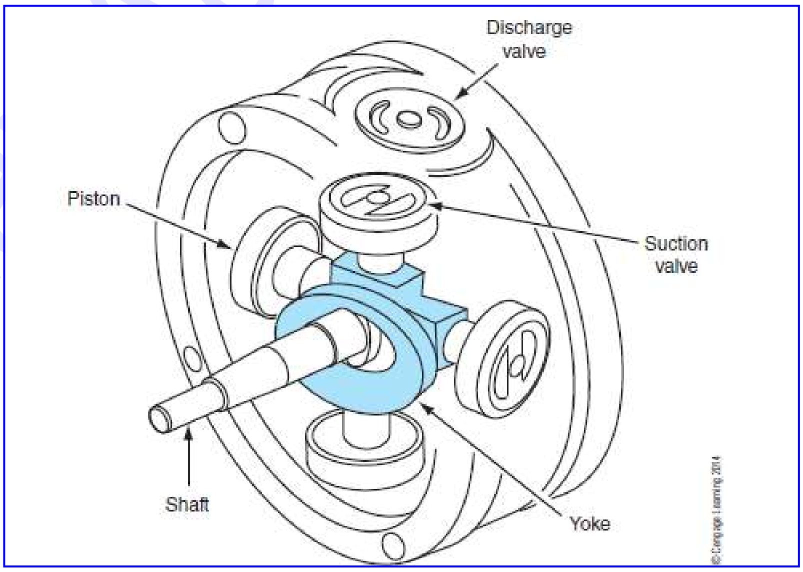
This two-cylinder compressor uses a crankshaft to move the pistons up and down. Refrigerant flow is controlled by the suction and discharge reeds in the valve plate.



Scotch Yoke Compressors:

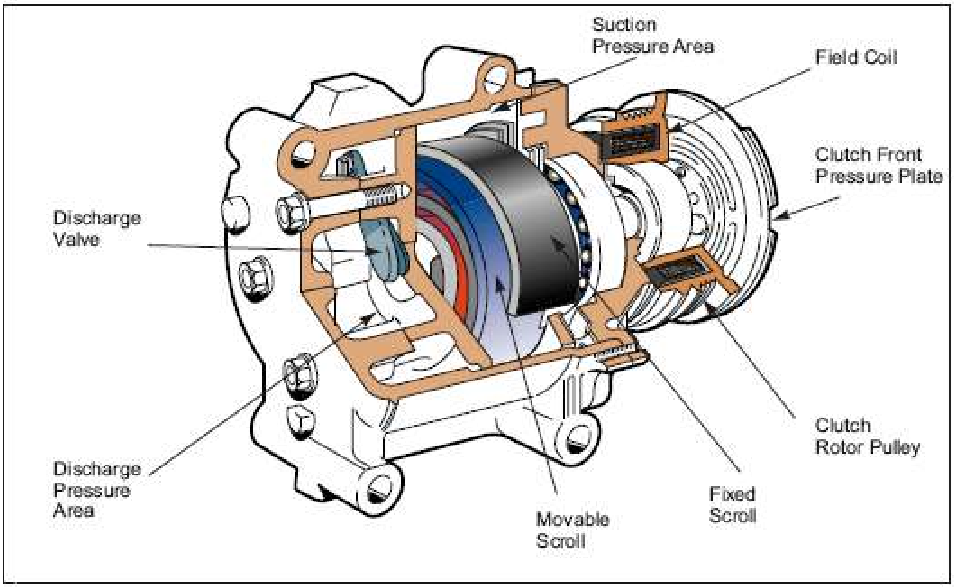
A Scotch yoke compressor has two pairs of pistons that are driven by a slider block on the crankshaft. The pistons are connected by a yoke.



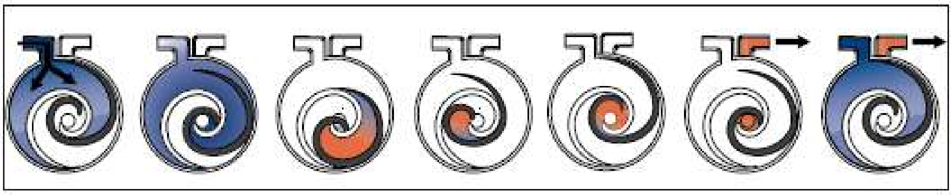


Scroll Compressors:

This compressor uses a unique design with two scrolls, one fixed and one is movable, both are inter-leaved. The movable spiral is able to ORBIT or oscillate without actually fully rotating. The movable scroll is connected to the input shaft via a concentric bearing. As the movable spiral oscillates within the fixed spiral, a number of pockets are formed between the spirals. As these pockets decrease in size the refrigerant is squeezed, the pressure increases and is discharged through a reed valve at the discharge port in the rear section of the compressor.

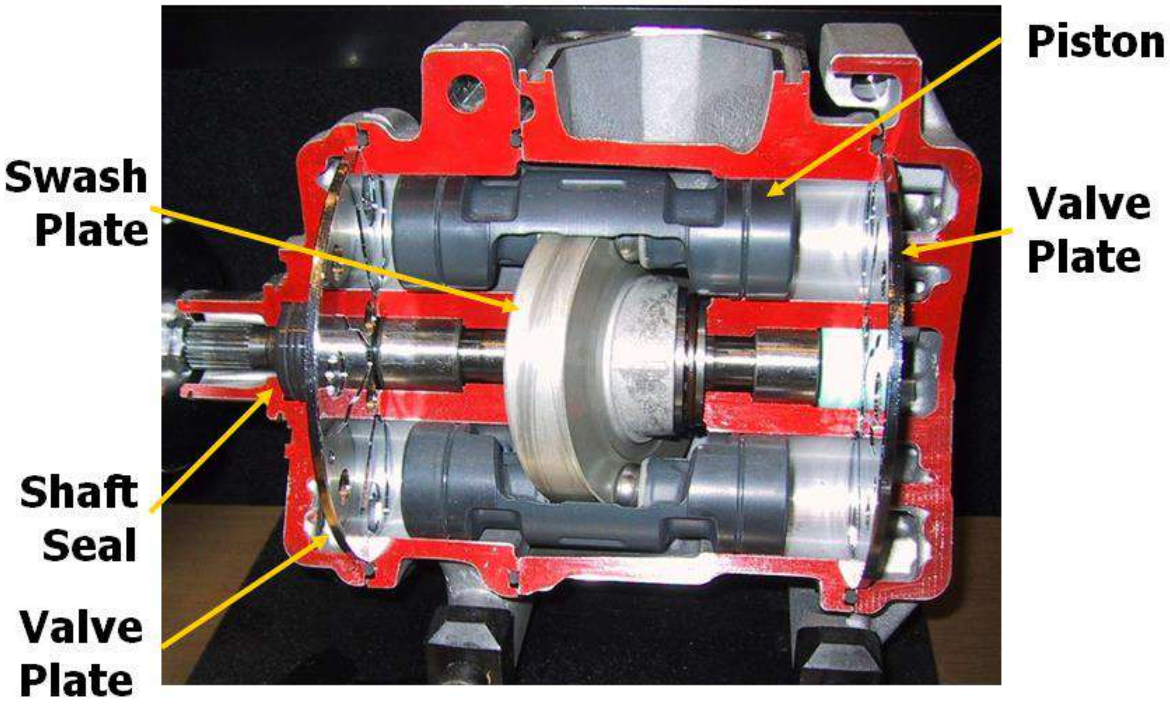


Compression Cycle



Swash Plate Compressors:

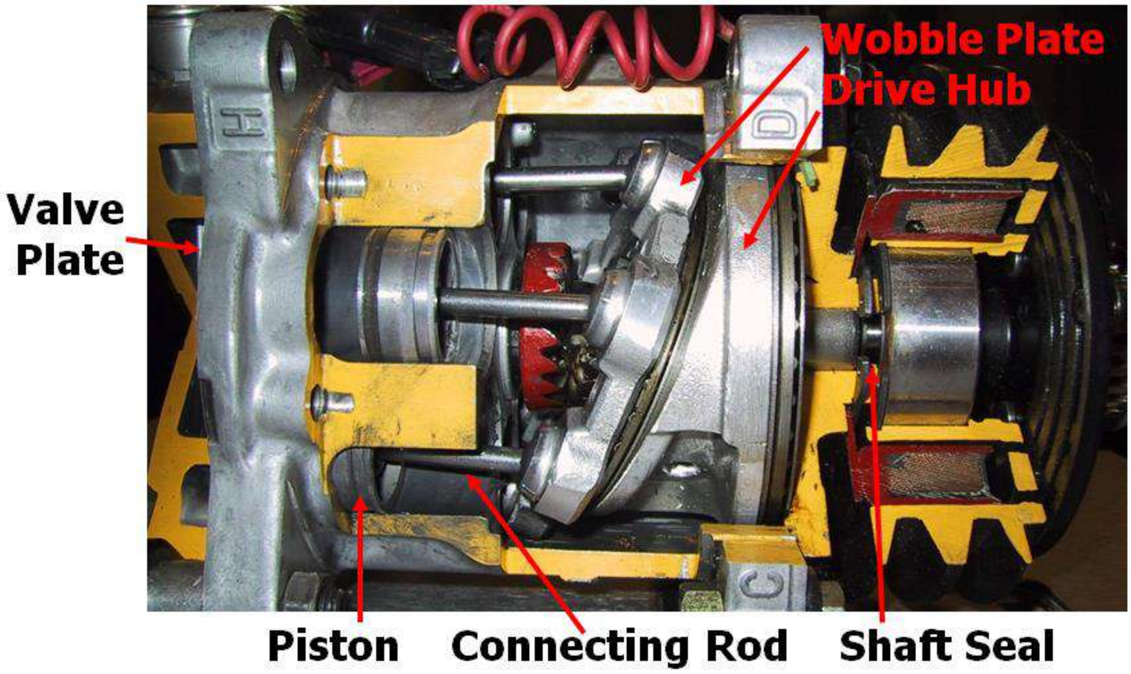
The swash plate is mounted at an angle onto the drive shaft. It drives three double-ended pistons. Two sets of reeds control the refrigerant flow in and out of the cylinders.

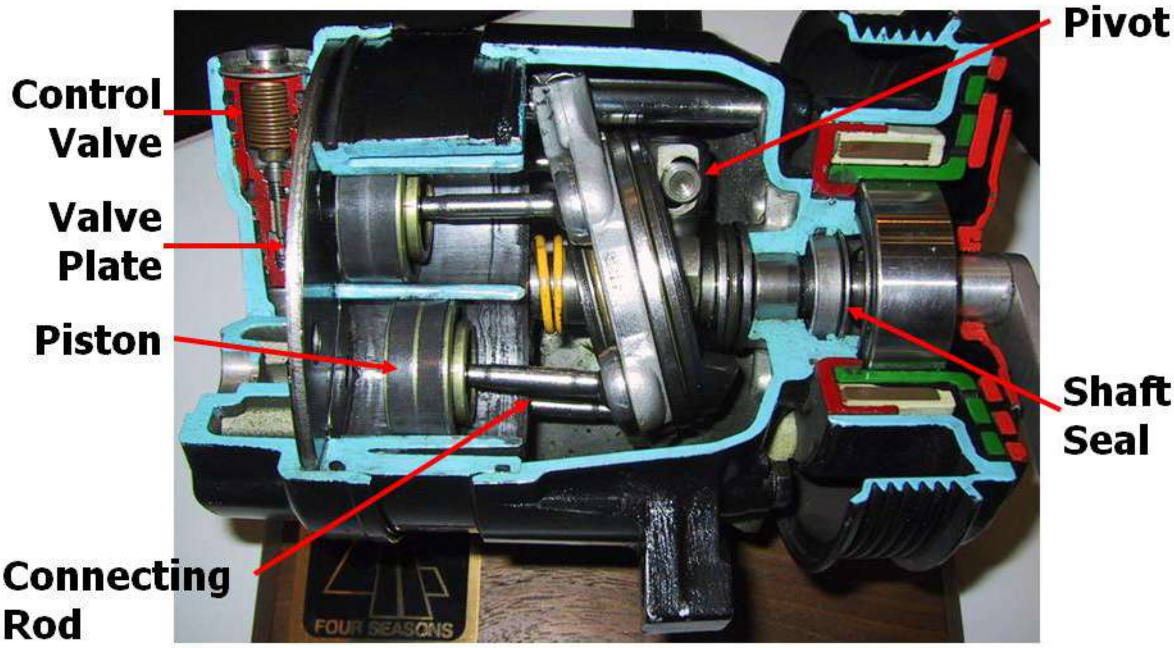


Wobble Plate Compressors:

This control valve senses and responds to the system suction pressure or A/C system demand. Through regulation of compressor crankcase pressure, the wobble plate angle, and therefore compressor displacement is variable.

In general, the compressor discharge pressure is much greater than the compressor crankcase. Which is greater than or equal to the compressor suction pressure. **At maximum displacement**, compressor crankcase pressure is equal to the compressor suction pressure. At **reduced or minimum** displacement, the compressor crankcase pressure is greater than the suction pressure.



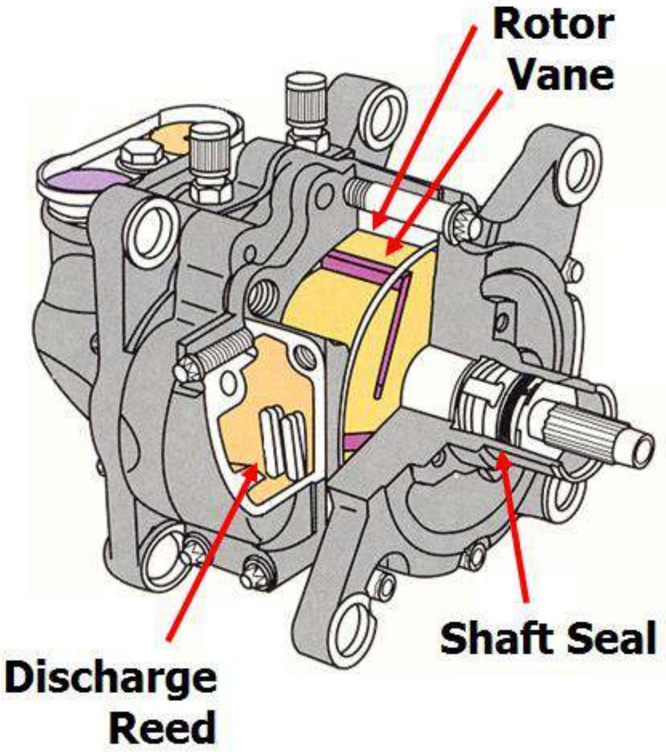


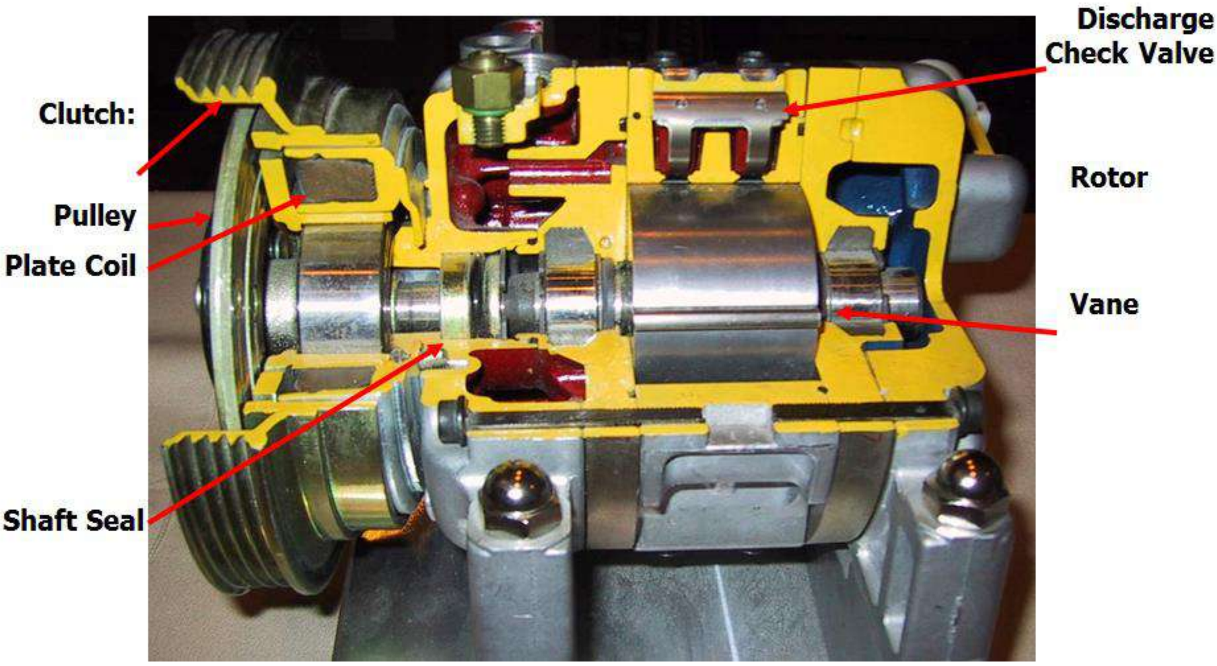
Vane Compressors

Rotary vane compressors consist of a rotor with three or four vanes and carefully shaped rotor housing. As the compressor shaft rotates, the vanes and housing form chambers.

The R134a is drawn through the suction port into these chambers, which become smaller as the rotor turns. The discharge port is located at the point where the gas is fully compressed. The vanes are sealed against the rotor housing by centrifugal force and lubricating oil. The oil sump and oil pump are located on the discharge side, so that the high pressure forces oil through the oil pump and then onto the base of the vanes keeping them sealed against the rotor housing.

During idle an occasional vane noise from the compressor may be heard. This is due to the time taken for lubricating oil to circulate through the A/C system.





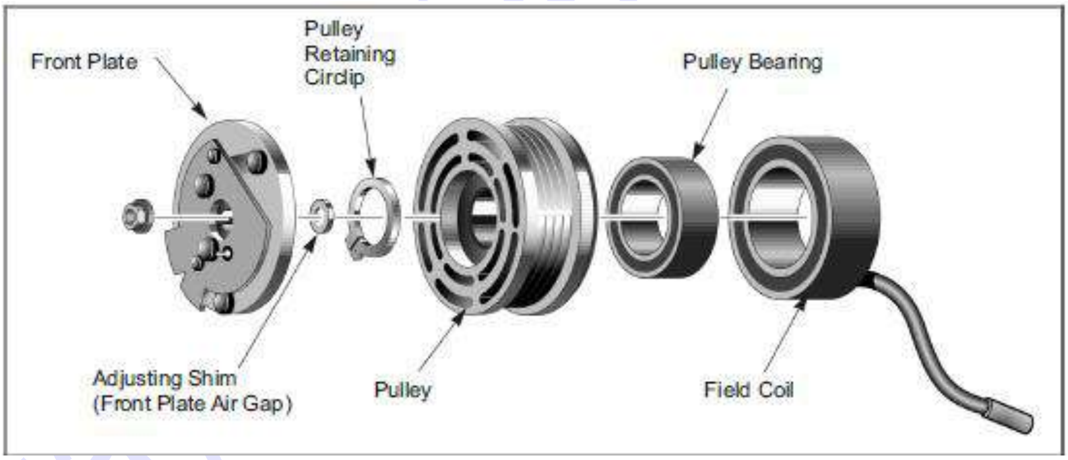
The Compressor Clutch:

The compressor Clutch Assembly has 3 major components.

1. The Coil
2. The Pulley
3. The Clutch

— The compressor is an electromagnet Clutch Assembly
— that can engage and disengage to the compressor drive.
— The compressor Pulley always turns when the engine or motor is running,

The clutch is designed to connect the rotor pulley to the compressor input shaft when the field coil is energized. The clutch is used to transmit the power from the engine crankshaft to the compressor by means of a drive belt. When the clutch is not engaged the compressor shaft does not rotate and refrigerant does not circulate the rotor pulley free wheels. The field coil is actually an electromagnet, once energized it draws the pressure plate towards it, locking the rotor pulley and the pressure plate together causing the compressor internals to turn, creating pressure and circulating refrigerant.



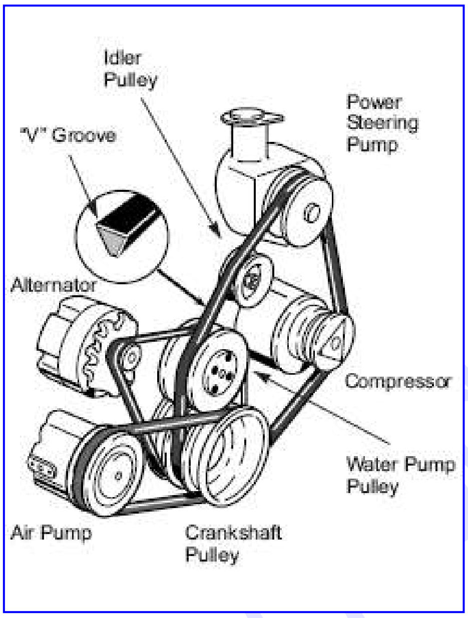
Compressors and Mount & Drive:

Mount & Drive: Consists of a bracket to mount the compressor to the engine, a belt idler pulley, compressor drive belt and possibly and extra drive pulley for the crankshaft.

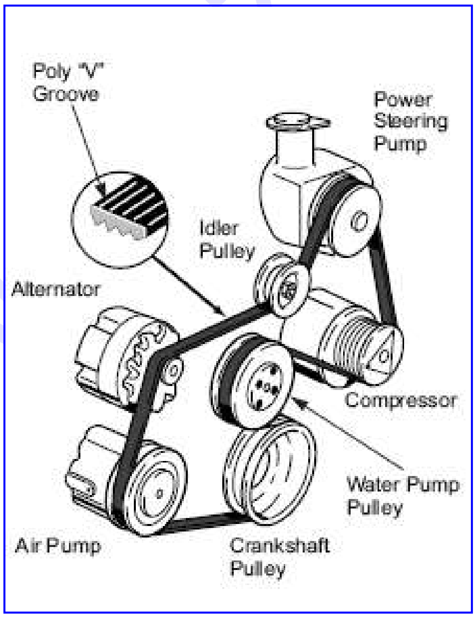
Compressor Mount: Manufactured of either plate, cast iron, steel or aluminum, this bracket should exhibit excellent noise absorption qualities especially if using a piston type compressor.

Idler Pulley: A small pulley normally used in conjunction with a belt adjusting mechanism, also used when a belt has a long distance between pulleys to absorb belt vibrations.

Drive Pulley: Some vehicles do not have an extra pulley to accommodate an A/C drive belt, in these cases an extra pulley is bolted onto the existing crankshaft pulley.



Multiple Belt Drive



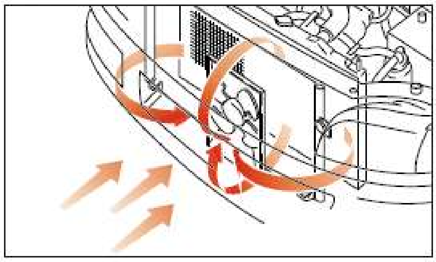
Serpentine Belt Drive

Foam seals

These seals are fitted in between the condenser and radiator to prevent the heated ambient air exiting above, below or to the sides of the space in between (normally 25mm) the radiator and condenser.

As ambient air is drawn through condenser by the condenser or radiator fan, its temperature increases. If gaps are present between the condenser and radiator this heated air can be circulated back through the condenser. This results in the increased condenser temperature and causes reduction in the performances of the A/C system.

Without Foam Seals



Condenser electric fan

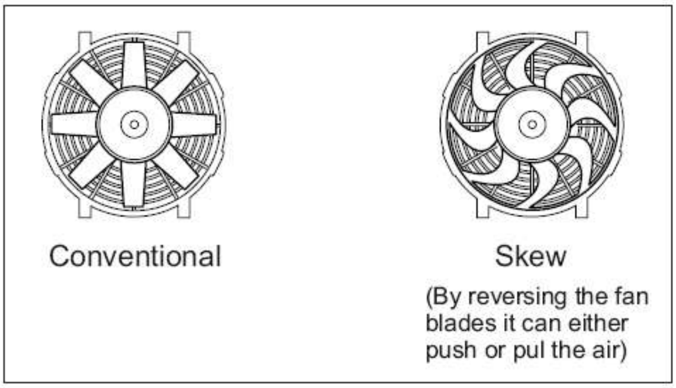
Most vehicles with air conditioning require an electric fan to assist air flow, either pushing or pulling the air through the condenser, depending on which side of the condenser the fan is placed.

The majority of vehicles using R134a require this additional condenser cooling due to the higher operating pressures of R134a. Also most modern vehicles now have smaller grilles or bumper bar openings. This causes poor air flow conditions especially by the amount of air flow over the condenser.

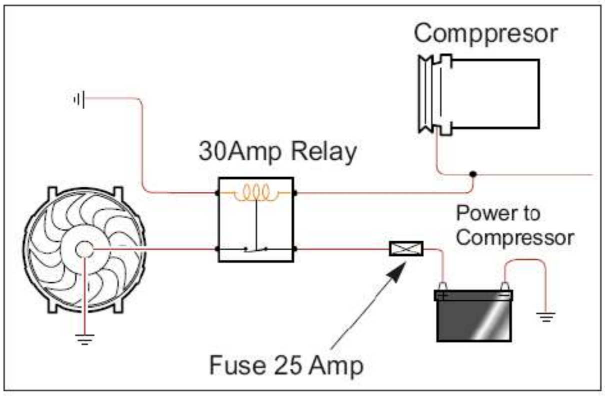
The condenser fan is operated with A/C engaged in various ways:

- Medium pressure switch;
- Indirect connection to the compressor clutch
- Via the Electronic Control Module (ECM);
- Signal from the A/C switch activation.

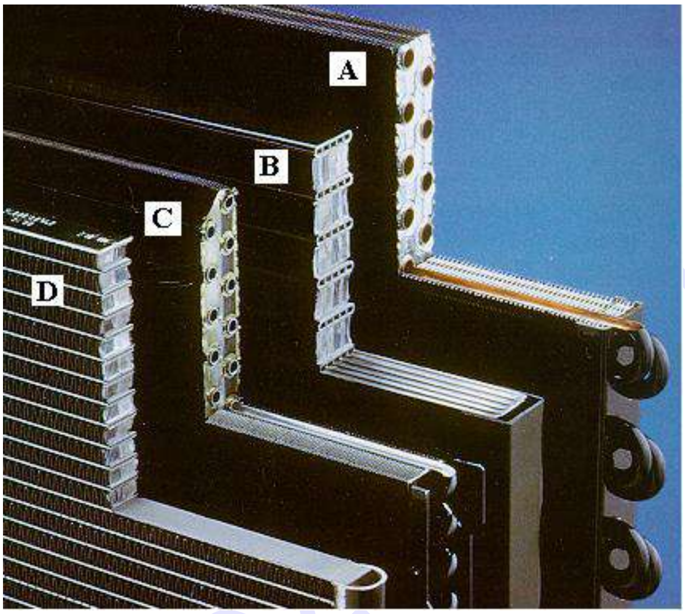
Fan Types



Basic Circuit



Condenser Types:



The Condenser function is to act as a heat exchanger and allow heat to flow from the hot refrigerant to the cooler outside air.

R134a entering the condenser will be a high-pressure high temperature vapor. As the R134a vapor travels through the tubes of the condenser heat is given off to the cooler ambient air; the refrigerant vapor condenses and changes to a liquid state. At this point a large amount of heat is given off by the R134a. The refrigerant will now be a hot, high pressure liquid.

Design types:

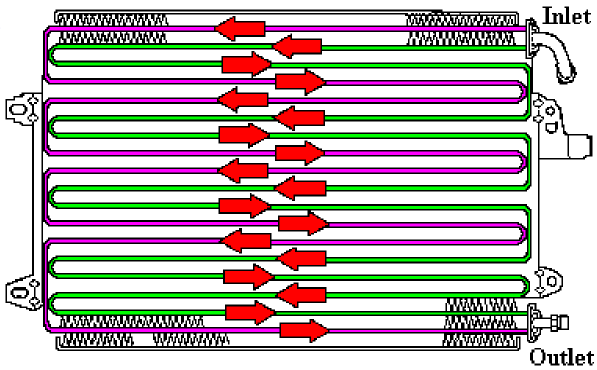
Condensers **A** and **C** are round tube, serpentine condensers.

Condenser **B** is an oval/flat tube, serpentine condenser.

Condenser **D** is an oval/flat tube, parallel flow condenser.

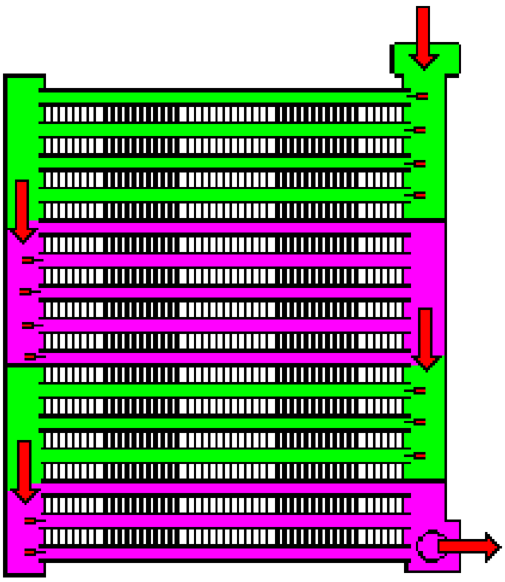
Flat tube condensers are more efficient.

Serpentine



This type of condenser consists of one long tube which is coiled over and back on itself with cooling fins in between the tubes. Refrigerant flows from the upper inlet to the bottom outlet through two tubes. These tubes wind back and forth though the condenser.

Parallel flow:



This design is very similar to a cross flow radiator. Instead of refrigerant travelling through one passage (like serpentine type), it can now travel across numerous passages. This will give larger surface area for the cooler ambient air to contact. Refrigerant flows from the upper inlet to the bottom outlet through groups of parallel tubes. Some carry refrigerant from the right to the left, and others move it back to the right side.

Expansion Devices:

There are two styles of expansion devices:

i. The TXV can open or close to change flow. It is controlled by the superheat spring, thermal bulb that senses evaporator outlet temperature, and evaporator pressure. The three major types of expansion valves:

1. Internally balanced TXVs are the most common.
2. Externally balanced TXVs are used on some larger evaporators.
3. Block valves route the refrigerant leaving the evaporator past the thermal sensing diaphragm so a thermal bulb is not needed.

Internally Balanced

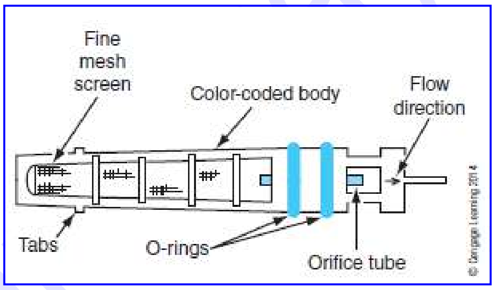
Externally Balanced

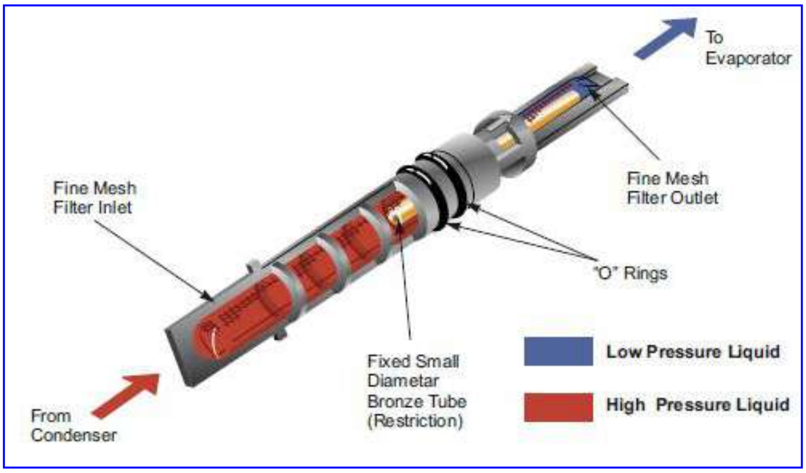
Block Valve

ii. Orifice Tubes: Most OTs has a fixed diameter orifice.

The OT used in a modern vehicle is a tubular, plastic device with a small metal tube inside. The color of the OT is used to determine the diameter of the tube. A plastic filter screen is used to trap debris that might plug the tube.

Some older General Motors vehicles used an OT that resembled a brass fuel filter.





The Evaporator:

R134a enters the evaporator coil as a cold low-pressure liquid. As this liquid passes through the evaporator coil, heat moves from the warm air blowing across the evaporator fins into cooler refrigerant. This air that has now been cooled is then ducted into the cabin via the blower motor. When there is enough heat to cause a change of state, a large amount of the heat moves from the air to the refrigerant. This causes the refrigerant to change from a low pressure cold liquid into a cold vapor. (Latent heat of evaporation).

As the warmer air blows across the evaporator fins, moisture contained in that air (humidity) will condense on the cooler evaporator fins. Condensed moisture then runs off through the drain tubes located at the underside of the evaporator case.

- Located inside the vehicle, the Evaporator serves as the heat absorption component. The Evaporator provides several functions. Its primary duty is to remove heat from the inside of your vehicle. A secondary benefit is dehumidification. On humid days you may have seen this as water dripping from the bottom of your vehicle.
- The ideal temperature of the evaporator is 32° Fahrenheit or 0° Celsius. Refrigerant enters the bottom of the Evaporator as a low pressure liquid. The warm air passing through the Evaporator fins causes the refrigerant to boil (refrigerants have very low boiling points). As the refrigerant begins to boil, it can absorb large amounts of heat.

Serpentine evaporator:

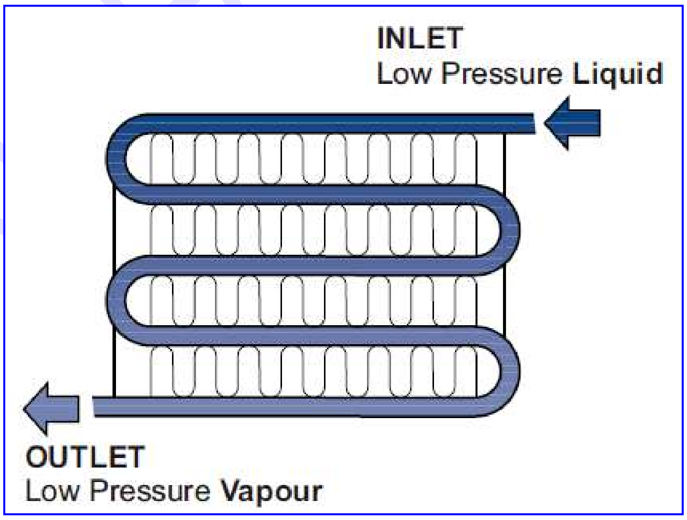
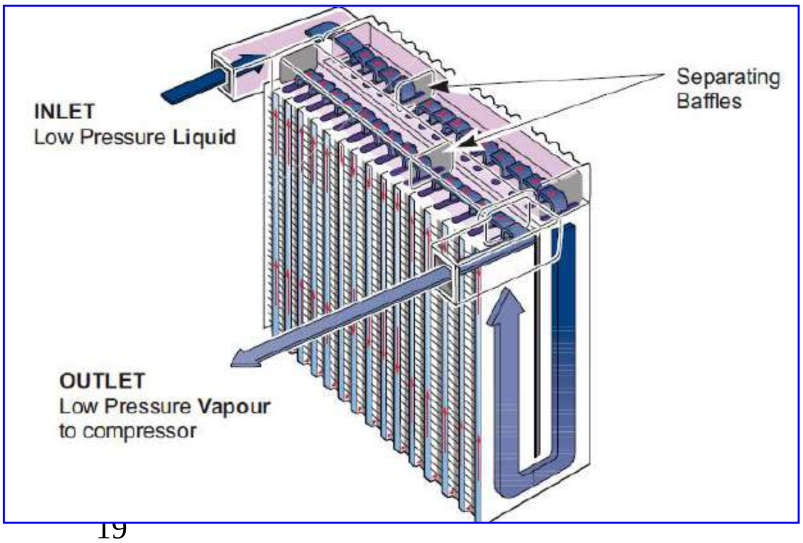


Plate & Fin Laminated Evaporators:

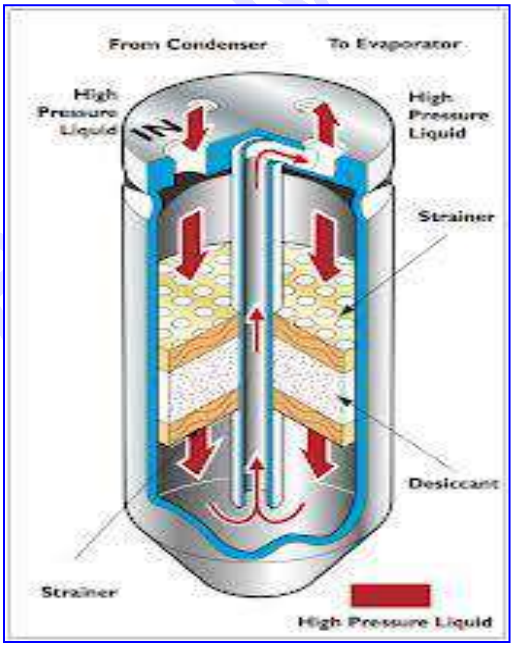


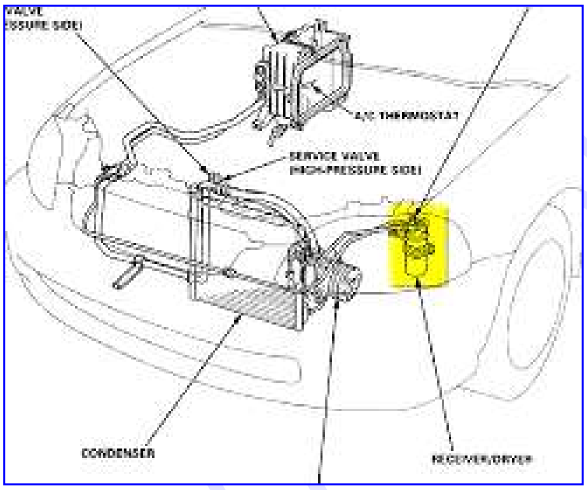
The Receiver:

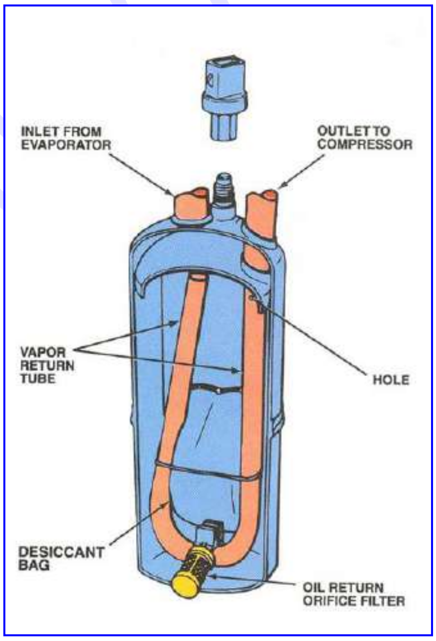
— The Receiver/dryer is used on the high side of systems that use a thermal expansion valve. This type of metering valve requires liquid refrigerant. To ensure that the valve gets liquid refrigerant, a receiver is used. The primary function of the Receiver/dryer is to separate gas and liquid. The secondary purpose is to remove moisture and filter out debris.

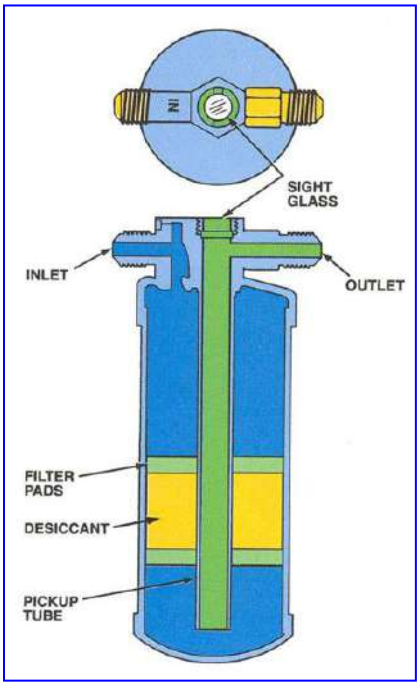
— A receiver dryer is mounted in the liquid line of a TXV system. It is used to:

- To store a reserve of refrigerant.
- Hold the desiccant bag that removes water from the refrigerant.
- Filter the refrigerant and remove debris particles.
- Provide a sight glass so refrigerant flow can be observed.
- provide a location for switch mounting



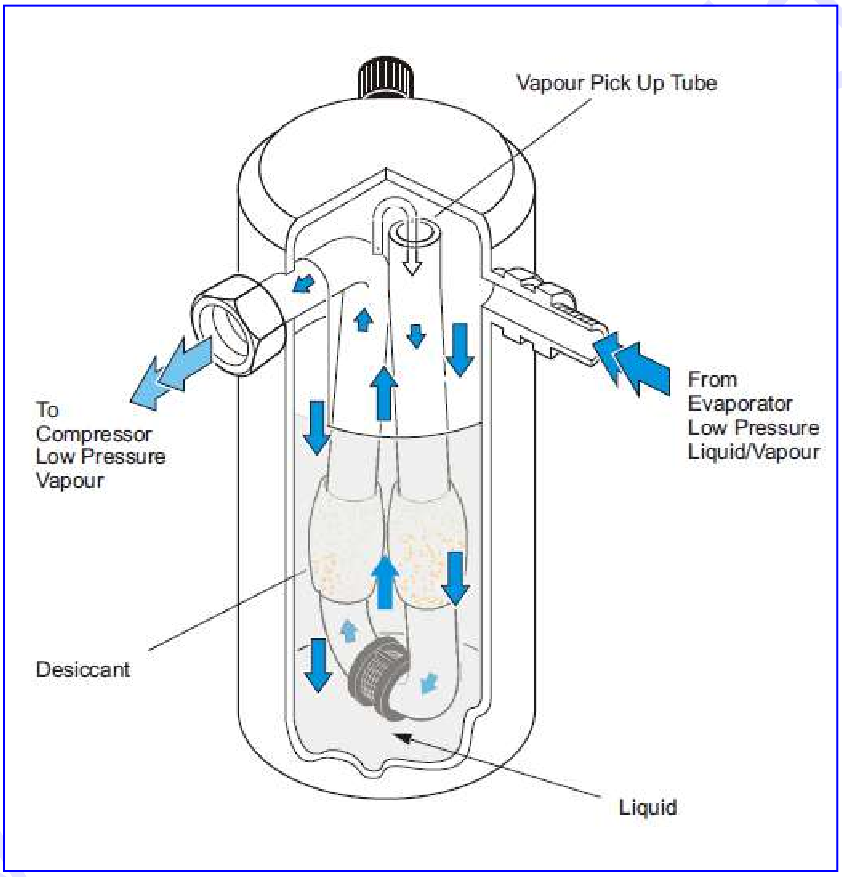






Accumulator (Orifice Tube System):

The function of the accumulator is to store refrigerant, filter particles, absorb moisture and separate vaporous R134a from liquid R134a. The normal process of the Orifice Tube system works when R134a leaves the evaporator coil as a mixture of vapor and liquid. This liquid enters the accumulator and falls to the bottom. The vapor rises to the top and continues onto compressor. The liquid R134a in the bottom of the accumulator gradually vaporizes off. This vapor rises, and then pulls into the compressor.

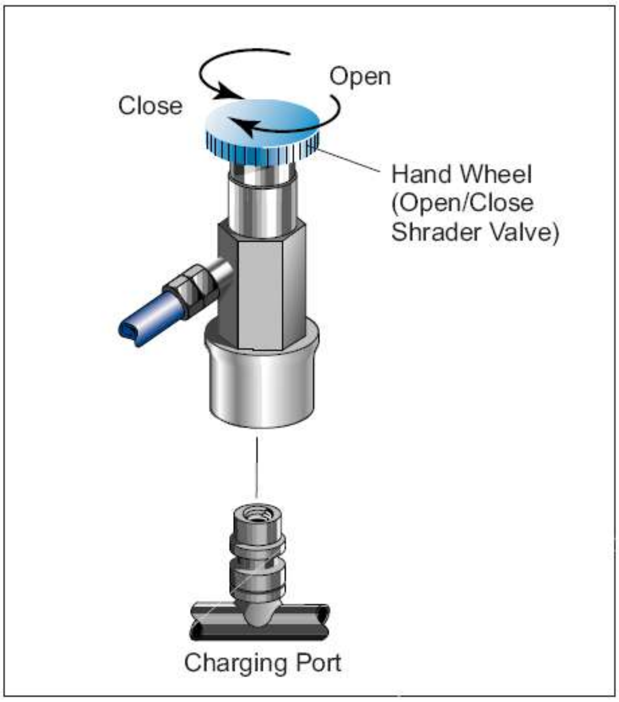


Charging Ports

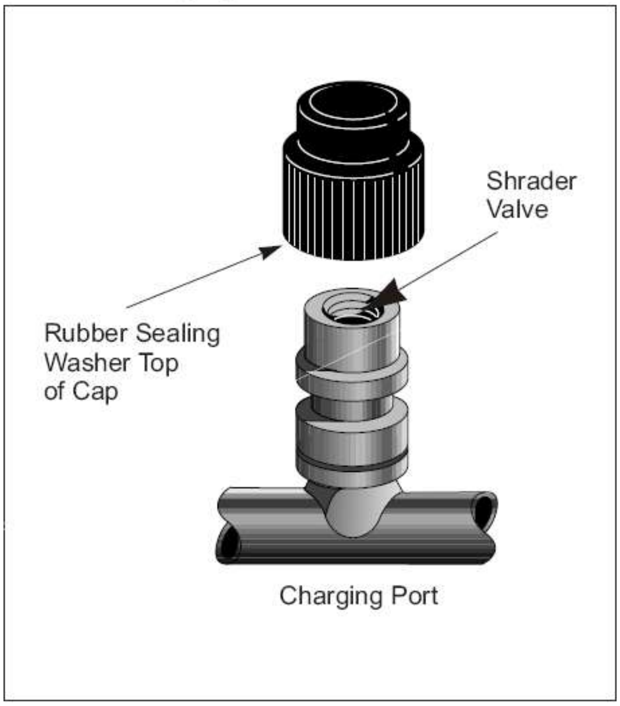
Components

Charging ports are fitted onto components such as hoses, tubes and filter dryers receivers. These charge ports enable the A/C system to be serviced and tested whilst under pressure. Different size ports identify the high and low sides of the A/C system. A plastic cap with rubber seal is used to close the charge port opening and avoid leaking. A dedicated design of charging valve has also been developed to suit the R134a charging ports. Most valves will leak slightly. Ensure that the plastic protection cap is fitted. Valves designed for R134a must only be used in R134a systems. This is because of the seal material used.

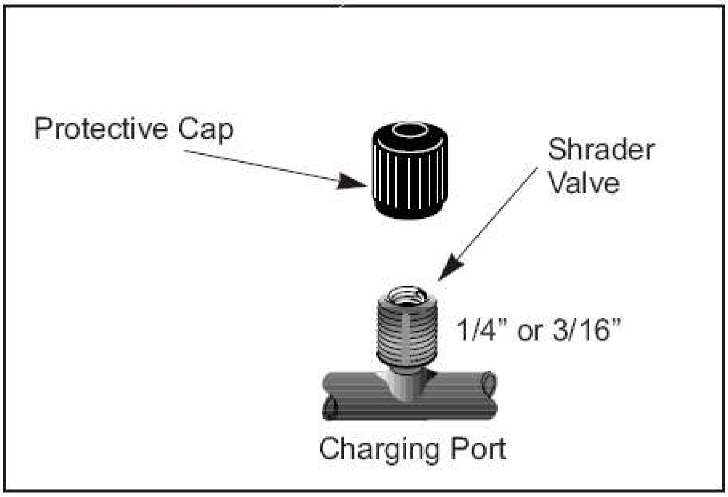
R134a Quick Coupler



R134a Charging Port



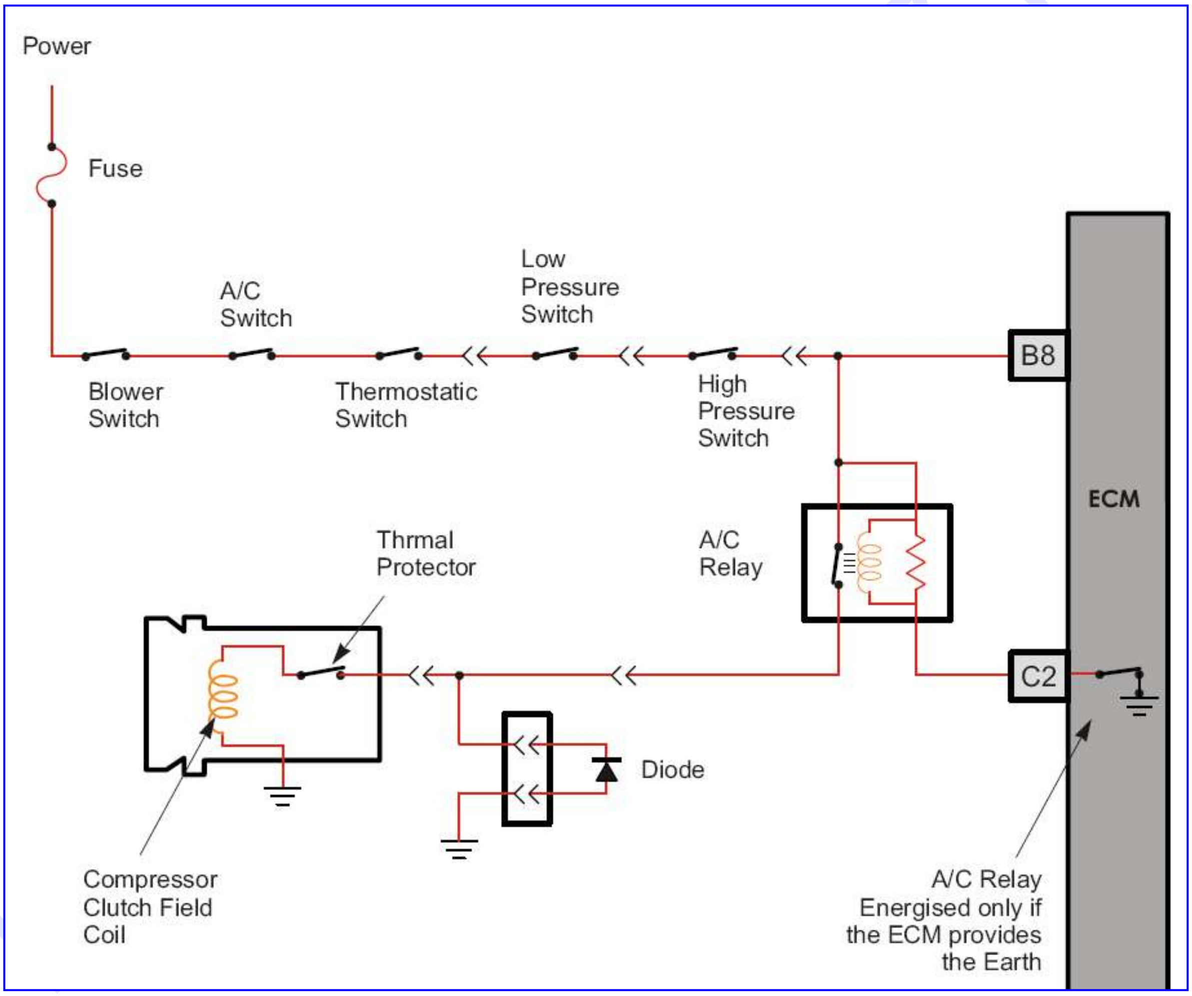
R12 Charging Port



Wiring A/C System

Control/Wiring layout (Series Connection)

Pressure switches are connected in series with the compressor clutch. If an "under" or "over" system pressure occurs the pressure switch will "open circuit" breaking the circuit to the compressor clutch. With electronic fuel injected vehicles the ELECTRONIC CONTROL MODULE (ECM) is usually interconnected into the A/C wiring circuit. When the A/C switch is engaged a request signal is sent to the ECM, if the A/C circuit is intact, i.e. the pressure switches are a closed circuit, the ECM activates a relay by creating an earth and power is supplied to the compressor clutch. Also an RPM increase generally takes place to avoid engine stall whilst at idle.



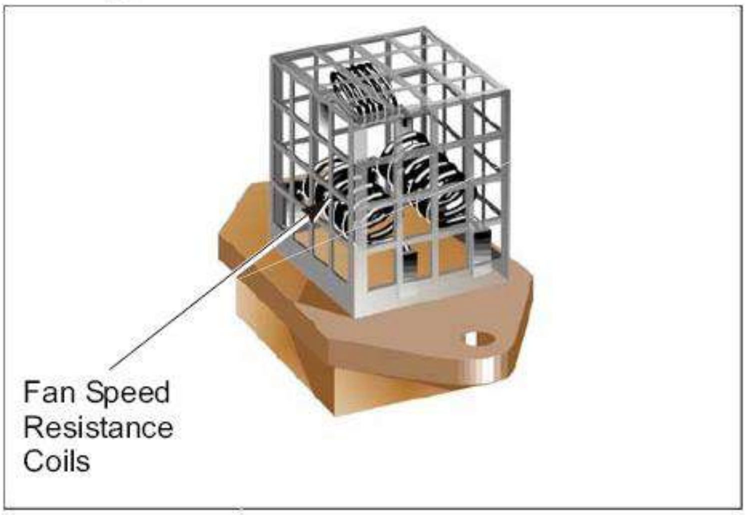
Blower Speed Controls:

Coil type

This blower speed regulator simply consists of coiled wires connected in series. These coiled wires are of varied thickness. The current flows through either one or a combination of all the coils. The resistance of the coil(s) alter the blower speeds.

The highest blower speed when selected is normally from direct battery voltage via a relay.

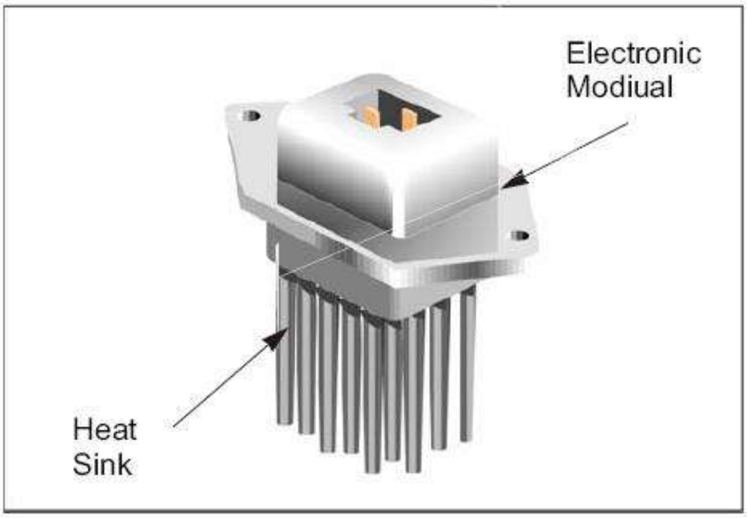
Coil Type



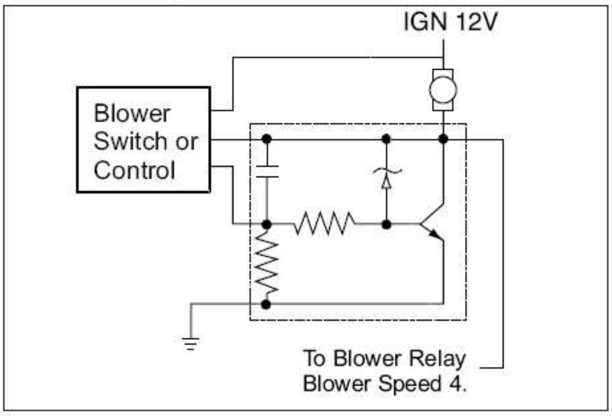
Electronic

The function of the electronic controller is to convert low current signals from the ECM to a higher current, varying the voltage to the blower motor. Blower speeds may be infinity variable and usually can use up to 13 speeds. This type of speed controller is normally used with the electronic climate control (ECC) system. The highest blower speed when selected is normally from direct battery voltage via a relay.

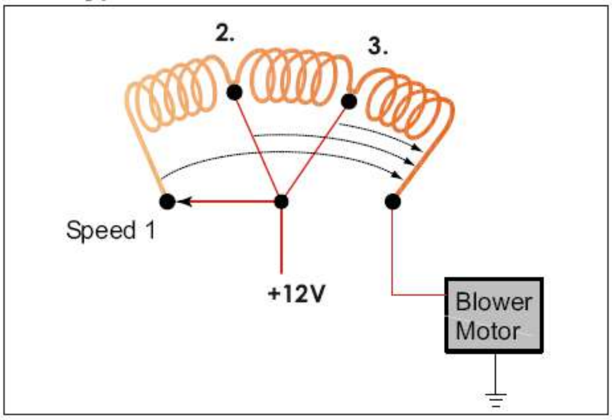
Electronic Type



Electronic Type

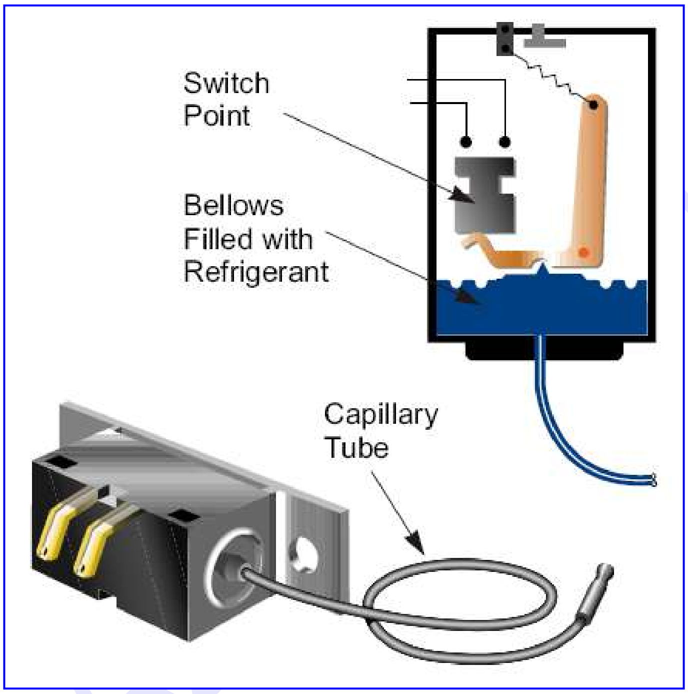


Coil Type



Compressor Cycling Controls:

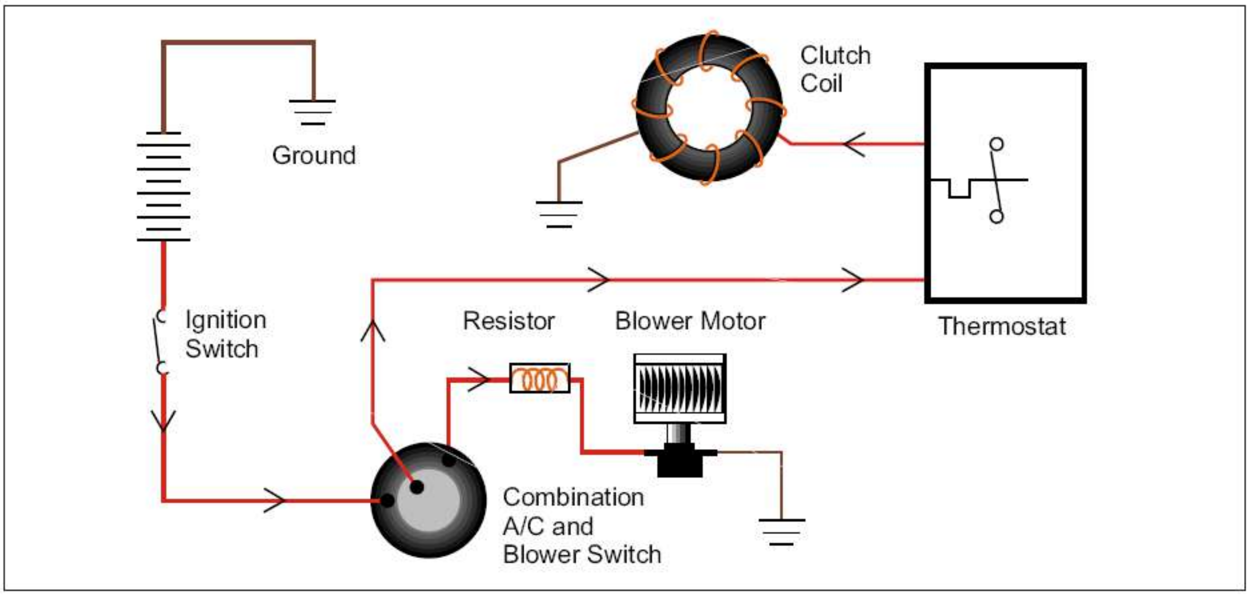
Thermostatic switch (Anti ice-up device)



The thermostat is connected in series to the compressor clutch. When the temperature of the evaporator coil approaches freezing (00C), this temperature is sensed by the thermostat capillary tube which is in contact with the evaporator fins. The capillary tube contains refrigerant which expands or contracts depending on the temperature on this tube. The points inside the thermostatic switch open up when the refrigerant in the capillary tube contracts (sensing a cold evaporator coil) and interrupt the A/C electrical circuit turning the compressor off.

When the evaporator temperature rises again to a preset point (4 - 5 0C) the thermostat points then close. The refrigerant in the capillary tube has expanded (sensing a warmer evaporator coil and the electrical circuit is reestablished to the compressor clutch.

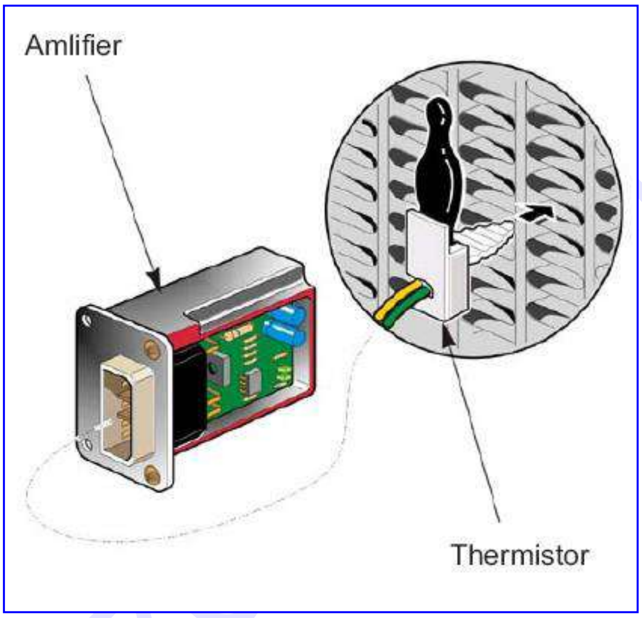
Electrical Circuit



Compressor Cycling Controls

Thermistor & Amplifier

This has the same function as the thermostatic switch except rather then mechanical action with contact points and capillary tube, the thermistor and amplifier is electronically activated. The thermistor is a sensing probe but unlike the thermostat capillary tube it senses the air temperature coming off the evaporator coil.



Thermistor

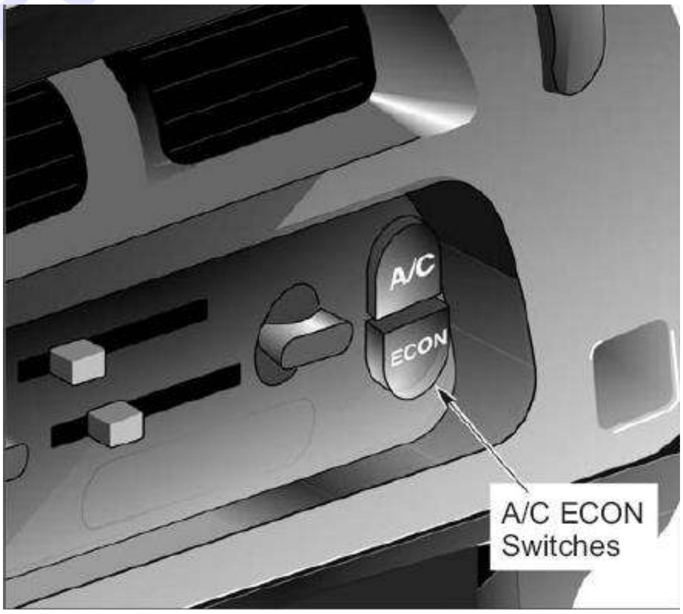
Electrical wiring containing a sensor which is a NTC resistor. (Negative Temperature Co-efficient).

Amplifier

A small electronic device containing a circuit board and electrical components. Thermistor resistance is amplified and used to control or switch the A/C clutch on or off.

Economy mode

This function is normally associated with the use of a thermistor amplifier. In economy (ECON) mode the compressor cut out temperature is set higher than a normal A/C mode. This means the compressor stays on for a lesser time, decreasing engine load and improving fuel economy and engine performance. Center vent temperatures will also be slightly higher due to the compressor cycling off at a higher evaporator temperature.

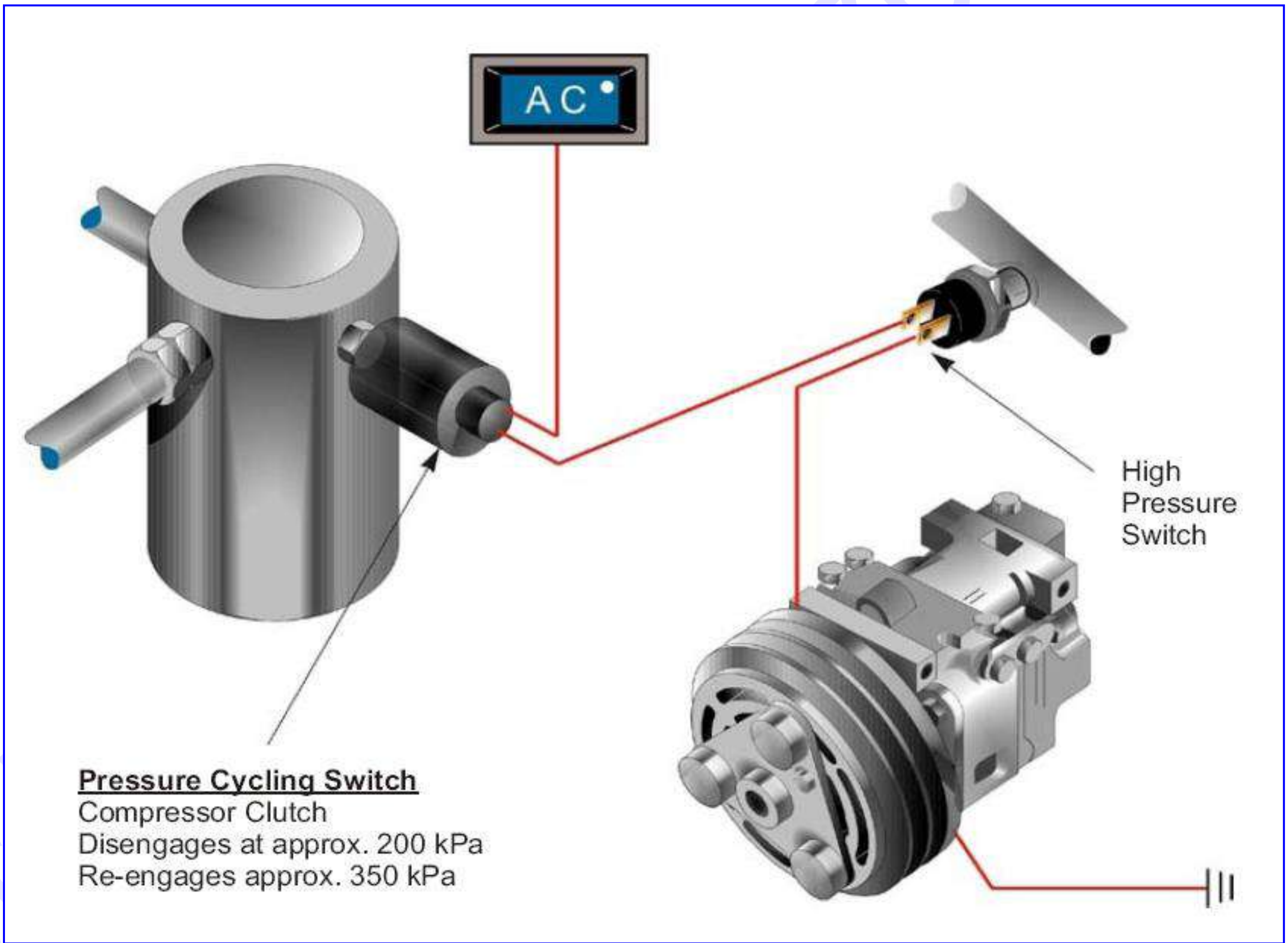


Pressure cycling switch - Electrical

Some vehicles using the Cycling Clutch Orifice Tube (CCOT) system utilize a pressure switch located in the low side of the A/C system between the evaporator and compressor for compressor control. This pressure switch is electrically connected in series with the compressor clutch. Once the low side pressure reaches approximately 200 kPa, the compressor clutch is deactivated by the pressure switch opening. A low side pressure of approximately 200 kPa corresponds to an evaporator coil temperature of approximately + 0.40C (above freezing point).

Once the compressor is deactivated the low pressure rises followed by the evaporator coil temperature rising. At a pre-determined low pressure point, the pressure switch reactivates the compressor clutch. The evaporator temperature lowers again and the compressor re-engages.

Note: Normally a low pressure cut off switch is not used with a pressure cycling switch as the pressure cycling switch is located on the low side. It serves as a low pressure cut off also.



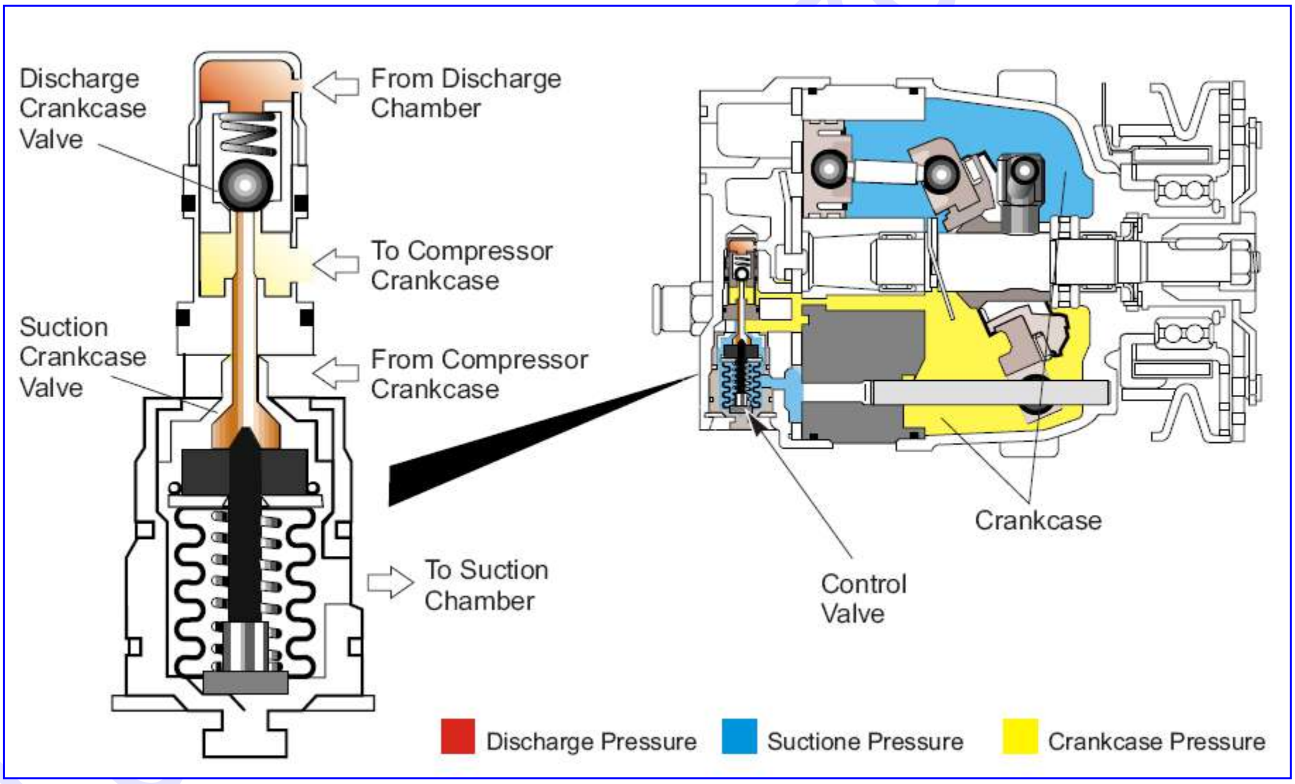
Pressure Control Valve - Mechanical

A/C Demand High

During periods of moderate to high A/C demand, system suction pressure will be greater than the control valve set point. During these periods, the control valve maintains a bleed from crankcase to suction. Crankcase pressure is therefore equal to suction pressure. The wobble plate angle, and therefore compressor displacement is at its maximum.

A/C demand low

During periods of low to moderate A/C demand, system suction pressure will decrease to the control valve set point. The control valve maintains a bleed from discharge to crankcase and prevents a bleed from crankcase to suction. The wobble plate angle, and therefore compressor displacement is reduced or minimized. During these periods, displacement is infinitely variable between approximately 5 and 100% of its maximum displacement.

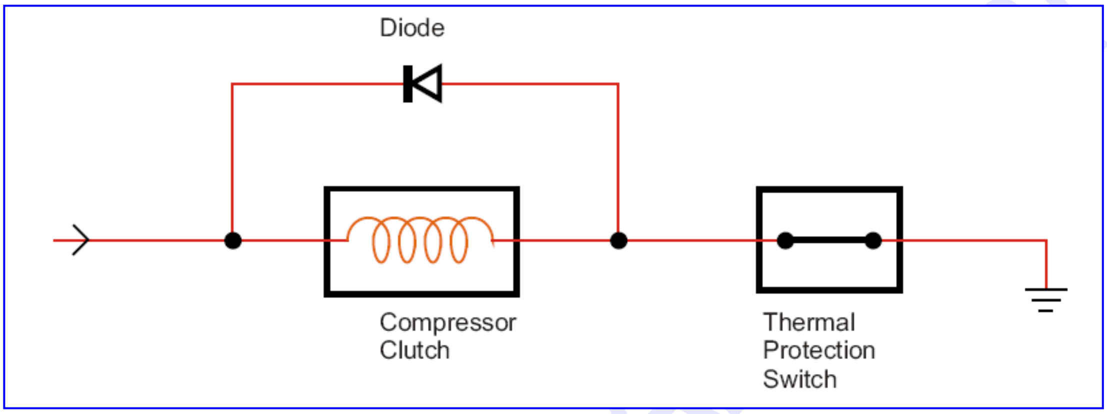


Variable Stroke Compressor

Protection Devices:

Clutch Diode

The clutch coil is an electromagnet with a strong magnetic field when current is applied. This magnet field is constant as long as the clutch is applied. When the power is removed the magnetic field collapses and creates high voltage spikes. These spikes are harmful to the ECM and must be prevented. A diode placed across the clutch coil provides a path to ground. This diode is usually taped inside the clutch coil connector.

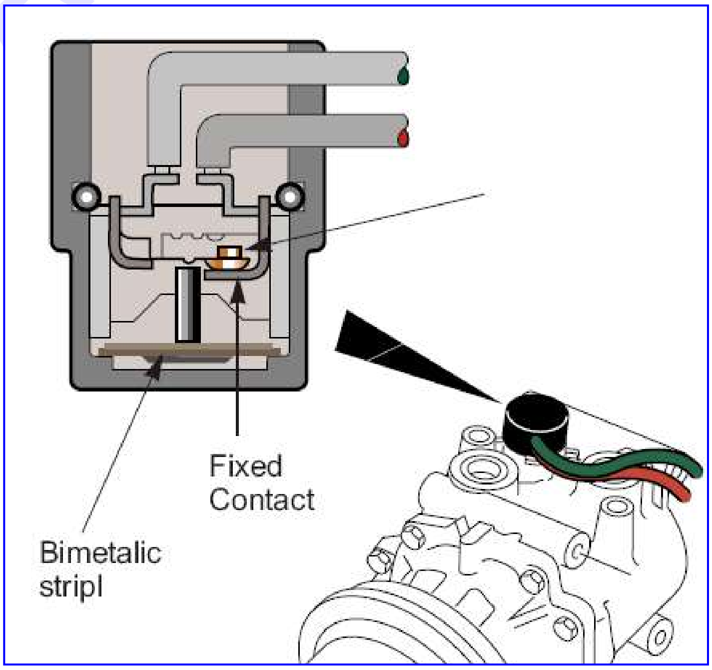


Thermal protection switch

The thermal protection switch is normally located on the compressor housing. This protection switch is used to prevent compressor damage through internal friction.

This switch senses the compressor case temperature and once this case temperature reaches a predetermined figure the electrical circuit to the compressor clutch is interrupted.

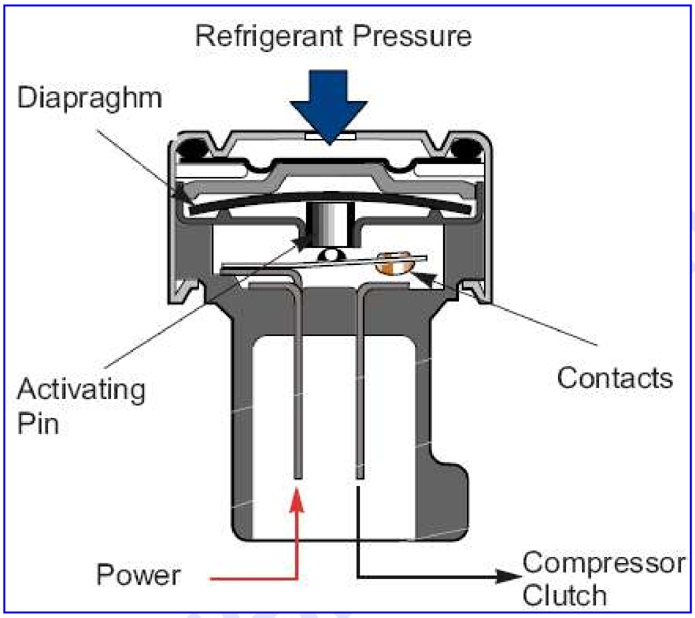
As the thermal protection switch is connected in series with the compressor clutch once the compressor case temperature lowers to a predetermined figure the compressor clutch is then re-energized.



Refrigerant Pressure Switches

Low pressure

Used to interrupt the electrical circuit to the compressor clutch. If the refrigerant pressure is too low or a problem exists in the A/C refrigerant system. (refer diagram).



High pressure

The power supply is interrupted when the refrigerant pressure is too high or a problem exists in the A/C refrigerant system.

Terminology

Binary switch - High/Low switch.

Trinary switch - High/Medium/Low switch.

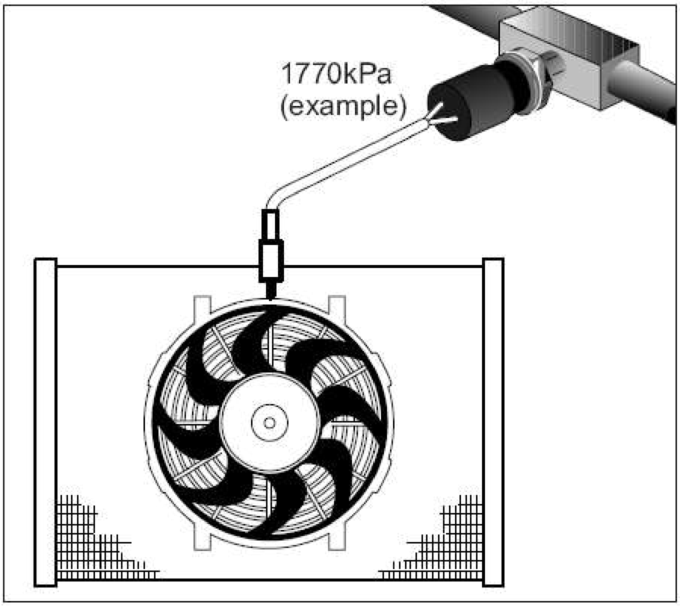
Condenser fan control

Medium pressure

Used to engage the condenser fan at a predetermined refrigerant pressure.

Example: Condenser fan high speed activation at 1770kPa refrigerant pressure.

These switches can be individual or a combination of the two or even three pressure ranges.



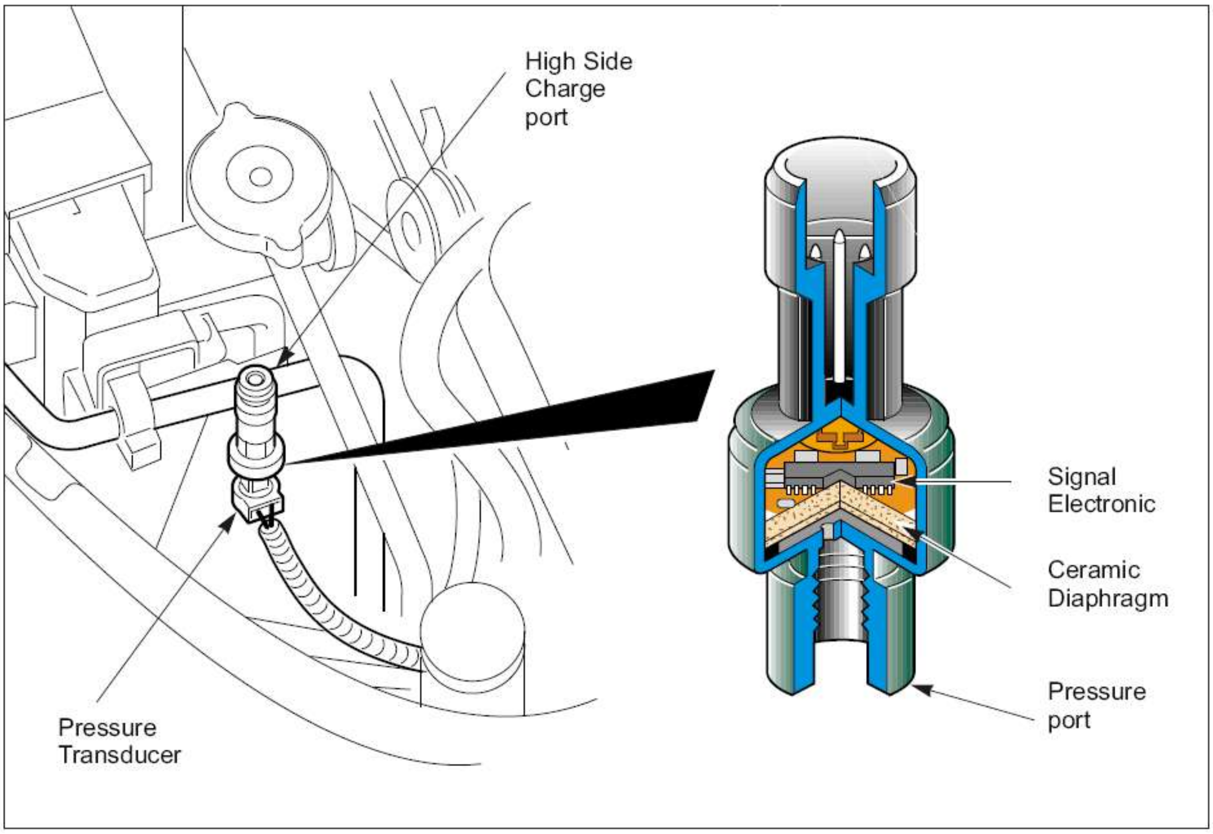
Pressure Transducer

The pressure transducer is a sealed gauge reference, capacitive pressure sensor with on board signal conditioning. It provides a 0.5 volt output and requires a 5 volt regulated power supply.

In operation the transducer sensor applies pressure via the deflection of a two piece ceramic diaphragm with one half being a parallel plate capacitor. Changes in capacitance influenced by the refrigerant pressure under the ceramic diaphragm are converted to an analog output by the transducer integral signal electronics.

The pressure transducer's electronics are on a flexible circuit board contained in the upper section of the transducer and provide linear calibration of the capacitance signal from the ceramic sensing diaphragm.

Benefits of using the pressure transducer over a normal type pressure switch is that the transducer is constantly monitoring the pressures and sending signals to the electronic control module (ECM), unlike the normal type pressure switch that has an upper and lower cut out points. The ECM will disengage the A/C compressor at low or high refrigerant pressures and electronic diagnostic equipment can be used to extract system pressure information making it easier when diagnosing problems.



Protection Devices

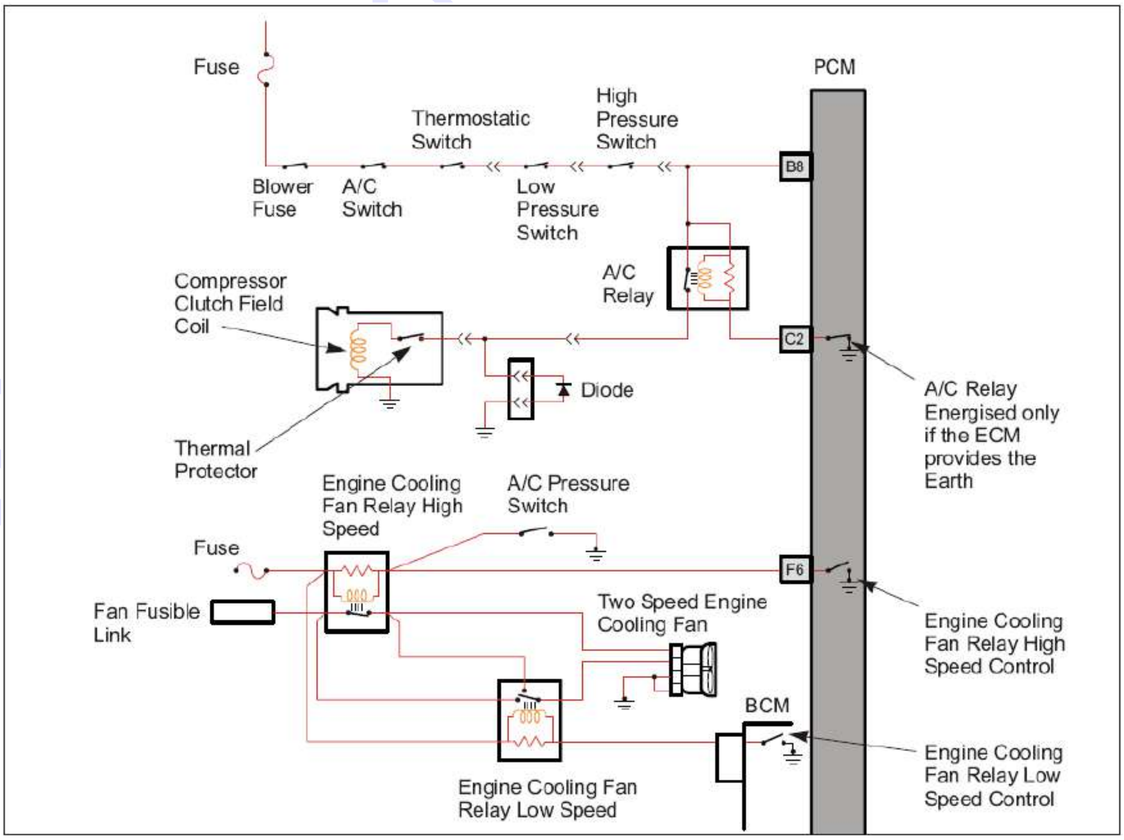
Engine Control Module (ECM)

Body Control Module (BCM)

Power Train Module (PCM)

Microprocessors (ECM, BCM & PCM) are used to engage and disengage the A/C electrical circuits controlling the compressor and condenser fan. Numeric signals from various sensors relating to engine speed, road speed, coolant temperature, A/C switch activation, pressure switches, A/C thermostatic switch, throttle position and kick down are constantly monitored by the ECM, BCM or PCM. This numeric signals are converted in the microprocessors to calculations required to:

- Deactivate the A/C compressor at high/low system pressures;
- Deactivate the A/C compressor at kick down;
- Active and deactivate the condenser fan;
- Increase engine idle speed when A/C system is activated;
- Deactivate the A/C compressor at high engine RPM;
- Delay A/C compressor engagement at engine cranking;
- Activate electrical engine fan at predetermined coolant temperature;
- Deactivate the A/C compressor when coolant temperature excessive;
- Deactivate the A/C compressor at wide open throttle (WOT)

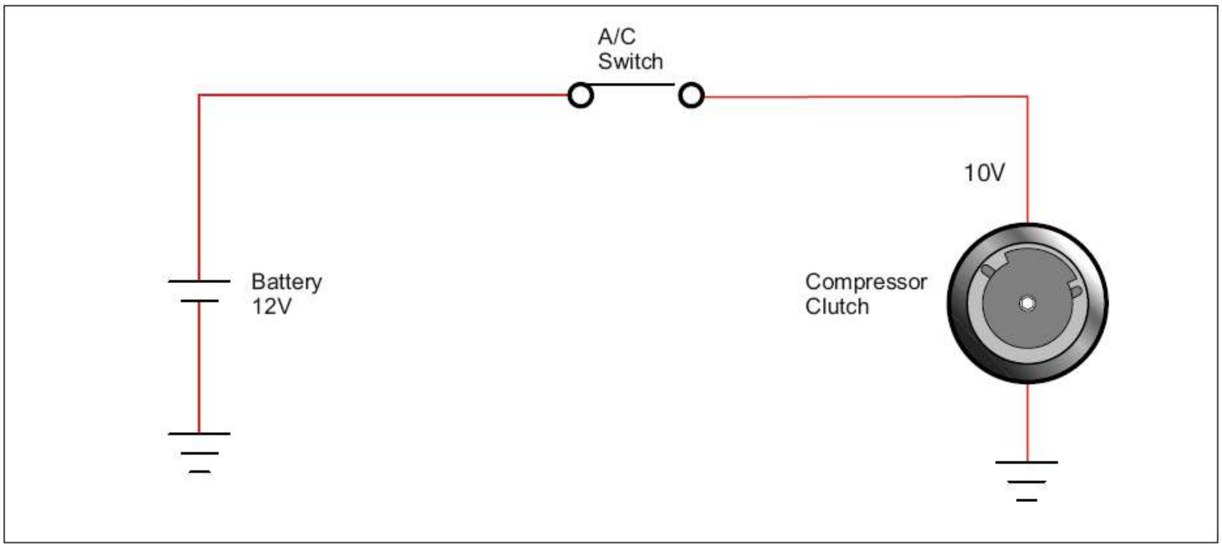


Relays

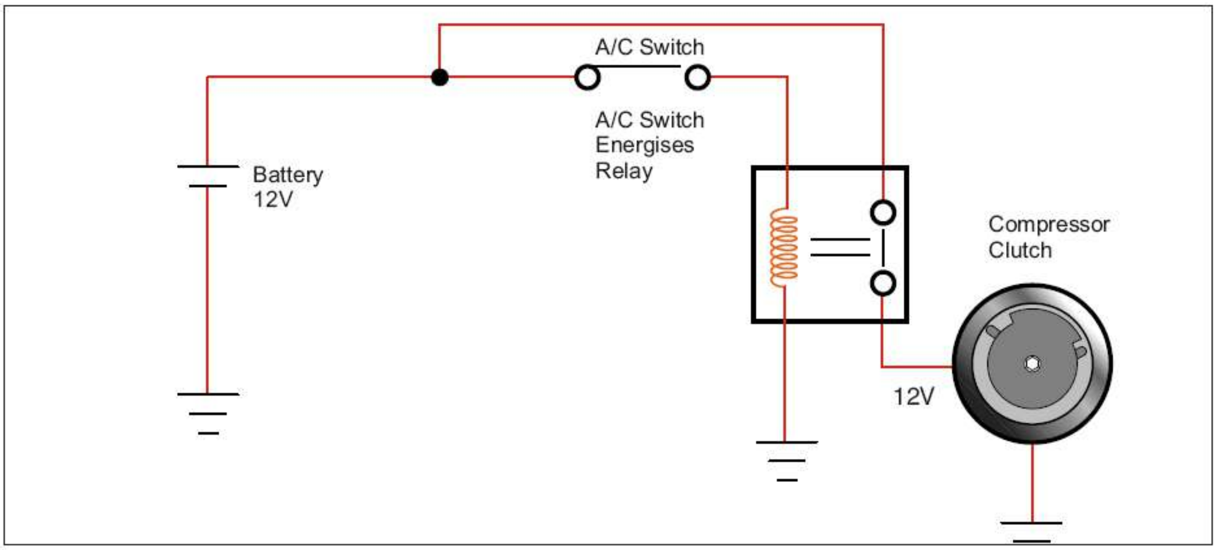
Relays are normally used in the A/C electrical circuit to protect switches that have a low current carrying capacity (i.e. a small contact area/weak pressure contact point) or for current draw differences between components.

Shown below is an example of the difference in a circuit with and without a relay.

Without Relay

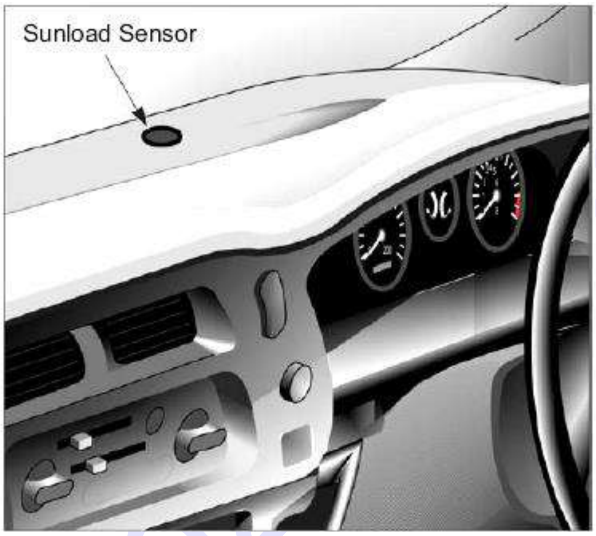


With Relay



Sensors

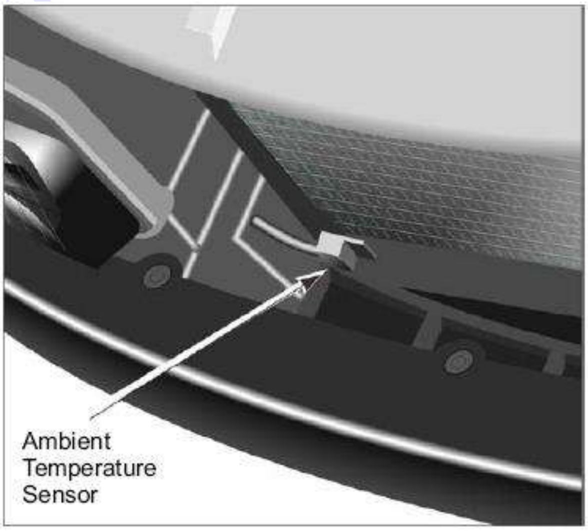
Sun load



The sun load sensor is a photochemical diode (PCD) located on top of the dashboard. This sensor sends a signal to the electrical climate control module (ECCM) indicating the strength of the sunlight (sun load) which influences the vehicle interior temperature.

If the sun load is high as signaled by the sun load sensor the ECCM will activate the highest blower fan speed and maximum cooling to compensate for this additional radiated heat load. Likewise, if the sun load is low (cloud cover) as sensed by the sun load sensor, the ECCM will reduce the blower fan speed and the system will not operate at maximum cooling.

Ambient temperature sensor



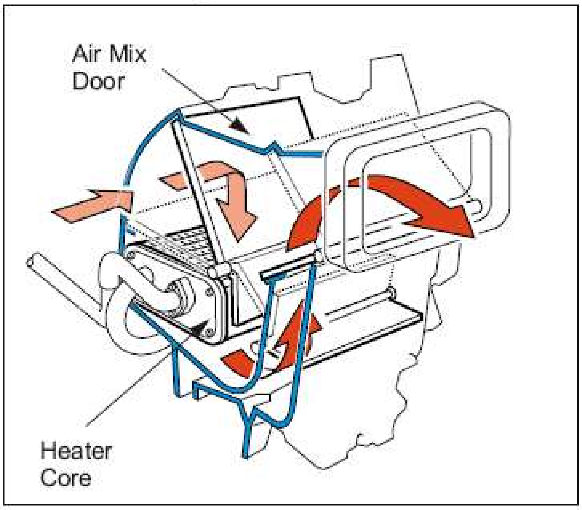
The ambient temperature sensor is a negative coefficient resistor (NTC) with low voltage input. The sensor alters resistance depending on the ambient air temperature surrounding it.

The sensor is located in the ambient air stream normally behind the bumper bar or front grille area. This sensor is used to monitor the outside temperature and is interconnected to a visual display in the instrument panel.

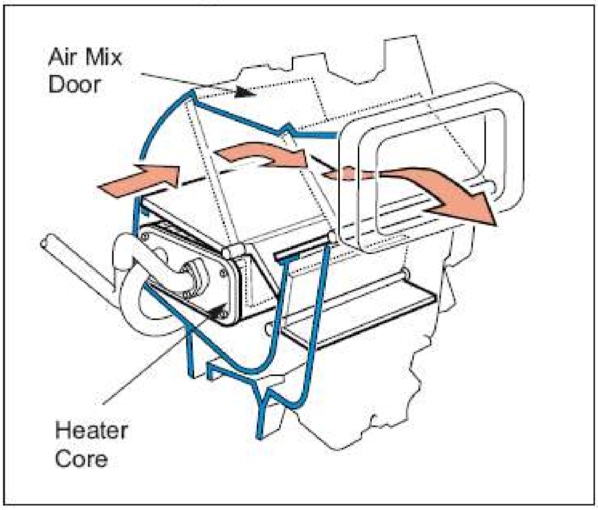
Air Mix Door

Temperature control is carried out by operating the temperature mode control, normally cable operated and connected to a door housed in the heater case. This door is located above the heater core and in the full cold position, completely covers the heater core. As more heat is required the door is operated and moves away from the heater core and allows radiant heat to rise and mix with the fresh or A/C air to increase the vent temperatures to the desired comfort level required.

Air Flow during Maximum Hot



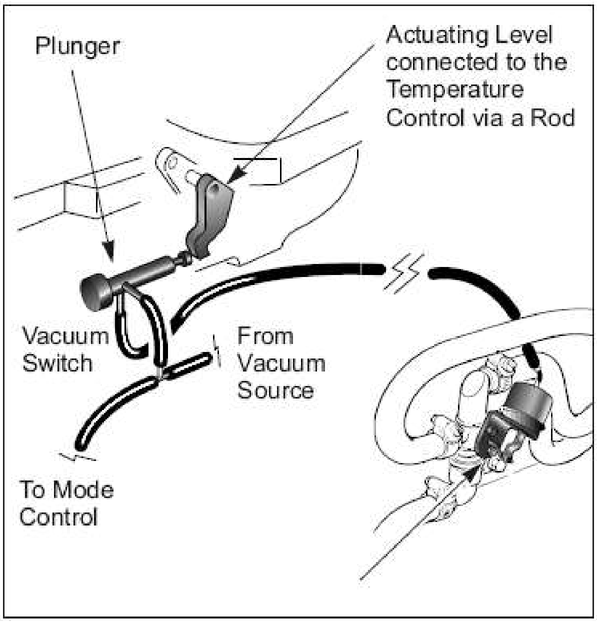
Air Flow during Maximum Cold



Heater Control

The heater tap is normally vacuum operated and has engine vacuum applied to it in the full cold position. This stops the flow of coolant to the heater core by keeping the heater tap closed.

Once heating has been selected, the vacuum is exhausted from the vacuum circuit via a vacuum switch, to the heater tap and the hot coolant then flows through to the heater core.



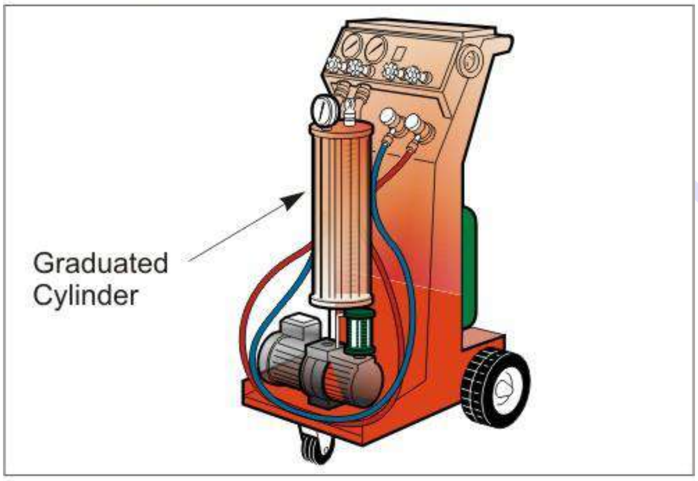
Charging Stations:

There are two methods of charging refrigerant into an A/C system. They are:

By volume - using a graduated charging dial cylinder,

By weight - using electronic scale with LCD read out.

Charging by volume



Both methods work well, but because R134a is charge sensitive and most A/C system filter drier's have no sight glass, it is recommended to charge the system to the manufacturers specification using electronic weighing scales. The advantage of using electronic scale over a dial - a - charge type is that most dial - a – charge cylinders only hold of 2 - 3 kilograms maximum (before being refilled) which is enough for approximately 2 - 3 A/C system charges.

The electronic scales type uses a refrigerant cylinder of up to 25 kilograms enabling 25 - 30 A/C system charges to take place before charging over the cylinder.

Electronic Refrigerant Evacuation and Charging System:

Refrigerant Evacuation and Charging System using the most up to date electronic intelligence and quality components.

The unit has been designed for ease of operation, accuracy and durability.

Features:

- Monitors suction and discharge system pressures.
- Displays amount of refrigerant in storage cylinder.
- Operator can select amount of refrigerant to be charged.
- Allows operator to select evacuation time.
- Automatic oil injection.
- Pause function on charge and evacuation procedures.

All in One Unit

Rather than have a unit that only recovery, evacuates and charges an A/C system, there are "all in one" units that carry out all the necessary servicing function. Operations are entered into an electronic keypad.

These include:

- *Charging to the specified amount.*
- *Evacuation for any duration required*
- *Recovering the refrigerant.*
- *Recycling the refrigerant.*
- *Injecting the lubricant.*
- *Flushing the a/c system*

All these function can be programmed into the unit via a control panel. The unit will automatically carry out all the pre-selected operations.

Recovery& Recycling, Evacuation and Charging System

takes time and worry out of air conditioning testing and servicing.

A once difficult process is now stream-lined and automatically completed by the system.

Functions:

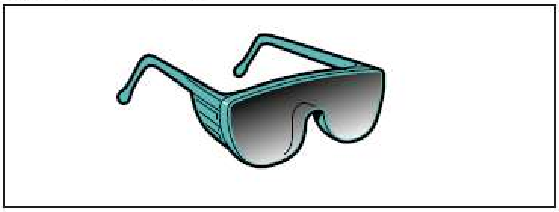
- Monitors a/c system working pressure.
- Displays amount of the refrigerant cylinder.
- Recovers and recycles refrigerant with pause function.
- Monitors and displays the amount of refrigerant and refrigerant oil recovered.
- Evacuates system with pause and time function.
- Automatically inject oil or UV dye.
- Electronically charges accurately with pause function.
- Electronically monitors and displays service intervals.
- Electronically refills refrigerant cylinder.
- Prints a report.

Refrigerant Safety

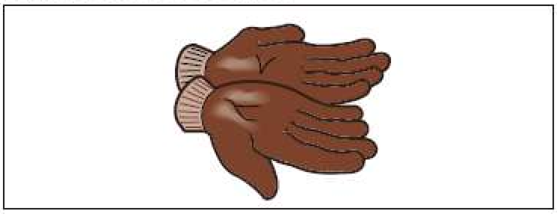
As R134a has a very low boiling point, care must be taken when it is been handled. The following safety precautions must be followed:

- Always wear eye protection.
- Wear gloves.
- Don't allow R134a to contact bare skin as this causes frostbites.
- Do not heat containers of R134a.
- Provide adequate ventilation when charging or recovering R134a as it is heavier than air.
- Use care when hot water steam cleaning the engine. Hot water on the air conditioning pipes and tubes could create thermal expansion of the refrigerant contained in the system.
- Avoid breathing R134a vapor.
- Do not transfer refrigerant from cylinder to cylinder using a pump without knowing when the bottle being filled has reached 80% of its capacity, as a remaining 20% is used for thermal expansion.

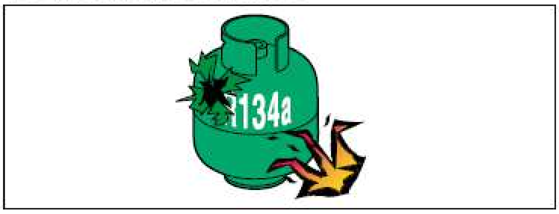
Eye Protection



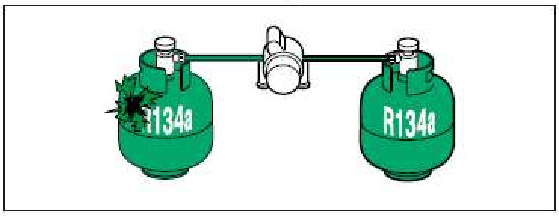
Hand/Skin Protection



Do Not Heat Container



Do Not Transfer Refrigerant



Avoid Breathing Refrigerant

Flushing a contaminated system

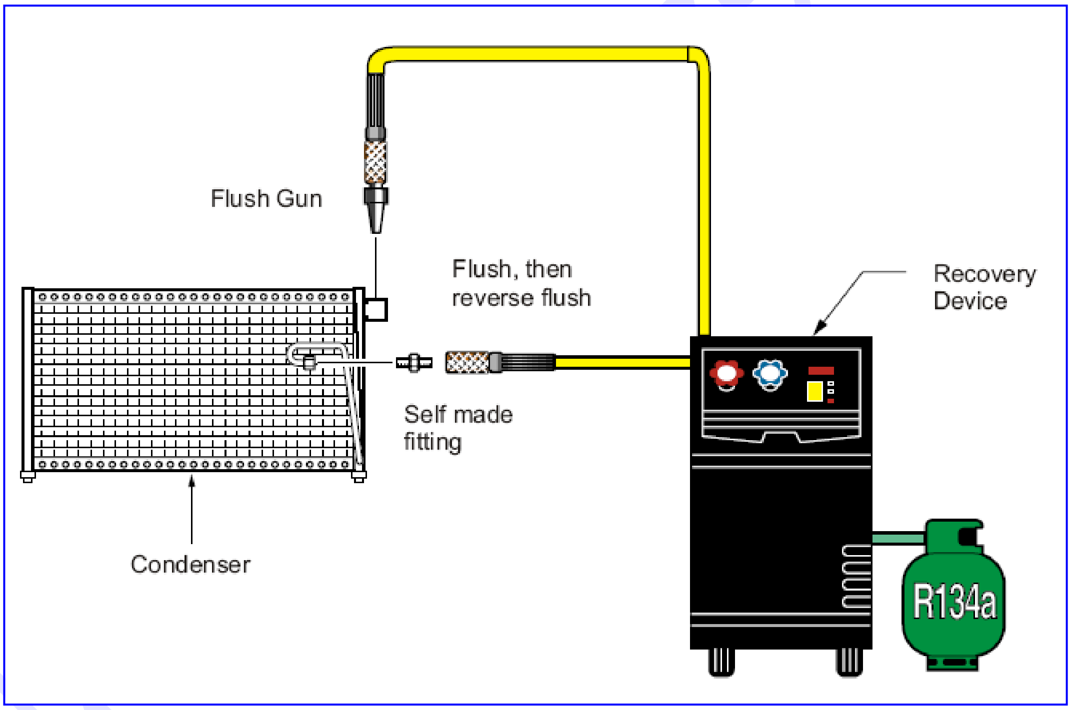
If a seized or damaged compressor is to be replaced, inspecting of discharge hose interior is advised.

On inspecting the interior of the discharge hose, if particles or silvers of aluminum are found, flushing of the A/C system is required including a new filter drier.

We recommend flushing individual components or system sections with refrigerant R134a, this refrigerant should be collected via a recovering machine and can be used again.

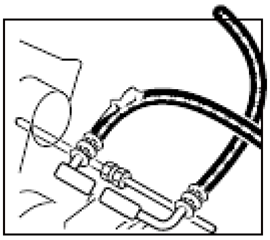
Components or tube connections (mostly self-made) will have to be used and flushing carried out with the refrigerant in liquid from i.e. the decanting cylinder turned upside down. Failure to flush a contaminated system will lead to blockage in the condenser filter drier or TX valve and possibly cause compressor damage.

After finishing flushing, blowing the system with dry nitrogen is recommended.

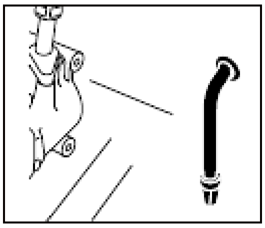


Preparations

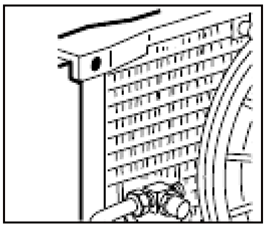
Before servicing or diagnosing an A/C system there are preliminary checks that should take place. These include:



Checking for visual hose damage and chaffing

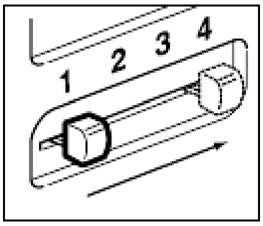


Compressor cycles on and off.
Evaporator drain hose not blocked.



Ensure the condenser cooling fins are not blocked with obstructions such as insects, leaves or grass.

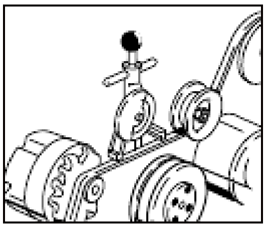
Condenser fan operates and runs in correct direction.



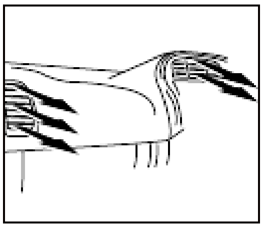
Heater turned off in the full cold mode position.

Blower fan has all speeds operational.

Air mix door fully closed.



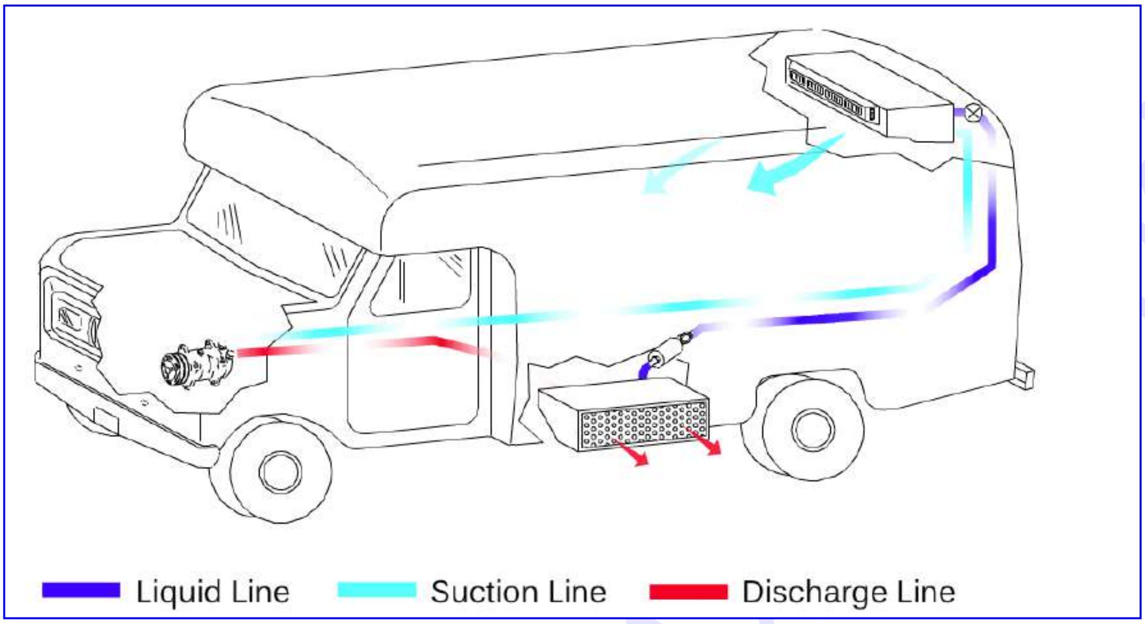
Inspect drive belts for correct tension and damage.

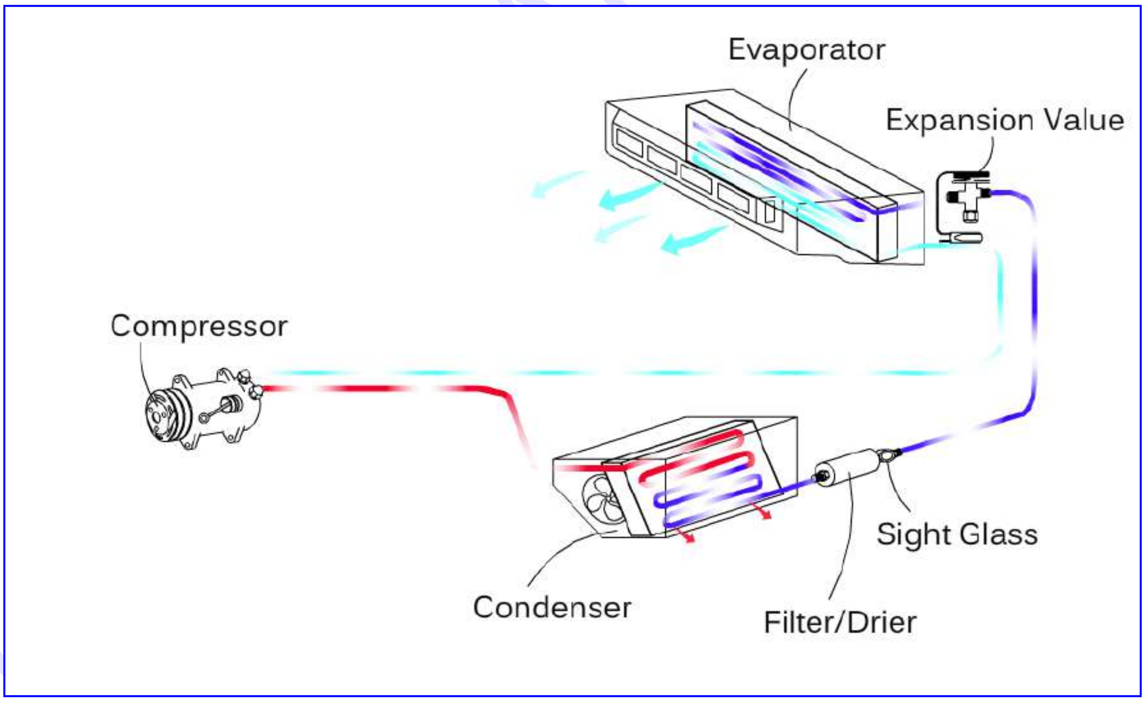


Dash vents open and close fully.

No air leaks between evaporator case and heater case.

Truck refrigeration units:


Liquid Line
Suction Line
Discharge Line


Evaporator
Expansion Value
Compressor
Sight Glass
Condenser
Filter/Drier

CHILLERS



Note: This lecture is depended on Trane clinic document.(2013)

Chiller There are a variety of water chiller types. Most commonly, they are absorption, centrifugal, helical rotary, and scroll. Some reciprocating chillers are also available. Chillers can be either air- or water-cooled. Major vapor-compression chiller components include an evaporator, compressor(s), condenser, and expansion device(s). Water-cooled chillers are typically installed indoors; air-cooled chillers are typically installed outdoors—either on the roof or next to the building.

Chiller evaporator: The evaporator section of a water chiller is a shell-and-tube, refrigerant-to-water heat exchanger. Depending on the chiller's design, either the refrigerant or the water is contained within the tubes. In a flooded shell-and-tube evaporator (Figure 1), cool, liquid refrigerant at low pressure enters the distribution system inside the shell and moves uniformly over the tubes, absorbing heat from warmer water that flows through the tubes.

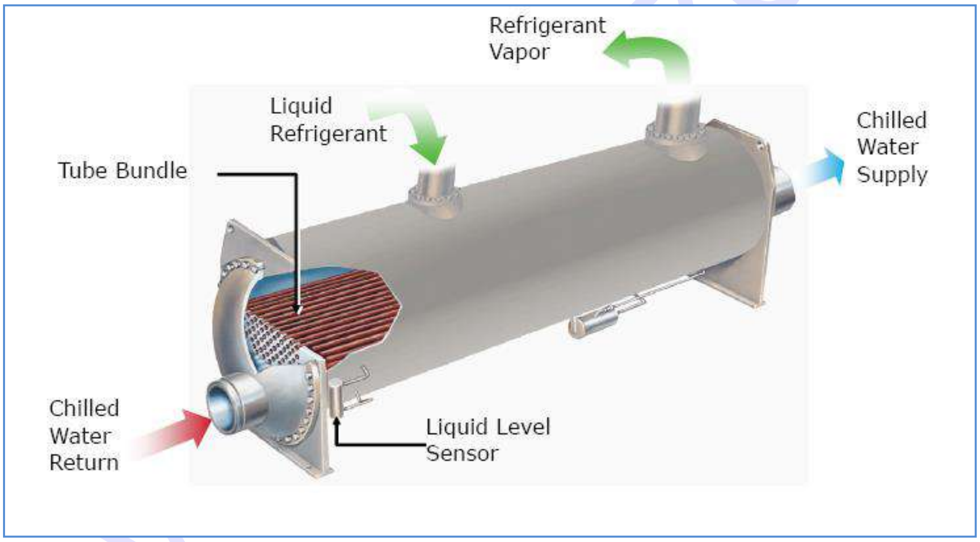


Figure 1. Flooded evaporator

Types of Water Chillers:

Water chillers using the vapor-compression refrigeration cycle vary by the type of compressor used. Reciprocating, scroll, helical-rotary, and centrifugal compressors are common types of compressors used in vapor-compression water chillers.

Absorption water chillers make use of the absorption refrigeration cycle.

A- Driving Sources:

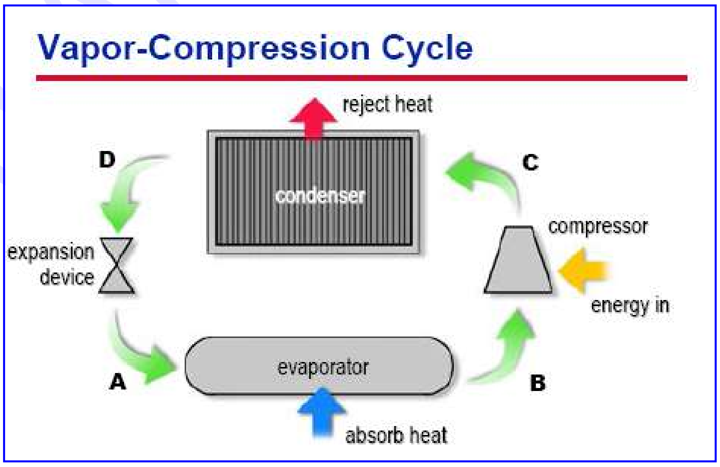
Compressor-driven: Vapor-compression water chillers use a compressor to move refrigerant around the system. The most common energy source to drive the compressor is an electric motor.

Heat-driven: Absorption water chillers use heat to drive the refrigeration cycle. They do not have a mechanical compressor involved in the refrigeration cycle. Steam, hot water, or the burning of oil or natural gas is the most common energy sources for these types of chillers.

B- Refrigeration system:

Vapor-Compression Water Chillers:

In the vapor-compression refrigeration cycle, refrigerant enters the evaporator in the form of a cool, low-pressure mixture of liquid and vapor. Heat is transferred from the relatively-warm air or water to the refrigerant, causing the liquid refrigerant to boil. The resulting vapor is then drawn from the evaporator by the compressor, which increases the pressure and temperature of the refrigerant vapor.



The hot, high-pressure refrigerant vapor leaving the compressor enters the condenser, where heat is transferred to ambient air or water at a lower temperature. Inside the condenser, the refrigerant vapor condenses into a liquid. This liquid refrigerant then flows to the expansion device, which creates a pressure drop that reduces the pressure of the refrigerant to that of the evaporator. At this low pressure, a small portion of the refrigerant boils (or flashes), cooling the remaining liquid refrigerant to the desired evaporator temperature. The cool mixture of liquid and vapor refrigerant travels to the evaporator to repeat the cycle.

<u>The vapor compression refrigeration system classification according to types of compressors</u>:

The type of compressor used generally has the greatest impact on the efficiency and reliability of a vapor-compression water chiller. The improvement of compressor designs and the development of new compressor technologies have led to more-efficient and -reliable water chillers.

The **reciprocating compressor** was the workhorse of the small chiller market for many years. It was typically available in capacities up to 100 tons [350 kW]. Multiple compressors were often installed in a single chiller to provide chiller capacities of up to 200 tons [700 kW].

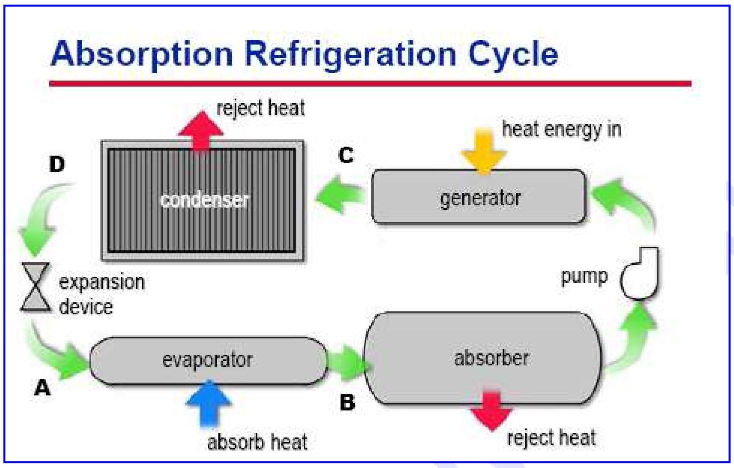
Scroll compressors have emerged as a popular alternative to reciprocating compressors, and are generally available in hermetic configurations in capacities up to 15 tons [53 kW] for use in water chillers. As with reciprocating compressors, multiple scroll compressors are often used in a single chiller to meet larger capacities. In general, scroll compressors are 10 to 15 percent more efficient than reciprocating compressors and have proven to be very reliable, primarily because they have approximately 60 percent fewer moving parts than reciprocating compressors. Reciprocating and scroll compressors are typically used in smaller water chillers, those less than 200 tons [700 kW].

Helical-rotary (or screw) compressors have been used for many years in air compression and low-temperature-refrigeration applications. They are now widely used in medium-sized water chillers, 50 to 500 tons [175 to 1,750 kW]. Like the scroll compressor, helical-rotary compressors have a reliability advantage due to fewer moving parts, as well as better efficiency than reciprocating compressors.

Centrifugal compressors have long been used in larger water chillers. High efficiency, superior reliability, reduced sound levels, and relatively low cost has contributed to the popularity of the centrifugal chiller. Centrifugal compressors are generally available in prefabricated chillers from 100 to 3,000 tons [350 to 10,500 kW], and up to 8,500 tons [30,000 kW] as built-up machines.

Absorption refrigeration systems:

Absorption Water Chillers So far, we have discussed water chillers that use the vapor-compression refrigeration cycle. Absorption water chillers are a proven alternative to vapor compression chillers. The absorption refrigeration cycle uses heat energy as the primary driving force. The heat may be supplied either in the form of steam or hot water (indirect-fired), or by burning oil or natural gas (direct-fired).



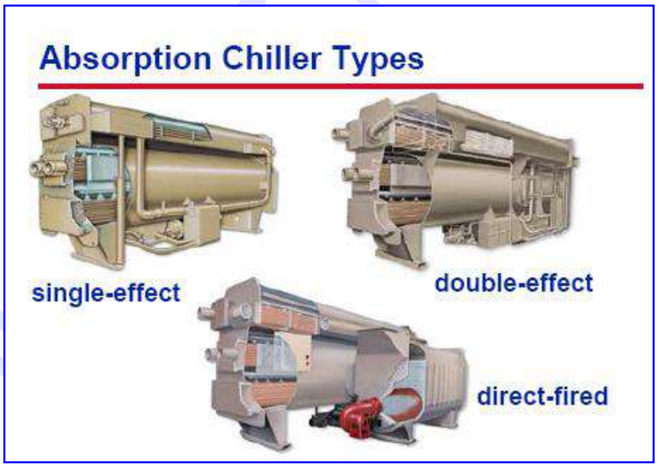
There are two fundamental differences between the absorption refrigeration cycle and the vapor-compression refrigeration cycle. The first is that the compressor is replaced by an absorber, pump, and generator. The second is that, in addition to the refrigerant, the absorption refrigeration cycle uses a secondary fluid called the absorbent. The condenser, expansion device, and evaporator sections, however, are similar. Warm, high-pressure liquid refrigerant passes through the expansion device and enters the evaporator in the form of a cool, low-pressure mixture of liquid and vapor. Heat is transferred from the relatively-warm system water to the refrigerant, causing the liquid refrigerant to boil. Using an analogy of the vapor-compression cycle, the absorber acts like the suction side of the compressor—it draws in the refrigerant vapor to mix with the absorbent. The pump acts like the compression process itself—it pushes the mixture of refrigerant and absorbent up to the high-pressure side of the system. The generator acts like the discharge of the compressor—it delivers the refrigerant vapor to the rest of the system.

The refrigerant vapor leaving the generator enters the condenser, where heat is transferred to cooling-tower water at a lower temperature, causing the refrigerant vapor to condense into a liquid. This high-pressure liquid refrigerant then flows to the expansion device, which creates a pressure drop that reduces the pressure of the refrigerant to that of the evaporator, repeating the cycle.

Absorption water chillers generally have a higher first cost than vapor compression chillers. The cost difference is due to the additional heat-transfer tubes required in the absorber and generator(s), the solution heat exchangers, and the cost of the absorbent. This initial cost premium is often justified when electric demand charges or real-time

electricity prices are a significant portion of the electric utility bill. Because electric demand charges are often highest at the same time as peak cooling requirements, absorption chillers are often selected as peaking or demand-limiting chillers.

Because the absorption chiller uses only a small amount of electricity, backup generator capacity requirements may be significantly lower with absorption chillers than with electrically-driven chillers. This makes absorption chillers attractive in applications requiring emergency cooling, assuming the alternate energy source is available. Some facilities, such as hospitals or factories, may have excess steam or hot water as a result of normal operations. Other processes, such as a gas turbine, generate waste steam or some other waste gas that can be burned. In such applications, this otherwise wasted energy can be used to fuel an absorption chiller. Finally, cogeneration systems often use absorption chillers as a part of their total energy approach to supplying electricity in addition to comfort cooling and heating.



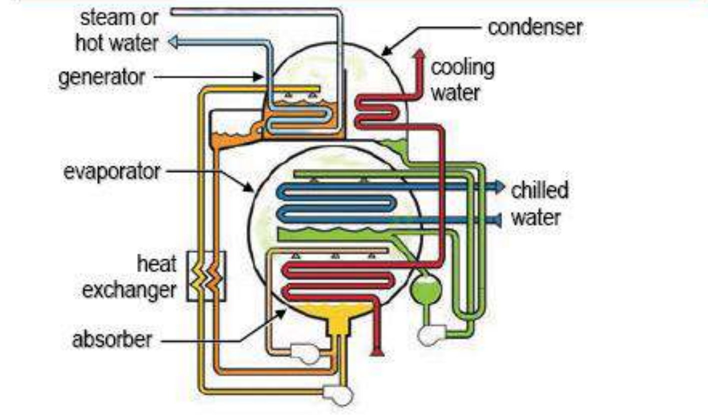
There are three basic types of absorption chillers. They are typically available in capacities ranging from 100 to 1,600 tons [350 to 5,600 kW].

Indirect-fired, single-effect absorption chillers: operate on low-pressure steam (approximately 15 psig [205 kPa]) or medium-temperature liquids (approximately 270°F [132°C]), and have a coefficient of performance (COP) of 0.6 to 0.8. In many applications, waste heat from process loads, cogeneration plants, or excess boiler capacity provides the steam to drive a single-effect chiller. In these applications, absorption chillers become conservation devices and are typically base-loaded. This means that they run as the lead chiller to make use of the "free" energy that might otherwise be wasted.

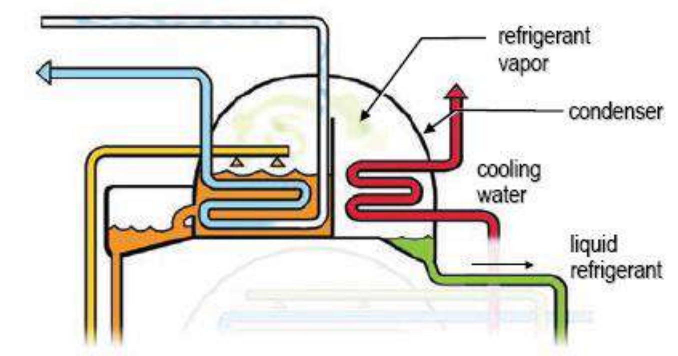
Indirect-fired, **double-effect absorption chillers** require medium-pressure steam (approximately 115 psig [894 kPa]) or high-temperature liquids (approximately 370°F [188°C]) to operate and, therefore, typically require dedicated boilers. Typical COPs for these chillers are 0.9 to 1.2.

The **direct-fired absorption chiller** includes an integral burner, rather than relying on an external heat source. Common fuels used to fire the burner are natural gas, fuel oil, or liquid petroleum. Additionally, combination burners are available that can switch from one fuel to another. Typical COPs for direct-fired, double-effect chillers are 0.9 to 1.1 (based on the higher heating value of the fuel). Higher energy efficiency and elimination of the boiler are largely responsible for the increasing interest in direct-fired absorption chillers. These types of absorption chillers have the added capability to produce hot water for heating. Thus, these "chiller–heaters" can be configured to produce both chilled water and hot water simultaneously. In certain applications this flexibility eliminates, or significantly down-sizes, the boilers.

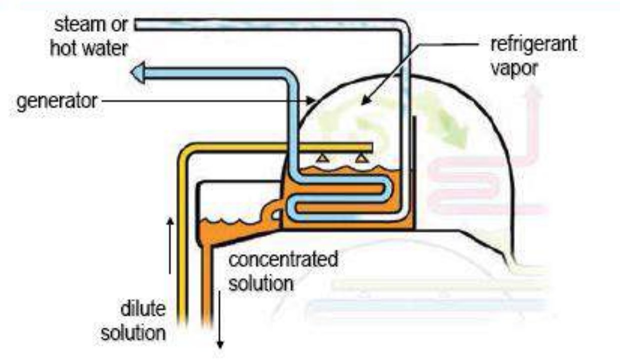
Absorption Refrigeration Cycle



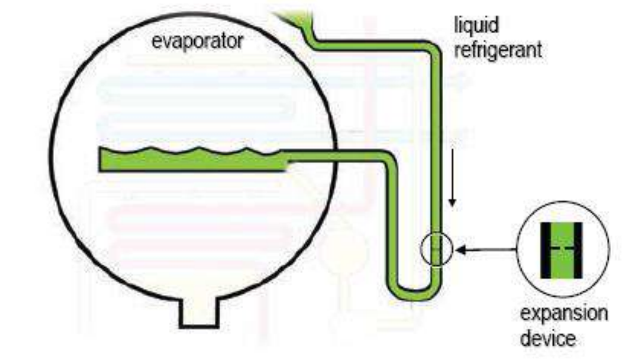
Condenser



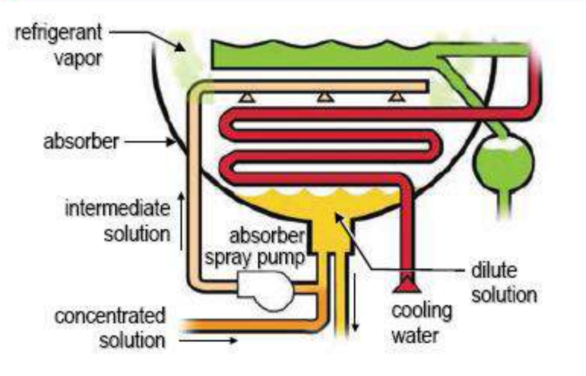
Generator



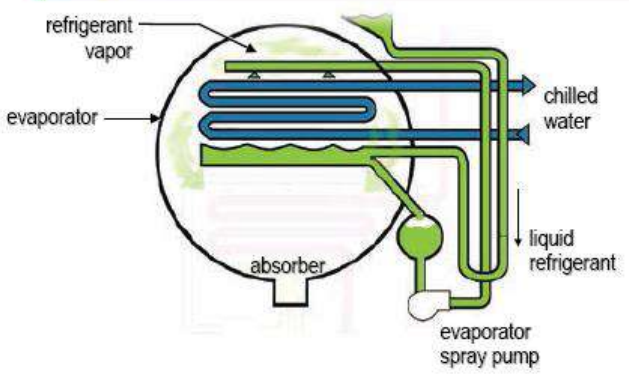
Expansion Device

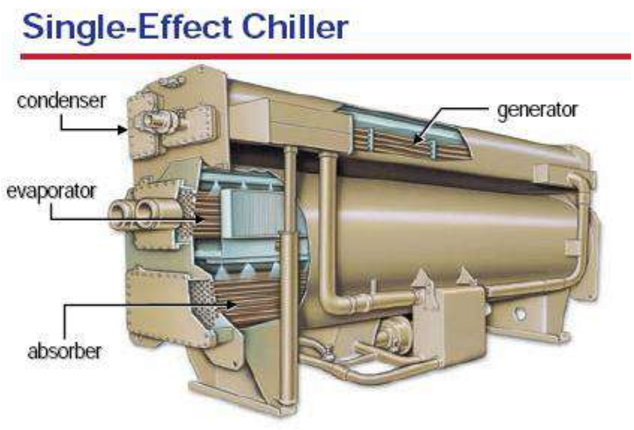


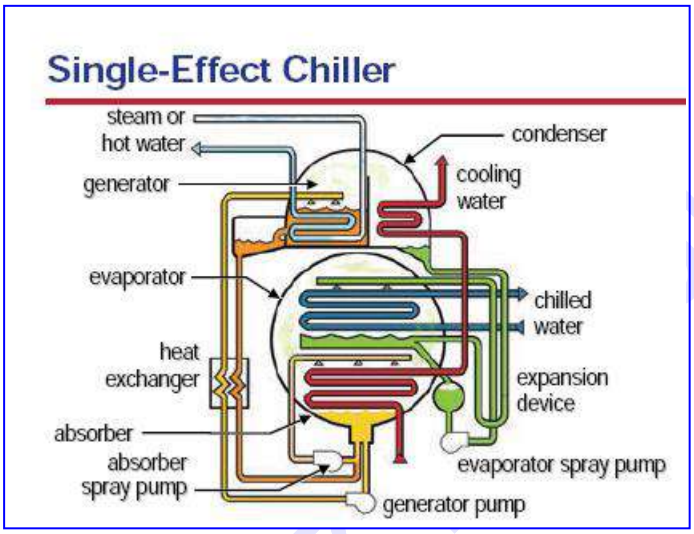
Absorber

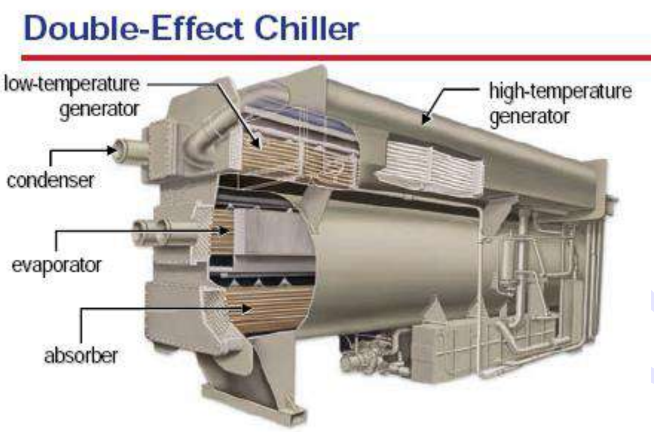


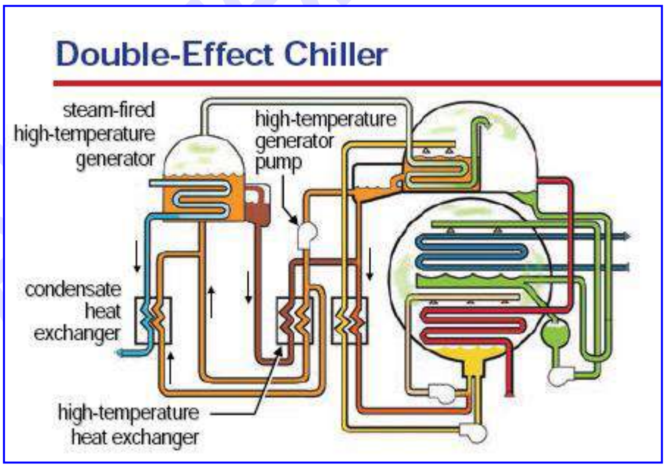
Evaporator

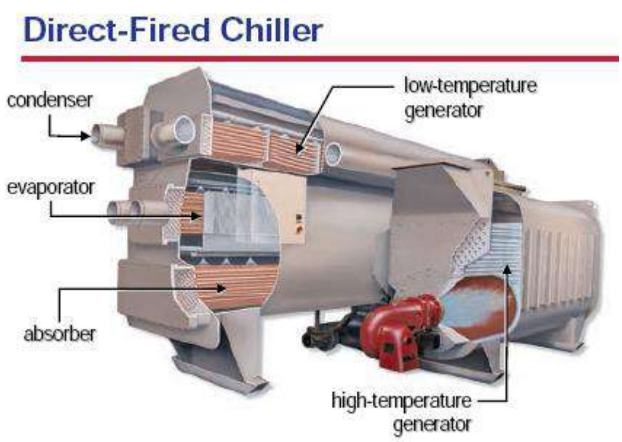


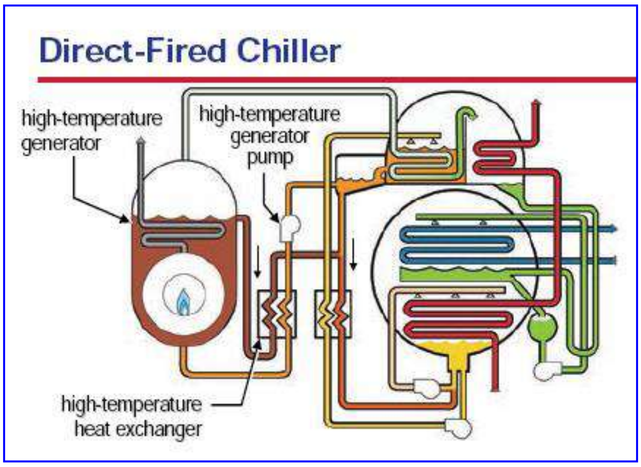

Single-Effect Chiller
condenser
generator
evaporator
absorber


Single-Effect Chiller
steam or
hot water
condenser
generator
cooling
water
evaporator
chilled
water
heat
exchanger
expansion
device
absorber
absorber
spray pump
evaporator spray pump
generator pump

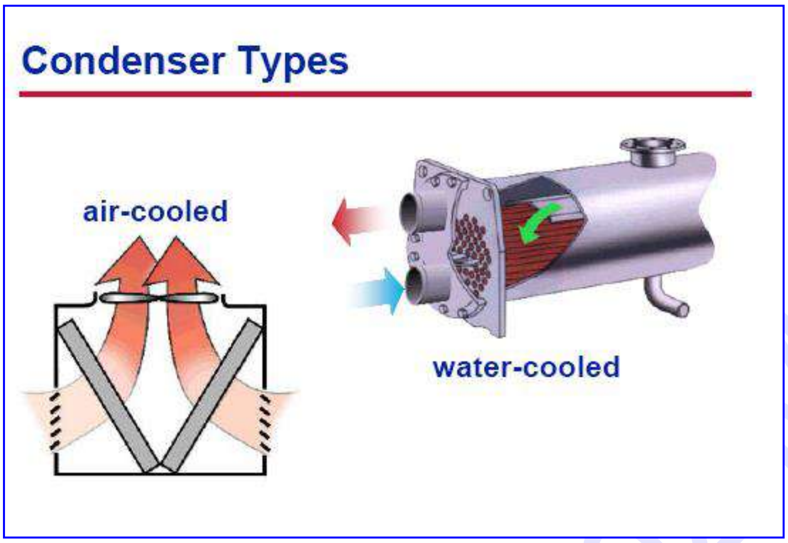

Double-Effect Chiller
low-temperature
generator
high-temperature
generator
condenser
evaporator
absorber


Double-Effect Chiller
steam-fired
high-temperature
generator
high-temperature
generator
pump
condensate
heat
exchanger
high-temperature
heat exchanger


Direct-Fired Chiller
condenser
low-temperature
generator
evaporator
absorber
high-temperature
generator


Direct-Fired Chiller
high-temperature
generator
high-temperature
generator
pump
high-temperature
heat exchanger

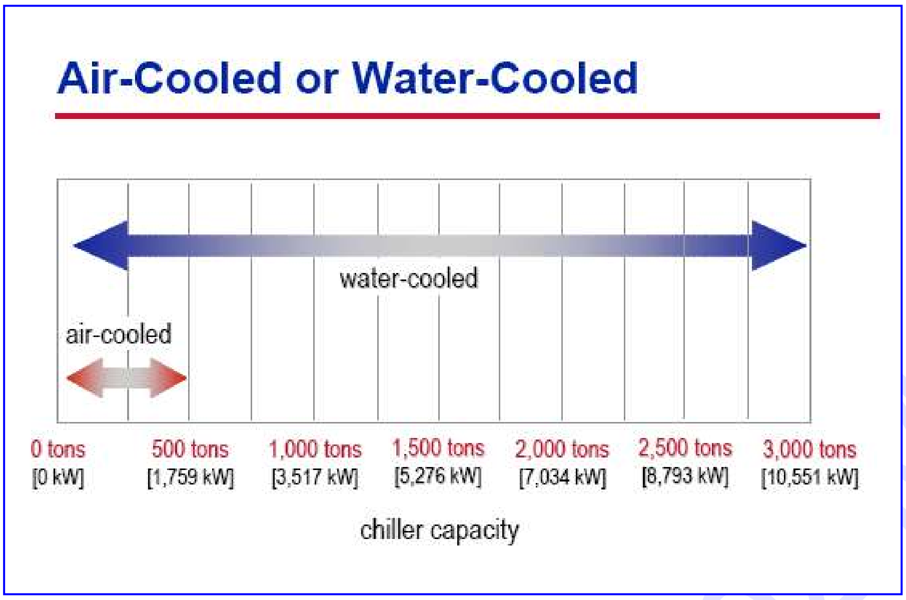
C- **Condenser cooling types:**



Water-cooled condenser: To cool a building or process, the transferred heat must ultimately be rejected outdoors or to another system (heat recovery). The total amount of heat rejected includes the sum of the evaporator load, the compressor work, and the motor inefficiency. In a hermetic chiller, where the motor and compressor are in the same housing, these loads are all rejected through the condenser. In an open chiller, where the motor is separate from the compressor and connected by a shaft, the motor heat is rejected directly to the surrounding air. The evaporator load and the compressor work are rejected through the condenser, and the motor heat must be taken care of by the equipment room's air-conditioning system.

Air-cooled condenser Air-cooled chillers do not use condenser-water, since they reject their heat by passing ambient air across refrigerant-to-air heat exchangers. In packaged air-cooled chillers, the manufacturers improve performance by staging fans in response to chiller load and ambient, dry-bulb temperature. Air-cooled chillers can also be split apart. One technique is to use an indoor remote evaporator with a packaged air-cooled condensing unit outdoors. Another technique is to locate the compressor(s) *and* the evaporator indoors (also known as a condenser less chiller) with an air-cooled condenser outdoors. It is also possible to have an indoor air-cooled condenser.

Air-cooled versus water-cooled condensers One of the most distinctive differences in chiller heat exchangers continues to be the type of condenser selected—air-cooled versus water-cooled. When comparing air-cooled and water-cooled chillers, available capacity is the first distinguishing characteristic. Air-cooled condensers are typically available in packaged chillers ranging from 7.5 to 500 tons [25 to 1,580 kW]. Packaged water-cooled chillers are typically available from 10 to nearly 4,000 tons [35 to 14,000 kW].



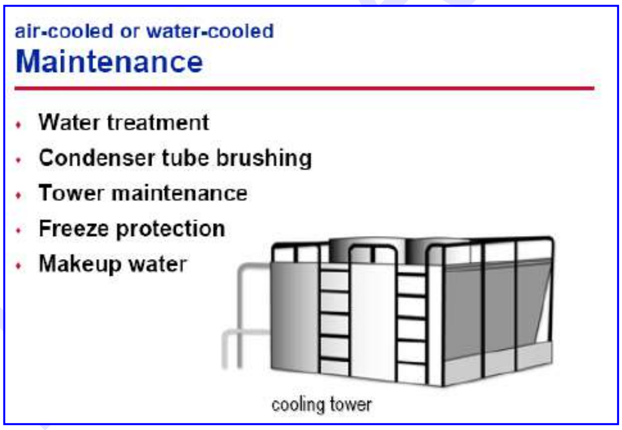
1- **Maintenance** A major advantage of using an air-cooled chiller is the elimination of the cooling tower. This eliminates the concerns and maintenance requirements associated with water treatment, chiller condenser-tube cleaning, tower mechanical maintenance, freeze protection, and the availability and quality of makeup water. This reduced maintenance requirement is particularly attractive to building owners because it can substantially reduce operating costs. However, see "Energy efficiency" below.

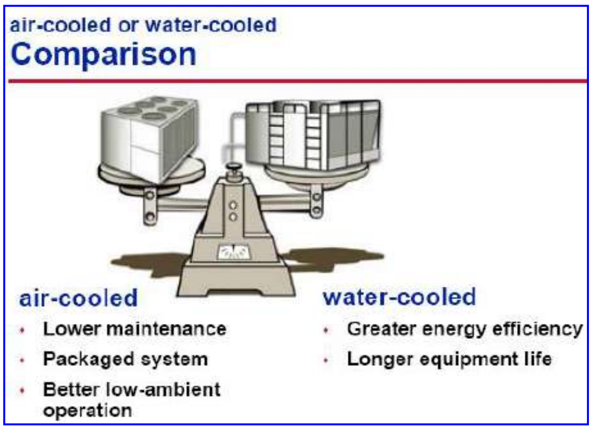
Systems that use an open cooling tower must have a water treatment program. Lack of tower-water treatment results in contaminants such as bacteria and algae. Fouled or corroded tubes can reduce chiller efficiency and lead to premature equipment failure.

2- **Low-ambient operation** Air-cooled chillers are often selected for use in systems with year-round cooling requirements that cannot be met with an airside economizer. Air-cooled condensers have the ability to operate in below-freezing weather, and can do so without the problems associated with operating the cooling tower in these conditions. Cooling towers may require special control sequences, basin heaters, or an indoor sump for safe operation in freezing weather. For process applications, such as computer centers that require cooling year-round, this ability alone often dictates the use of air-cooled chillers.

3- **Energy efficiency** Water-cooled chillers are typically more energy efficient than air-cooled chillers. The refrigerant condensing temperature in an air-cooled chiller is dependent on the ambient dry-bulb temperature. The condensing temperature in a water-cooled chiller is dependent on the condenser-water temperature, which is dependent on the ambient wet-bulb temperature. Since the design wet-bulb temperature is often significantly lower than the dry-bulb temperature, the refrigerant condensing temperature (and pressure) in a water-cooled chiller can be lower than in an air-cooled chiller. For example, at an outdoor design condition of 95°F [35°C] dry-bulb temperature, 78°F [25.6°C] wet-bulb temperature, a cooling tower delivers 85°F [29.4°C] water to the water-cooled condenser. This results in a refrigerant condensing temperature of approximately 100°F [37.8°C]. At these same outdoor conditions, the refrigerant condensing temperature in an air-cooled condenser is approximately 125°F [51.7°C]. A lower condensing temperature, and therefore a lower condensing pressure, means that the compressor needs to do less work and consumes less energy.

Another advantage of an air-cooled chiller is its delivery as a “packaged system.” Reduced design time, simplified installation, higher reliability, and single-source responsibility are all factors that make the factory packaging of the condenser, compressor, and evaporator a major benefit. A water-cooled chiller has the additional requirements of condenser-water piping, pump, cooling tower, and associated controls. Water-cooled chillers typically last longer than air-cooled chillers. This difference is due to the fact that the air-cooled chiller is installed outdoors, whereas the water-cooled chiller is installed indoors. Also, using water as the condensing fluid allows the water-cooled chiller to operate at lower pressures than the air-cooled chiller. In general, air-cooled chillers last 15 to 20 years, while water-cooled chillers last 20 to 30 years. To summarize the comparison of air-cooled and water-cooled chillers, air-cooled chiller advantages include lower maintenance costs, a pre-packaged system for easier design and installation, and better low-ambient operation. Water-cooled chiller advantages include greater energy efficiency (at least at design conditions) and longer equipment life.





Equipment Rating Standards:

Air-Conditioning & Refrigeration Institute (ARI)

- Standard 550/590–1998: centrifugal and helical-rotary water chillers
- Standard 560–1992: absorption water chillers

The Air-Conditioning & Refrigeration Institute (ARI) establishes rating standards for packaged HVAC equipment. ARI also certifies and labels equipment through programs that involve random testing of a manufacturer's equipment to verify published performance. These equipment rating standards have been developed to aid engineers in comparing similar equipment from different manufacturers. Chiller full-load efficiency is described in terms of kW/ton and coefficient of performance (COP). Additionally, two efficiency values developed by ARI that are receiving increased attention are

the ***Integrated Part-Load Value (IPLV)*** and **Non-Standard Part-Load Value (NPLV).**

ARI's part-load efficiency rating system establishes a single number to estimate both the full- and part-load performance of a stand-alone chiller. As part of ARI Standard 550/590–1998, *Water-Chilling Packages Using the Vapor-Compression Refrigeration Cycle*, and ARI Standard 560–1992, *Absorption Water Chilling- Heating Packages*, chiller manufacturers may now certify their chiller part-load performance using the IPLV and NPLV methods. This gives the engineering community an easy and certified method to evaluate individual chillers. Understanding the scope and application limits of IPLV and NPLV is, however, crucial to their validity as system performance indicators.

Part-Load Efficiency Rating

Integrated Part-Load Value (IPLV)

Weighted-average load curves

Based on an "average" single-chiller installation

Standard operating conditions

Non-Standard Part-Load Value (NPLV)

Weighted-average load curves

Based on an "average" single-chiller installation

Non-standard operating conditions

Standard Rating Conditions:

The standard rating conditions used for ARI certification represent a particular set of design temperatures and flow rates for which water-cooled and air-cooled systems may be designed. They are not suggestions for good design practice for a given system—they simply define a common rating point to aid comparisons.

In fact, concerns toward improved humidity control and energy efficiency have changed some of the design trends for specific applications. More commonly, chilled-water systems are being designed with lower chilled-water temperatures and lower flow rates. The water flow rate required through the system is decreased by allowing a larger temperature difference through the chiller.

Standard Rating Conditions

chiller type	evaporator flow rate	condenser flow rate	rating standard
vapor-compression • reciprocating • scroll • helical-rotary • centrifugal	2.4 gpm/ton [0.043 L/s/kW]	3.0 gpm/ton [0.054 L/s/kW]	ARI 550/590–1998
absorption • single-effect	2.4 gpm/ton [0.043 L/s/kW]	3.6 gpm/ton [0.065 L/s/kW]	ARI 560–1992
• double-effect, indirect-fired	2.4 gpm/ton [0.043 L/s/kW]	4.0 gpm/ton [0.072 L/s/kW]	
• double-effect, direct-fired		4.5 gpm/ton [0.081 L/s/kW]	

water leaving evaporator = 44°F [6.7°C]
water entering condenser = 85°F [29.4°C]

ASHRAE/IESNA Standard 90.1–1999

- Energy Standard
- Building design and materials
- Minimum equipment efficiencies
- HVAC system design

standard 90.1-1999 efficiency requirements

Electric Vapor-Compression Chillers

chiller type	capacity	minimum efficiency*	
air cooled	all capacities	2.8 COP	3.05 IPLV
water-cooled reciprocating	all capacities	4.2 COP	5.05 IPLV
helical-rotary, scroll	< 150 tons [528 kW]	4.45 COP	5.2 IPLV
	150 to 300 tons [528 to 1,056 kW]	4.9 COP	5.6 IPLV
	> 300 tons [1,056 kW]	5.5 COP	6.15 IPLV
centrifugal	< 150 tons [528 kW]	5.0 COP	5.25 IPLV
	150 to 300 tons [528 to 1,056 kW]	5.55 COP	5.9 IPLV
	> 300 tons [1,056 kW]	6.1 COP	6.4 IPLV

* as of October 29, 2001

standard 90.1-1999 efficiency requirements

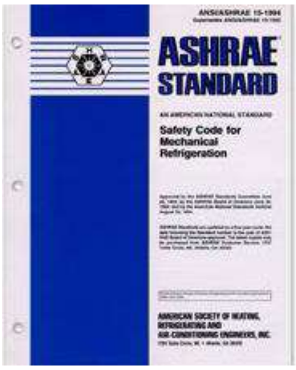
Water-Cooled Absorption Chillers

chiller type	capacity	minimum efficiency*	
single-effect	all capacities	0.7 COP	
double-effect indirect-fired	all capacities	1.0 COP	1.05 IPLV
direct-fired	all capacities	1.0 COP	1.0 IPLV

* as of October 29, 2001

ASHRAE Standard 15–1994

- **Safety standard for refrigerating systems**
- **Mechanical equipment room:**
    - Refrigerant monitors
    - Alarms
    - Mechanical ventilation
    - Pressure-relief piping



Another standard that is related to chilled-water systems, ASHRAE Standard 15–1994, *Safety Code for Mechanical Refrigeration*, is intended to specify requirements for safe design, construction, installation, and operation of refrigerating systems. This standard covers systems of all sizes that use all types of refrigerants. Because absorption chillers use water as the refrigerant, however, they are exempt from this standard.

For many chilled-water systems in which the chillers are located indoors, the standard requires the refrigeration equipment to be installed in a mechanical equipment room. The requirements for this mechanical-equipment room include refrigerant monitors and alarms, mechanical ventilation, pressure-relief piping, and so forth.

Chilled-water pump: The chilled-water pump creates pressure to circulate chilled water within the loop. Generally, the pump must overcome the frictional pressure losses caused by the piping, coils, and chiller and the pressure differential across open control valves in the system. The pump, while working at the system static pressure, does not need to overcome this static pressure.

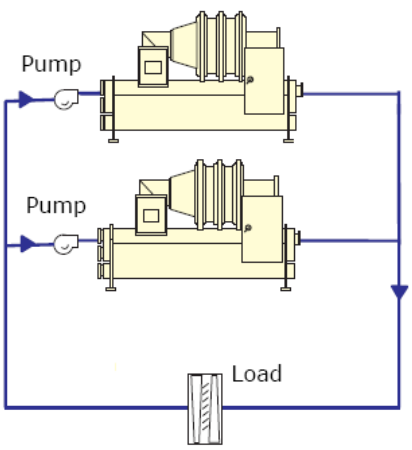
The chilled-water pump is typically located upstream of the chiller; however, it may be anywhere in the system, provided that the pump:

- Meets the minimum pump net positive suction-head requirements. That is, the system pressure at the pump inlet must be both positive and high enough to allow the pump to operate properly;
- Maintains the minimum dynamic pressure head at critical system components (usually the chiller). If the dynamic pressure head is not high enough at these components, proper flow will not be established through them;
- Accommodates the total pressure (static head plus dynamic head) on system components such as the chiller's evaporator, valves, etc.

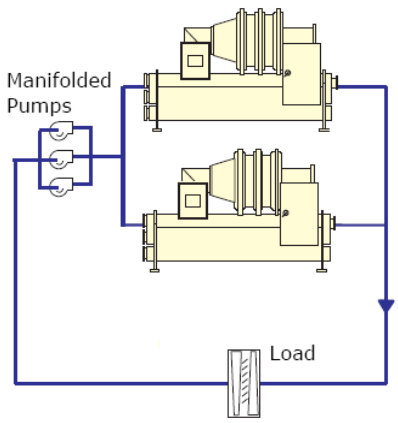
Note that the pump heat is added to the water and must be absorbed by the chiller. Generally, this represents a very small temperature increase.

Multiple pumps are often used for redundancy. Depending on the terminal control devices and system configurations, the chilled-water pumps may be either constant- or variable-flow.

Pump per chiller In either a primary–secondary or variable-primary-flow system, using one pump per chiller simplifies system hydraulics (Figure 2). The pump can be selected to produce the flow and pressure drop necessary for the specific chiller. Bringing on additional pumps changes system hydraulics, but only minimally. One drawback of such a system is a lack of redundancy, since the pump and chiller are dedicated to one another. This may be overcome by using a spare pump, pipes, and valves so that the spare pump could work with any chiller during emergency conditions.



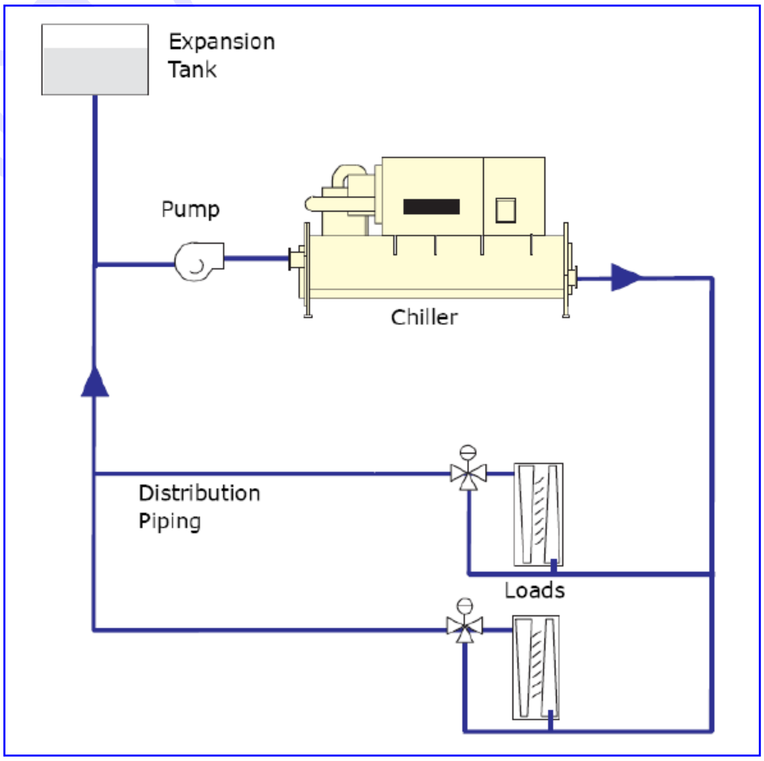
Mani folded pumps In an effort to resolve the redundancy consideration, some designers prefer to manifold pumps and provide *n*+1 pumps, where *n* is the number of chillers (Figure 3). Such an arrangement allows any pump to be used with any chiller. However, system hydraulics becomes more complicated. Unless all piping runs and evaporator pressure drops are equal, the amount of water flowing to each chiller will differ. Mani folded pumps present a control opportunity when low ΔT is experienced. Either pump configuration can be successful; one pump per chiller simplifies the hydraulics, while mani folded pumps allow redundancy.



Distribution piping:

By itself, the distribution system is easy to understand. Figure below shows a simplified distribution system consisting of multiple cooling coils, each controlled by a thermostat that regulates the flow in its respective coil. The valves may be either three-way or two-way. As previously discussed, three-way valves require constant water flow, while two-way valves allow the water flow in the system to vary. As flow varies, the pump may simply ride its curve or use a method of flow control such as a variable-speed drive.

Simplified distribution system



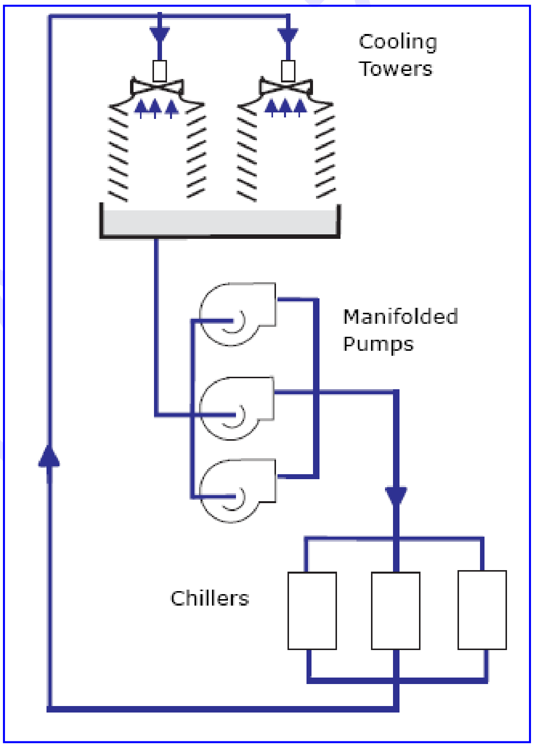
Cooling tower:

To reject heat, water is passed through a cooling tower where a portion of it evaporates, thus cooling the remaining water. A particular cooling tower's effectiveness at transferring heat depends on water flow rate, water temperature, and ambient wet bulb. The temperature difference between the water entering and leaving the cooling tower is the range. The temperature difference between the leaving water temperature and the entering wet-bulb temperature is the approach.

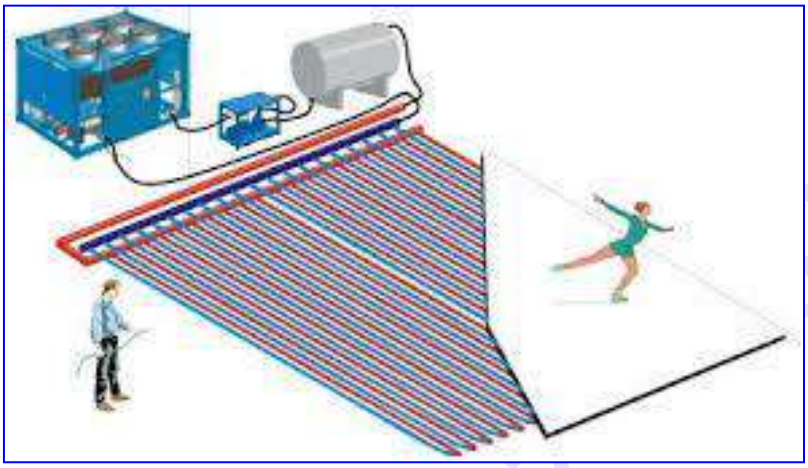
Effect of load on cooling tower performance

Effect of ambient conditions on cooling tower performance

Condenser-water pumping arrangements:

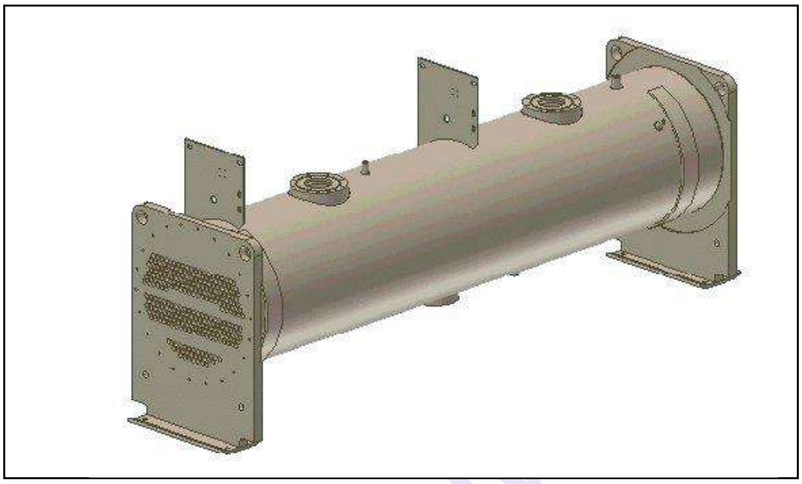


Ice rink with chiller:

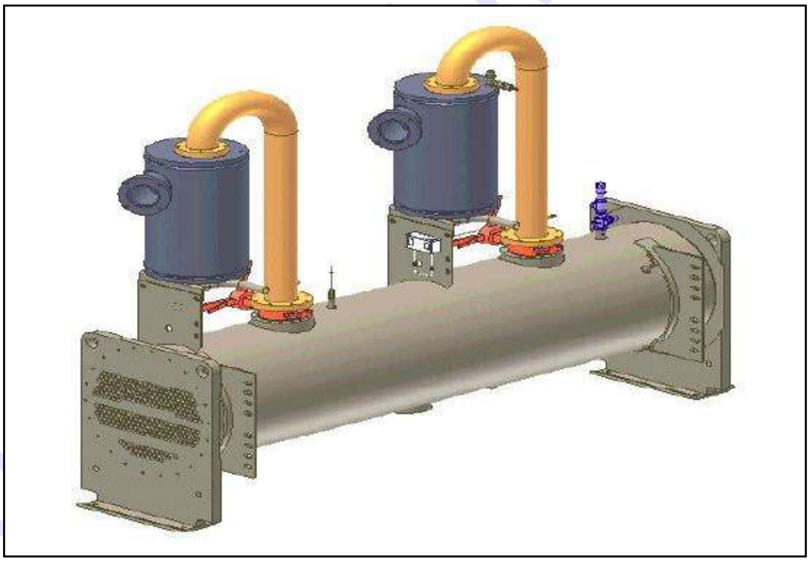


Water cooled Chiller layout:

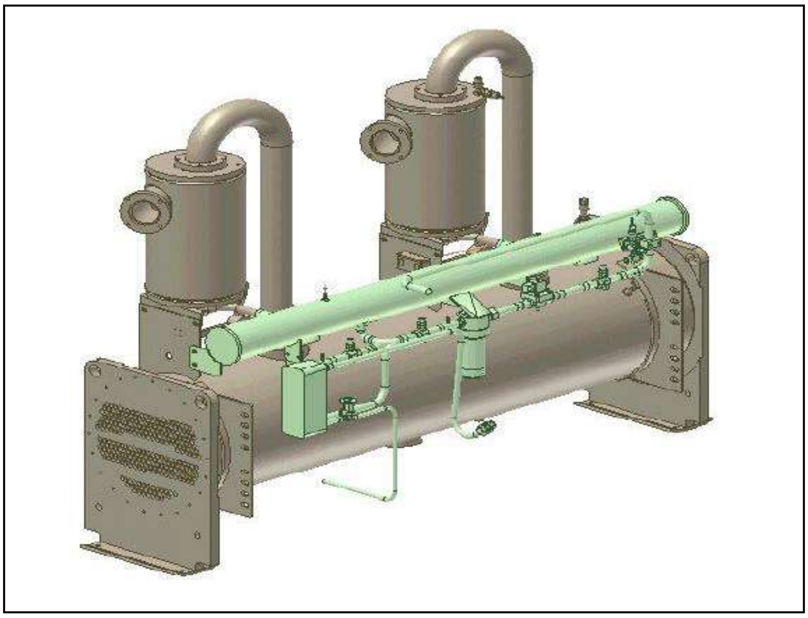
Condenser assembly



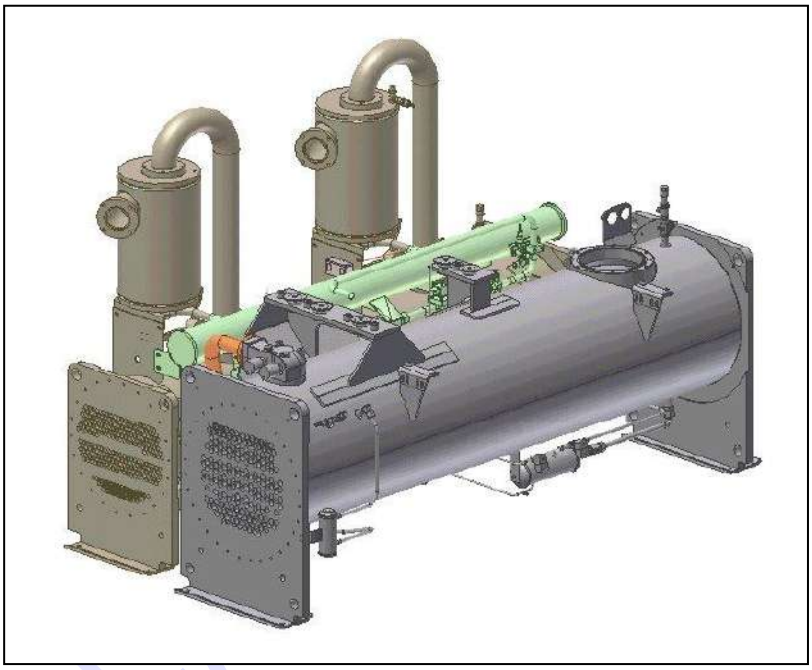
Oil separators



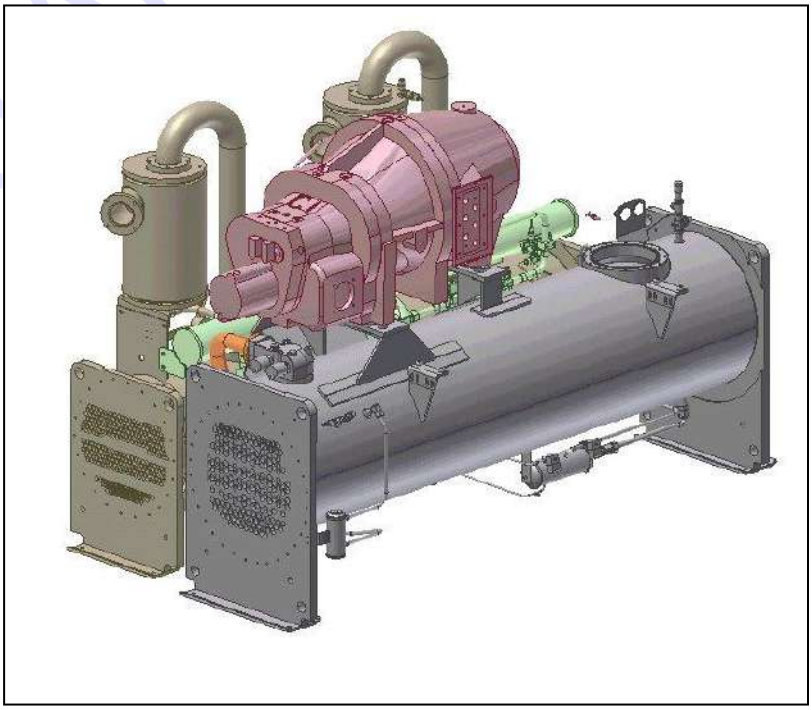
Oil circuit



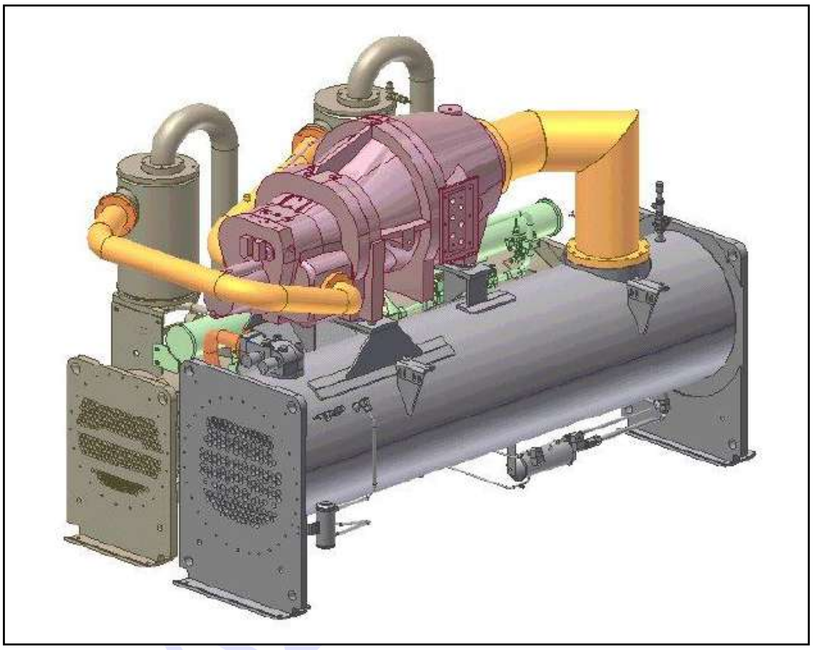
Evaporator assembly



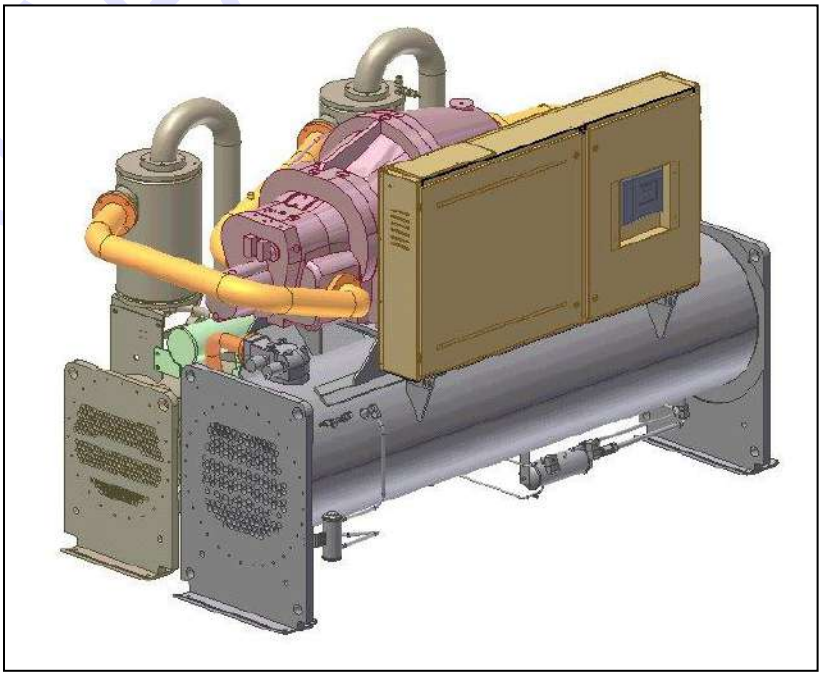
Compressor



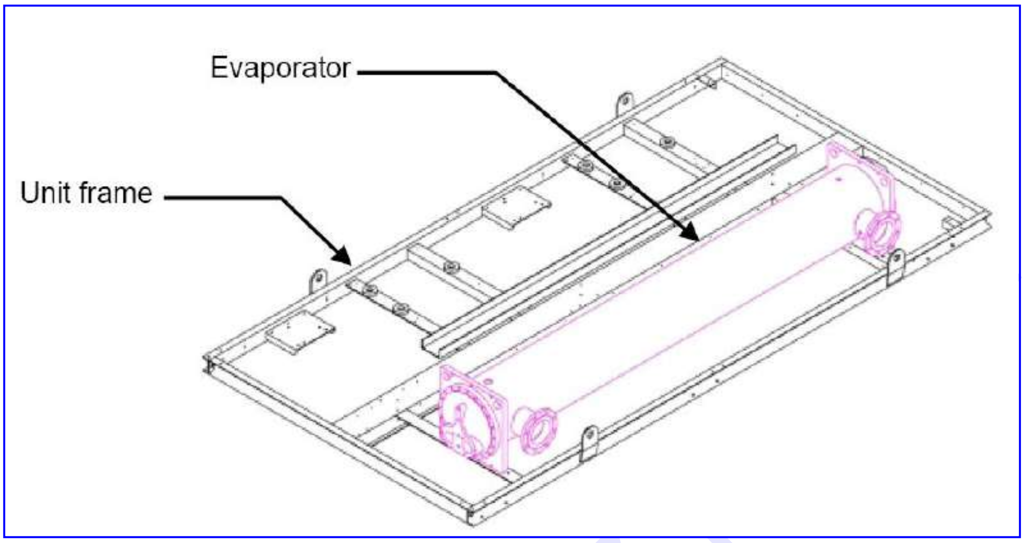
Discharge and suction lines

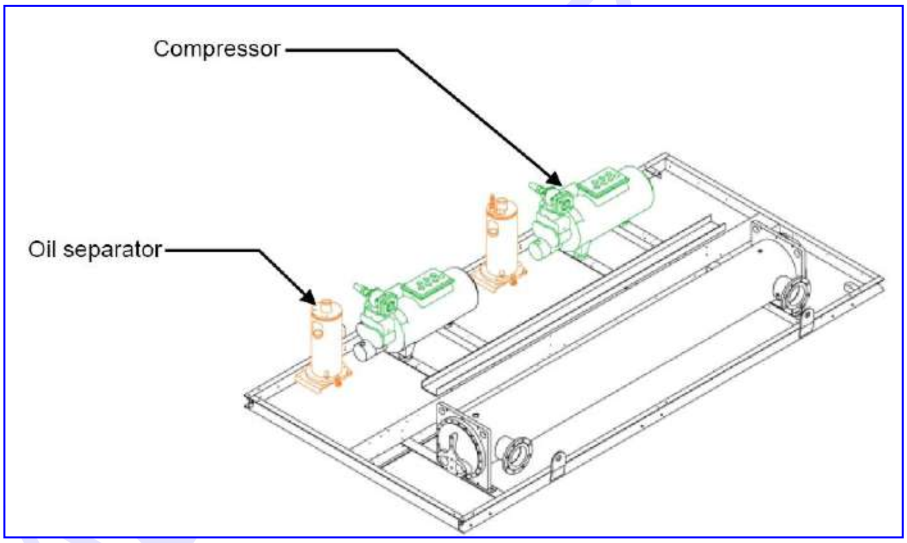


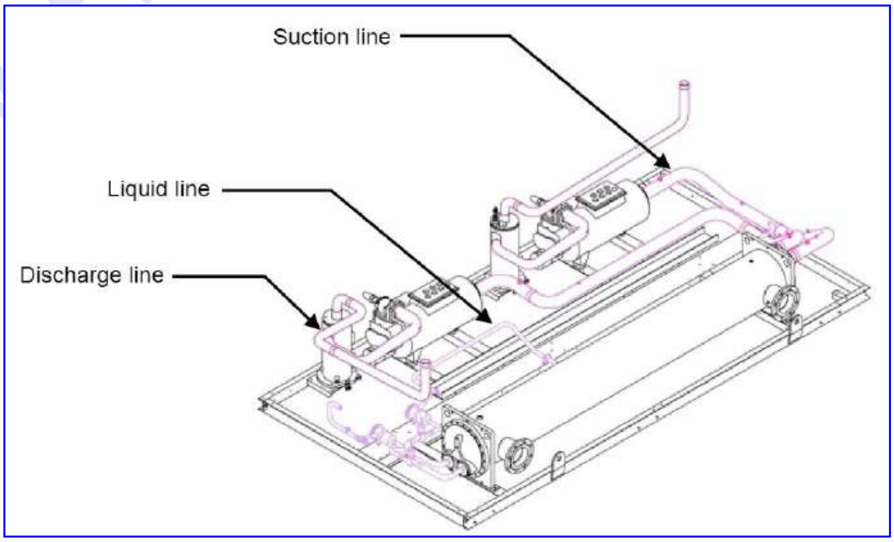
Electrical panel

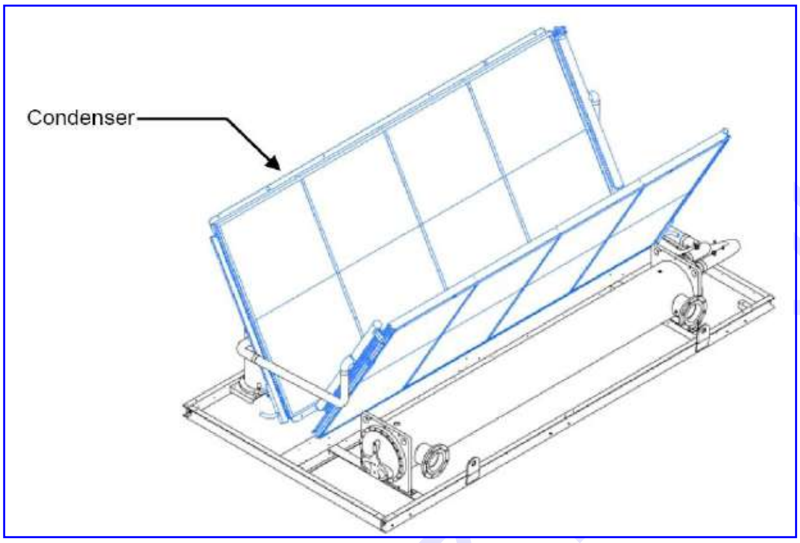


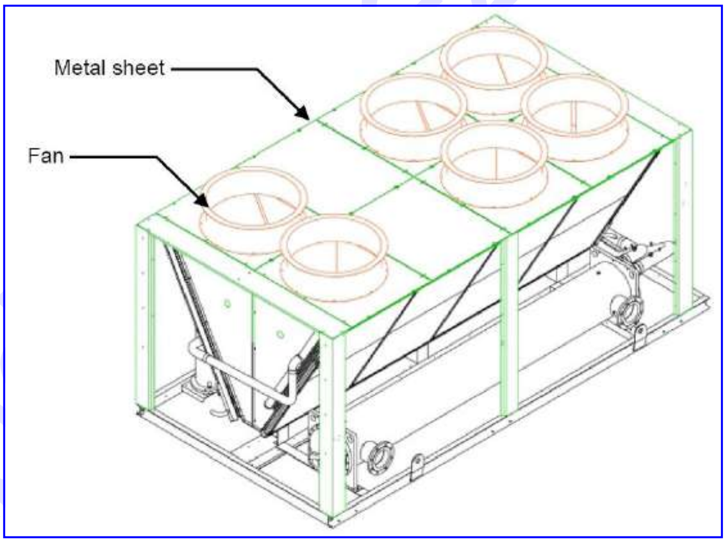
Air cooled Chiller layout::

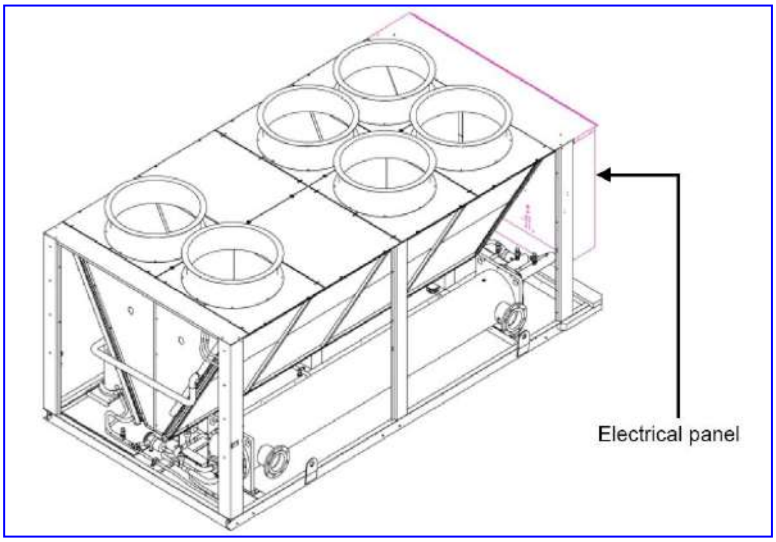







Condenser


Metal sheet
Fan


Electrical panel

Cold Room and Warehouse

Planning and design of the cold room

Introduction

Increases the importance of keeping food with the increasing number of urban residents, and this increasing is needs of the large quantities of food produced in areas. And you need some products such as vegetables and seasonal fruits to store and save even remain good throughout the year. The only way that we can by keeping food in its original condition is cooling in the cooling warehouses because of the role played by the cooling warehouses in food security. But before the planning and design of the cooling warehouses, you must know the following:

Specifications of the project:

- The quality of the food chilled or frozen
- Rates of cooling and freezing
- Types of cooling warehouses
- Place the implementation of cooling warehouses
- Sources of energy available
- Future expansions

The objectives of cooling warehouses:

- To maintain the desired temperature within the refrigeration warehouses changed whatever the outside air temperature.
- To maintain the relative humidity and air velocity within the refrigeration warehouses.
- To achieve cooling rates and freezing required.
- Reduce the rates of heating and cooling from/to warehouses.

Cooling rooms consist of cooling and freezing rooms and places of help, such as:

- Machinery room
- Generate electricity room
- The water cycle
- Loading dock and drag,
- Office of the Director and Workers.

Before the planning of the cooling plant, we must determine the technological processes in order to avoid intersection of operations or breach of the terms of the technological processes cooling.

Basic dimensions of the cold rooms and warehouses:

To determine the dimensions of cold rooms and warehouse, which are depend on how the storage of food on the floor of the refrigeration warehouses.

And can calculate the volume occupied foods or drugs from the relationship:

$m = C_v * V_p$ (kg or Ton)

Where:

m capacity of the cold room 9kg or Ton)

C_v volumetric loading ability according to type of foods of drugs (kg/m^3)

V_p the volume which the foods or drugs equipped (m^3)

And the relationship between the rate of loading surface and volumetric loading rate are:

$C_A = C_v * H_p$

C_A loading surface (kg/m^2)

H_p height of the food in cold room or warehouse (m)

The following table gives the volumetric loading rates for some food in the refrigeration warehouses:

Type of foods	C_v (kg/m^3)	Notes
vegetable	350	
fruits	400	
Dairy (yogurt)	800	Packing in cartoons
Eggs	270	Packing in cartoons
cheese	500	
Dairy(yogurt or milk)	600	Packing in bottles
meet	400	
meet	630	Packing in cartoons
Chicken	350	Packing in cartoons

In the field of refrigeration warehouses preferred to use the pilot projects that have a fixed storage capacities, namely: 100, 500, 2000, 4000, 6000, 10.000 tons of food.

There are two methods to set the dimensions of cold stores:

The first method:

Let H the height of the room

H_p the height of the productions according to the dimensions of cartons and the spacing between it.

C_v volumetric loading ability according to type of foods of drugs (kg/m^3)

A_p the area which the production Occupied.(m^2)

$$V_p = \frac{m}{C_v} = A_p \cdot H_p$$

To find the ground area of the cold room or warehouse:

$$A = \frac{A_p}{\eta_A}$$

Where η_A is using factor for the area depend on the boxes or cartons and the Ashley between.

In general arrange goods and food so away from the wall 20 cm and 60 cm ceiling and floor 10 cm and uses aisle width of 120 to 220 cm if the forklift working and the value of factor for the area depends on the size of the room, as in the following table:

Type of room	A	η_A
Small	A <100 m^2	0.75 – 0.80
Middle	100- 400 m^2	0.80 -- 0.85
large	A > 400 m^2	0.85 – 0.90

The second method:

The area which the goods or foods is use $m = C_A \cdot A_p$

The area of the cold room or warehouse $A = \frac{A_p}{\eta_A}$

Then we fixed the room dimensions which must be multiply the 6 number, and the ratio of the length to the width 1:1 or 1:2

Find the height of the productions H_p according to the type of packing for the materials, and then we fixed the height of the room which must be higher than Hp and suitable to let the forklift working easy.

What we do if we have fixed room dimensions?

Planning requirements for cooling warehouses

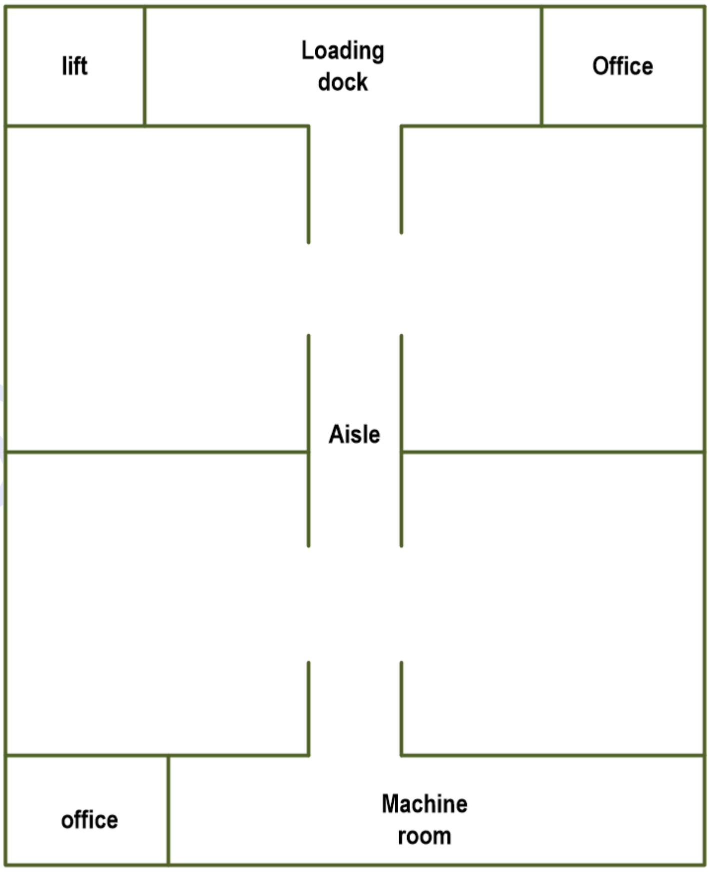
Can be summarized as planning requirements for cooling warehouses following key points:

First, reduce the initial cost:

The cost of construction works constitutes 50% of the initial cost. So you must work to reduce the cost of construction works by sticking to the pilot projects that have fixed storage capacities. Any commitment to certain standard dimensions for the length and width of the room so that after each 6 m or its complications. In addition to all this you must perform the following steps as a single unit:

1. Assembly places different services with cold rooms and freezers in one building instead of several separate buildings.
2. Use the walls of the prefabricated concrete panels or insulation.
3. Increase warehouse workers use ground cooling.

In general, the distance must be allocated to the corridors and places of services less what can be. The following figure shows the horizontal view of cooling room. And we find that the percentage of space allocated for the corridor, offices and machinery room is small compared with the areas allocated to cooling rooms.



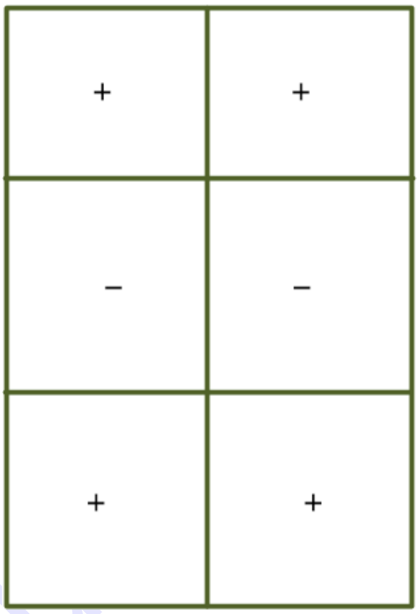
Second, **to reduce operating expenses**:

Can reduce operating expenses by reducing the dropout rates of heat through the walls and roof of a warehouse cooling, by following the following cases:

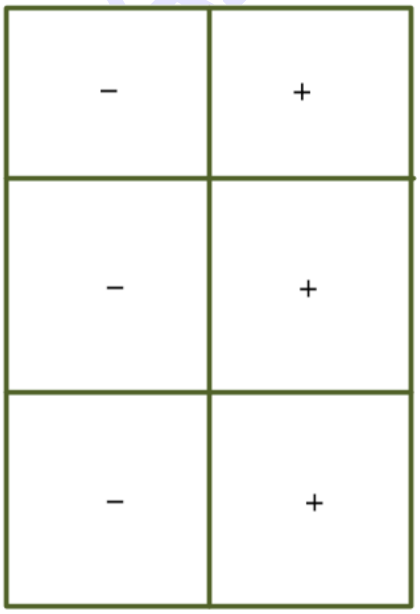
1. Warehouses cooling design in the form of a parallelogram nominally horizontal 1 x 2 or 1 x 3 or 1 x 4 so that the longest side in the north and places of services in the south.
2. Protection of the walls and ceilings of the sun's rays.
3. Corridors are not connected directly to the rooms and the use of outside air curtain airbags to reduce the rates of change in the air, especially for the freezer rooms.
4. Use sidewalks closed.

Third: **assembling cold rooms:**

When planning cooling warehouses must assemble room's negative temperature (freezer rooms) and the rooms are positive temperature (Refrigeration) together, whether the assembly in the vertical direction or horizontal direction, as shown in the following figures:



Vertical assembly

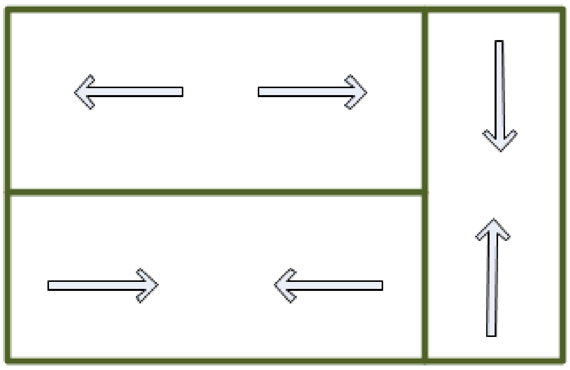


Horizontal assembly

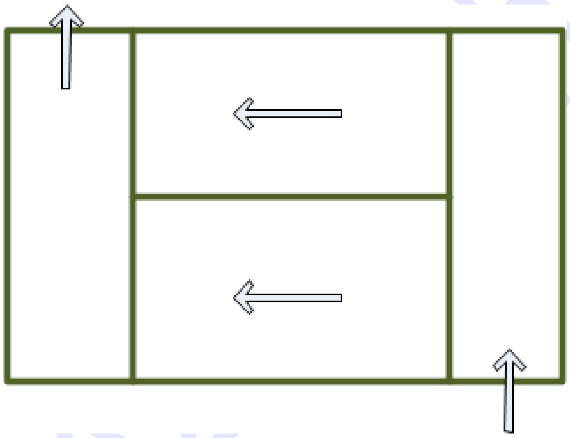
So as to facilitate and regulate the piping system to the rooms, including a row. Upon assembly rooms must take into account the removal of the rooms negative for the ceiling and walls most exposed to sunlight.

Fourth, facilitate the movement of food:

Requires organizing and facilitating the movement of food to be this movement within the shortest possible way, so that cannot happen intersection or reverse movement. The following figure illustrates the movement of food within the refrigeration warehouses:



Multi-Moving



Single-Moving

The motion system is better than unilateral movement bilateral system, and leads to a reduction in the time required loading and with drawing food from the rooms. As the worker to use the ground for a unilateral movement is smaller than its counterpart for bilateral movement system. Preferably in a multi-story warehouses transporting food to the upper floors mediated elevators.

Fifth: Cooling System

When planning a cooling warehouses must take into account the cooling system, which can achieve cooling requirements. The question here: Do we use cooled machines each serving a separate machine room and one of the cold rooms? Or use a centralized system, each serving a common cooling place together, and needs to be room machines and accessories? At the moment preferably cooled machines use a separate room to run and thus reduce energy consumption.

Sixth: security precautions

When planning a cooling warehouses must take into account the various security precautions, namely:

i. Fire
ii. Get rid of harmful odors
iii. Maintain the walls and doors of the collision Forklifts
iv. Maintain the rooms of collapse as a result of the pressure difference inside and outside the rooms prefabrication.

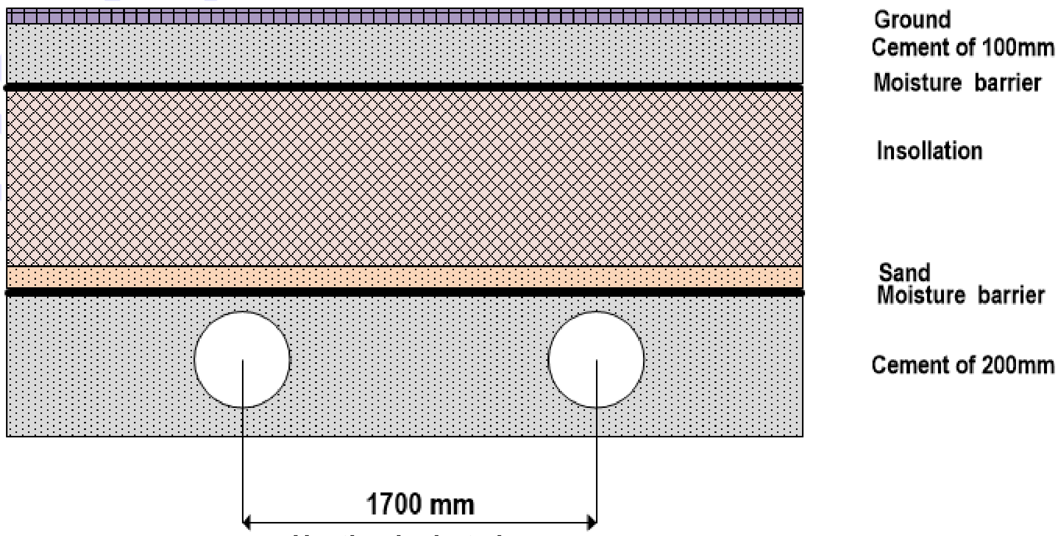
In prefabricated warehouses cooling, pour a concrete slab in the armed 30x30m floor walls, and mounted unit is equal to the air pressure on the walls overlooking the fairways. All doors fitted Refrigeration and freezing means external and internal to open the door, and an electric heater on the part of the doors of rooms to prevent freezing of water vapor condensing and freezing on the doorstep.

Seventh: heating the soil beneath freezer rooms

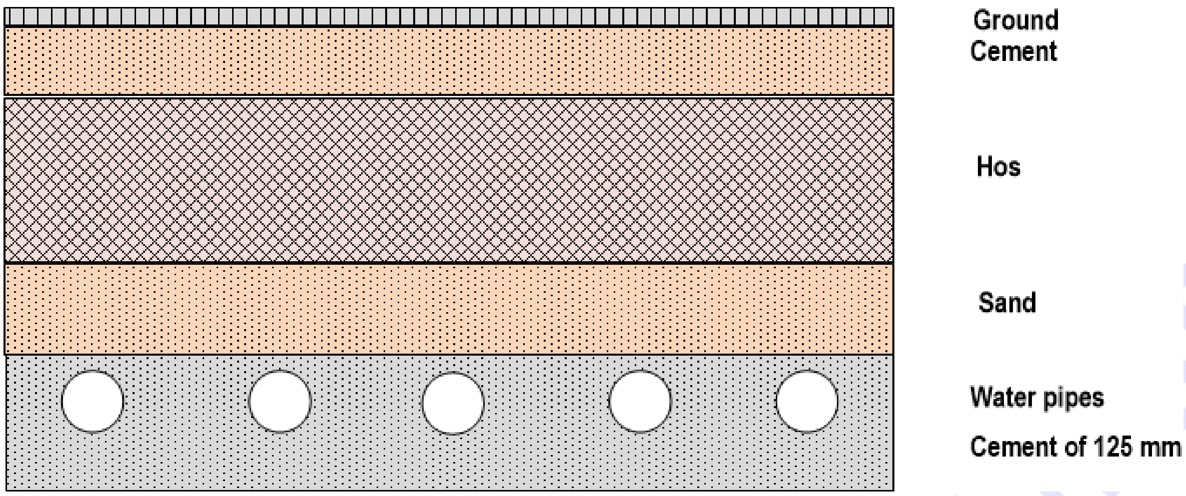
The heat transfer from the soil (20 m) to the freezer rooms (-18 m) leads to the freezing of water in the soil beneath freezer rooms, and thus to extend the soil in the vertical direction and sabotage floor rooms. In some cases that is lead to a shift in the foundations if the soil has been extended in the horizontal direction. So you raise the floor about 1.2m from the street level floor and heating the soil beneath freezer rooms , at an average rate 5 W per square meter (m^2) of floor space.

Warm the soil using the electric grid or network of tubes through which water is hot or warm air being or group of pipes through which hot air.

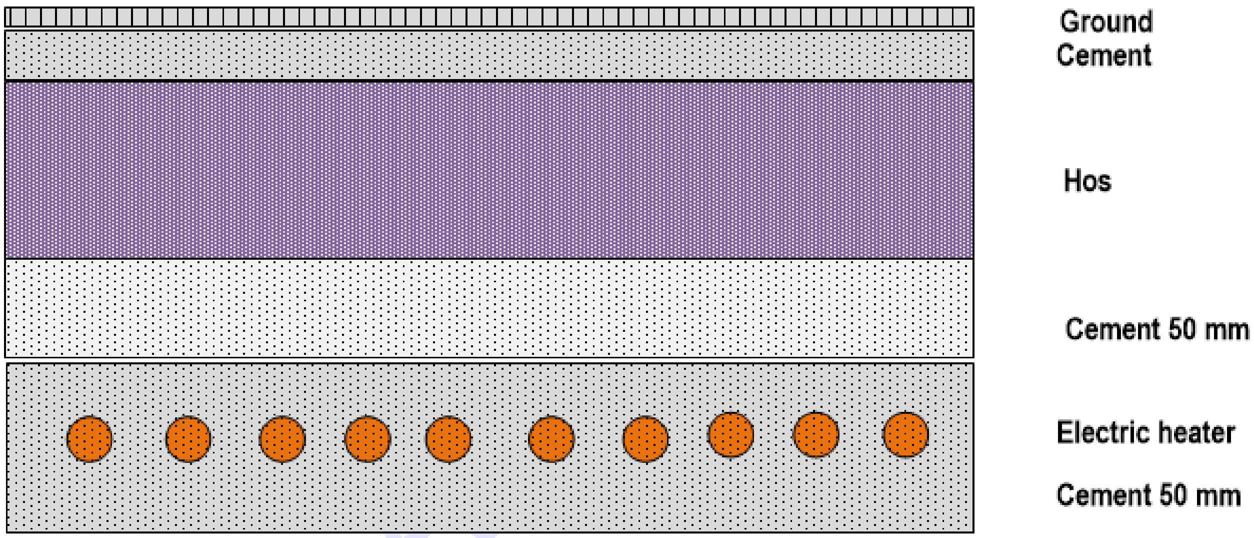
The following sections show the shapes of the ground cooling warehouses, using warm air, hot water and electrical grid:



Heating by hot air



Heating by hot water



Heating by Electric heaters

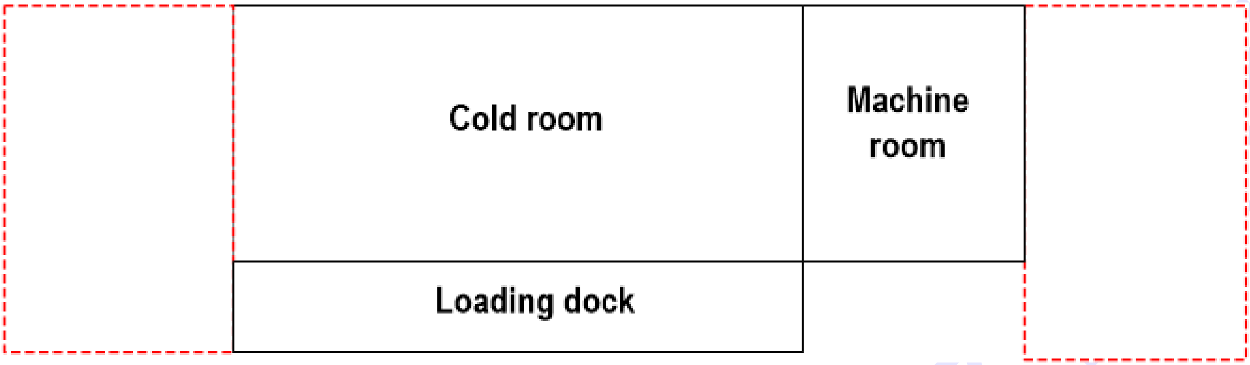
The heating layer in these forms thick concrete layer (Q) buries the heating pipes, and pipe diameter (d) and the distance between the axes (S). The following table gives the dimensions favorite heating layer:

Type of heating	Thickness of layer mm	Pipe diameter mm	Distance between pipes mm	Pipes materials
Air	100 - 500	100 200 – 250 100,200,250	500 1000 – 1500 1500 - 2000	PVC Ceramics Cement
Water	125 – 500	30 – 40	700 – 900	PVC Steel
Electric heater	50 - 100	10 -18	330 - 700	steel

The heating system with widespread freezing warehouse is a system that uses a pipeline of pottery parallel to the width of the room and is open on both sides, so to allow free air flow from both sides. In some cases which is used in Europe, electric heating system.

Eighth: future expansions

Could be future expansions vertical or horizontal, as shown in the figure below:



Leave the area adjacent to the cold rooms or room machines, in order to facilitate the process of linking places new refrigeration ancient places without turning off the old rooms during an expansion. Be vertical expansions by increasing the number of floors, and this requires the work of the foundations of concrete strong armed bear future expansions. Accompanied by vertical expansions is to spend the money to set up the foundations and the installation of elevators with large capacities.

Conclusion:

We conclude from this study that the planning requirements for warehouses cooling which are:

Reduce the initial cost

Reduce operating expenses

Assembling cold rooms

Facilitate the movement of food

The cooling system

Security precautions

Heating the soil beneath freezer rooms

Future expansions cannot be achieved entirely at once.

So this planning is the most important and the most difficult branch in refrigeration because he is without fixed laws and depends on the experience to achieve most of the requirements at the same time

Design

Different factors have to be taken into consideration when designing a cold storage room. Thickness of the insulation is on the walls. In the case of deep-freezing, a greater insulating layer thickness is usually applied. The insulation value of the isolated walls is an important aspect. A door frame heater has to be installed at cold storage room temperatures below 0°C - in particular with deep-freeze rooms - so that the door doesn't freeze shut. Moreover it is necessary to install an under floor heating system in deep-freeze rooms and cold storage rooms which have a room temperature below 0ºC in order to prevent ice build-up on and below the floor. A certain air exchange must also be ensured. This should only be as big as required so that new cold storage room air isn't unnecessarily cooled again and thus no energy is wasted. A ventilation pressure relief valve or an overflow valve for equalizing the pressure between the cold storage room and the surrounding air (two-way pressure equalization) should be provided. If the pressure is not equalized in the cold storage room, the air inside cools and the volume "shrinks" thus creating a vacuum. The consequence would be that the cold storage room walls and ceiling would ultimately collapse. When entering and leaving a cold storage room, it can easily occur that an undesired high air exchange is taking place. In extreme cases, this air exchange can lead to the scenario where the cold storage room temperature can no longer be retained by the refrigeration plant - not to mention the additional energy costs. In cases where frequent use of the cold storage room cannot be avoided, a strip curtain or an air lock respectively, can be used to minimize air exchange.

According to ISO 27000, it is required by law that an alarm device is fitted in cold storage rooms with a volume of more than 10m3 (rooms in which people can walk into). The alarm has to be visually and audibly perceptible. It must be ensured, even for smaller cold storage rooms, that a person can leave the room at all times. This means that even if a cold storage room is closed from the outside, an opening from the inside also has to be possible.

Cold rooms types:

Refrigeration systems for cold storage rooms are available, for example, as clip on devices. Such a device combines the compressor and the registries (evaporator and condenser) in a single housing. It is mainly used for cold storage rooms with a volume of less than 30 m3 and only one temperature zone. The clip on unit can be installed on or next to the cold storage room. Clip on units consist of 1 compressor, 1 condenser and 1 evaporator each.

Another option available for cold storage rooms is the remote condensing unit. This design consists of a condensing unit which is connected to the evaporator by pipelines. The evaporator is normally installed on the cold storage room ceiling and equipped with one or more fans which allow air to circulate in the cold storage room. This type of cold storage room is suitable for use in buildings as well as outdoors. Cold storage rooms with a remote condensing unit consist of 1 compressor, 1 condenser and 1 evaporator each. The condensing unit is intended, for example, for cold storage rooms of this type. Major users such as supermarkets or central warehouses use centralized refrigeration systems with several compressors, which are installed as a compressor network. These plants can be installed separately from the actual cold storage rooms and are connected to the individual cold storage rooms using pipes. Refrigeration regulators can be deployed for solenoid valve control in order to regulate each evaporator individually. A compressor pack consists of several compressors, 1 condenser, various cold storage rooms and usually several refrigeration cabinets or show cases.

Temperature Regulation Function

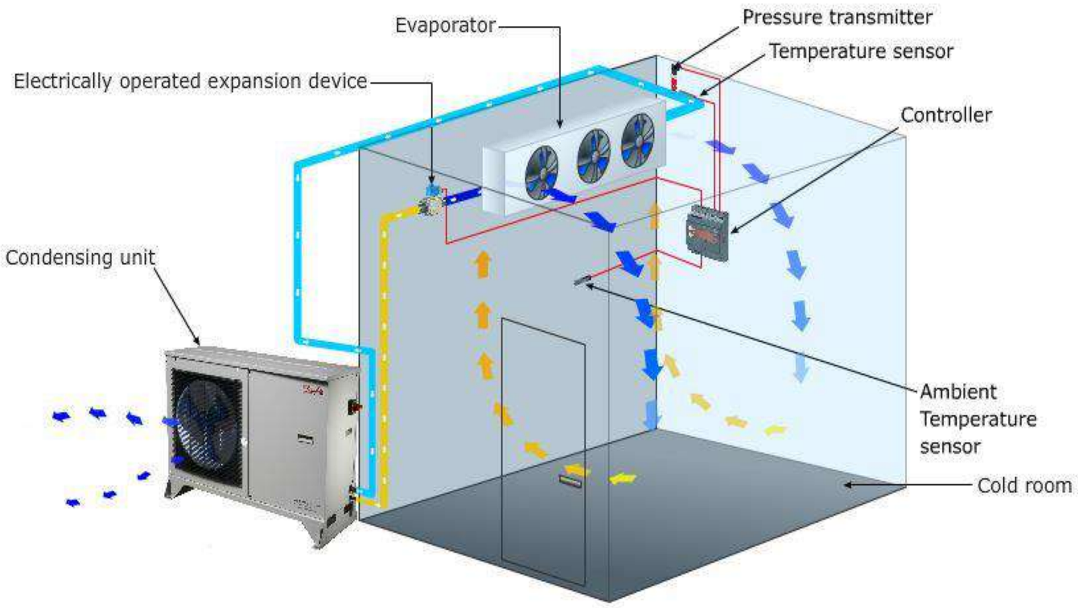
The temperature regulation function is mostly undertaken by a refrigeration controller in the cold storage room. A refrigeration regulator always needs as minimum one control sensor in standard version. This sensor measures the room temperature for use in a normal cold storage room. For this reason, the sensor is normally positioned so that it absorbs the temperature coming from the return air flow leading to the evaporator. The result is then displayed and processed by the refrigeration regulator as an actual value. This actual value is always compared with the refrigeration regulator's set point. The set point can be arbitrarily determined in the regulator. Besides the set-point, a difference (hysteresis) can be determined as well. The sum of the set point and the difference gives the upper switching value, whilst the set point itself represents the lower switching value of the temperature control. When the upper switching value is reached, the cooling (the compressor or the solenoid valve) is switched on and when the set point temperature is reached it is switched off again. This is how the room temperature is always retained in the same range. This temperature control function can be viewed as the most important basic function of the refrigeration controller.

Cold Storage Room Zones

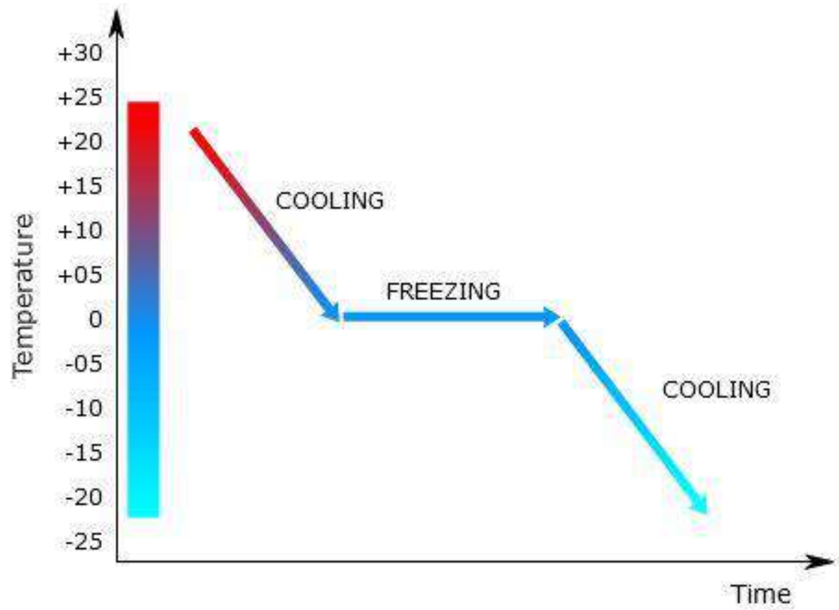
The conditions which need to be ensured in a cold storage room are dependent on the types of products that are stored there. The temperature required in the respective cold storage room can also be dependent on the expected storage period, as well as on the question of whether a fresh product is to be stored there and frozen afterwards. The most common cold- or freezer rooms are cold storage rooms. The evaporating temperature in such cold storage rooms ranges between – 10ºC and 0ºC. The type of regulation which is used depends on the type of product which is to be stored as well as the desired quality. The type of use (MBP/LBP) and the volume of the cold storage/freezer room are often used as rule of thumb, in order to perform a simplified calculation of the heat input coming through the walls and thus the refrigerating capacity. This calculation is sufficient in most cases. Heat inputs are associated with room temperature, wall surface and air exchange. A more precise calculation can be obtained, by taking the food properties into account and by analyzing all of the thermal loads. These factors should be individually incorporated into the calculation of the freezer/ cold storage rooms.

Thermostatic or Electronic Expansion Valves

Simple refrigeration circuits can be used for cold storage rooms. Simple refrigeration circuits are cost-effective and not complicated, however they do have some disadvantages, for example, the risk that stored products, which are not packed or covered, will dry out. Thermostatic expansion valves are installed as injection valves in most cold storage rooms. An electronic superheat controller offers several advantages for anyone who might be looking for a better solution. The evaporator should be filled with refrigerant at all times for optimal use. Even in the event of strong capacity fluctuations (that is, part-loads), the amount of refrigerant, which is to be injected, can be dosed accurately. This is done by promptly transmitting the current superheating in the evaporator - using a pressure transmitter and a very sensitive temperature sensor - to the electronic regulator. The regulator can now take measures to reach ideal small superheating. This adaptive regulation of the refrigerant injecting leads to optimal use of the evaporator and thereby, to the highest possible evaporation pressures which are feasible in this specific plant. However, this not only means a reduced electricity bill for the user. Due to the lower temperature differences between the evaporation and room temperature, there is a reduced dehumifying of air in the room and with it less dry out of the refrigerated goods. The same configuration means that, for example, vegetables, which are stored in a room with an evaporator with electronic expansion valve regulation, remain visually presentable and fit for sale for a longer period of time than with thermostatic expansion valves. Furthermore, the refrigerated goods dry out less. If the design of the evaporator is somewhat too small, a larger evaporator allows you improve the conditions even further with the effects "higher evaporation temperature" and "less dehumidification".



Defrosting



Frost will build up on the surface of an air cooler if its temperature is at or below 0°C. Frost which builds up on the evaporator can arise in different forms, that is as snow (powdery snow or snowflakes), as solid ice or in any other intermediate form respectively.

Frost is caused by the withdrawal of water from the goods as well as from the atmospheric humidity (air which flows through the air cooler). Defrosting is understood as the removal of frost which has built up on the surface of the evaporator. Defrosting can be carried out by feeding electrically generated heat, hot / cold gas on the high pressure side, warm air out of the cold storage room or warm water respectively combined heating media.

Defrosting can help prevent the excessive built up of frost on the refrigeration surfaces, which reflects in a good heat transfer and an optimal operation of the plant. Moreover, regular defrosting brings about an unobstructed circulation of air, whereby the air cooler performance improves.

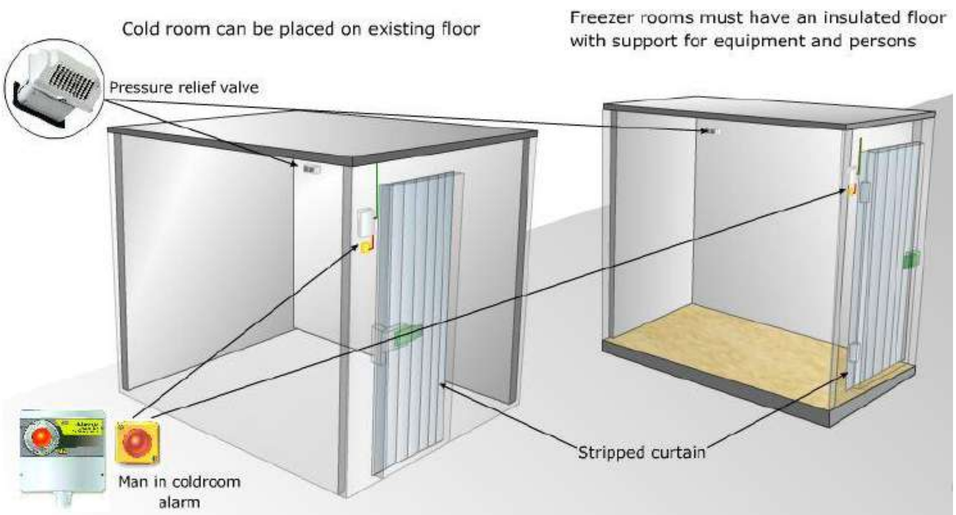
How often, and the length of time for which defrosting is carried out is dependent on, among other things, the stored products and their moisture content as well as air exchange and humidity. How many times a day the door to the cold storage door is opened or somebody enters the room also plays a major role. The cold storage room needs to be defrosted as often as required and above all in a timely manner. If the defrosting period is too short and not all of the ice melts then even more ice will build up with time.

The type of defrosting is just as important as the defrosting time/frequency. There are three customary defrosting methods. Air circulation (thawing out in the cold storage room), electric, and hot gas defrosting. Natural defrosting (air circulation) with the help of air is possible if the temperature in the cold storage room is higher than +4°C. Cooling of the cold storage room is stopped but the fan continues to run. This process can take longer than the other defrosting methods, however, defrosting can also be sped up by increasing the temperature. This process is energetically advantageous since no additional heat is produced which has to be removed from the cold storage room again later on.

Electric defrosting is the most common and at the same times a simple defrosting method for cold storage rooms. The air cooler just has to be installed with electric heaters and connected with electrical cables. This tends to be a more expensive defrosting method from an energy point of view because it uses a lot of energy. On the other hand, electric defrosting can be well controlled and represents perhaps the only feasible defrosting option. Defrosting can be started using a real-time clock, time intervals or manually and ended according to a pre-set temperature or after a certain period of time.

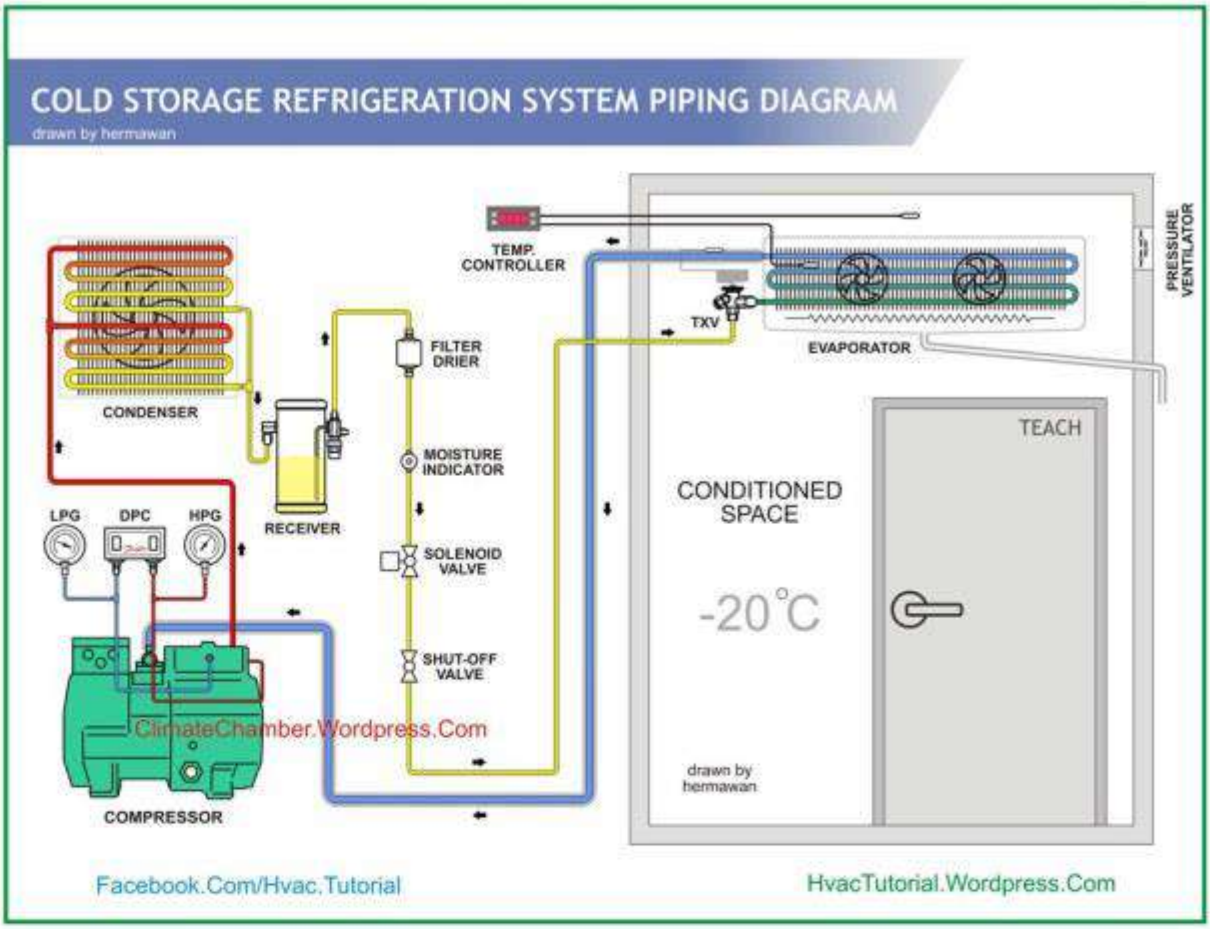
The third defrosting method, namely hot gas defrosting, involves gas being diverted from the high pressure side of the refrigeration plant to be used for the defrosting. In principle, energy is saved through the hot gas defrosting method. However hot gas defrosting is a relatively complicated defrosting method and is mainly used in large plants with several evaporators. Evaporators can be operated at the same time as the air cooler which is to be defrosted, thus defrosting alternately. More valves are required for hot gas defrosting and the control system is also more complicated than both of the other common defrosting methods. When hot gas defrosting, it is highly recommended that a liquid separator is built in, in order to protect the compressor. A pressure regulator can also protect the compressor from high suction pressure. Cold gas defrosting can also be an alternative to hot gas defrosting. This simply involves extracting the high-pressure refrigerant from the suction dome instead of directly out of the hot gas line.

However it's not only the defrosting method that is important; energy costs can be reduced by skipping a defrosting operation, especially if it isn't needed. Skipping every fifth defrosting process is already a huge energetic advantage. It's very important that the plant is only defrosted at the programmed times. If this is not the case, then defrosting could be started at unfavorable times (e.g. when awaiting delivery of goods) Fitting a refrigeration regulator with defrost on demand can be positively reflected, by itself, in the user's electricity bill.



Conclusion

There are certain points that have to be taken into consideration when designing, assembling and using cold storage rooms - we learnt more about this in these two editions from "what you need to know about refrigeration". Careful commissioning and regular maintenance ensure that the plant runs smoothly and that energy is not wasted unnecessarily. Energy improvements are also possible for existing plants by fitting electronic expansion valves and refrigeration regulators for defrost on demand.


COLD STORAGE REFRIGERATION SYSTEM PIPING DIAGRAM
drawn by hermawan
TEMP. CONTROLLER
PRESSURE VENTILATOR
TXV
EVAPORATOR
FILTER DRIER
CONDENSER
RECEIVER
MOISTURE INDICATOR
LPG
DPC
HPG
SOLENOID VALVE
SHUT-OFF VALVE
TEACH
CONDITIONED SPACE
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ClimateChamber.Wordpress.Com
COMPRESSOR
drawn by hermawan
Facebook.Com/Hvac.Tutorial
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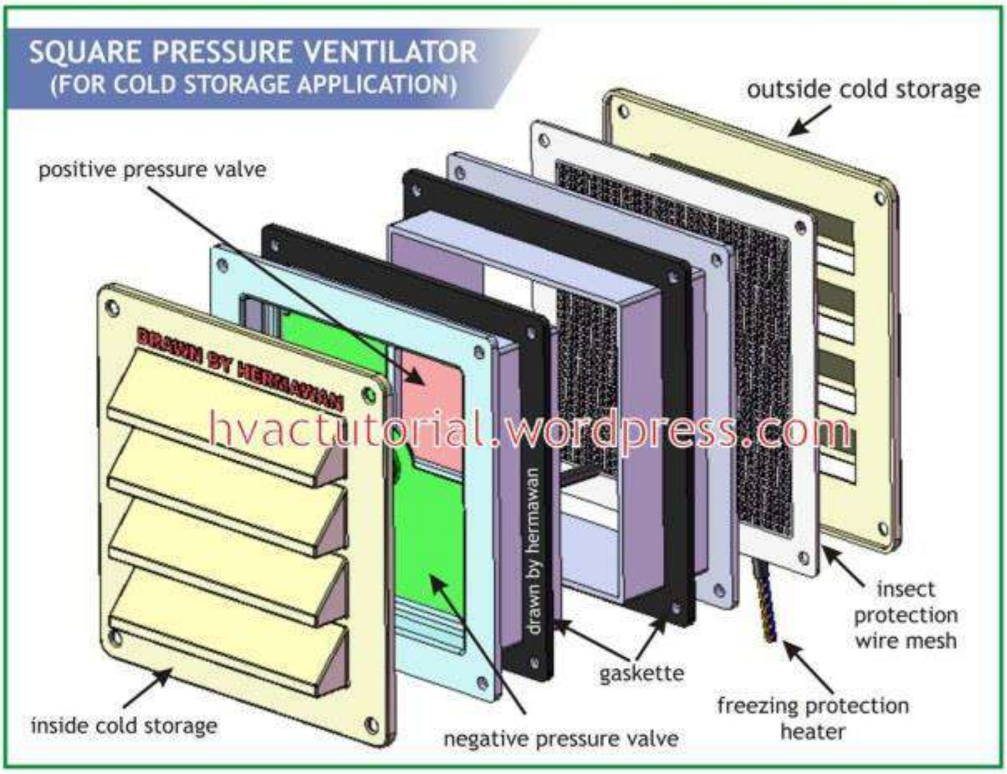
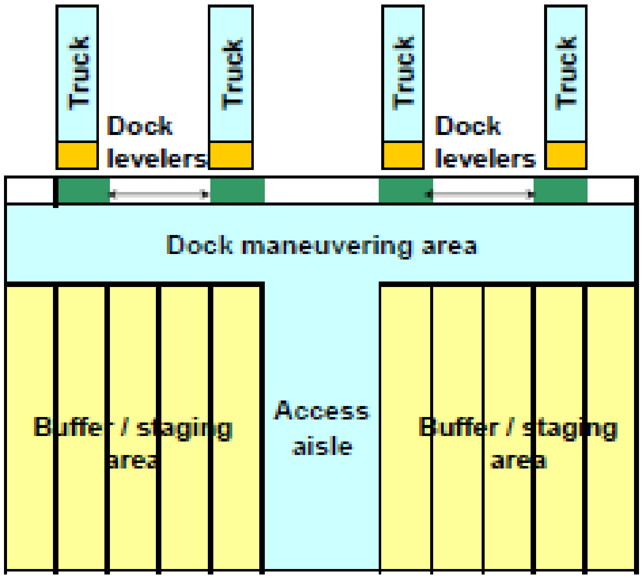
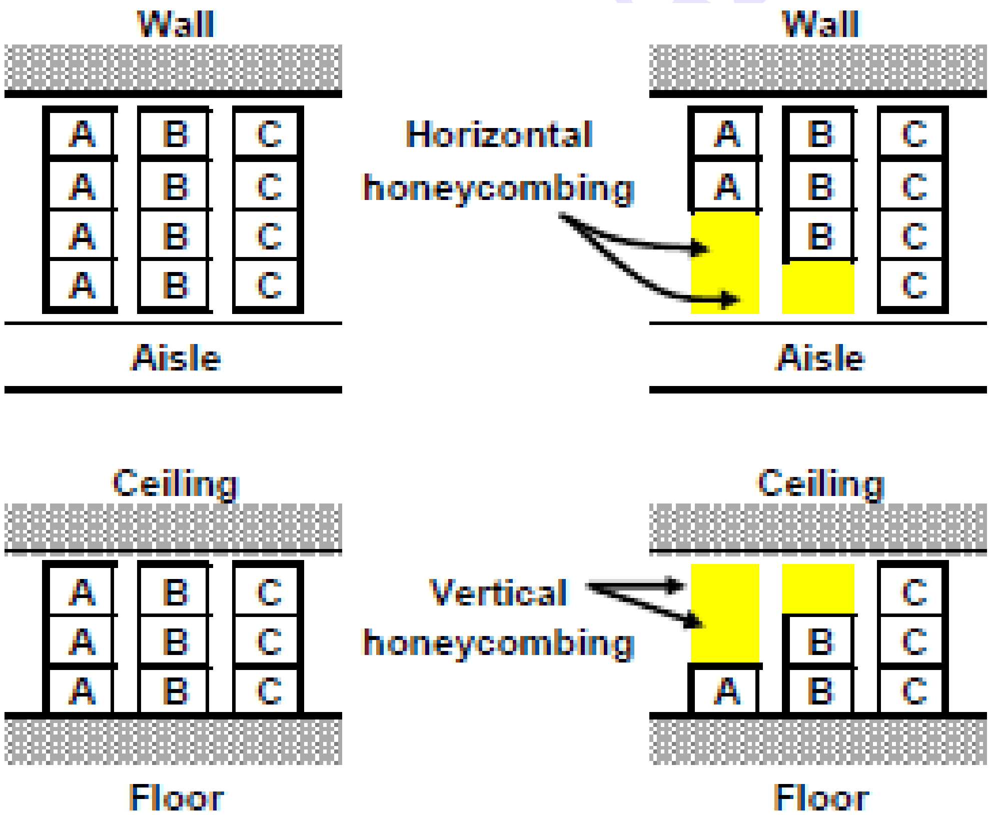
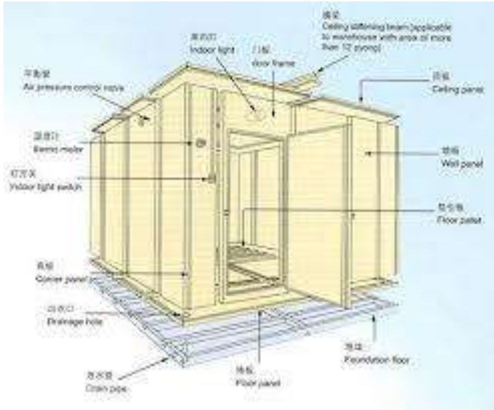

SQUARE PRESSURE VENTILATOR
(FOR COLD STORAGE APPLICATION)
outside cold storage
positive pressure valve
DRAWN BY HERMAWAN
hvactutorial.wordpress.com
drawn by hermawan
insect protection wire mesh
gaskette
freezing protection heater
inside cold storage
negative pressure valve

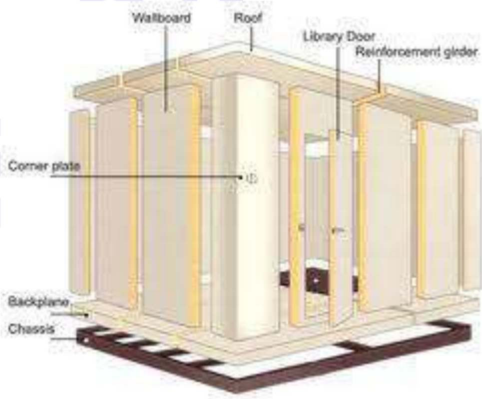
Loading and racking:





Cold room construction:



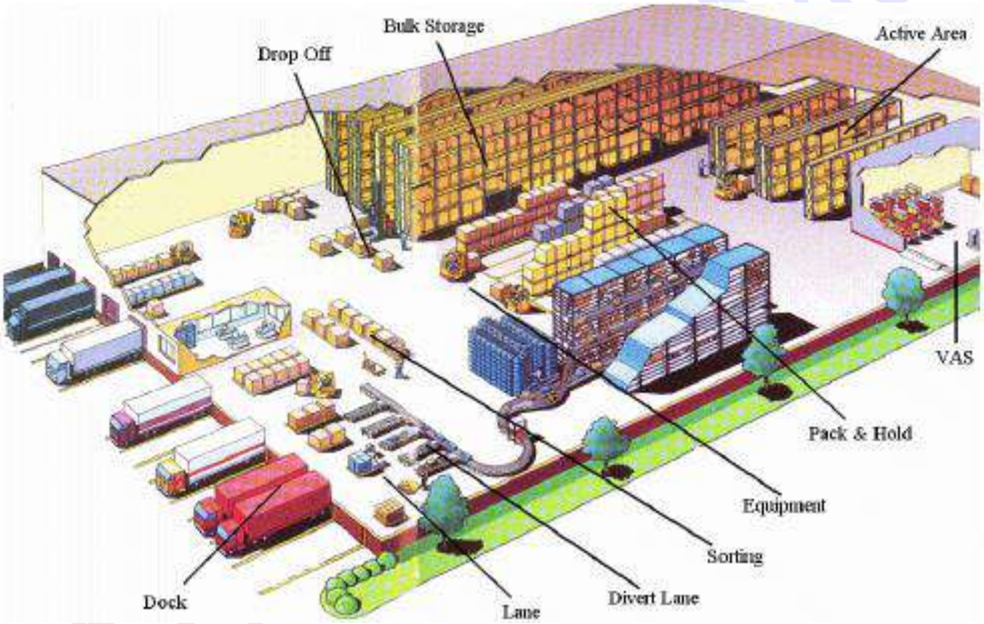


Warehouse:

Defines the physical layout and related attributes of a warehouse

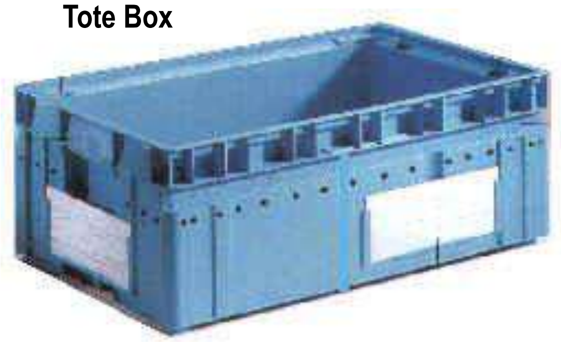
Warehouse layout includes:

- Zones
- Locations
- Equipment
- Stations



STORAGE EXAMPLES:

Tote Box



Pallet

Storage/ Binning

Storing & Retrieval Using Reach Truck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UNIT 46 Domestic Freezers

OBJECTIVES

After studying this unit, you should be able to

- discuss the construction of typical freezer cabinets.
- identify three types of freezer evaporators.
- describe two types of freezer compressors.
- discuss two types of natural-draft condensers.
- explain the function of the capillary tube in the freezer.
- describe condenser efficiency relative to ambient air passing over it.
- explain procedures for defrosting a freezer manually.
- discuss procedures for removing spoiled food odors from the box.
- describe procedures for moving upright and chest-type freezers.

SAFETY CHECKLIST

✔ Technicians should wear appropriate back brace belts when moving or lifting appliances.
✔ Never place your hands under a freezer that has been lifted. Use a stick or screwdriver to position a mat under the freezer feet.
✔ Do not let dry ice come in contact with skin; it will cause frostbite.
✔ Never allow refrigerant pressures to exceed the manufacturer's recommendations.
✔ Always follow all electrical safety precautions.

Many of the components and operating systems in domestic freezers are the same as or similar to those in domestic refrigerators. Unit 45 should be studied first because many descriptions and procedures are not duplicated in this unit.

46.1 THE DOMESTIC FREEZER

The domestic freezer, unlike the refrigerator, is a one-temperature appliance. It operates as a low-temperature refrigeration system. Like the refrigerator, it is a stand-alone appliance, plugs into the power supply, and can be moved from one location to another. Freezers are normally not opened as often as refrigerators. Food is placed in them for long periods of time. The freezer may be located in an out-of-the-way place, such as a basement or storage room, away from the kitchen. The functions of the freezer are to hold food that has been purchased frozen and to freeze small amounts of food and hold it frozen.

Food to be frozen must be packaged correctly, in airtight packages. If not, freezer burn will occur. *Freezer burn* is a result of dehydration of the product. This is most noticeable in products that have a tear in the package. The product looks dry and burned in the vicinity of the tear. Actually it is dry. Freezer burn does not ruin the product, but makes it unattractive and may change the flavor. When freezer burn occurs, moisture in the vicinity of the tear in the package leaves the food and transfers to the air. The moisture is in the solid state while in the food and is changed to the vapor state in the air where it collects on the coil. It is then carried off during defrost. This process of changing from a solid to a vapor is known as sublimation. Ice cubes become smaller if stored for long periods of time in the freezing compartment. This is sublimation. Moisture changes from a solid to a vapor and collects on the evaporator as ice. It is melted during defrost and leaves in the condensate.

Another problem the owner may have when freezing food in the home freezer is the amount of time it takes to freeze the products solid. This is accomplished with flash freezers in a packing plant. The flash freezer may pass the food over a flash of very cold air that will freeze it instantly, **Figure 46–1.** In a home freezer this is not possible. Some freezers that have forced-draft evaporators may have a quick-freeze rack that is located in the fan discharge, the coldest air in the box, **Figure 46–2.** The velocity of the air and the temperature will greatly speed the freezing process. This is not comparable to flash freezing done commercially. Quick freezing in a home freezer can be used for small amounts of food only. The system has very small capacity.

Many owners may purchase a quarter or half carcass of beef that has been butchered and wrapped and try to freeze the whole amount at one time in a home freezer. This causes problems. Food that is frozen slowly will have ice crystals

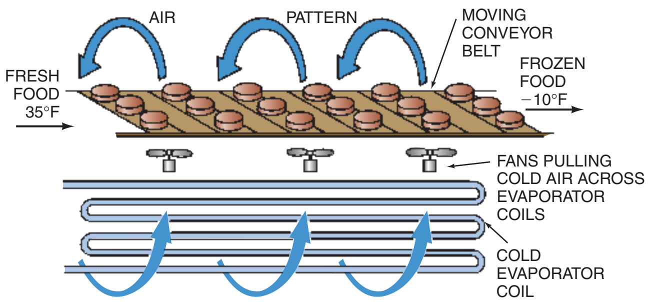


Figure 46–1 A commercial flash freezer.

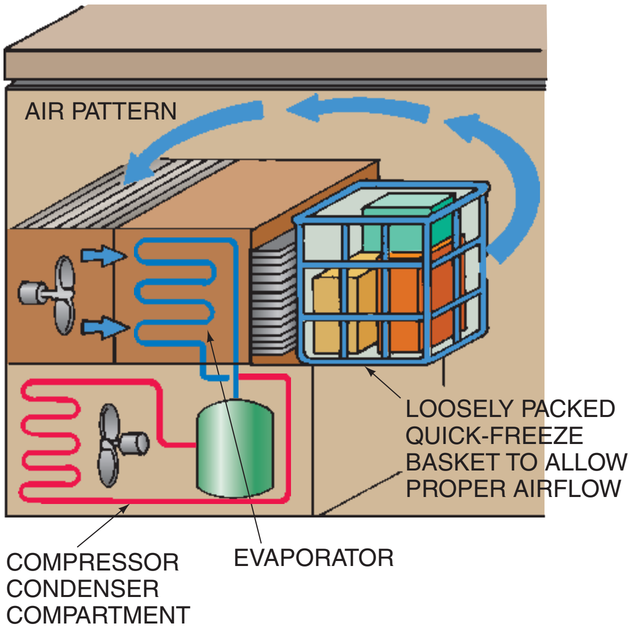


Figure 46–2 The quick-freeze section in a freezer.

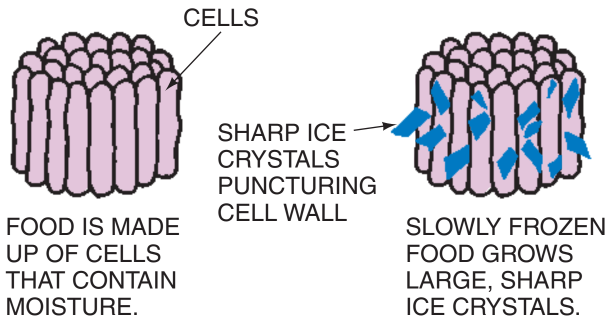


Figure 46–3 Food frozen slowly has large ice crystals.

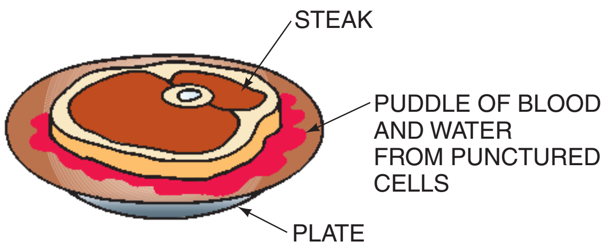


Figure 46–4 Large ice crystals may puncture the cell walls of the food.

form in the product cells, **Figure 46–3.** This may puncture the cells of the product. You may have noticed that a steak frozen by the store tastes different from a steak that you carried home and froze. The difference is in the time it takes to freeze the steak. You may have noticed the puddle of water and blood when you thawed the steak. This is the loss due to puncture of the cells, **Figure 46–4.** You may have transported the steak home in the car where it may warm up to 70°F or higher; then you may place it in the freezer where it must be lowered to 32°F before it starts to freeze. The best policy is to lower the temperature of the product to as close to 32°F as possible by placing it in the coldest place in the refrigerator for several hours, then move it to the freezer and locate it in the coldest place in the freezer. This may be a quick-freeze compartment or on the evaporator plate, **Figure 46–5.**

46.2 THE CABINET OR BOX

The actual box is normally made of sheet metal on the outside with metal or plastic on the inside. The outside of the box may be painted any color fashionable at the time. It may match the rest of the appliances in the kitchen. The box may be an upright type or a chest type, **Figure 46–6.** When upright, the door may open to the left or right, for convenience. When the freezer is a chest type, the door is called a lid and raises, **Figure 46–7.**

The upright box takes up much less space and is often used in the kitchen where floor space is a premium. It is probably not as efficient as a chest type, because every time

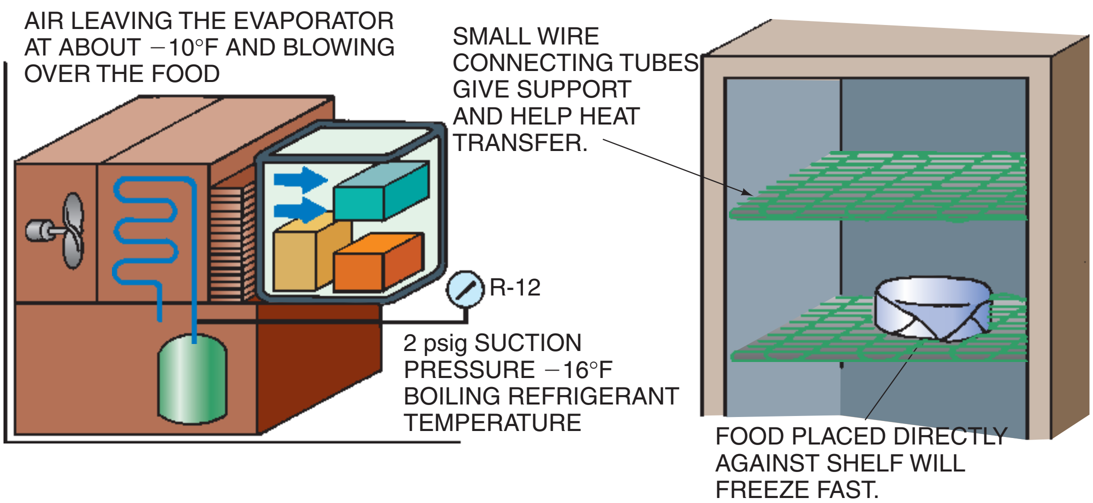


Figure 46–5 Two quick-freeze methods—using a special compartment or placing food directly on the evaporator.

Figure 46–6 Upright and chest-type freezers. *Photos by Bill Johnson*

the door is opened, air in the box falls out the bottom of the opening, **Figure 46–8.** This does not change the food temperature much, just the air temperature that must be recooled. Moisture also enters with the air and will collect on the coils. Door opening should be kept at a minimum. When a chest-type freezer is opened, the air stays in the box, **Figure 46–9.**

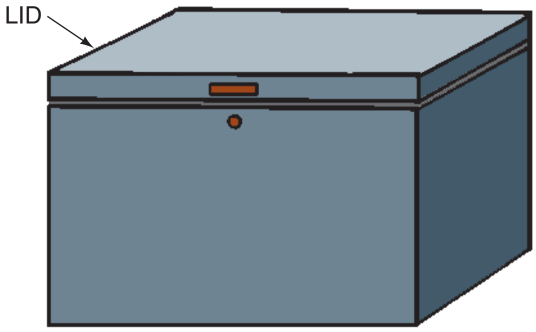


Figure 46–7 On a chest-type freezer, this door is known as a lid.

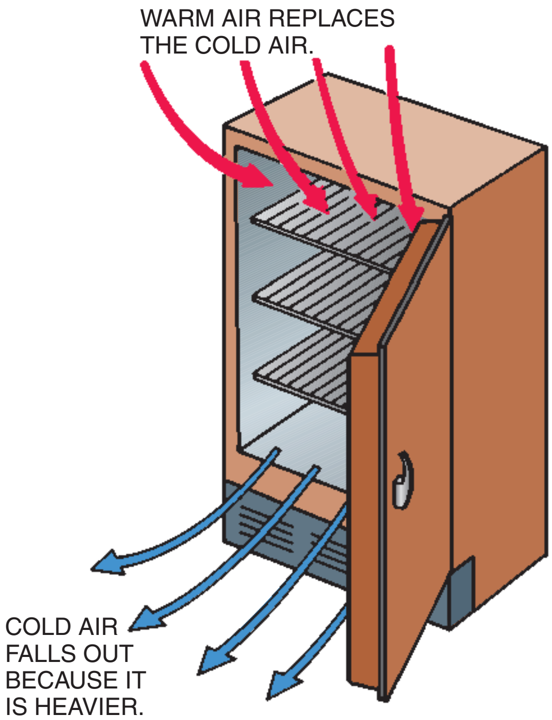


Figure 46–8 Cold air falls out of an upright freezer.

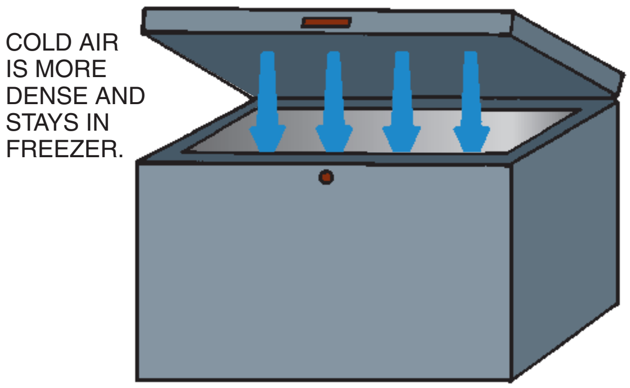


Figure 46–9 Cold air stays in a chest-type freezer.

Locating food in a chest type is not as easy as in an upright freezer because the upright freezer will have multiple shelves. The chest-type freezer may have baskets that lift out so the storage on the bottom may be reached. This is important because food cannot be kept fresh indefinitely in a freezer. Fish and pork have one storage time and beef another. If kept longer, the food taste may change, particularly if not packaged tightly. Some professional packing companies use complete airtight packaging called shrink packing, which will keep the food satisfactorily much longer. Shrink packaging pulls the package closer to the food and eliminates air.

The box location is limited by the type of condenser and the temperature for which the box is designed. The types of condensers will be discussed later, but keep in mind that all refrigeration devices must have airflow for heat exchange.

The outside temperature at which the box is designed to operate is determined by the particular manufacturer. For example, the same box may not be able to operate at outside temperatures during the summer and winter. This is partly due to the operation of the condenser in the winter. The box insulation may not be adequate for location in extreme heat in the summer.

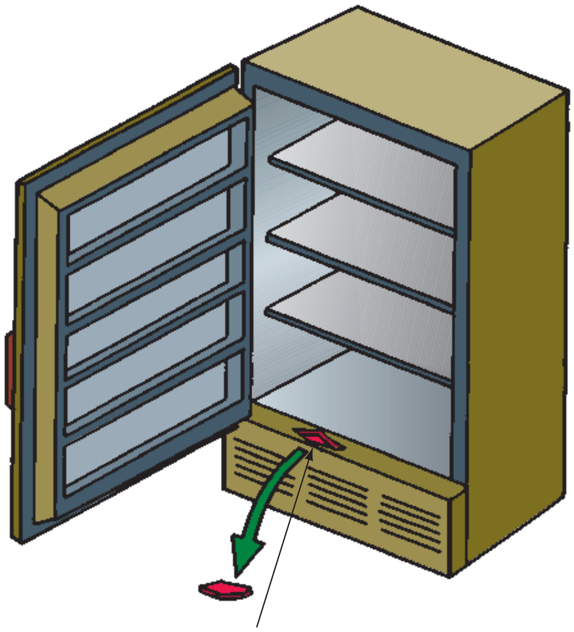


Figure 46–10 If frozen food is dropped, it may break the plastic rail in a freezer.

46.3 CABINET INTERIOR

The inside of many freezers may have a lining of plastic. This plastic is strong and easy to clean and maintain. However, it may be brittle at the low temperatures inside the box, so care should be taken not to strike it. Some boxes have metal liners and plastic trim. The metal may be either painted or coated with porcelain.

The walls of the typical modern box are much like the refrigerator, a sandwich construction of metal or plastic on the inside and metal on the outside with foam insulation between. Many older boxes will have fiberglass between the walls.

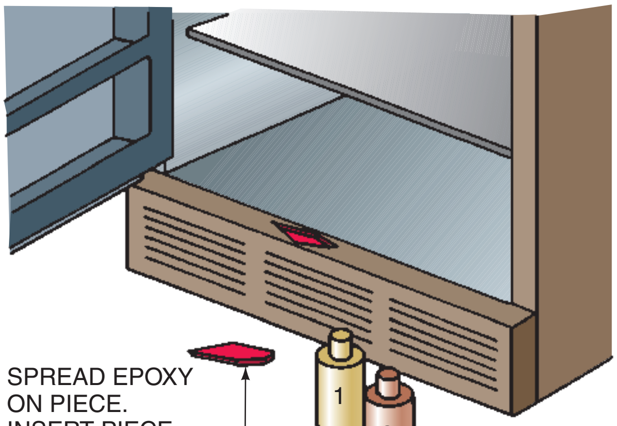


Figure 46–11 The piece may be glued back in place when the freezer is defrosted and cleaned.

Inside the Upright Box

The upright box will have door storage for small packages. This door must be strong to hold the weight of the packages and the door itself. Care must be used not to abuse the door or it may warp. It is not uncommon for a package of frozen meat to drop on the bottom rail of plastic in an upright freezer and break it, **Figure 46–10.** This should be repaired. Duct tape, the kind used for duct systems, may be used to seal the damaged area until the next time it is defrosted, then the spot may be repaired by fastening the piece back with epoxy glue, **Figure 46–11.** The glue may not be applied while the box is cold.

The upright box has many of the same gasket and door alignment features as the refrigerator. The gaskets must remain tight fitting, and the door must remain in alignment or leaks will occur, **Figure 46–12.** Leaks will cause the compressor to run more than it was designed to and cause frost buildup. Defrost is discussed in Section 46.11, "Controls." Many freezers are manual defrost because defrost is not needed as often with freezers as with refrigerators because the doors are not opened as often.

The evaporator, which freezes the food inside, may be one of three types—a forced air, a shelf, or a plate in the wall of the freezer, **Figure 46–13.** Forced-air units may have fast-freeze compartments, **Figure 46–14.** When plate evaporators are used, they may be the tube type with wires connecting them or the stamped type used to make a shelf, **Figure 46–15.**

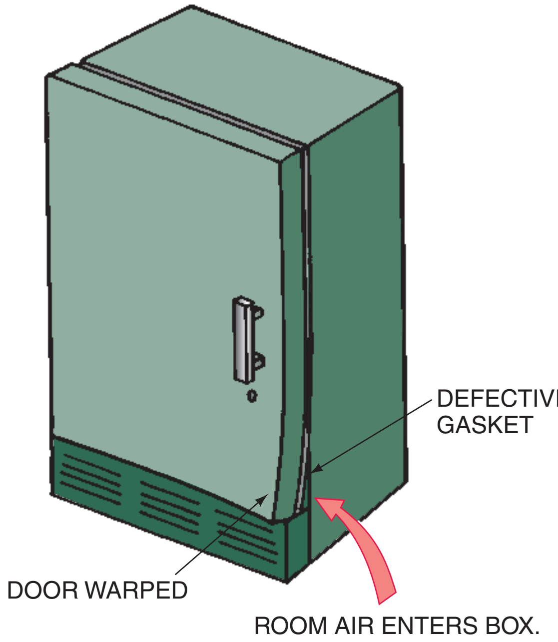


Figure 46–12 The door gaskets must be in good condition and the door must fit right, or moisture-laden air will enter the freezer.

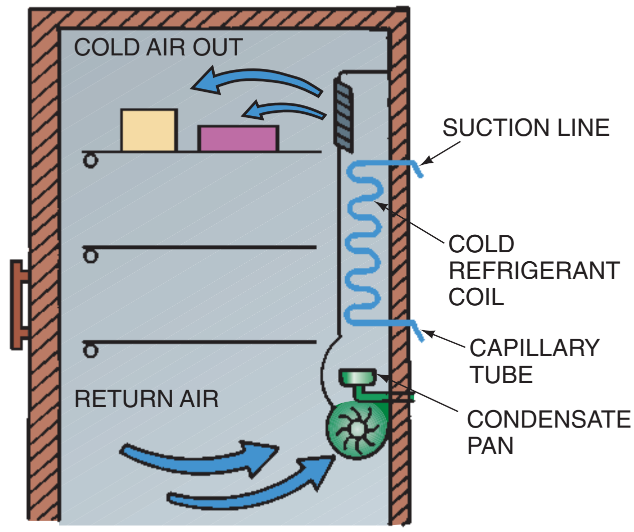


Figure 46–14 The forced-air type may use the discharge air from the cold evaporator for fast freezing.

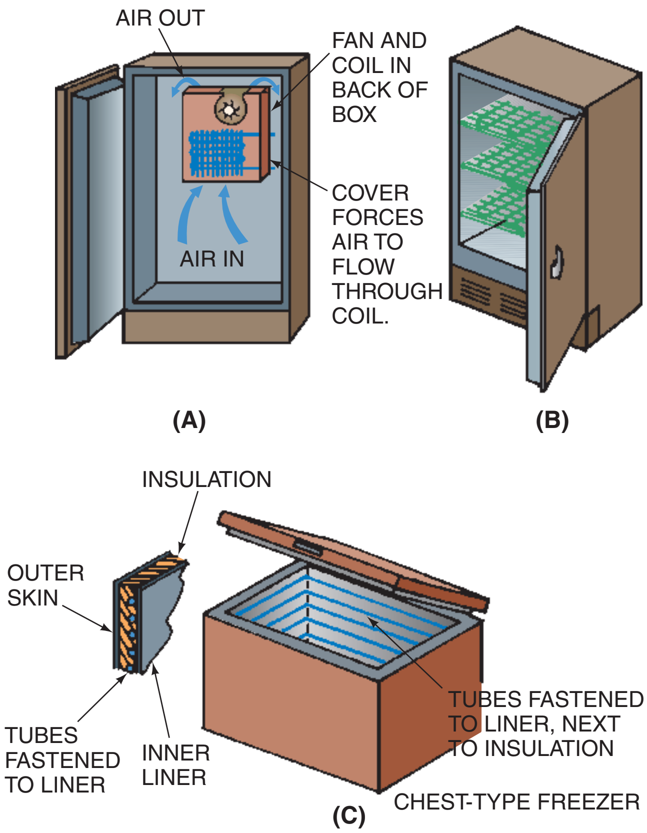


Figure 46–13 Three types of evaporators. **(A)** Forced air. **(B)** Shelf. **(C)** Plate (wall).

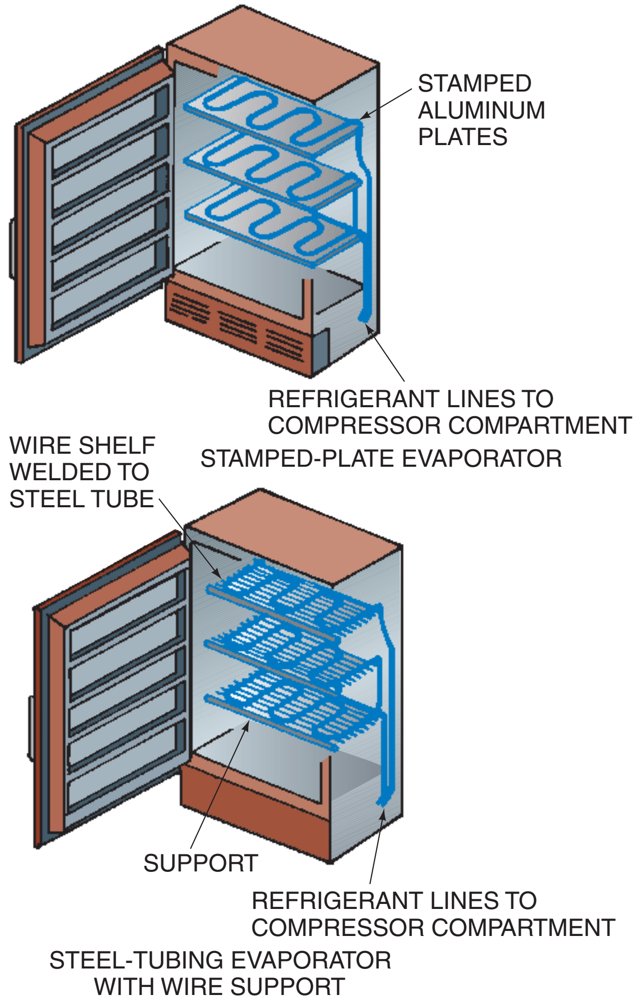


Figure 46–15 Plate evaporators may form the shelves, using stamped plate or steel tubing with wire.

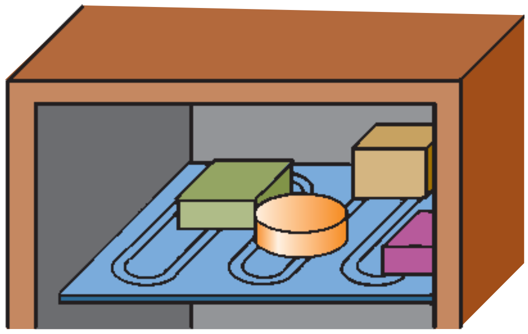


Figure 46–16 Placing food directly on the evaporator plate or tube will help to quickly freeze the food.

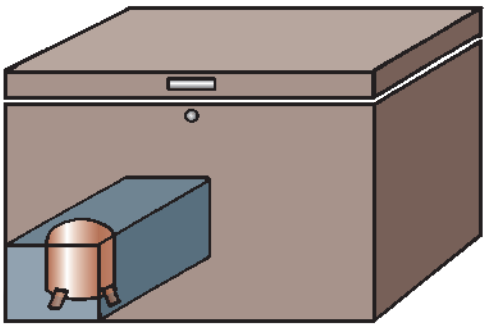


Figure 46–18 The compressor is located under the hump in a chest-type freezer.

When the plate or tube evaporator is used, the fastest method for freezing food is to lay it directly on the plate, **Figure 46–16.** There is a limited amount of available plate surface area.

A light is normally located in the freezer in order to see the food. A door switch is used to turn the light on and off.

Inside the Chest-Type Freezer

The lid is on hinges at the back, and the liner may be metal or plastic. Gaskets are located around the lid of the box. These gaskets must be in good condition, or air with moisture will leak in. There will be a fast-frost buildup, normally right inside the lid where air is leaking in, **Figure 46–17.**

The chest-type freezer has a hump in one end of the compartment. The compressor is located under the hump, **Figure 46–18.** It may have a forced-air fan coil at the same end for fast freezing, **Figure 46–19.**

Care should be taken when loading a chest-type freezer or food will be hard to find at the bottom. Larger parcels should be located on the bottom, and all parcels should be dated. Most freezers have baskets that may be set aside while looking for parcels at the bottom.

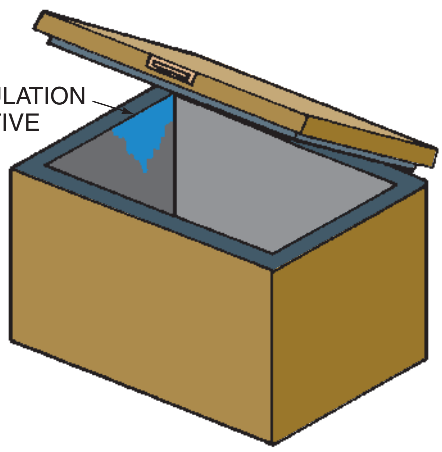


Figure 46–17 A leaking lid gasket will cause fast frost.

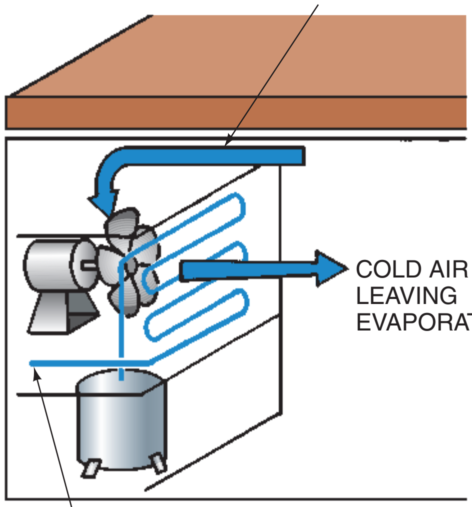


Figure 46–19 A small forced-draft evaporator may be located on one end and used as a fast freezer.

46.4 THE EVAPORATOR

The evaporator is the device that allows heat to be absorbed into the refrigerant and is located inside the freezer. It may be a forced-air type or a tube or plate with natural draft.

The forced-draft type is typically located behind a panel with a fan, prop or centrifugal type, passing air over it, **Figure 46–20.** This type may have automatic defrost because the evaporator is in a location where the thawed moisture may be drained from the cabinet interior without dripping on the food, **Figure 46–21.**

When the evaporator is a plate type or tube type, no fan is used. The evaporator may be the shelf, and it must be a manual defrost because the water from thawed ice cannot be collected automatically.

Another type of plate evaporator uses the wall of the interior of the box as the evaporator plate. This is accomplished by fastening the tubing to the inner metal liner of

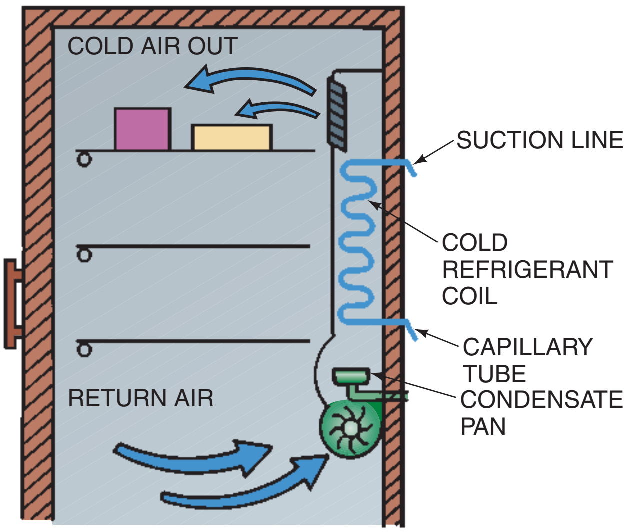


Figure 46–20 The forced-draft evaporator and fan are usually located behind a panel.

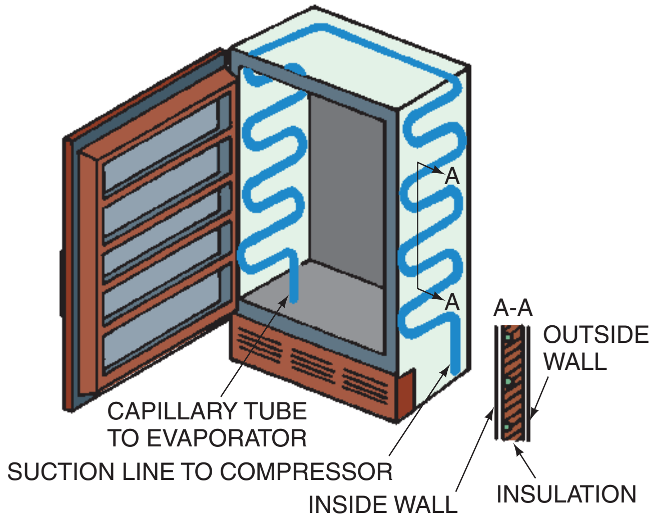


Figure 46–22 A plate-type evaporator using the freezer walls as the plate. The evaporator tubes are fastened to the liner of the box.

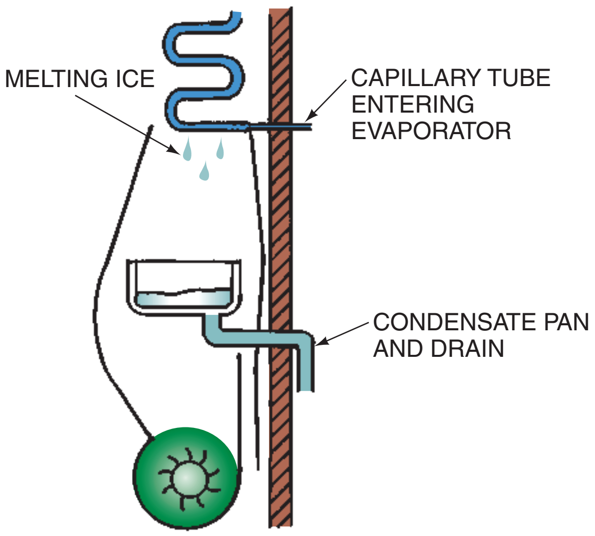


Figure 46–21 The evaporator must have a pan for catching condensate during defrost.

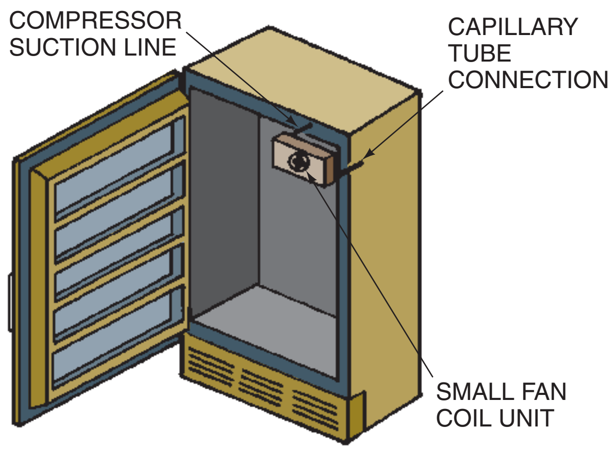


Figure 46–23 When a plate-type evaporator is defective, a small forced-draft evaporator may be installed and substituted if necessary.

the box, **Figure 46–22.** This type of evaporator is the hardest to service because the inner liner must be removed for service. If the liner has foam insulation, it is next to impossible to remove and not economical to do so. If necessary, a forced-draft evaporator could be substituted, **Figure 46–23.** The new evaporator must be sized by someone with experience.

Evaporators may be made of aluminum tubing when they are forced-draft or stamped-shelf type. When tubing is used for shelves, the evaporator is normally made of steel. This gives it strength to hold the food and provides a method of fastening the wire connectors to the tubes, **Figure 46–24.** The support wires may not be connected easily with aluminum tube types.

Figure 46–24 Shelf-type evaporators are normally steel tubing with wire to add support. *Photo by Bill Johnson*

46.5 THE COMPRESSOR

Compressors in domestic freezers are like the ones in domestic refrigerators. They may be rotary or reciprocating, **Figure 46–25.** Refer to Unit 45, "Domestic Refrigerators," for the description of compressors.

The compressor is located at the back of the box on the bottom if the box is an upright, **Figure 46–26.** The box must be moved from the wall when service is needed. When it is a chest type, the compressor will be at one end or the other, but still is usually serviced from the back, **Figure 46–27.** Some manufacturers in the past have mounted the compressor and an air-cooled forced-draft condenser on a tray that may slide out for service. With this design the lines to the compressor must be formed in a coil to allow them to be extended for service, **Figure 46–28.**

46.6 THE CONDENSER

All home freezers have air-cooled condensers. They may be the chimney type located at the back of the box, in the walls of the box, or a forced-draft type with a fan, **Figure 46–29.**

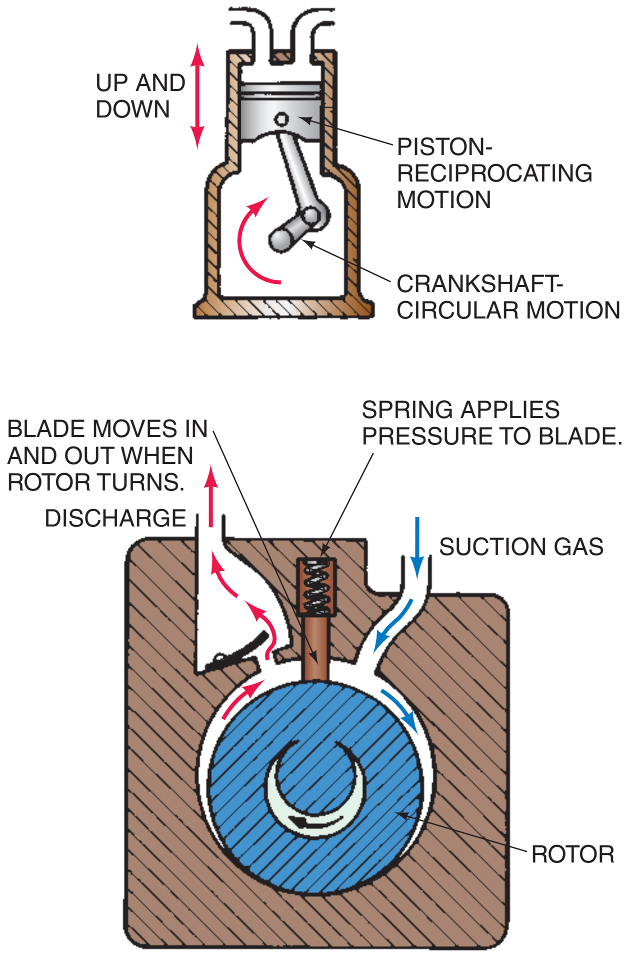


Figure 46–25 Freezer compressors are either reciprocating or rotary.

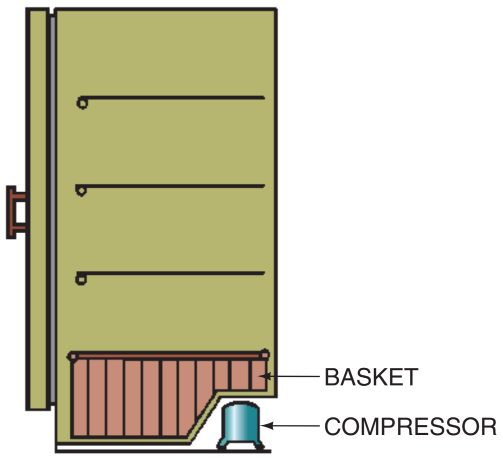


Figure 46–26 The compressor compartment is on the bottom and at the back on a typical upright freezer.

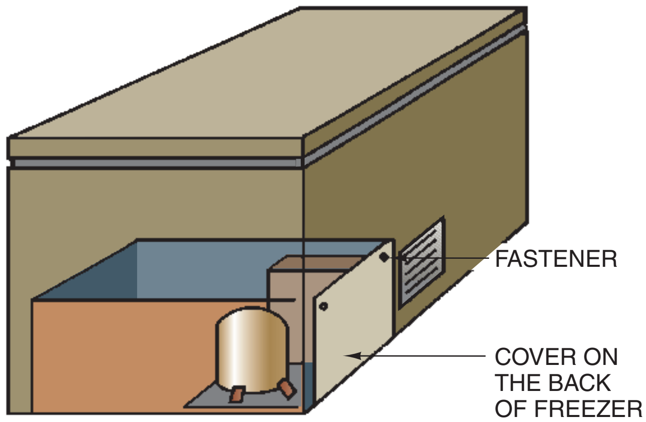


Figure 46–27 The chest-type compressor compartment is on the end but is usually serviced from the back.

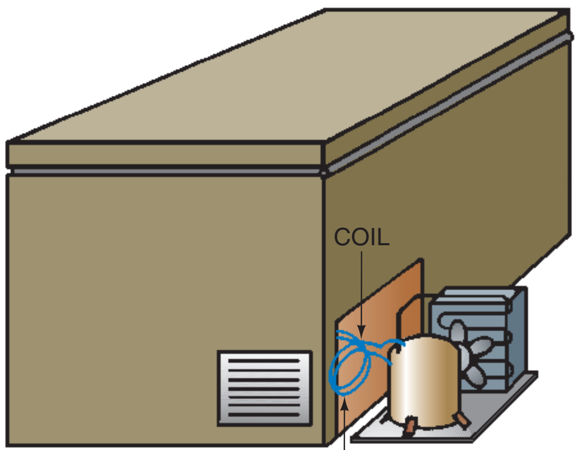


Figure 46–28 When the compressor is on a tray, the lines must be coiled in such a manner as to allow the compressor to slide out.

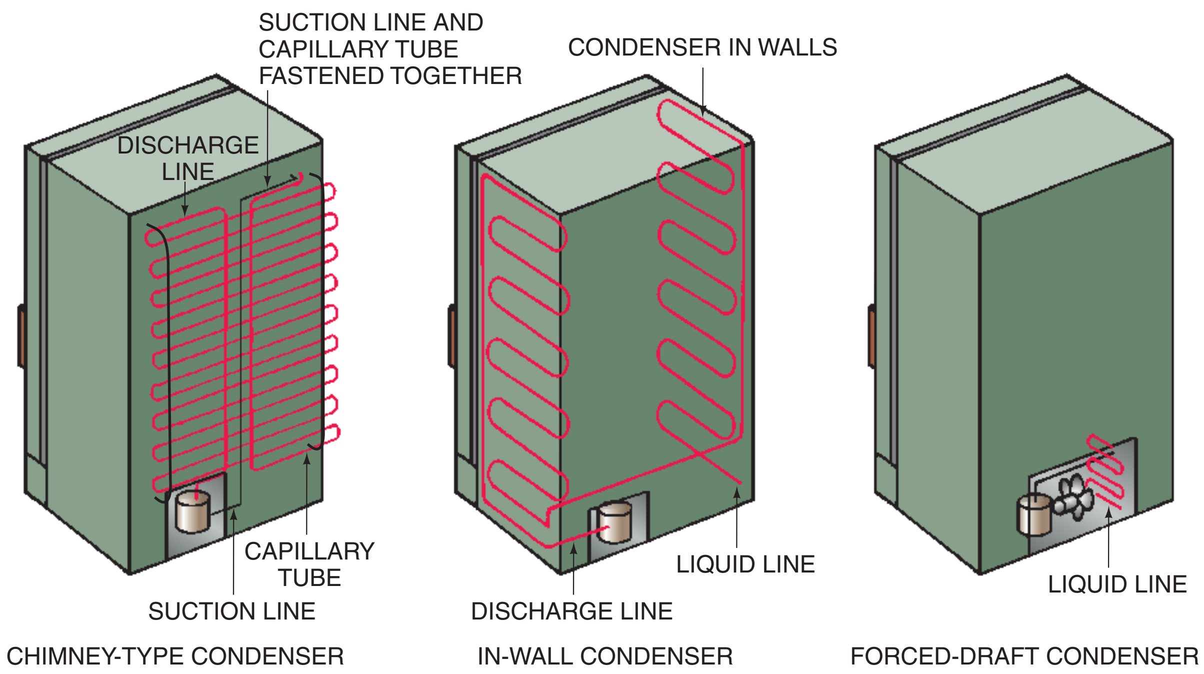


Figure 46–29 The condensers may be chimney type, in the wall, or forced draft, but they must all have airflow.

The chimney-type located at the back of the box must be located where enough air can flow over it, **Figure 46–30.** Note that the air flows from the bottom to the top. This box cannot be located back in an alcove because there will not be enough air circulation. The same rules apply as with a refrigerator.

These chimney-type condensers may be made of stamped steel or steel tubes connected with wires, **Figure 46–31.** They normally require no routine care, except to keep lint, dust, or dirt from covering them, **Figure 46–32.**

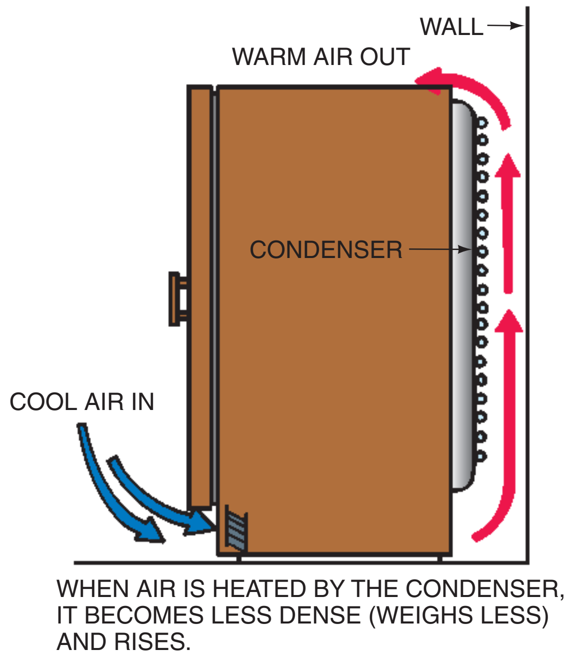


Figure 46–30 The chimney-type condenser must be located where it can have natural-draft circulation.

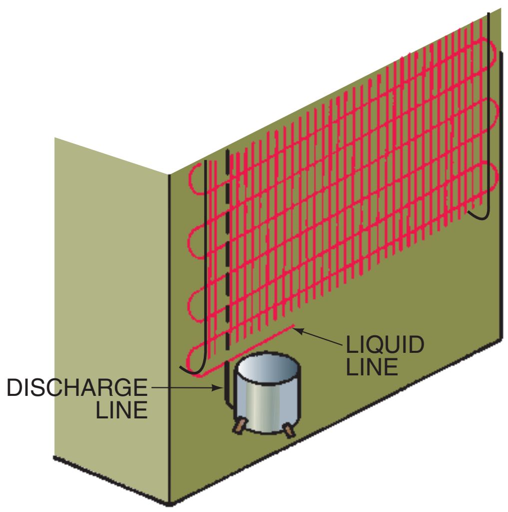


Figure 46–31 Some of the chimney-type condensers have steel tubes connected with wires.

When the condenser is located in the wall of the box, the tubing is fastened to the outside panel. The condenser will not be obvious. The outside of the box will be very warm, **Figure 46–33.** Air must be allowed to circulate along the sides.

The forced-draft condensers are typically used with units that have automatic defrost and may require more care. They are smaller and have air forced over them. Lint or large particles may be trapped in the fins, **Figure 46–34.** The air in conjunction with the heat of the discharge line may be used to evaporate any water from defrost, **Figure 46–35.**

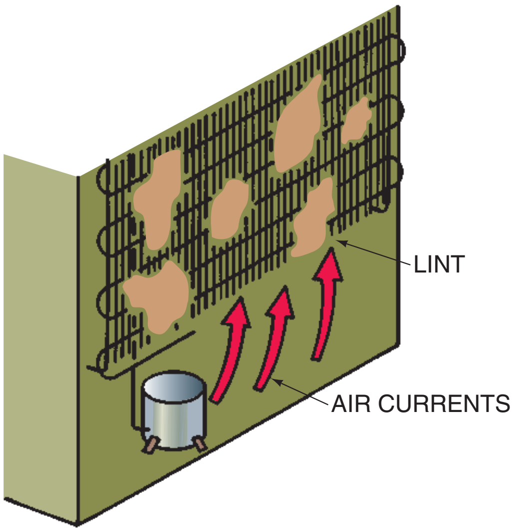


Figure 46–32 Condensers with wires are a natural place for lint to collect.

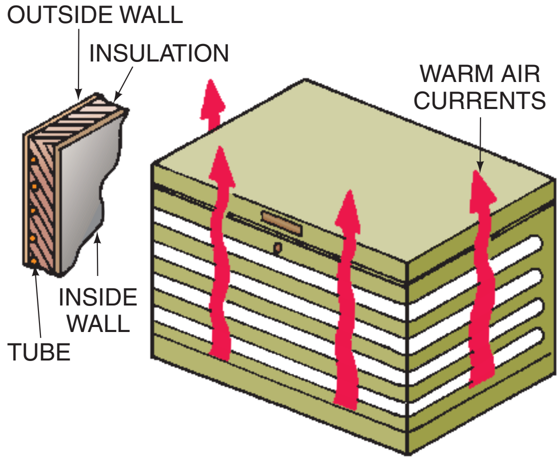


Figure 46–33 Condensers in the wall of the freezer must have natural-air circulation.

Many freezers with forced-draft condensers are located in laundry rooms. These rooms have more lint than other parts of the house and may be much warmer. These freezers must be more closely observed because of lint and temperature. Lint will collect in the fins of the condenser and the defrost drain pan and can cause a problem.

46.7 THE METERING DEVICE

The capillary tube is the typical metering device for home freezers. These follow the same general design rules as for domestic refrigerators. They are fastened to the suction line for a heat exchange. See Unit 45 for information on capillary tubes. Some domestic freezers use R-22 for the refrigerant, so the technician should be sure to look at the nameplate to determine the correct refrigerant and capillary tube selection.

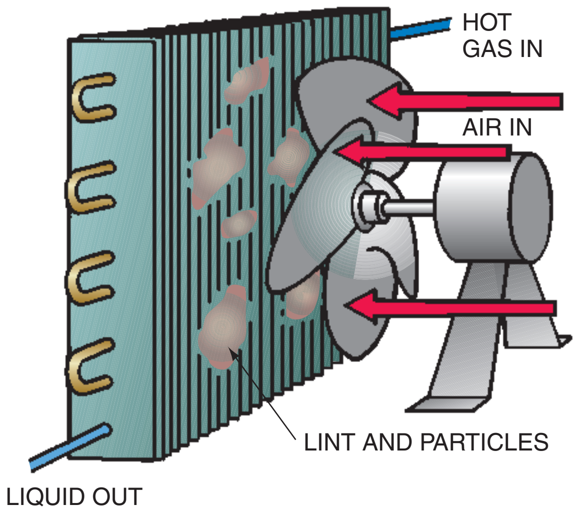


Figure 46–34 Forced-draft condensers have fins. They are normally close to the floor and will collect particles such as lint and dust.

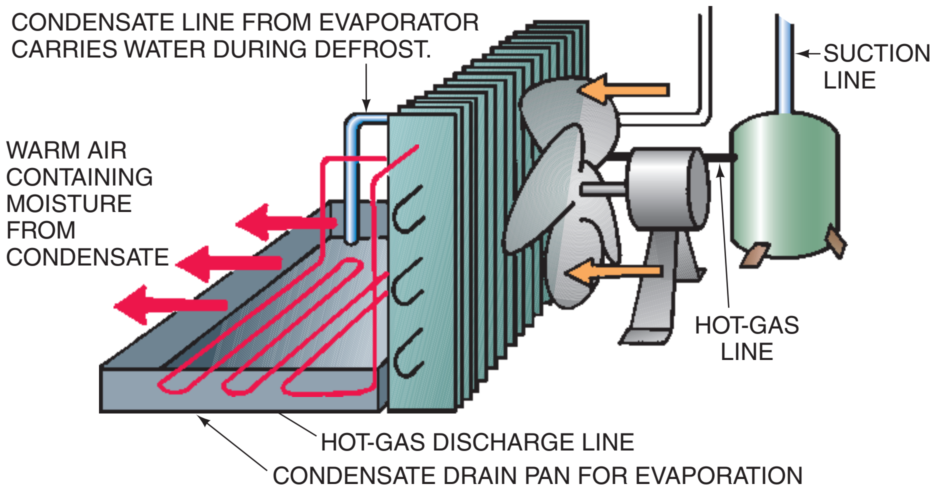


Figure 46–35 The discharge air in conjunction with heat in the discharge line may be used to evaporate condensate from defrost.

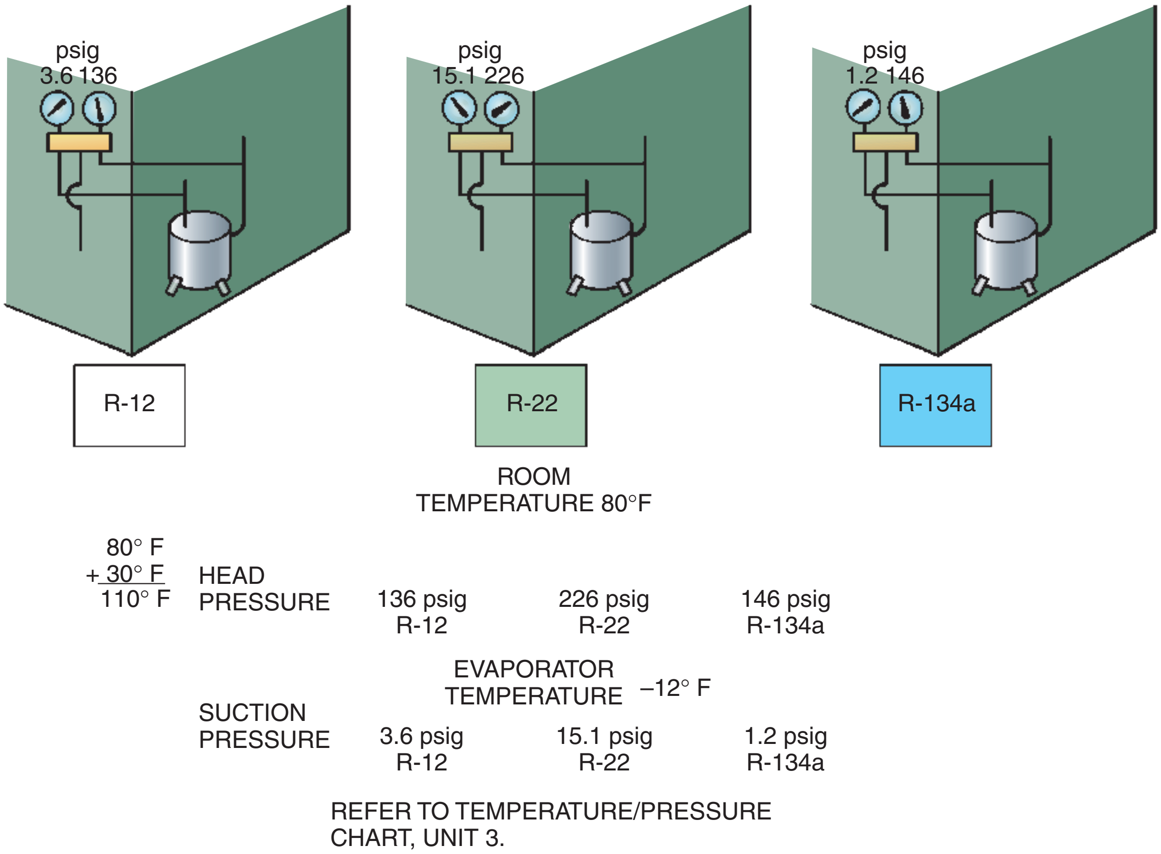


Figure 46–36 R-12, R-22, or R-134a may be used for the refrigerant in a domestic freezer. Be sure to read the nameplate.

46.8 TYPICAL OPERATING CONDITIONS, EVAPORATOR

The common refrigerants used for domestic freezers are R-12, R-22, and those alternative environmentally friendly refrigerants manufactured in recent years, like R-134a and some refrigerant blends. The technician must first read the unit nameplate to determine the type of refrigerant and then use a temperature/pressure chart to arrive at the correct pressures. The home freezer must be operated with a box inside temperature cold enough to freeze ice cream hard. The following pressures and temperatures may be found in the temperature/pressure chart, **Figure 3–38.** Some of the pressures are fractions of a psig and are estimated between the numbers on the chart. For ice cream to be frozen hard, the temperature must be about 0°F. Some ice cream with a lot of cream and sugar content will not be frozen hard until about −10°F. These will be slightly soft at 0°F. The evaporator must operate at a temperature that will lower the air temperature to a minimum of 0°F. When the air temperature is 0°F, the coil temperature for a plate-type evaporator may be as low as −18°F. This corresponds to a pressure of 1.3 psig for R-12, 11.3 psig for R-22, and 2.2 in. Hg vacuum for R-134a, the three refrigerants used in domestic freezers.

When the evaporator is a forced-draft type, the coil temperature may be a little higher because the air is forced over the evaporator. When the air temperature is 0°F, the coil temperature may be about −12°F, which corresponds to a pressure of 3.6 psig for R-12, 15.1 psig for R-22, and 1.2 psig for R-134a, **Figure 46–36** and **Figure 46–37.** These are temperatures and pressures at the end of the cycle, at about the time the compressor is to stop. Temperatures and pressures during a pulldown will, of course, be higher, depending on the box temperature.

All pressures for the condenser are determined using gage readings. The freezer, like the refrigerator, may have no gage ports. Gage readings should not be taken except as a last resort. Unit 45 explains the reason and if readings are needed, how to obtain them.

46.9 TYPICAL OPERATING CONDITIONS, CONDENSER

All freezers are air cooled because of the need for them to be transportable. The condensers are either natural- or forced-draft type. The typical freezer is designed to be located in living space so the design air temperatures are from about 65°F to 95°F. Most residences should be maintained within this temperature range most of the time. The condenser then will have air passing over it from about 65°F to 95°F. The condenser should be able to condense the refrigerant to 25°F to 35°F higher than these conditions. This is a fairly wide spread in temperature difference and has to do with condenser efficiency. The more efficient the condenser, the closer the condensing temperature is to the air passing over it. A condenser that condenses at 25°F higher than the ambient

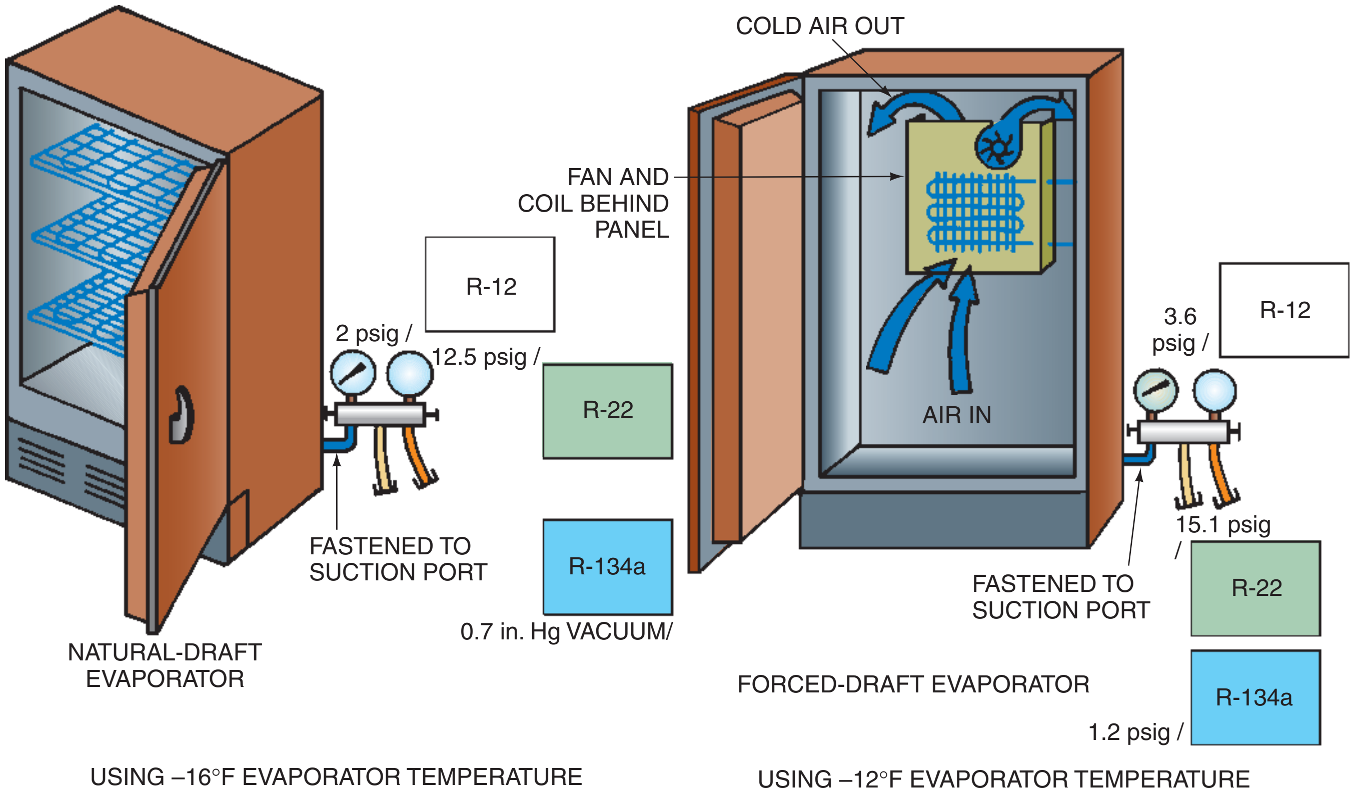


Figure 46–37 Some typical evaporator conditions, forced- and natural-draft evaporators.

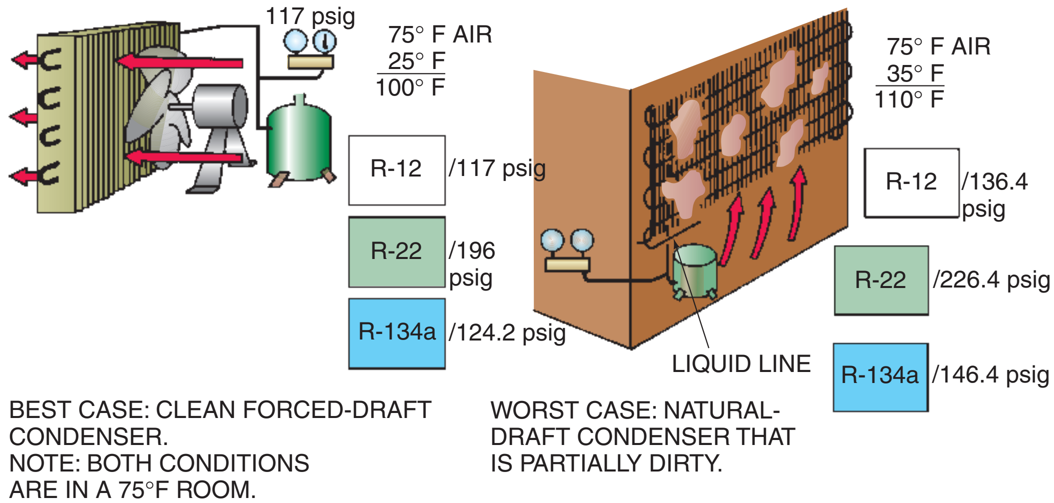


Figure 46–38 The refrigerant typically condenses at 25°F to 35°F higher than the ambient temperature.

temperature is more efficient than a condenser that condenses at 35°F higher than the ambient, **Figure 46–38.** Some typical head pressures for R-12, R-22, and R-134a are shown in **Figure 46–39.**

46.10 TYPICAL OPERATING CONDITIONS, COMPRESSOR

The compressor is the heart of the system, and the technician should be able to readily recognize problems with the compressor. The compressor is hot to the touch on a freezer that is operating normally. All compressors are air or refrigerant cooled. When air cooled, there should be fins on the compressor. Refrigerant-cooled compressors may be cooled with the suction gas, and it may have an oil cooler to help cool the compressor; see Unit 45.

The compressor should not be noisy. If the freezer is not level, the compressor may bind, and it may vibrate. Leveling a freezer is important. The compressor is mounted on rubber feet to keep it quiet. If a compressor is setting level and steady and still has vibration, check the lines to see whether they are secure, **Figure 46–40.** If vibration and noise

	FORCED-AIR CONDENSER	NATURAL-DRAFT CONDENSER
COOL ROOM	65° F + 25° F 90° F CONDENSING TEMPERATURE 100 psig R-12 168 psig R-22 104.4 psig R-134a	65° F + 30° F 95° F CONDENSING TEMPERATURE 108 psig R-12 182 psig R-22 114 psig R-134a
NORMAL ROOM	75° F + 25° F 100° F CONDENSING TEMPERATURE 117 psig R-12 196 psig R-22 124 psig R-134a	75° F + 30° F 105° F CONDENSING TEMPERATURE 127 psig R-12 211 psig R-22 135 psig R-134a
HOT ROOM	95° F + 25° F 120° F CONDENSING TEMPERATURE 158 psig R-12 260 psig R-22 171 psig R-134a	95° F + 30° F 125° F CONDENSING TEMPERATURE 169 psig R-12 278 psig R-22 184.6 psig R-134a
HOT ROOM DIRTY CONDENSER	95° F + 35° F 130° F CONDENSING TEMPERATURE 181 psig R-12 297 psig R-22 198.7 psig R-134a	95° F + 35° F 130° F CONDENSING TEMPERATURE 181 psig R-12 297 psig R-22 198.7 psig R-134a

Figure 46–39 Some typical R-12, R-22, and R-134a head pressures.

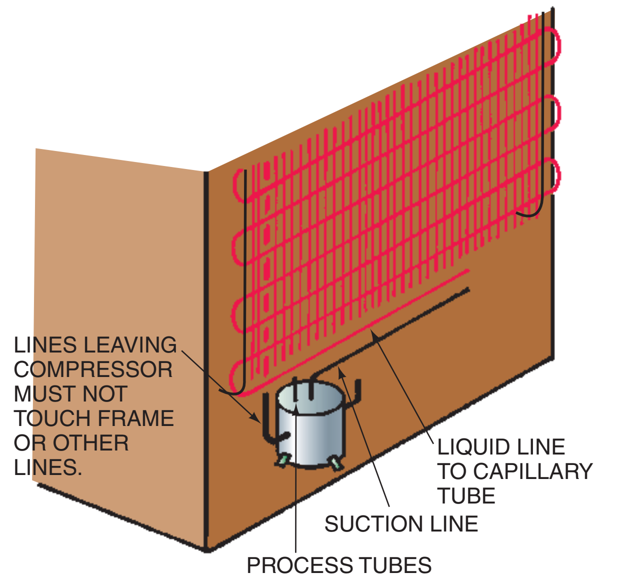


Figure 46–40 Check lines to make sure that they are secure.

still persist, the compressor may have liquid refrigerant returning to it. If so, the compressor will sweat on the side, **Figure 46–41.**

If the capacity of the compressor is questioned, as when the unit is not cold enough, first suspect an extra load. A light

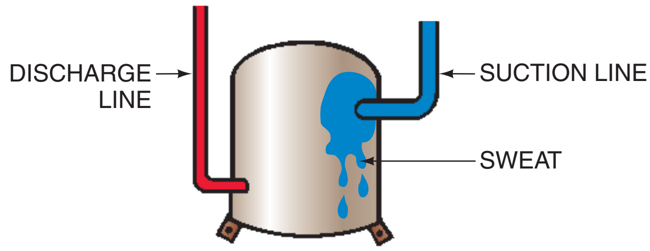


Figure 46–41 If liquid refrigerant is returning to the compressor, it will be sweating on the side.

remaining on will keep the compressor running all the time, but the space temperature may be cold enough. A gasket leak will cause an extra load. The owner may be using the box too often and opening the door too much. All conditions should be analyzed before the compressor is considered defective, **Figure 46–42.** The compressor may not be pumping to capacity. See Unit 45 for information on analyzing the compressor.

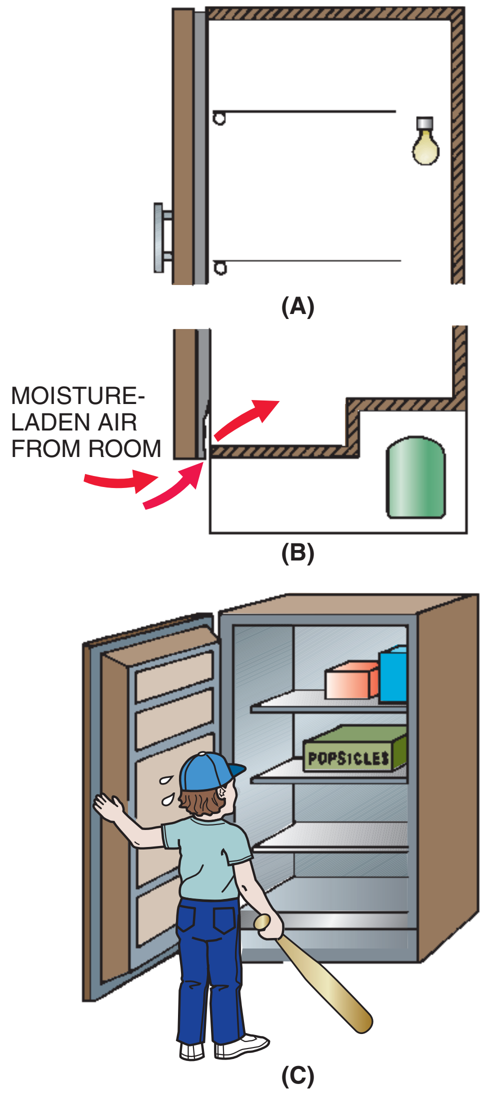


Figure 46–42 A light remaining on, a gasket leak, or opening the door too many times may keep the compressor running while the space temperature seems to be cold enough.

46.11 CONTROLS

Controls for freezers are simple except for those controlling automatic defrost. A typical freezer has only two controls: a thermostat, **Figure 46–43,** and a door switch for turning off the light (and possibly a fan on some models). As with any control circuitry, the technician must know what the manufacturer's intent was when the system was designed. A wiring diagram is normally fastened to the back of the box.

There are panel heaters to prevent sweat like those on refrigerators. These devices will appear on the wiring diagram, but the manufacturer's literature may have to be consulted for their exact location.

On a freezer with automatic defrost, the evaporator must be located in such a manner that the ice will melt and the condensate drain to a place where it will evaporate. This is typically a forced-draft type, **Figure 46–44.** The controls are similar to a refrigerator. Compressor running time may be used to instigate defrost. Electric heaters may be energized to accomplish defrost. A drain heater may be located in the drain to make sure that the water does not freeze in the drain. **Figure 46–45** shows a typical diagram.

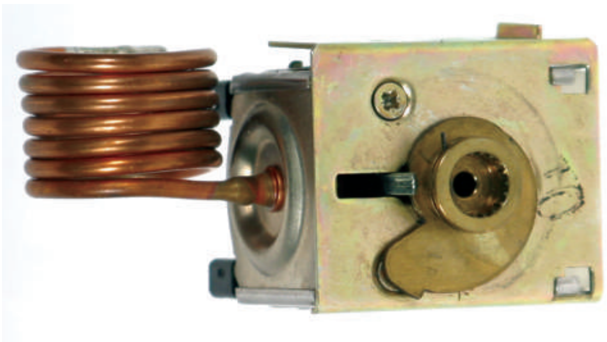


Figure 46–43 A cold control (thermostat) for a freezer. *Photo by Bill Johnson*

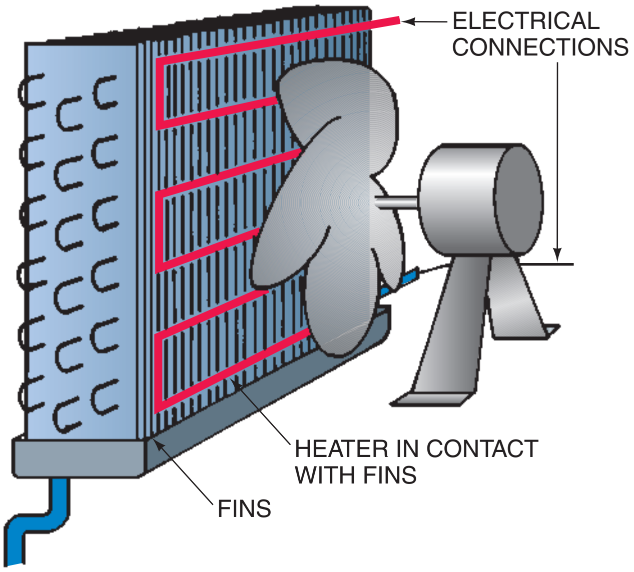


Figure 46–44 A forced-draft evaporator with automatic defrost.

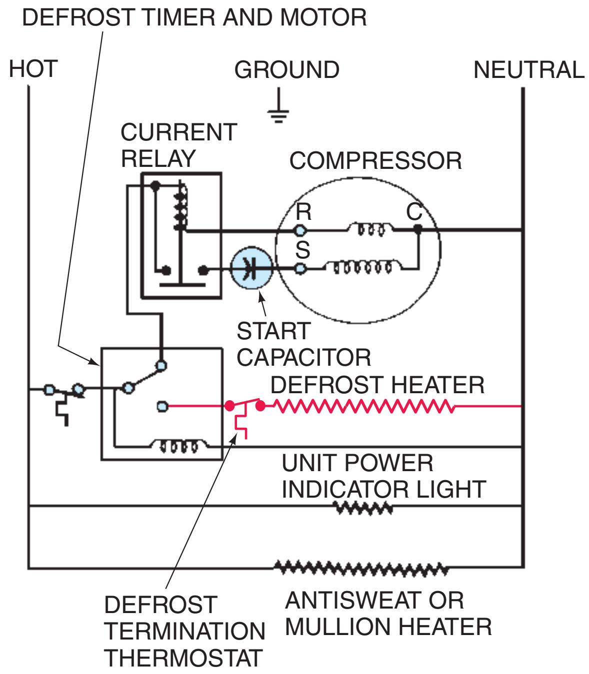


Figure 46–45 A typical wiring diagram with automatic defrost.

46.12 SERVICING THE FREEZER

The same tools and techniques are used for servicing freezers as for refrigerators. However, when servicing freezers, the technician does not have to think about the fresh-food compartment, only the low-temperature compartment. The type of box determines the type of service. For example, a box that has a forced-draft evaporator will have a fan motor that can cause problems. These fans run many hours per year. Usually they are wired in parallel with the compressor and will be off when the compressor is off and during defrost. These fan motors are very small open-type shaded-pole motors with permanently lubricated bearings, **Figure 46–46.** The technician should remember that the fan may be controlled

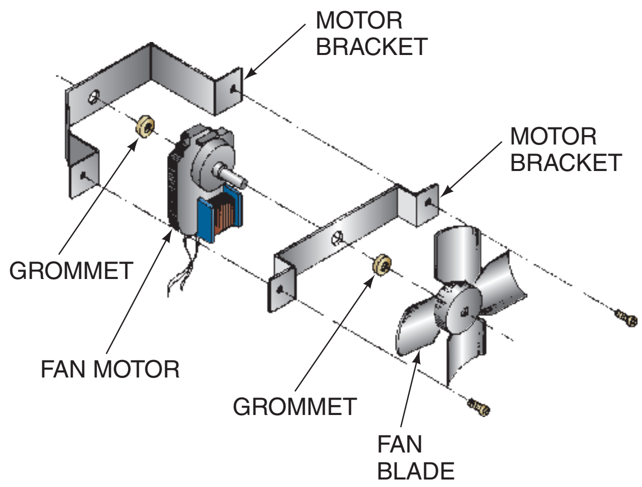


Figure 46–46 Small fan motors usually have permanently lubricated bearings. *Courtesy White Consolidated Industries, Inc.*

by a fan switch and may stop normally when the door is opened. To hear the fan with the door open, the switch must be depressed.

If the fan does not run, some food may have to be removed so that you can remove the fan panel to determine what the problem is. Typically, the fan motor may be stuck. If this is the case, a little lubrication may be added, **Figure 46–47.** It may be allowed to run temporarily until a replacement is obtained. The fan motor should be changed or it will probably fail again. SAFETY PRECAUTION: A freezer is not considered an attended appliance. It may not be opened regularly. It must be kept reliable, and no chances should be taken with the food.

Proper defrost methods must be used for manual defrost. The food may be removed, and external heat may be used to defrost the box. The food may be placed in ice chests and a fan used to circulate room air into the freezer compartment, **Figure 46–48.** Pans with hot water may be placed in the box with the door shut to aid defrost, **Figure 46–49.**

It is not uncommon for the owner to get impatient with slow defrost and start chipping the frost, puncturing a hole in the evaporator. SAFETY PRECAUTION: Never use sharp instruments to hasten ice removal. The coil may be punctured and

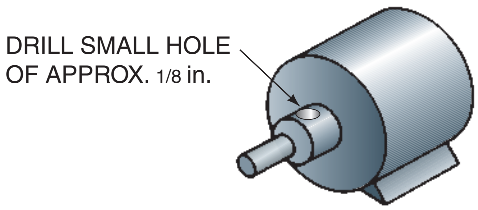


Figure 46–47 A fan motor may be drilled and lubricated for a temporary repair.

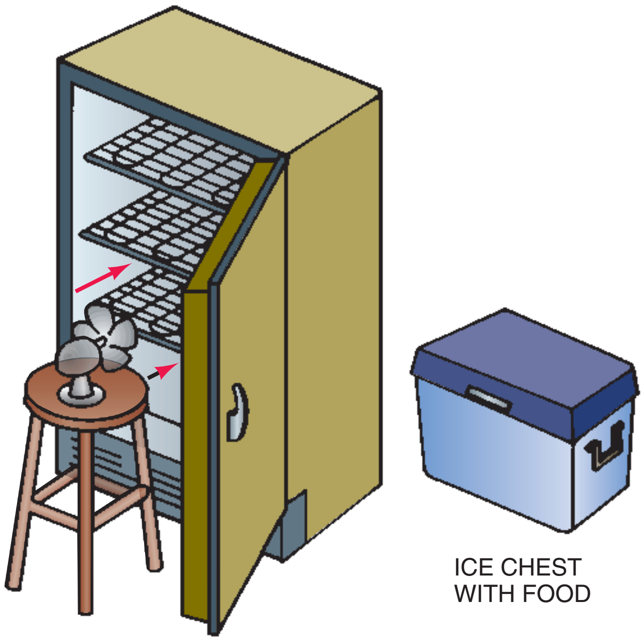


Figure 46–48 Food may be placed in ice chests during manual defrost. A fan may be used to circulate room air over the evaporator to defrost ice.

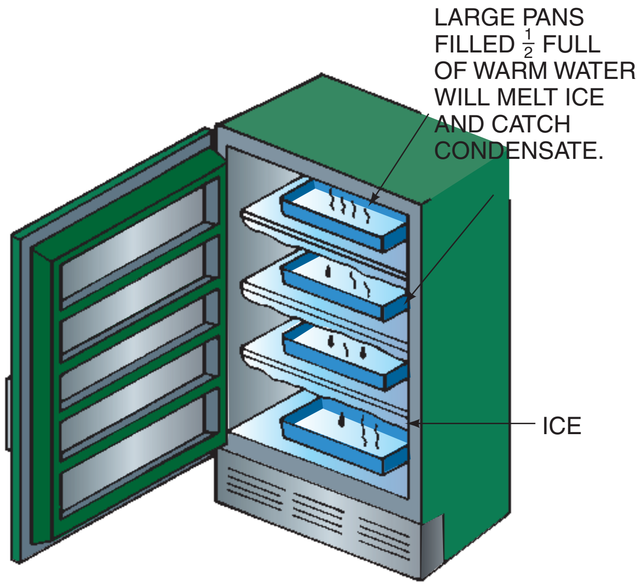


Figure 46–49 Pans of hot water may be used for defrost.

the refrigerant will leak out. Later the owner may start the unit and water will be drawn into the system. When this happens the evacuation procedures described in Unit 45 should be used.

The freezer may have a forced-draft condenser with a fan motor. Again, care must be taken that the fan motor is operating properly and is reliable because the freezer is not attended regularly. The fan motor may blow air over the defrost condensate water. This is a place that is likely to collect dust, lint, and pests, **Figure 46–50.**

Freezers, like refrigerators, are more easily serviced in a shop. However, food storage may be a problem. The food is frozen and when the owner discovers the freezer is not working, the food may still be frozen. If so, it will stay frozen for several hours if the door remains shut. This gives the owner and the service technician time to develop a plan. Some companies may have a freezer to loan.

If the food has thawed, it may only be soft and still cold. If so, it is still edible. The problem is consuming it before it spoils. If the food has spoiled in the freezer, the owner and the technician will have an odor problem, **Figure 46–51.**

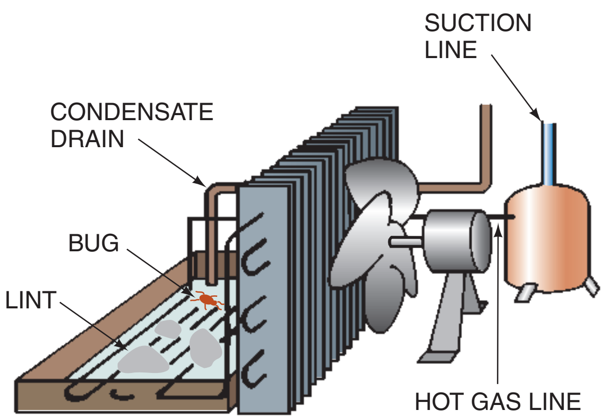


Figure 46–50 A condensate pan at the bottom of the unit is likely to collect dust, lint, and other debris.

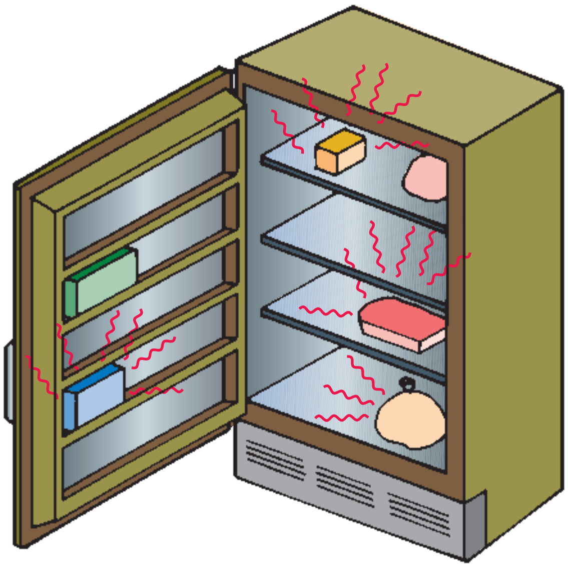


Figure 46–51 Spoiled food in a freezer will generate an odor.

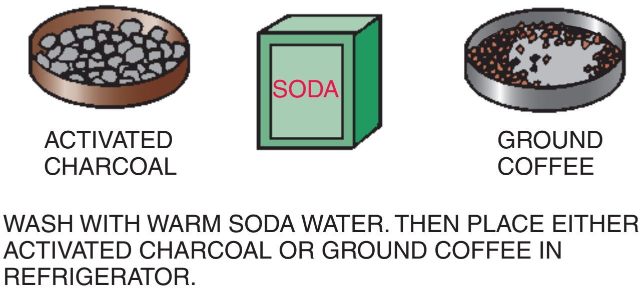


Figure 46–52 Activated charcoal, ground coffee, or soda powder will help to absorb odors.

When the entire box has become saturated with the odor of spoiled food, the box may or may not be salvageable. If it has fiberglass insulation, the technician may not be able to remove the odor because the insulation is saturated. One method used to salvage a unit is to clean the box, open the door, and let it air out, preferably in the sun for several days. The box may then be shut and started and the temperature lowered. Special products from the manufacturer may then be used to absorb the odor. Activated charcoal, ground coffee, or soda powder in a dish placed in the freezer with the door closed may absorb the odor, **Figure 46–52.** If the freezer still has an odor when cooled and odor-absorbing devices have been used, it may have to be replaced.

46.13 MOVING THE FREEZER

SAFETY PRECAUTION: The technician must use great care when lifting and moving any heavy object. Think out the safest method to move any object. Special tools and equipment should be used at all times. Technicians should wear appropriate back brace belts when moving and lifting objects, **Figure 46–53.** When it is necessary to lift, lift with your legs, not your back. Keep your back straight. A refrigerator or freezer is among the heaviest and most awkward types of equipment to move. The surroundings or the freezer may be damaged when the freezer is moved. Freezers are frequently located in tight places and often need to be moved upstairs or downstairs. The correct moving devices must be used. NOTE: Because of oil migration, never lay a freezer on its side.

Figure 46–53 Use a back brace to lift objects. Use legs, not back; keep back straight. *Courtesy Wagner Products Corp.*

Moving Upright Freezers

Refrigerator hand trucks with wide belts are used for upright boxes, **Figure 46–54.** These must be used in such a manner that they do not damage the condenser or let the door swing

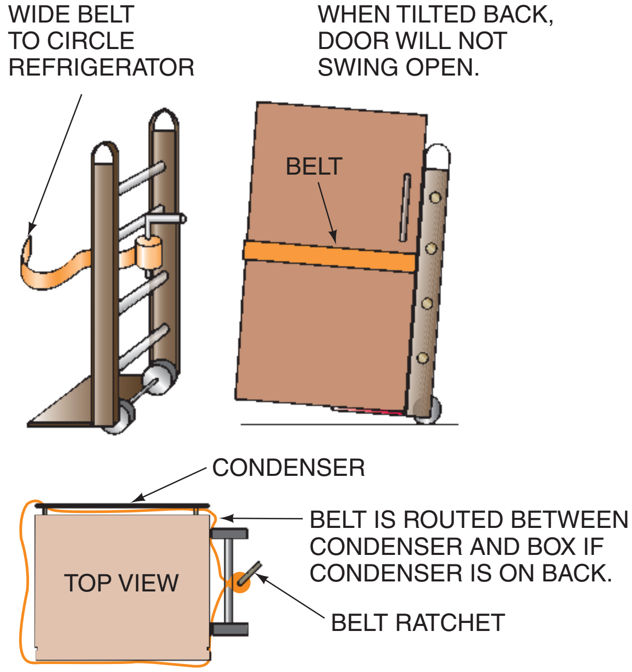


Figure 46–54 Refrigerator hand trucks.

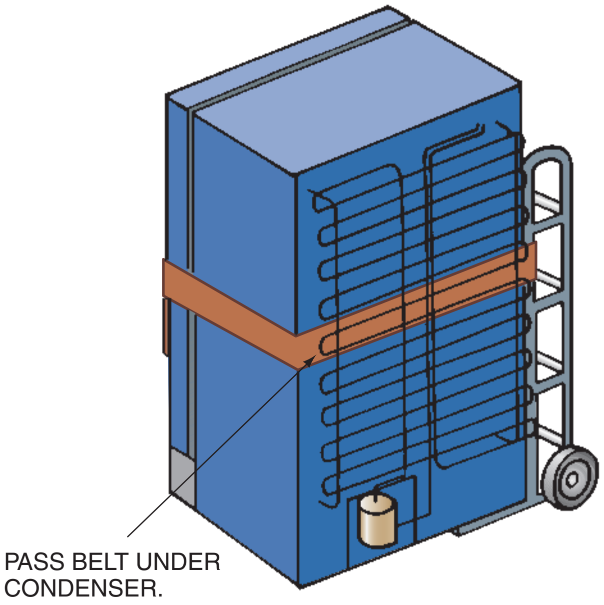


Figure 46–55 Pull the belt between the condenser and the box when the condenser is in the back.

open, **Figure 46–55.** The box should be trucked from the side where the door closes if possible. Freezers or refrigerators should not be moved with food in them. The combination of food and freezer for a large unit may well be over 1000 lb. When repositioned, the box must be on a solid foundation, **Figure 46–56.**

The freezer may be moved far enough out from the wall for service without removing the food if done carefully. If the freezer is located on a floor that must be protected, the technician is responsible for knowing how to accomplish the move without causing damage to the floor or freezer. A small rug may be used under the legs if the box does not have wheels. A correct mat will slide across a fine-finished floor without causing damage to the floor.

The technician should slightly tilt the box over to one side and have someone slide the mat under the feet. Then the box must be tilted to the other side for the other feet. This method can be used only where there is room to tilt the unit, **Figure 46–57.** If there is no tilt room, the freezer may have to be pulled out from the wall far enough for the technician to place the mat under the front feet—and then the box may be pulled out from the wall far enough for service, **Figure 46–58.** The front feet may be screwed upward one at a time and a mat placed under them—and then screwed back out if no side or backward tilt is possible, **Figure 46–59.** Care should be used when placing a mat under the feet. SAFETY PRECAUTION: Do not let the freezer fall on your hands. A screwdriver or stick may be used to slide the mat under the feet, **Figure 46–60.**

Figure 46–57 Enough room is available to tilt the freezer and place a mat under the feet.

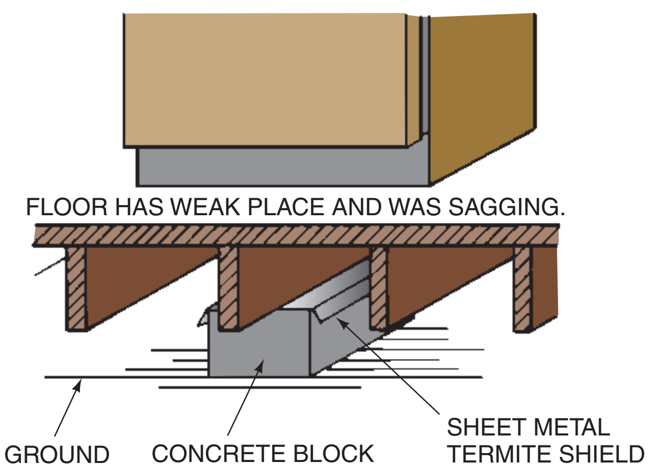


Figure 46–56 Freezers must be on a solid foundation.

Figure 46–58 The freezer may be pulled out a few inches for the purpose of placing a mat under the feet.

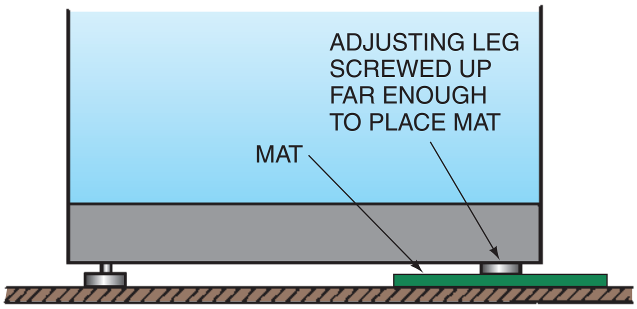


Figure 46–59 The feet may be screwed upward, one at a time, to work the mat under the feet.

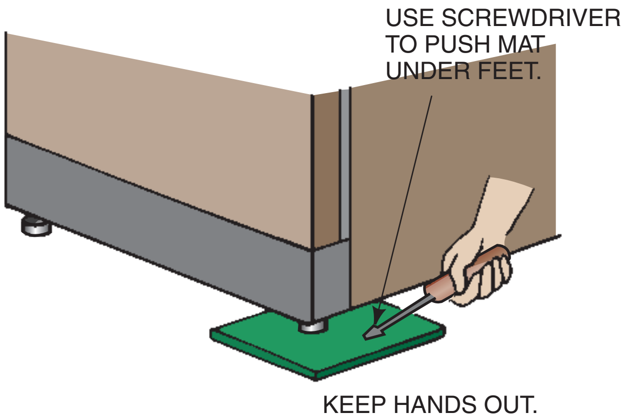


Figure 46–60 Use a small stick or long screwdriver, not your hands, to place the mat.

Moving Chest-Type Freezers

Chest-type freezers are more difficult to move than upright freezers. They may be larger, take up more floor space, and contain more food. Refrigerator two-wheel hand trucks will not work as well on chest-type freezers because the freezer is longer than it is tall, **Figure 46–61.**

When a chest-type freezer must be moved out from the wall for service, the same guidelines apply as for the upright

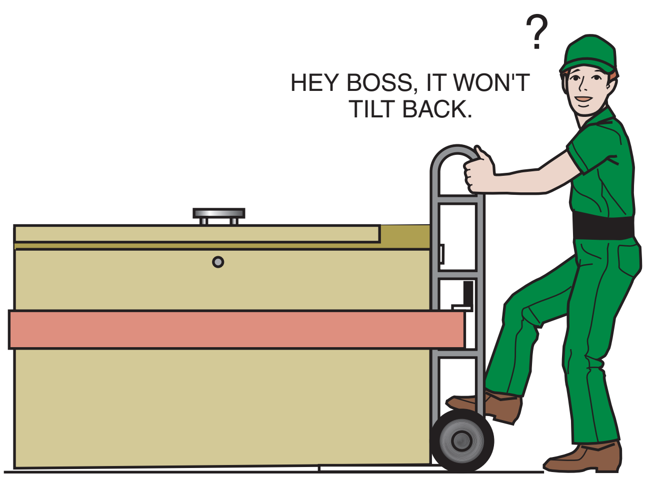


Figure 46–61 Refrigerator hand trucks will not work on a chest-type freezer.

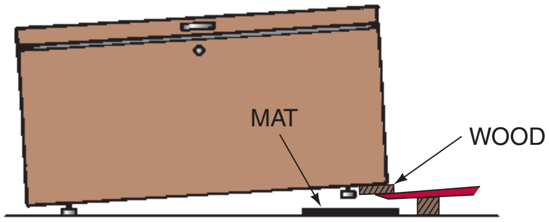


Figure 46–62 A mat can be placed under a chest-type freezer by using a pry bar.

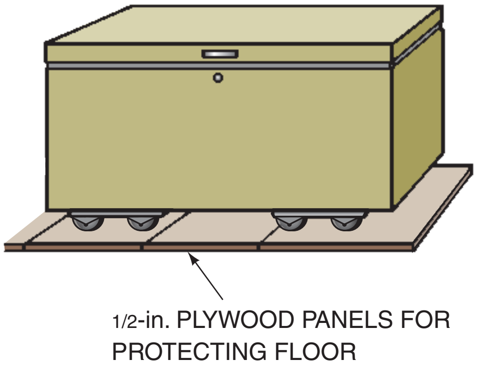


Figure 46–63 The use of two dollies with four wheels each is a good choice for moving a full chest-type freezer.

freezer. By carefully using a pry bar on a piece of plywood, a mat can be placed under the feet, **Figure 46–62.**

When the chest-type freezer is moved from one room to another, two four-wheel dollies, **Figure 46–63,** may be used. The freezer must carefully be raised to the level of the dollies. This requires at least two people and caution. The freezer is manufactured in a size to enable it to be moved through standard doors, but care should be used when moving the dolly wheels over the threshold.

46.14 TEMPORARY FOOD STORAGE

The technician often must help the owner find a place in which to store food temporarily while a freezer is being repaired. If the freezer is still under warranty and a problem arises, the technician will probably be obligated to help find a place to store the food. Some appliance companies may send out a new freezer and merely change the food over if another box of the same type is available. The old box may be moved to the dealer's shop, repaired, and sold as a used freezer. If this box was originally sold to the customer as a special model, it may have to be repaired. In this case, the technician may move another box to the site and transfer the food to the loaned box until the repair is made. If this is not possible, dry ice may be used to store the food. In a chest-type freezer, the dry ice may be placed in the freezer on top of the food. SAFETY PRECAUTION: A layer of protection is placed between the dry ice and the food, **Figure 46–64.** Do not shut the lid tight; leave a small gap for the CO to escape from the dry ice. The food in upright freezers should be emptied into boxes. The dry ice is placed on top of the food with a layer of protection between the food and dry ice.

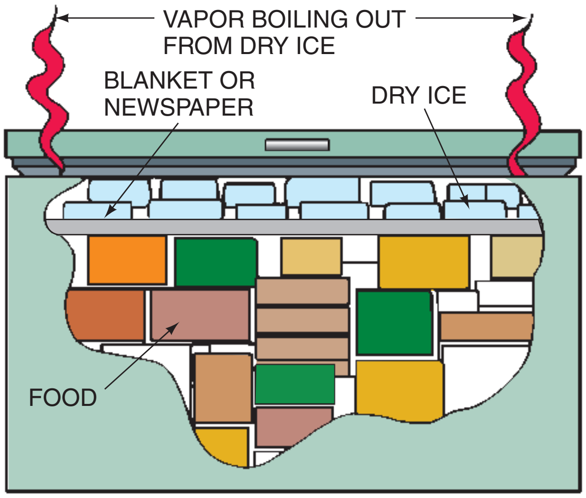


Figure 46–64 A layer of protection is placed between the food and the dry ice.

Dry ice is very cold and will dehydrate the food if placed in contact with it. SAFETY PRECAUTION: The technician should never allow dry ice to come in contact with skin, or frostbite will occur. Use heavy gloves or better still, a scoop to handle the dry ice. About 20 lb of dry ice per 5 ft^3 of freezer capacity will hold the food for 24 hours.

46.15 SERVICE TECHNICIAN CALLS

SERVICE CALL 1

A homeowner who lives in the country calls. This customer has recently purchased a freezer and has had a steer killed, butchered, quick frozen, and placed in the new freezer. *The problem is that the condenser fan motor has failed, and the freezer compressor is running all the time.* The food is still frozen hard, but the temperature is beginning to rise.

The technician arrives and notices right away that the condenser fan is not running. The customer has a thermometer in the box, and it reads 15°F. No time can be wasted. The box is moved from the wall for access to the fan motor. The freezer is unplugged, and the technician checks the fan motor. It turns freely, so the technician removes one motor lead and an ohm check is performed. The motor has an open circuit through the windings, **Figure 46–65.** The technician does not have a motor and must get one. The technician asks the customer whether she has a floor fan that may be used for the condenser until a new fan motor is obtained. She has one, so the technician places the fan where it can blow over the condenser coil and plugs in the fan, **Figure 46–66.** The fan is allowed to operate for about 10 min to remove some of the excess heat from the condenser. The freezer is plugged in, and the compressor starts. The technician can then perform another call on the way to town and back and save time. The freezer will operate and be pulling down while the trip is made.

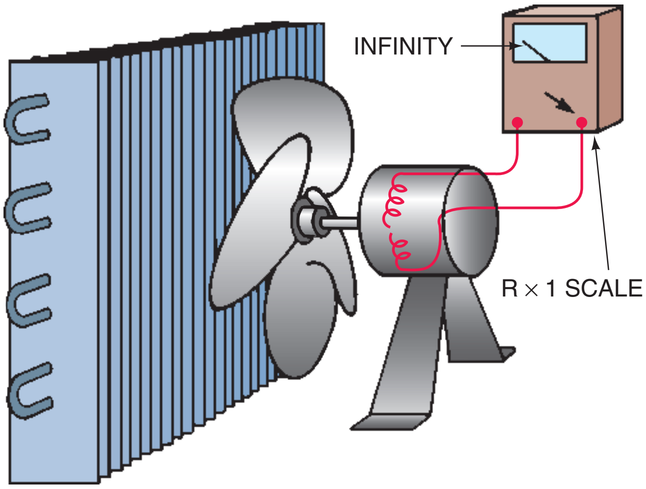


Figure 46–65 A motor with an open circuit through the windings.

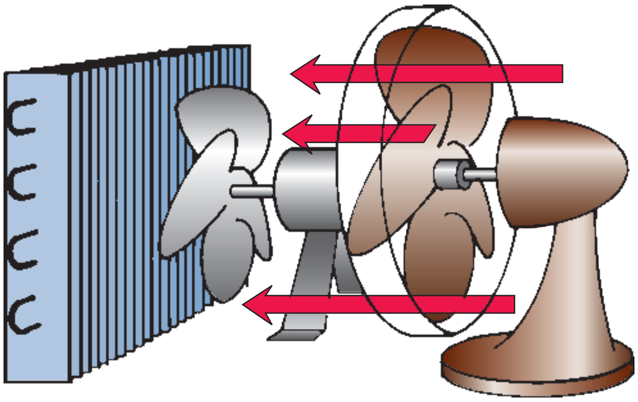


Figure 46–66 A fan placed where it can temporarily pass air over the condenser.

About 3 hours later the technician arrives back to the job; the freezer is still running. The door is opened, and the thermometer is checked. It indicates 1°F, so the freezer temperature is going down. The technician unplugs the freezer and replaces the fan motor. All panels are replaced with the proper fasteners, and the freezer is plugged in. The compressor and the new condenser fan start. The freezer is moved back to the wall and the technician leaves.

SERVICE CALL 2

A customer calls to report that the freezer is running all the time. *This freezer has a vertical condenser on the back, and it is covered with lint. The freezer is located in the laundry room. It is summer, and the laundry room is hot from the summer heat and the clothes drier.*

The technician arrives and checks the temperature with a thermometer. It is already evident that the box is not cold enough because the ice cream is not hard. The technician places the temperature probe between two packages and closes the door. In about 5 min the instrument shows 14°F. While the temperature of the probe was pulling down, the

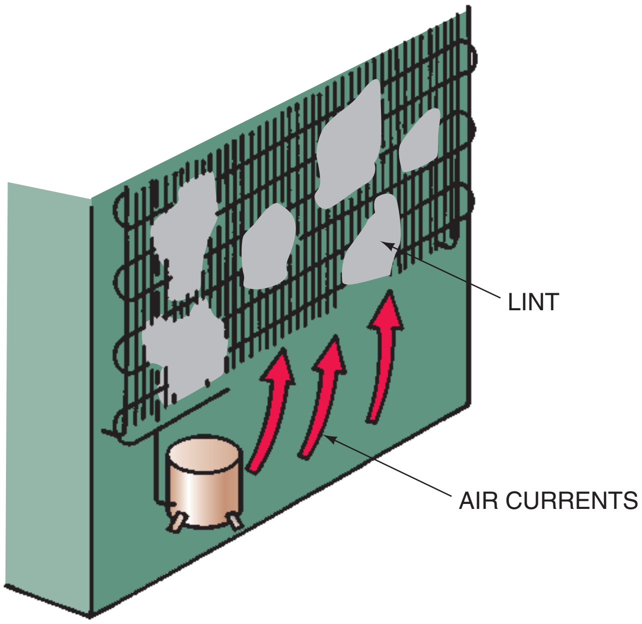


Figure 46–67 A dirty chimney-type condenser.

technician had a look around at the surroundings. It is evident that the condenser is dirty and the room is hot, **Figure 46–67.** The freezer is pulled out from the wall. A vacuum cleaner with a brush is used to remove the lint from the condenser. The technician then slides the box back to the wall. The technician can do no more and gives the owner the following directions: "Do not dry any more clothes until the next morning." A small dial-type thermometer is sold to the customer and placed in the food compartment. The technician calls the customer the next morning and asks what the temperature indication is. It is −5°F, so the box is working fine.

SERVICE CALL 3

A customer calls and says his freezer shocked him when he touched it and at the same time touched the water heater located beside it. *The problem is that the freezer has a slight ground circuit due to moisture behind the box.* The house is old and only has a two-prong wall plug. These are ungrounded, and an adapter has been used to plug the freezer into the wall outlet. The water heater is wired straight to the electrical panel where it is grounded. The customer is advised not to touch the box. It cannot be unplugged, or loss of food may result.

The technician arrives and takes in a volt-ohmmeter and tools. The technician uses the meter to check the voltage between the freezer and water heater, duplicating the situation the customer had been in, **Figure 46–68.** The voltmeter indicates 115 V. This could be a dangerous situation. The technician removes the fuse to the freezer circuit and pulls it from the wall. When it is unplugged, the technician discovers at least half of the problem—a two-prong plug. If the unit were connected through a three-prong plug and grounded, the same type of ground that occurred would flow through the green ground wire.

The technician then fastens one lead of the ohmmeter to the hot plug and the other to the ground (green) plug for the freezer. The meter selector switch is turned to R × 1 and the meter indicates infinity. The technician then starts turning the meter indicator switch to indicate higher resistances. When the switch is turned to R × 10,000, the meter reads 10; 10 × 10,000 means that a circuit of 100,000 Ω exists between the hot wire and the cabinet, **Figure 46–69.** If the cabinet had been properly grounded, the current flow through this circuit would have blown the fuse but would have flowed to the ground through the green ground wire, **Figure 46–70.** The technician must now find the circuit.

The compressor is disconnected while the meter is still connected, and the reading still remains, **Figure 46–71.** The circuits are eliminated, one at a time, until the technician discovers the junction box at the bottom of the unit to be damp due to water dripping from a very slight leak at a water heater valve. The valve packing gland is tightened by the technician and the leak is stopped.

A hair drier is used to dry the junction box, and the ground is no longer present. The technician has a talk with the homeowner about the circuit and the danger involved. Before the technician leaves, an electrician is called to properly ground this circuit and several more that have the same potential problem. The technician has done all that can be expected. It would not have been satisfactory to leave the job without knowing an electrician was already coming to make the system safe.

SERVICE CALL 4

A customer reports that the beef they froze two weeks ago has no flavor, is dry, and seems to be tough. *The problem is that this is a new freezer—and sold to a person with no experience in freezing food.* The customer bought a side of beef that was not frozen and took it home to be frozen in the new freezer.

Ordinarily, the technician would not get involved in this, but this is an old customer and relations must be maintained. The technician calls the customer and asks her to thaw a steak tonight so that it can be checked in the morning. The technician sees a puddle of water and blood under the steak. The technician begins to ask questions. The customer explains how the meat was frozen. She picked it up at a packing house and made three stops before getting home; the weather was hot. The packing house clerk tried to get her to let them freeze the meat, but she thought of her own new freezer and felt that it would do a better job. She had put the whole side of beef in the freezer at one time, about 200 lb, packaged in small parcels.

The technician asks to see the owner's manual. In the manual, it plainly states that the freezer capacity to freeze meat is 40 lb for this 15 ft^3 freezer. She has a freezer full of

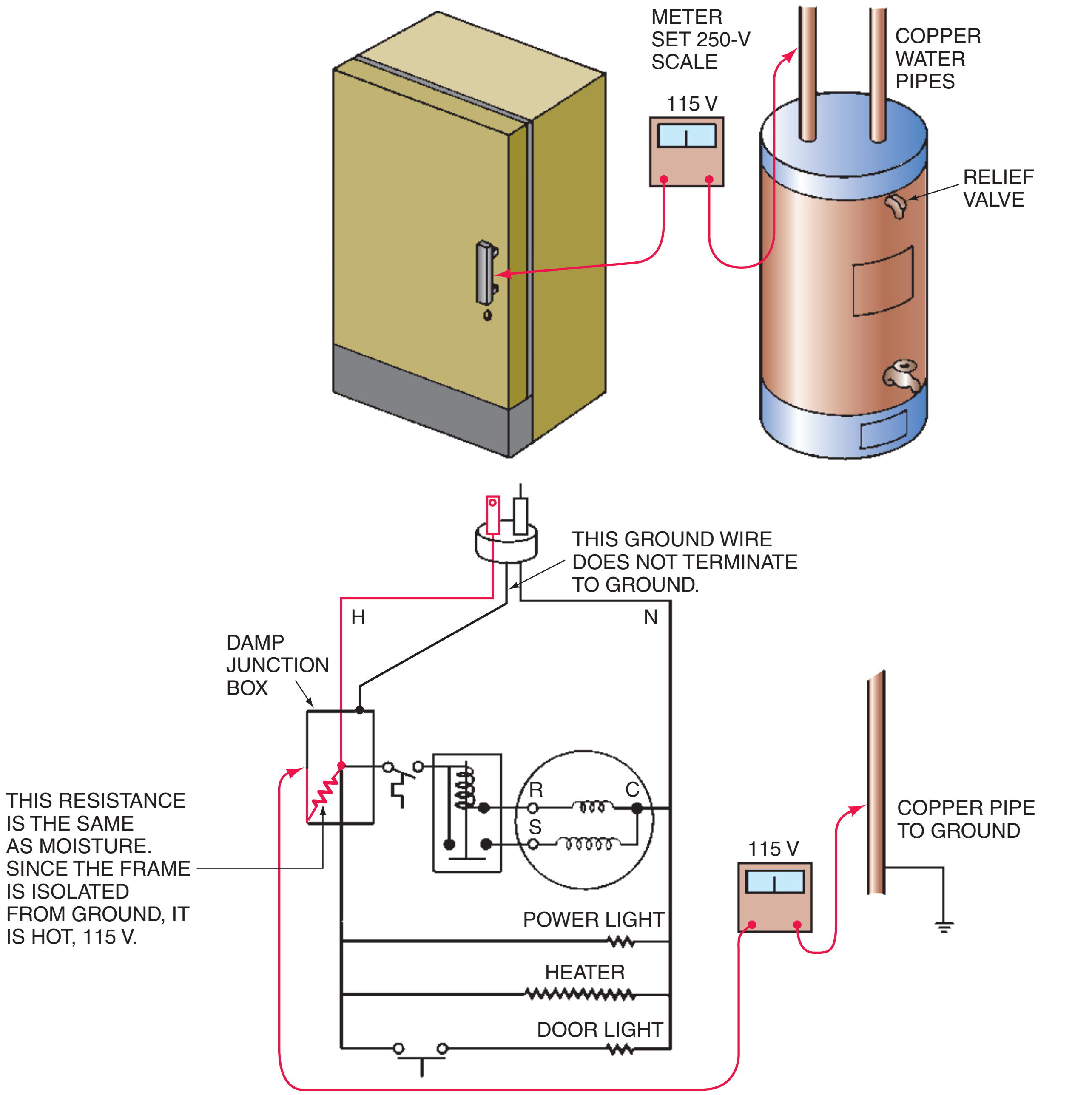


Figure 46–68 To determine the cause of the shock, a meter is being substituted for a person in the circuit.

meat that will not be of the best quality. This is partly the salesperson's fault for not explaining the freezer capabilities. The technician goes over the manual with the owner.

SERVICE CALL 5

A customer, who has been on vacation, calls. It was discovered that the freezer had warmed and thawed while they were gone. *The problem is that the freezer is located in the carport storage room, and the food has spoiled.*

The technician arrives with a helper. It is obvious that the freezer will have to be moved. They unload the freezer and dispose of the spoiled food. After the food is disposed of, the technician and helper move the freezer to the carport. The door is opened and the box washed with ammonia and water, several times. The door is left open for the sun to shine in. Now, the technician starts to find the problem. When the box is plugged in, the compressor does not start. A close examination shows that the common wire going to the compressor has been hot, **Figure 46–72.** The box is unplugged, and the wire is examined more closely and found to be burned in two in the junction box. The wire is replaced with proper connectors and the correct wire size. The box is plugged in again and the compressor starts. The technician can hear refrigerant circulating and feels that the box is in good working order now.

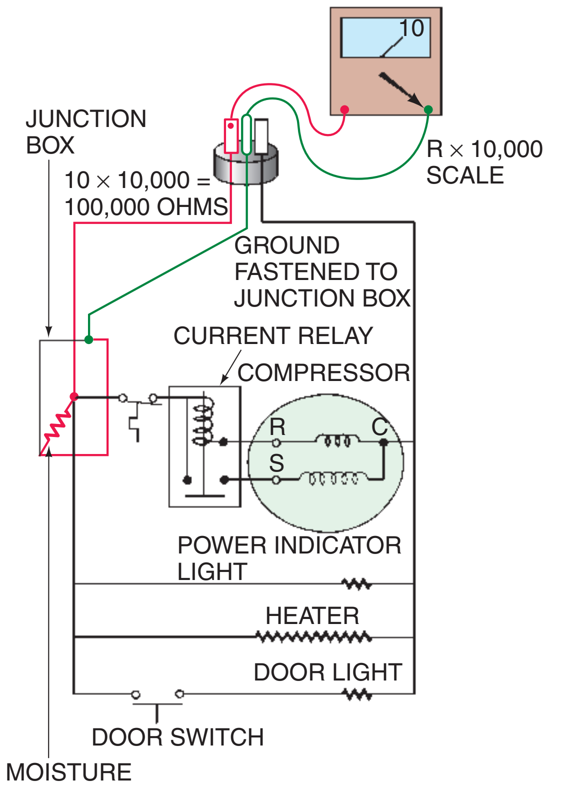


Figure 46–69 A resistance of 100,000 Ω is determined between the hot wire and the cabinet.

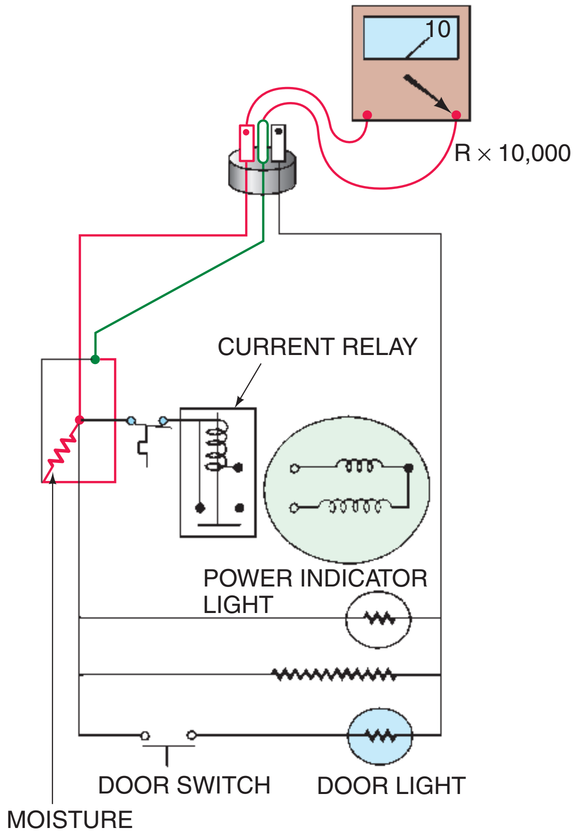


Figure 46–71 When the compressor is disconnected, the ground circuit is still present.

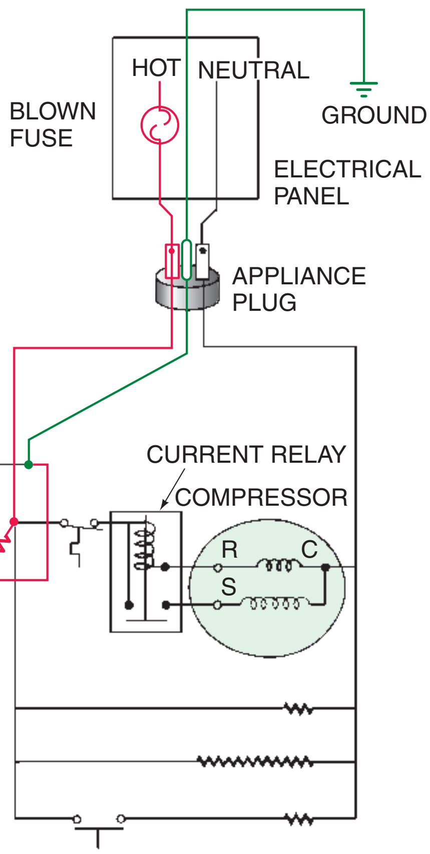


Figure 46–70 If this circuit had been properly grounded, a fuse might have blown.

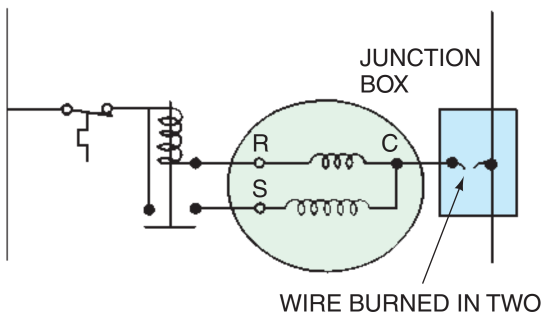


Figure 46–72 The insulation and wire are burned.

This box smells so bad that the technician advises the homeowner to try the following to remove the smell:

- Leave the box open for several days.
- Then close the box and place some activated charcoal, furnished by the technician, inside the box and start it.
- If odor is still present, spread ground coffee in several pans placed inside the box and leave the freezer running for several more days.
- Then wash the freezer inside with warm soda water—about a small package to a gallon of water—and let it run with more coffee grounds inside, for several days.

If this does not remove the odor, the box may need replacing. This seems like a long procedure, but a new freezer is expensive, and the old one should be saved if possible.

SERVICE CALL 6

A customer calls indicating that their freezer is not running and is making a clicking sound from time to time. *The problem is that the customer has added some appliances to the circuit and the voltage is low.* A small 115-V electric heater has been added to the mother-in-law's bedroom, and she is operating it all the time. The voltage is only 95 V at the wall outlet while the heater is operating. This is not enough voltage to start the freezer compressor. This is an old system with fuses. The homeowner has replaced the 15-A fuse with a 20-A fuse. The owner is advised to shut the freezer off until the technician can arrive and to keep the door to the freezer shut.

The technician arrives and places a temperature probe between two packages; the temperature reads 15°F after about 5 min. There is no time to spare. The technician decides to check the amperage and the voltage when starting the unit. An ammeter is fastened around the common compressor wire, and a voltmeter is plugged into the other plug in the wall outlet. The voltage is 105 V; this is low to begin with, **Figure 46–73.** The technician plugs the box in and watches the voltmeter and the ammeter. The compressor does not start and the voltage drops to 95 V—so the freezer is unplugged before it trips on the overload, **Figure 46–74.** It is time to look further into the house circuits.

The technician asks the owner whether any additional load has been added to the house. The heater in the mother-in-law's room is mentioned. The technician goes to the heater and finds it to be a 1500-W heater. This heater should draw 13 A by itself (Watts = Amperes × Volts. Solved for amperes would be Amperes = Watts divided by Volts or Watts = 1500 divided by 115 = 13 A). However, the house has only 110 V at the main so 1500 W divided by 110 V = 13.6 A for the heater under these circumstances, **Figure 46–75.** The fuse is checked and found to be a 20-A fuse. The rest of the circuits with the same wire size have 15-A fuses. A voltage check at the main electrical panel shows 110 V. This circuit is losing 5 V with just the electric heater operating.

The technician unplugs the electric heater and measures the voltage at the refrigerator outlet; it is 110 V. It is obvious that the electric heater must be moved to another circuit, a circuit by itself. A smaller heater would be a better choice. The technician examines the heater and discovers that it can be operated in a lower mode that consumes 1000 W. This should be enough heat for the small room. This would pull 9.1 A: 1000 W divided by 110 V = 9.1 A. Every little bit of savings helps. This place is operating at near maximum capacity.

Another circuit is found, and the heater plugged in at the lower output, 1000 W. The freezer is plugged in and starts; the voltage is 105 V while running, **Figure 46–76.** This is slightly above the −10% allowed for the motor voltage. The rated voltage of the box is 115 V, 115 × 0.10 = 11.5. The

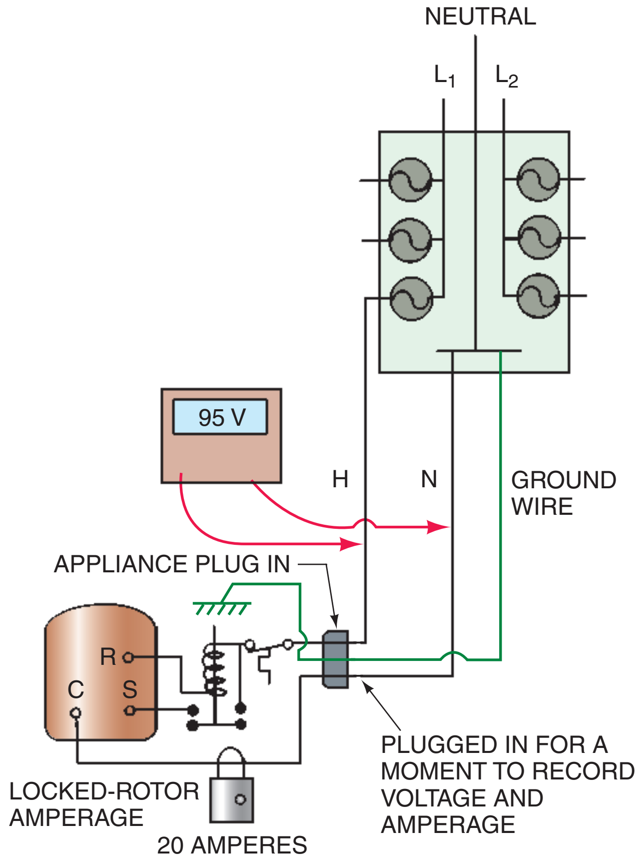


Figure 46–74 When the compressor is plugged in, the voltage drops to 95 V, and the compressor will not start.

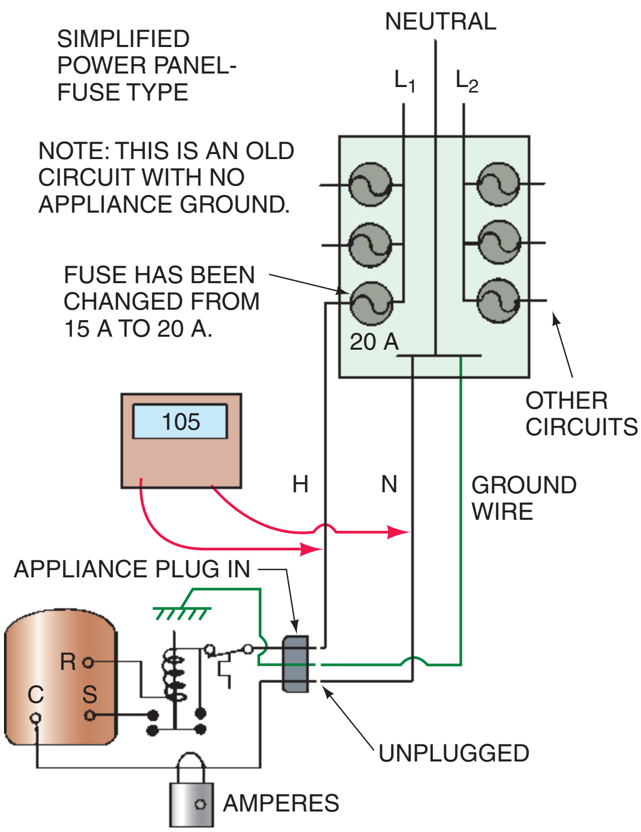


Figure 46–73 There are only 105 V in this circuit before the freezer is plugged in. The freezer will be an additional load on the circuit.

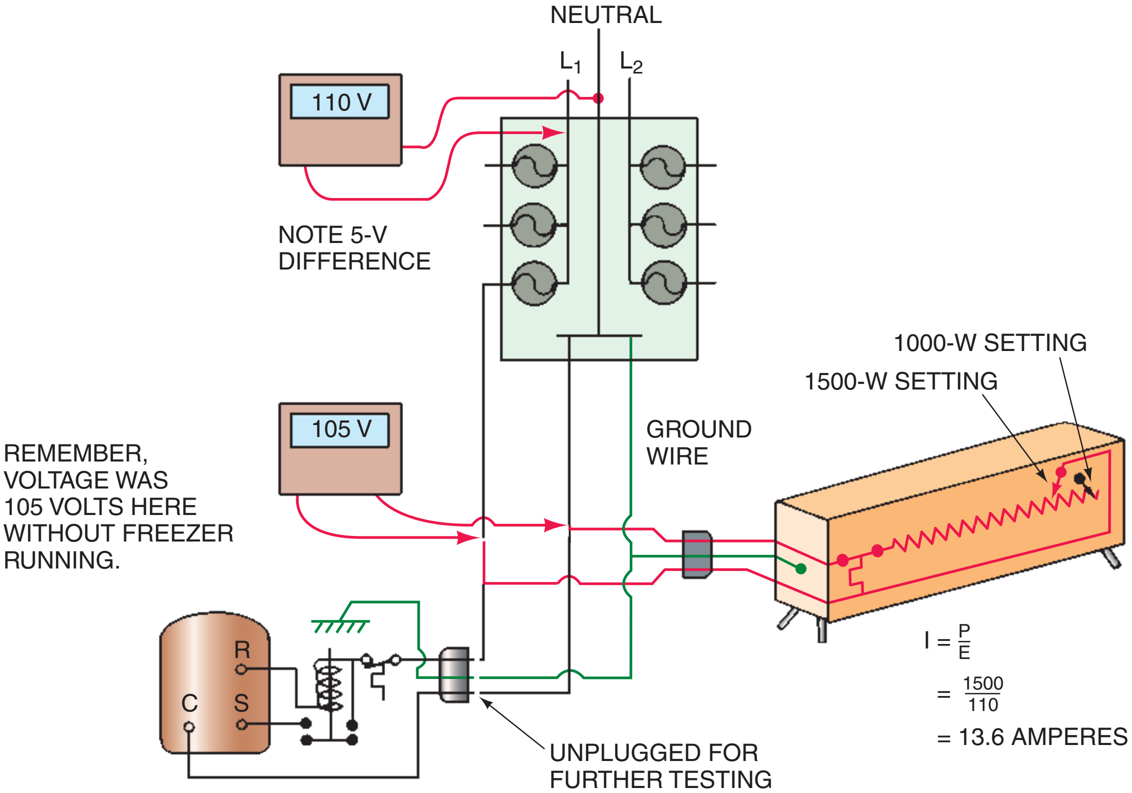


Figure 46–75 The home voltage is only 110 V; a 1500-W heater will pull 13.6 A at 110 V.

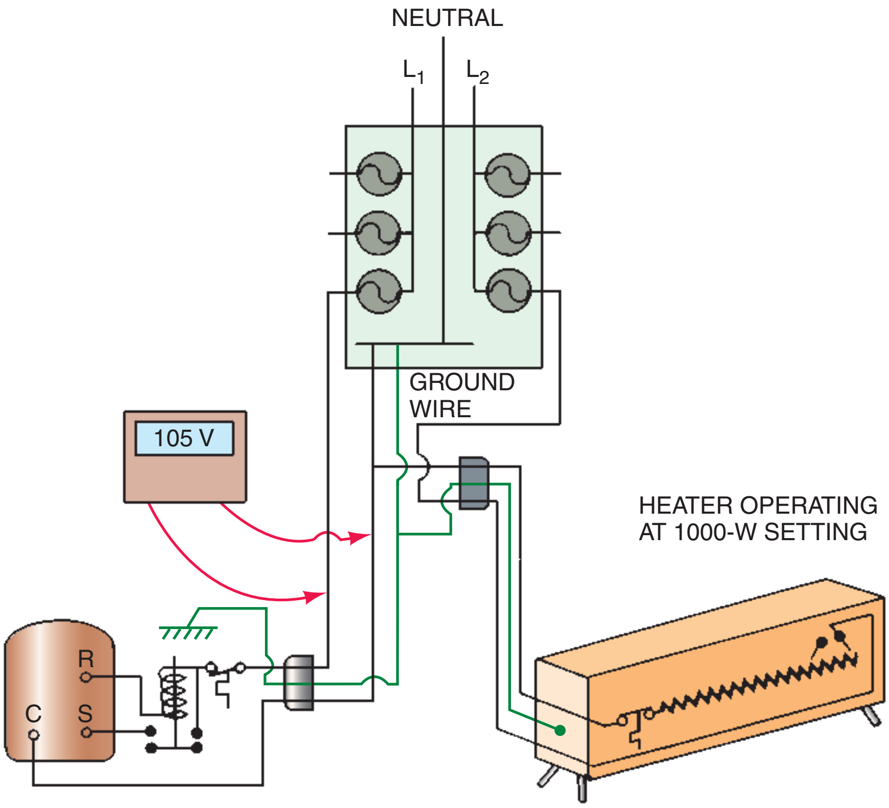


Figure 46–76 When the heater is moved to a new circuit, the freezer is operating at 105 V, which is a little low but is the best that can be done here.

rated voltage of 115 − 11.5 = 103.5 V. A minimum voltage of 103.5 V can be used. Before, when the freezer and the heater were in the circuit at the same time, it would not start.

The technician replaces the 20-A fuse with a 15-A fuse and advises the owner that an electrician should be consulted to rework the electrical system in the house. The owner did not realize the circuits were operating at near capacity.

SUMMARY

- Freezers are different from refrigerators because they operate only as low-temperature refrigeration systems.
- Freezers must be level.
- Domestic freezer cabinet boxes may be of an upright design with the doors swinging out or a chest-type with a lid that raises.
- These freezers are designed to operate in normal household temperatures and should not be located where temperatures reach hot or cold extremes.
- Door gaskets must remain tight fitting, or air leaks will occur, causing the compressor to run excessively and frost to build up inside the cabinet.
- Many freezers have manual defrost because the doors are not opened as often, and defrost is not needed as frequently.
- Plate-type evaporator design uses the evaporator as a shelf, and another type uses the wall of the interior of the box as the evaporator plate.
- Compressors can be rotary or reciprocating.
- The capillary tube is the typical metering device for domestic freezers.
- The condenser should be able to condense refrigerant at 25°F to 35°F higher than the ambient air. The more efficient the condenser, the closer the condensing temperature is to the air passing over it.
- Compressors are air or refrigerant cooled. An air-cooled compressor typically will have fins.
- Normally a wiring diagram is fastened to the back of the cabinet. This should be studied before you service the freezer.
- When servicing the freezer, check the forced-draft evaporator and condenser fans to ensure that they are operating properly.
- If food has spoiled, odor may be a problem. If the insulation is fiberglass and has been saturated, it is possible the odor cannot be eliminated.
- Before a freezer is moved, the food must be removed and placed where it will stay frozen.

REVIEW QUESTIONS

1. The process of ice changing from a solid to a vapor is known as
   A. freezer burn.
   B. vaporization.
   C. sublimation.
   D. solarization.

2. Upright freezers are generally ________ (more or less) efficient than a chest-type box.

3. Three types of evaporators that may be found in a household freezer are ________, ________, or a ________.

4. The compressor in a household freezer may be a reciprocating or a ________ type.

5. Home freezers are air-cooled and may have ________ or ________ type condensers.

6. Using the temperature/pressure chart in Unit 3, the psig for R-12 at −5°F would be ________.

7. Using the temperature/pressure chart in Unit 3, the psig for R-134a at −10°F would be ________.

8. The condenser should be able to condense refrigerant at ________ °F above the ambient air in the house.
   A. 5–15
   B. 15–25
   C. 25–35
   D. 35–45

9. The three common refrigerants used for home freezers are ________, ________, and ________.

10. Domestic freezers are ________ or ________ cooled.

11. If the compressor has liquid refrigerant returning to it, it will ________ on the side.
   A. be hot
   B. be warm
   C. sweat

12. Some freezers may have ________ heaters to prevent sweat on the cabinet.

13. If a forced-draft evaporator fan motor is wired in parallel with the compressor, when will it run?

14. Forced-draft condensers are typically used with units that have ________ defrost.
   A. automatic
   B. manual

15. When the air temperature in a domestic freezer is 0°F, the plate-type evaporator temperature may be as low as
   A. −18°F.
   B. −12°F.
   C. −6°F.
   D. 0°F.

16. How does the compressor that is operating normally feel to the touch?

17. What is a typical problem with evaporator fan motors?

18. What are two controls located on a freezer that doesn't have automatic defrost?

19. ________ ________ is a substance that may be used to keep food frozen while a component is being replaced on a freezer.

SECTION 9

Domestic Appliances

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 with 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.

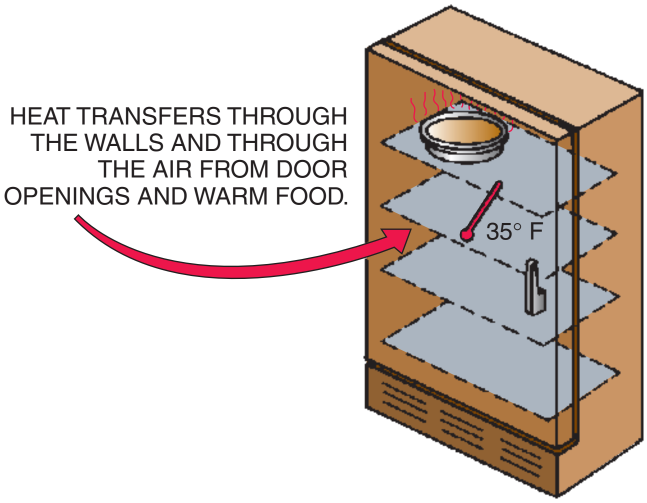


Figure 45–1 Warm food brings heat into the refrigerator.

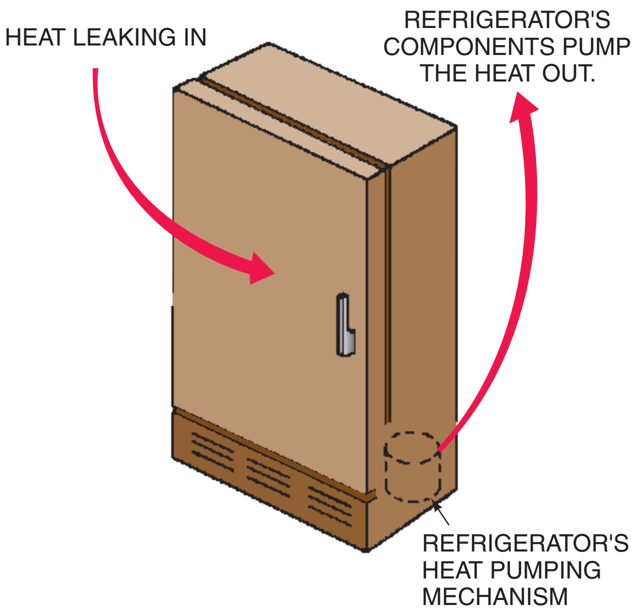


Figure 45–2 The refrigeration cycle moves the heat from the refrigerated box to the room, where it makes little or no difference.

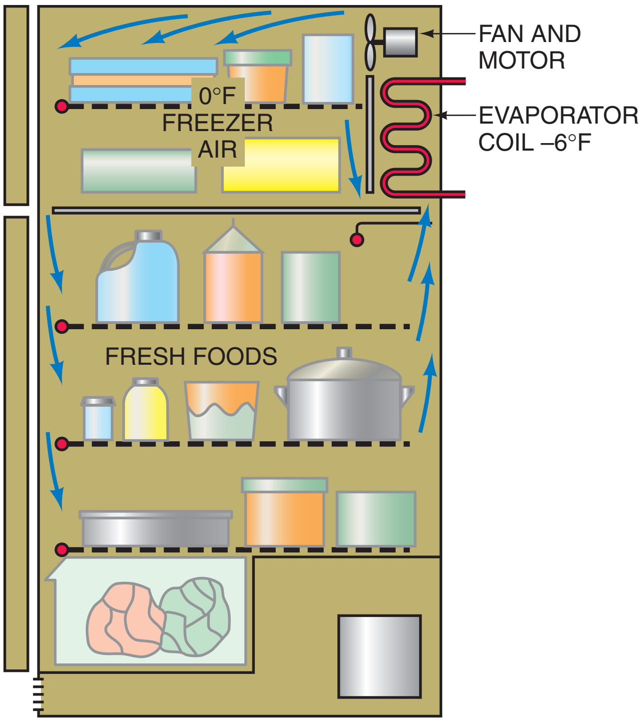


Figure 45–3 Air gives up heat to the cold coil.

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

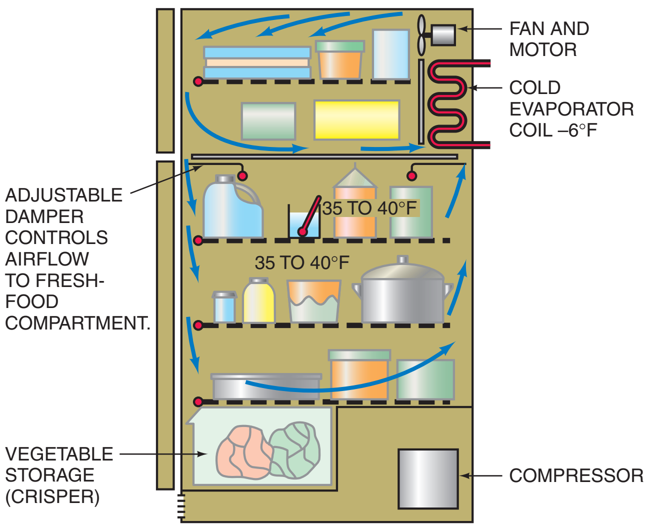


Figure 45–4 Cold air enters the box from the coil.

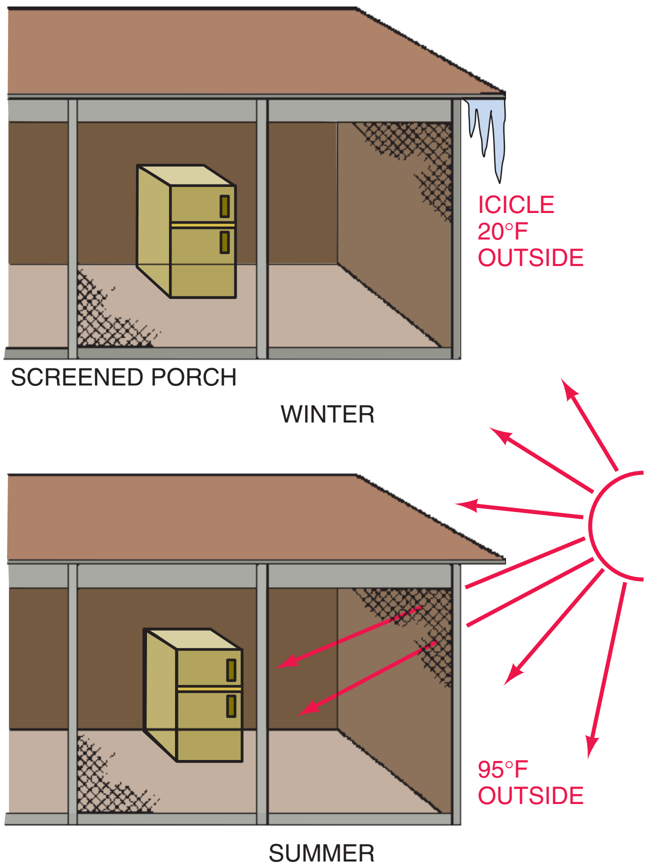


Figure 45–5 The ambient temperature for these refrigerators is not within their proper operating range.

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.**

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 accomplished 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.

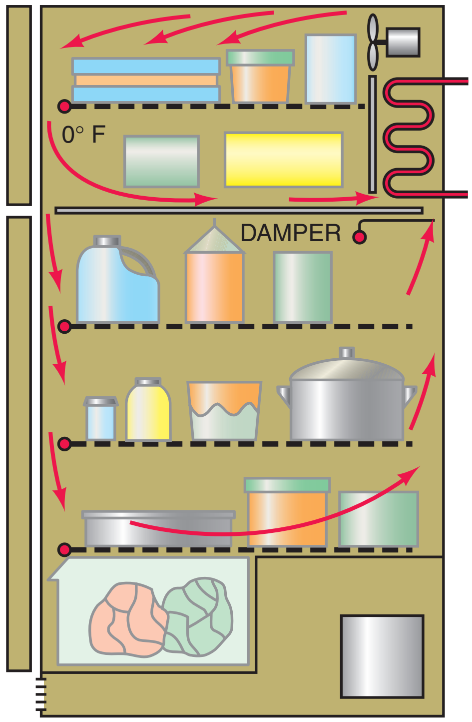


Figure 45–6 Air flows inside the refrigerated box from the low-temperature compartment to the medium-temperature compartment.

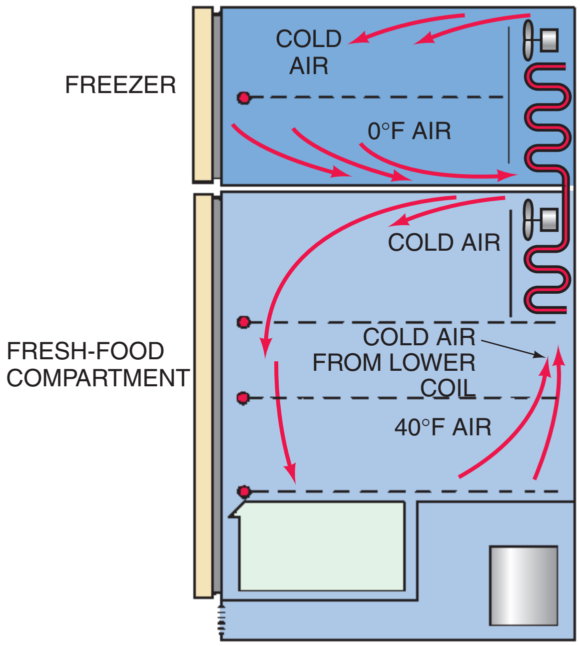


Figure 45–7 A two-evaporator box.

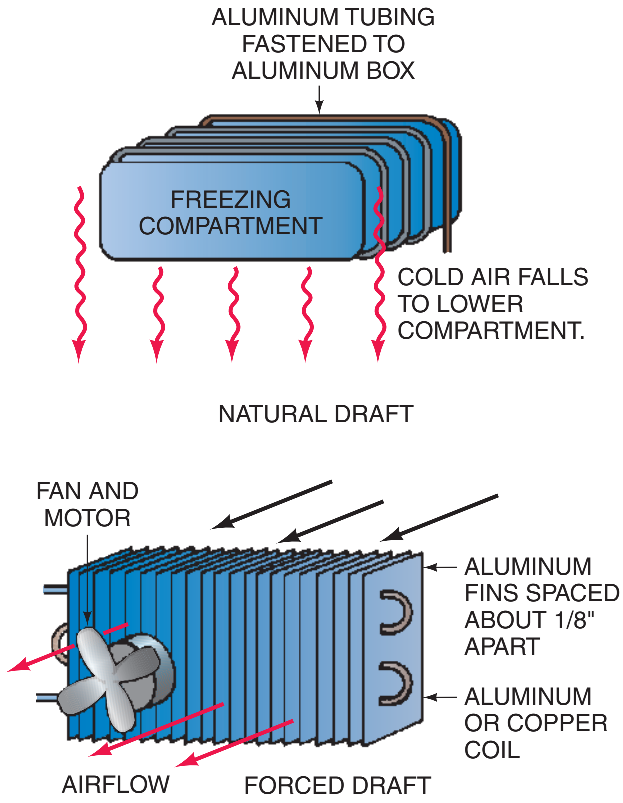


Figure 45–8 Natural-draft and forced-draft evaporators.

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

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

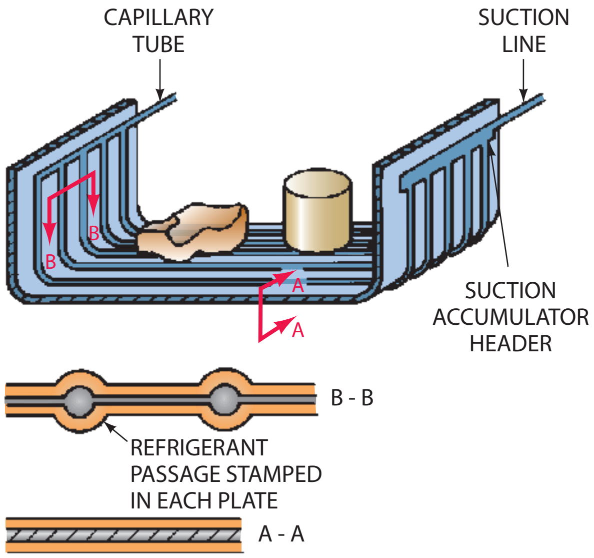


Figure 45–9 A stamped-plate evaporator.

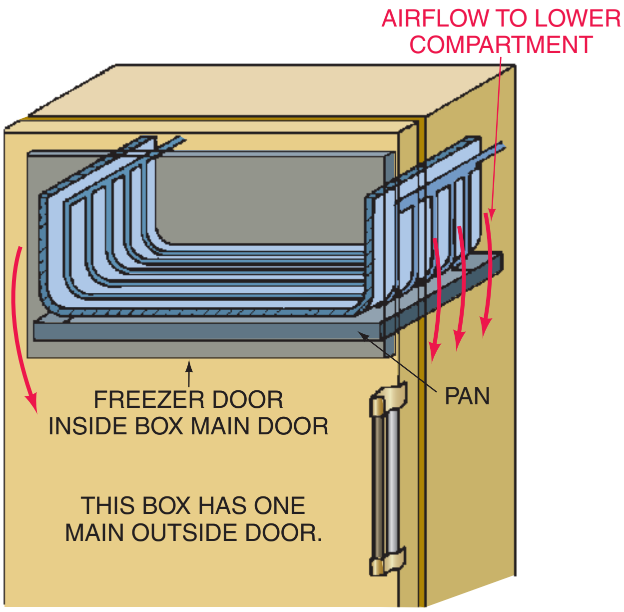


Figure 45–10 Air flows to the fresh-food compartment from the flat-plate evaporator.

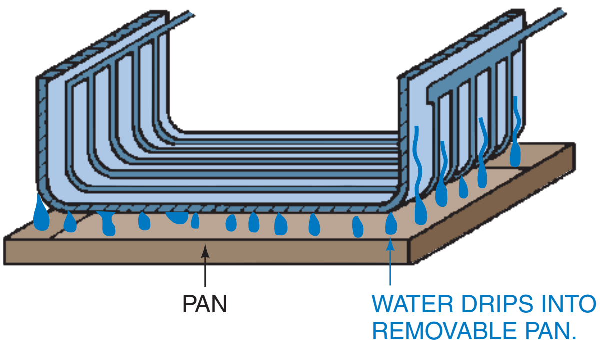


Figure 45–11 Manual defrost.

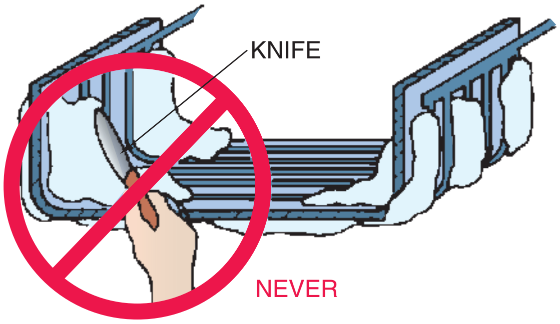


Figure 45–12 Sharp objects may puncture the evaporator. SAFETY PRECAUTION: Do not use sharp objects to chip frost and ice.

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.**

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

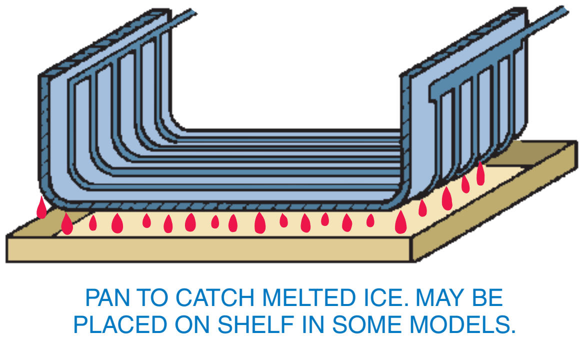


Figure 45–13 Melted ice (condensate) is caught in the pan.

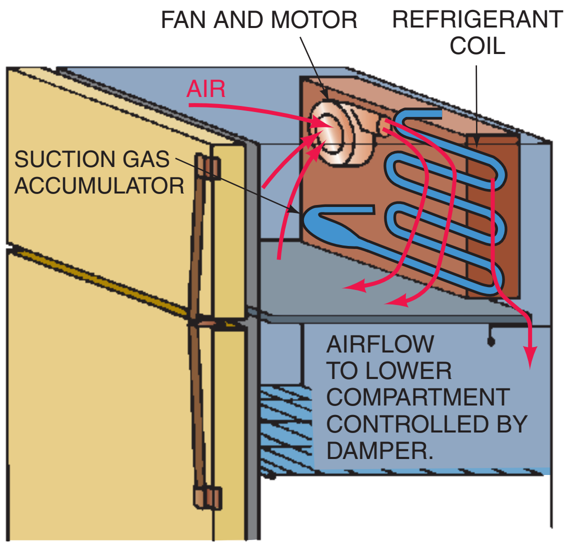


Figure 45–14 A forced-draft evaporator.

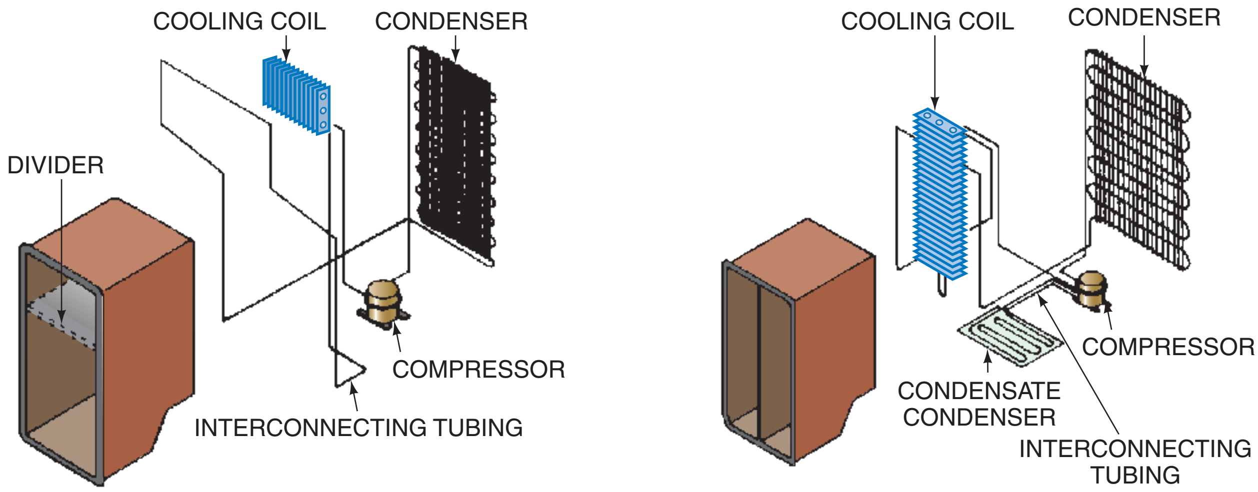


Figure 45–15 Typical evaporator locations in a refrigerator. *Courtesy White Consolidated Industries, Inc.*

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.

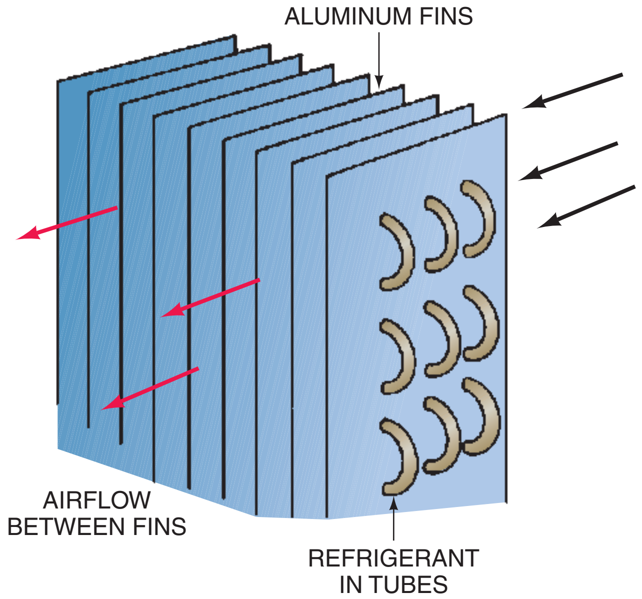


Figure 45–16 A forced-draft evaporator and fin spacing.

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.**

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."

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.**

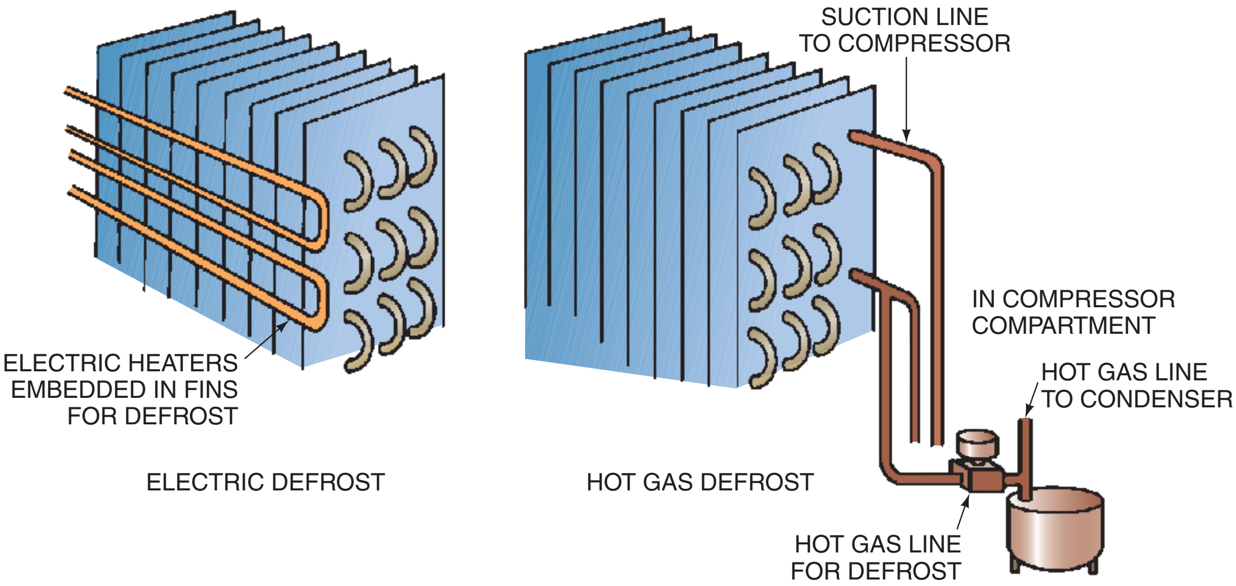


Figure 45–17 Electric and hot gas defrost.

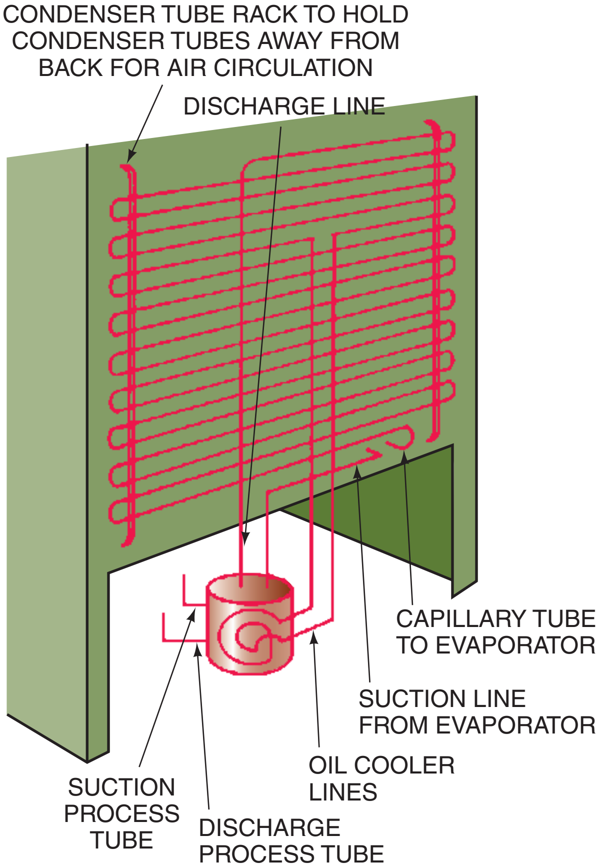


Figure 45–18 An illustration of a compressor and related piping at the refrigerator.

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

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

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

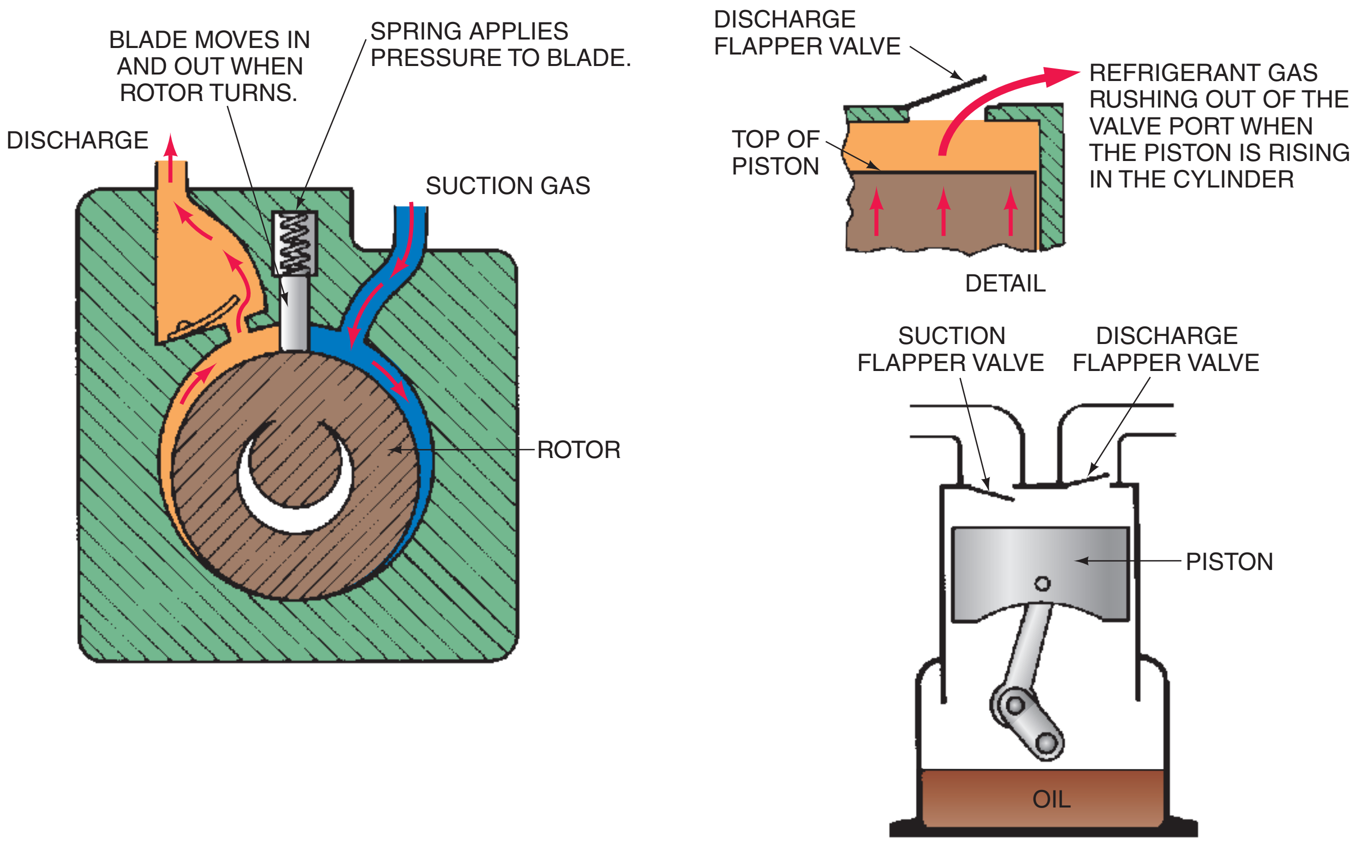


Figure 45–20 Rotary and reciprocating compressor action.

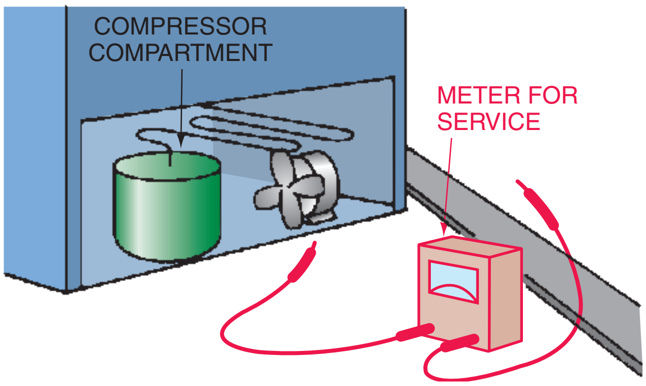


Figure 45–21 The refrigerator is moved from the wall to service the compressor.

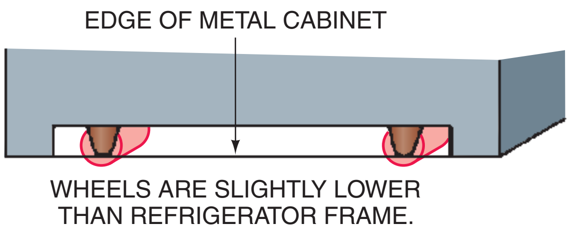


Figure 45–22 Wheels on a modern refrigerator.

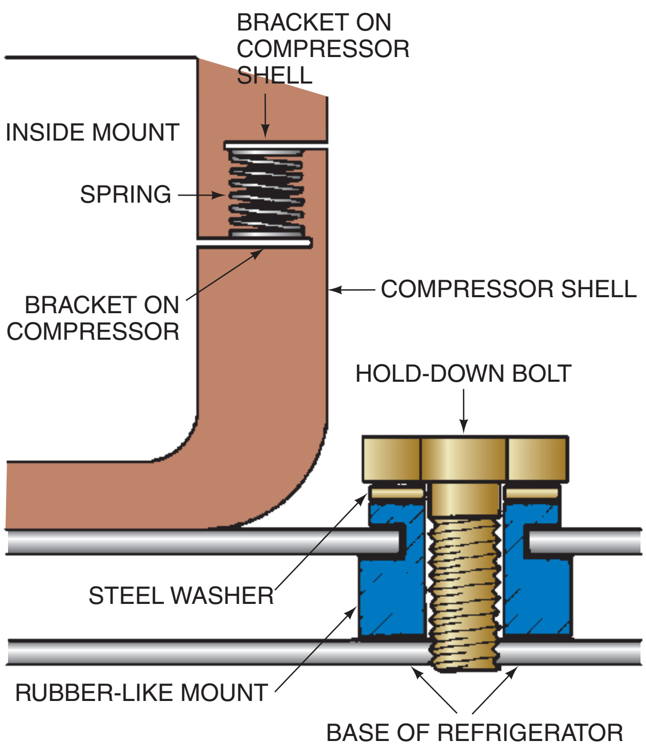


Figure 45–23 A compressor mount.

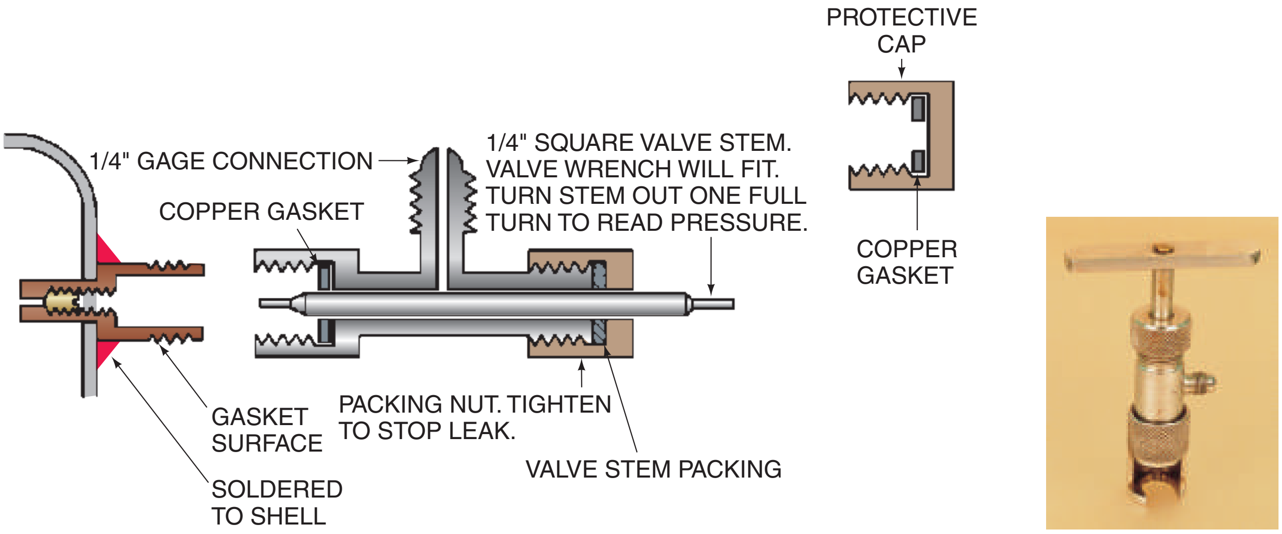


Figure 45–24 A special service port valve. ***(B)*** *Photo by Bill Johnson*

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 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 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 the 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 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.

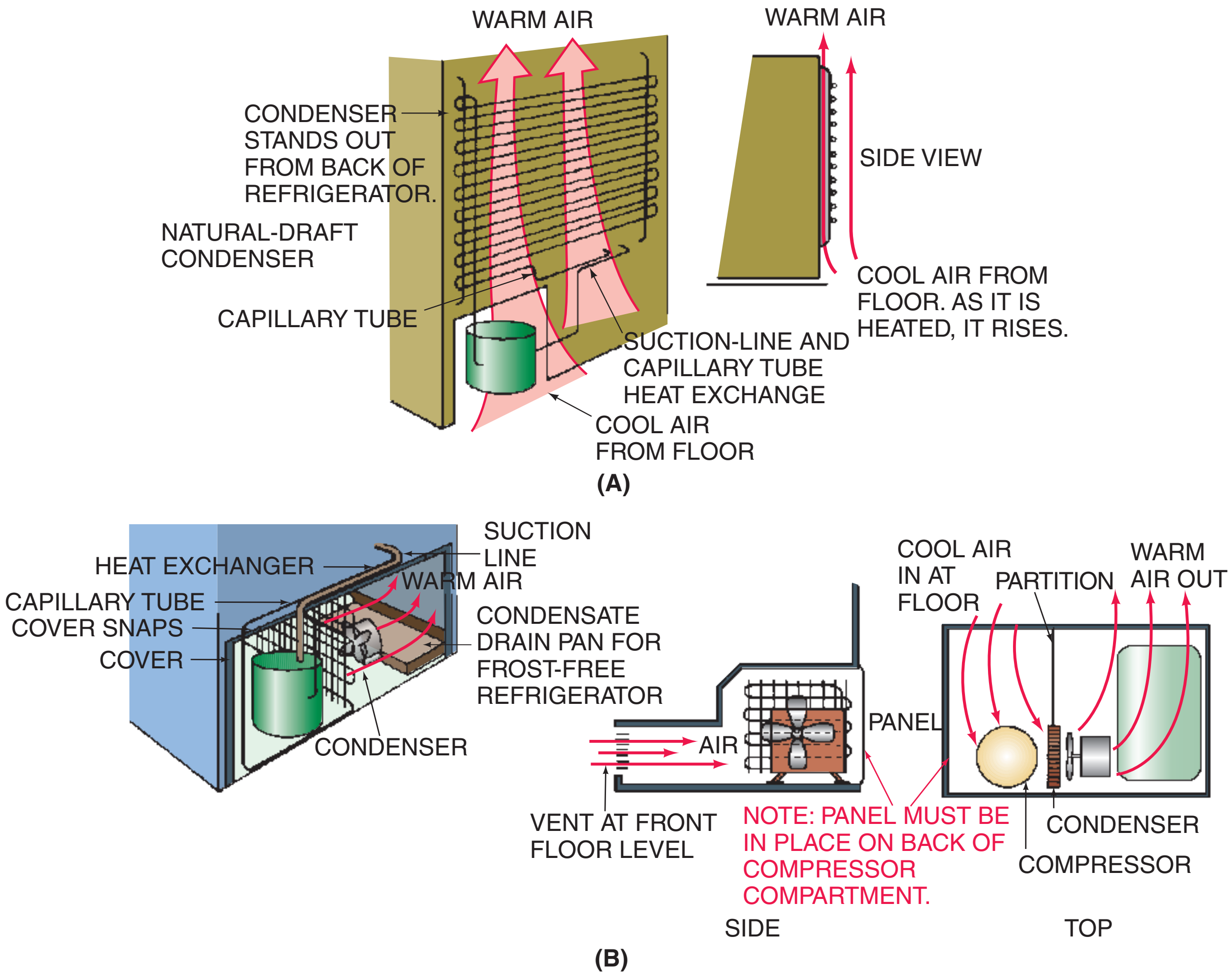


Figure 45–25 **(A)** Natural- and **(B)** forced-draft condensers.

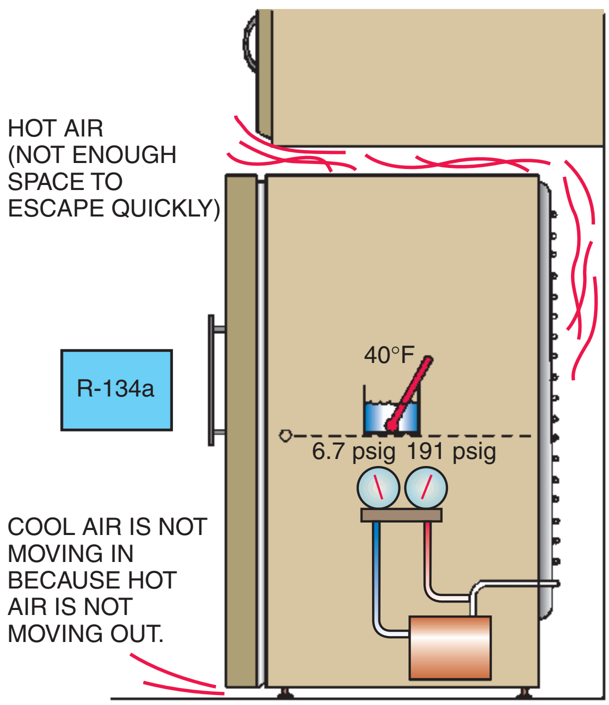


Figure 45–26 A unit running all the time due to poor location.

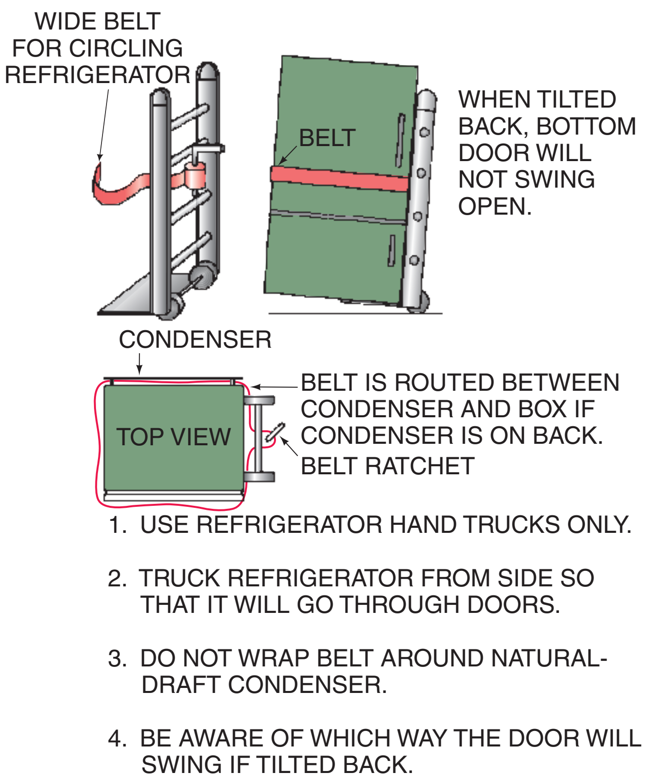


Figure 45–27 Care should be used when moving a refrigerator.

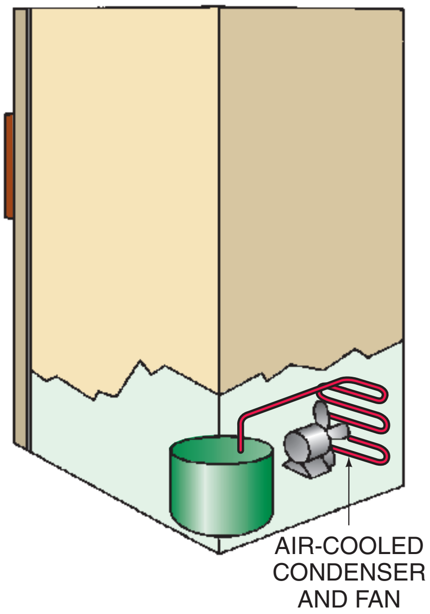


Figure 45–28 Location of a forced-draft condenser.

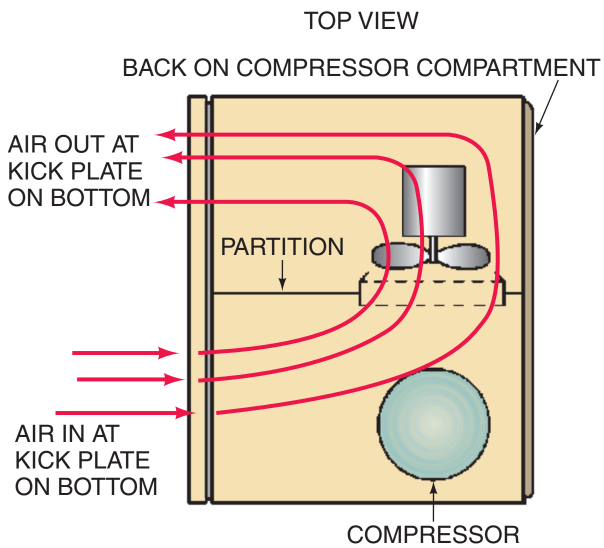


Figure 45–29 Airflow of a forced-draft condenser.

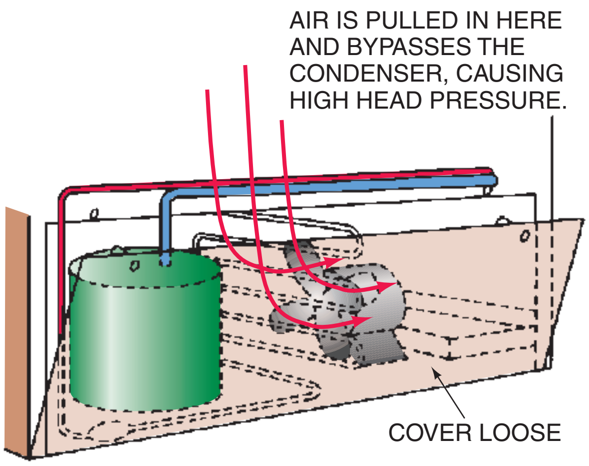


Figure 45–30 Cardboard partitions. Be sure to replace all cardboard partitions on a forced-draft condenser.

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 hours.

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.

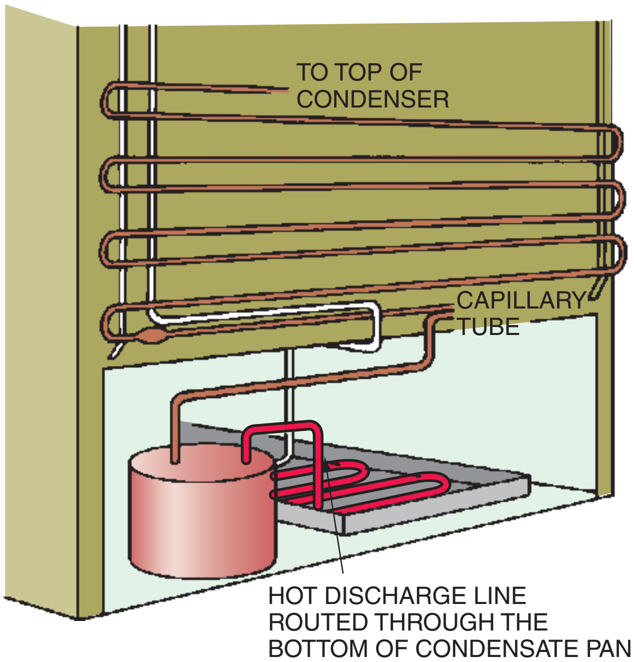


Figure 45–31 Compressor heat used to evaporate condensate.

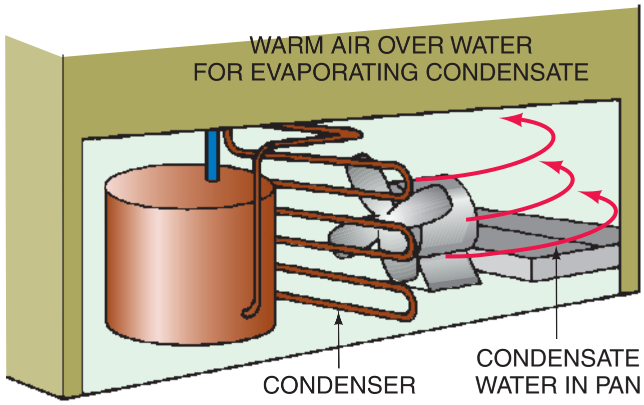


Figure 45–32 Warm air from the condenser used to evaporate condensate.

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.**

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.**

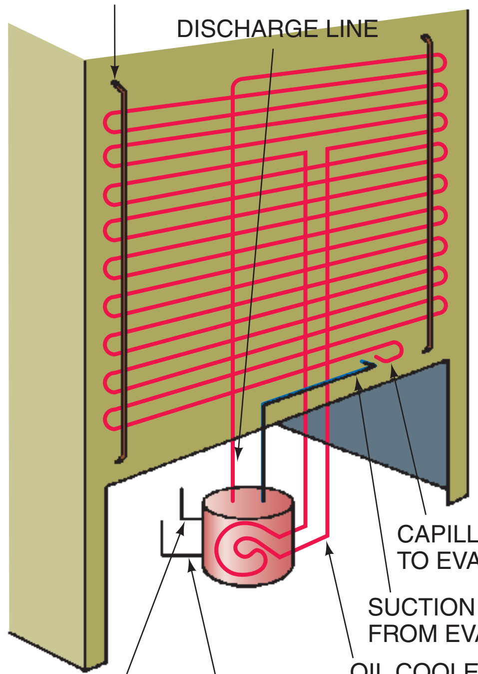


Figure 45–33 The oil cooler piping route.

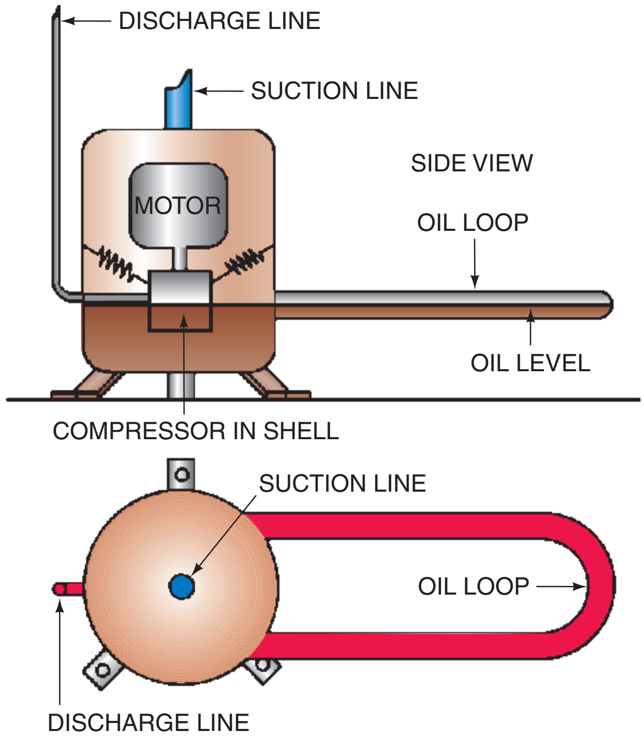


Figure 45–34 A loop for cooling oil.

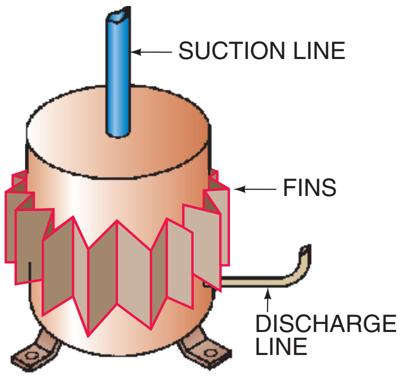


Figure 45–35 Some compressors have fins to cool them.

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.

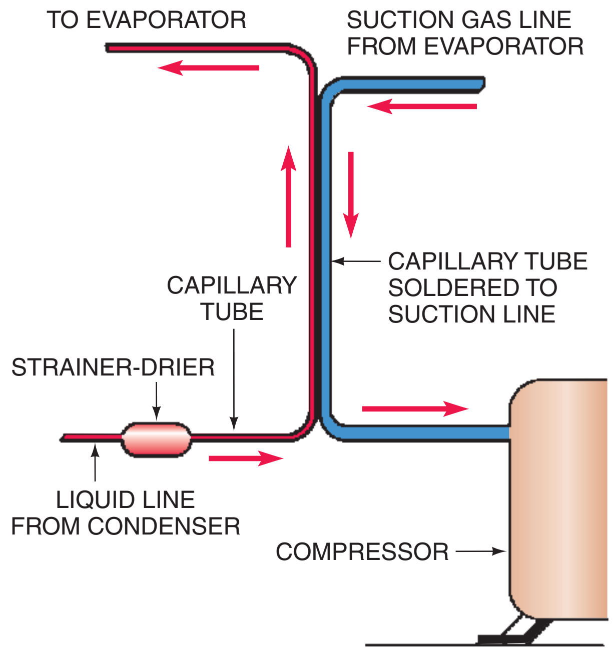


Figure 45–36 The capillary tube fastened to the suction line.

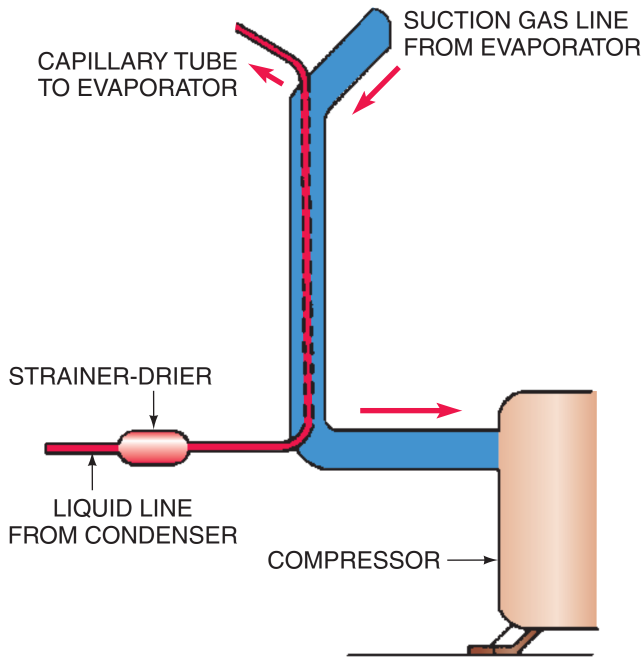


Figure 45–37 The capillary tube routed through the suction line.

Domestic refrigerators and freezers are not intended to be placed outdoors or in buildings where the temperatures vary from 65°F to 95°F—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,

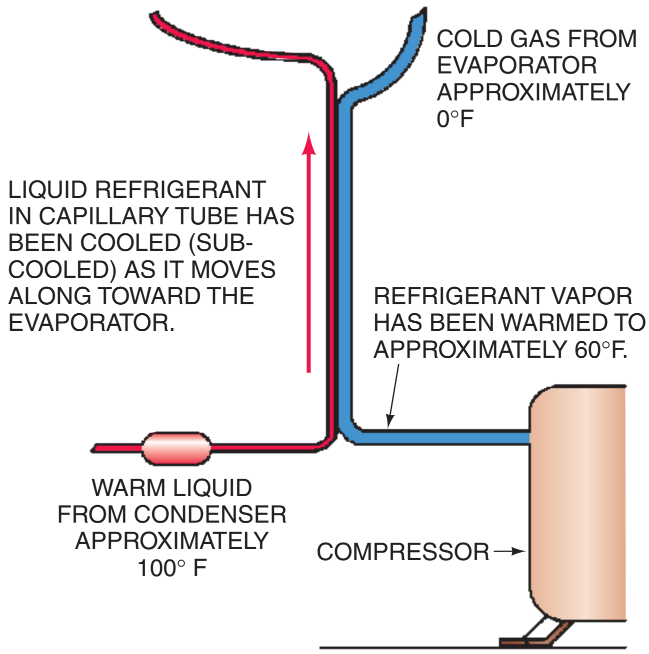


Figure 45–38 Heat exchange between the capillary tube and the suction line.

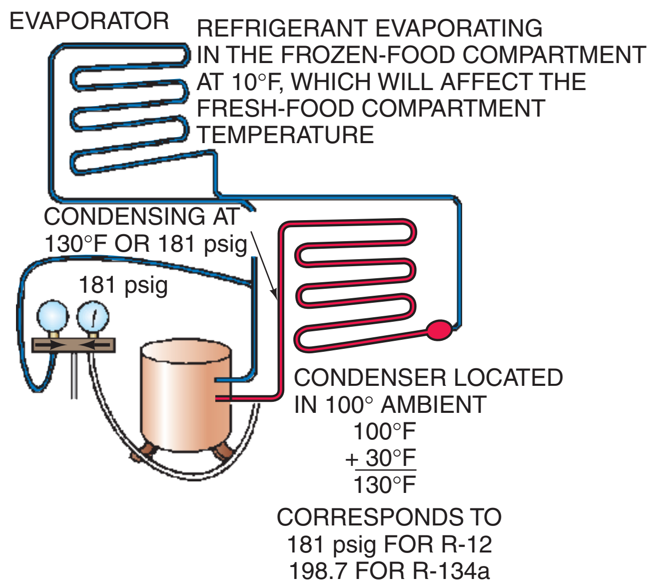


Figure 45–39 The capacity of the refrigerator is reduced by the high ambient temperature.

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

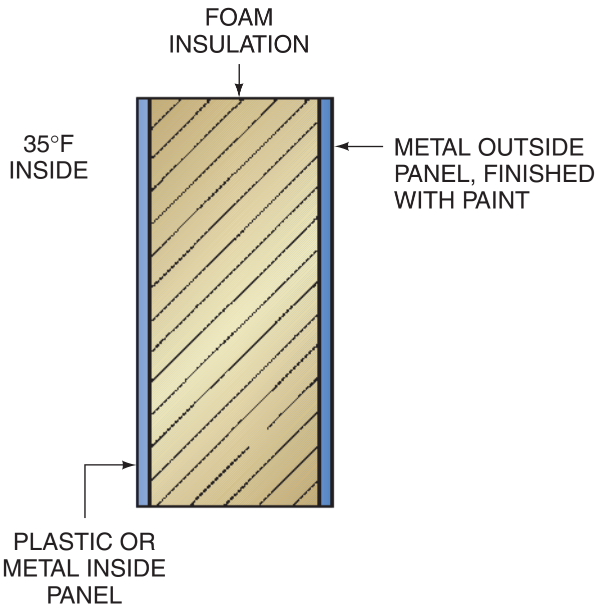


Figure 45–40 Sandwich construction of a refrigerator wall.

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 45–41 A one-door refrigerator. *Photo by Bill Johnson*

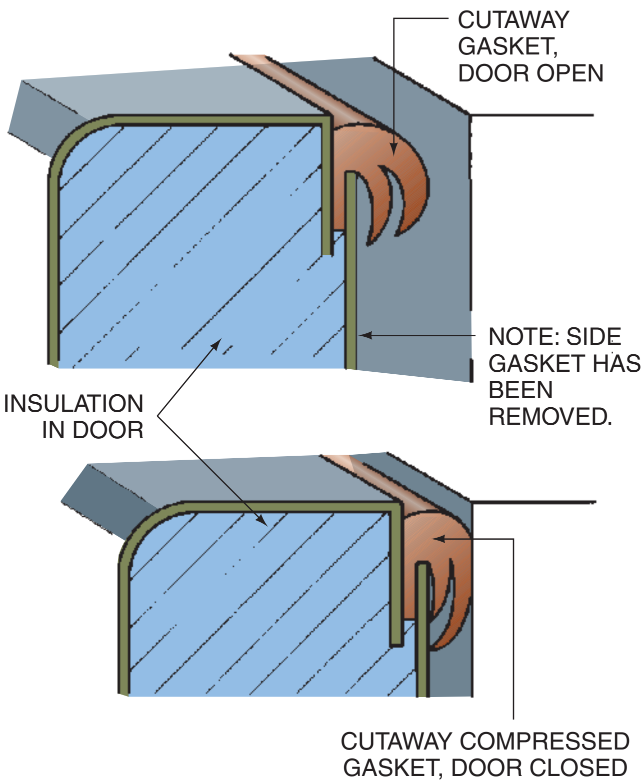


Figure 45–42 Early door gasket construction.

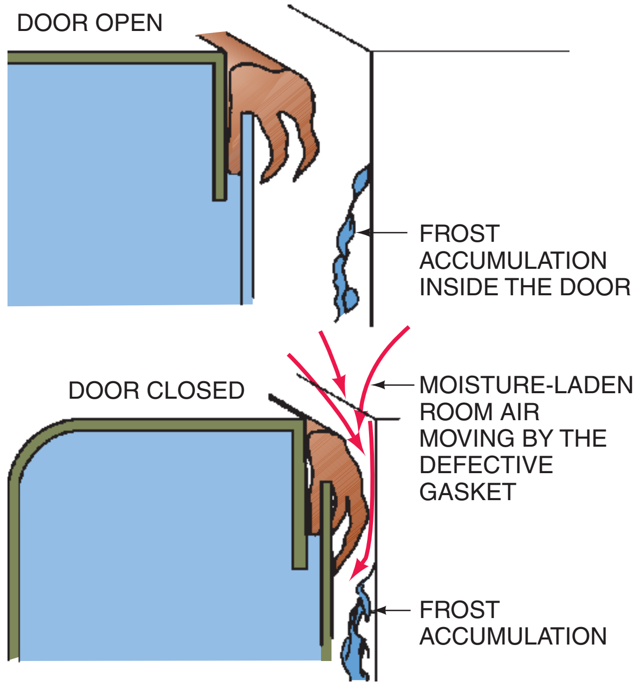


Figure 45–43 An older door gasket that is worn out, causing frost accumulation.

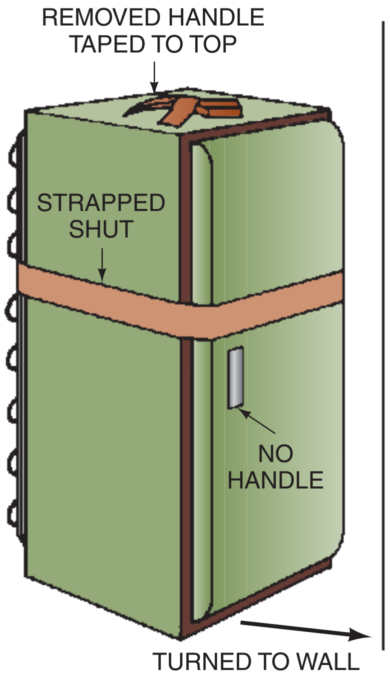


Figure 45–44 SAFETY PRECAUTION: Remove handle, turn to wall, and strap shut old refrigerators for maximum safety.

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.

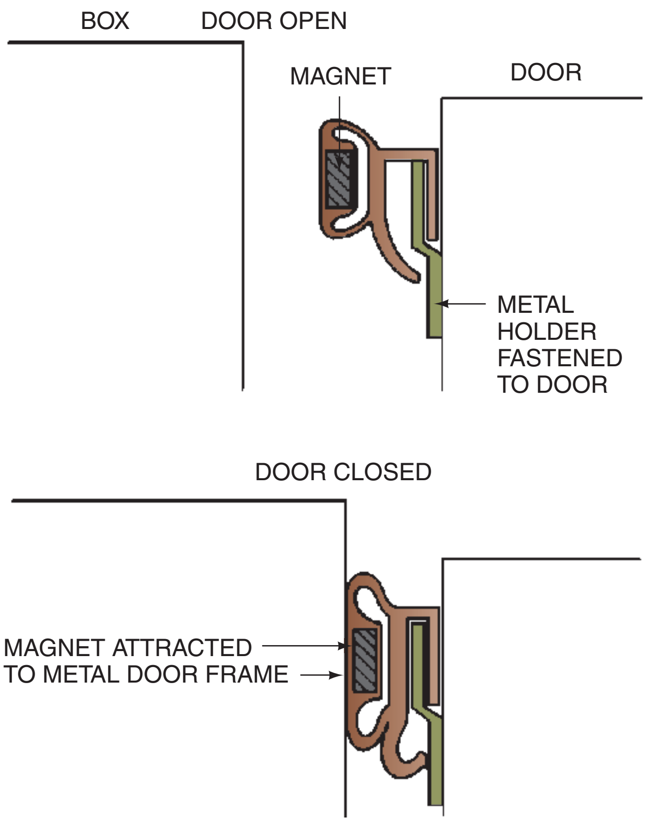


Figure 45–45 A modern refrigerator gasket with a magnet.

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.**

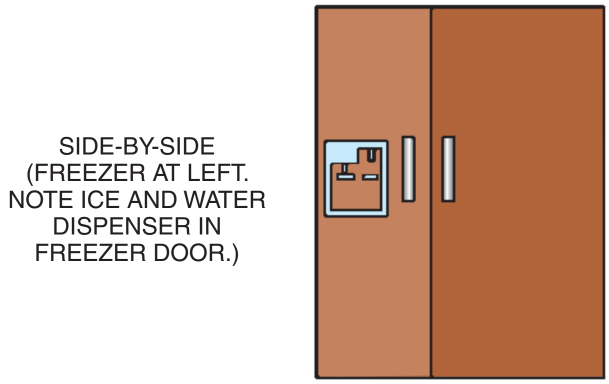


Figure 45–46 The typical side-by-side door arrangement.

Figure 45–47 Single and over-and-under door arrangements. *Photos by Bill Johnson*

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 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 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.

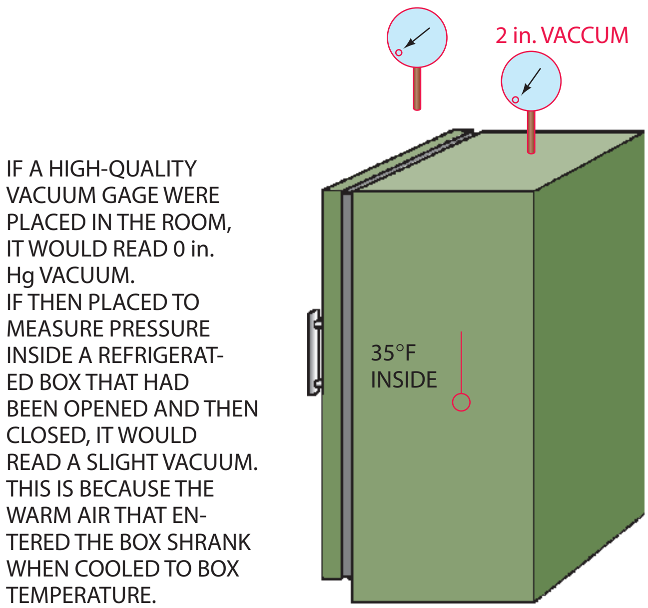


Figure 45–48 Cooled air inside the box may make it hard to open the door immediately after closing.

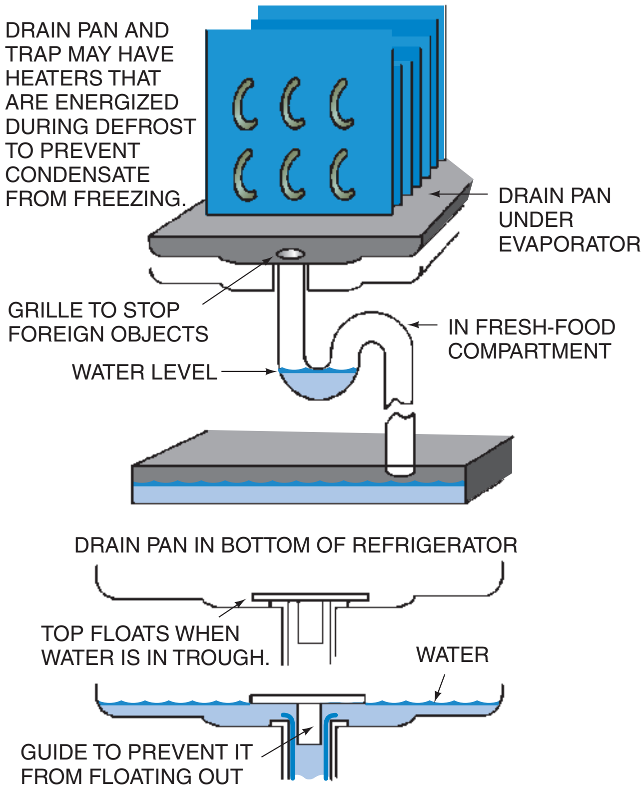


Figure 45–49 Two types of traps to allow condensate to drain and prevent air from entering.

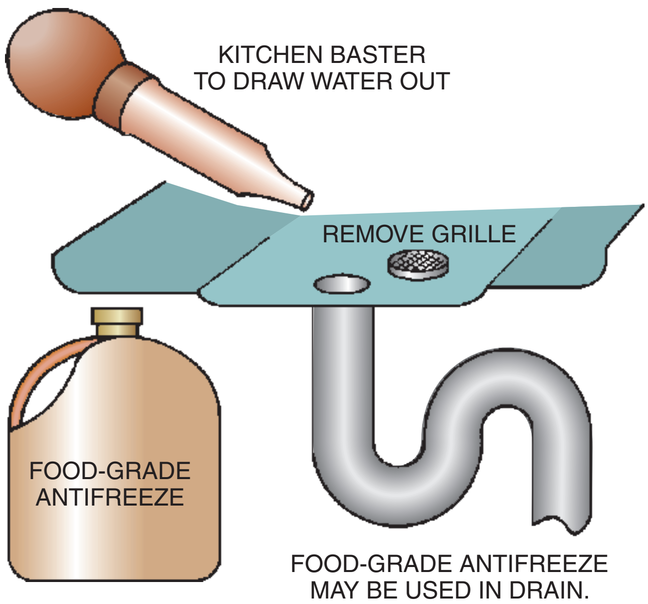


Figure 45–50 Service the drain trap for winter storage, or it may freeze.

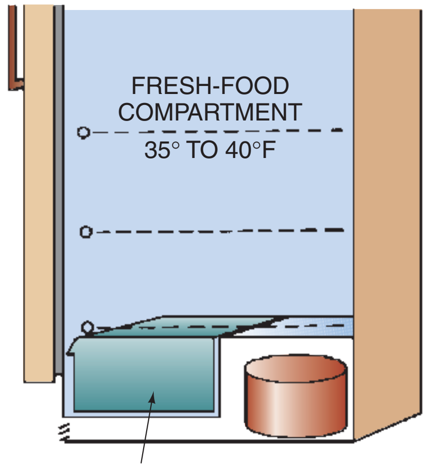


Figure 45–51 A crisper drawer.

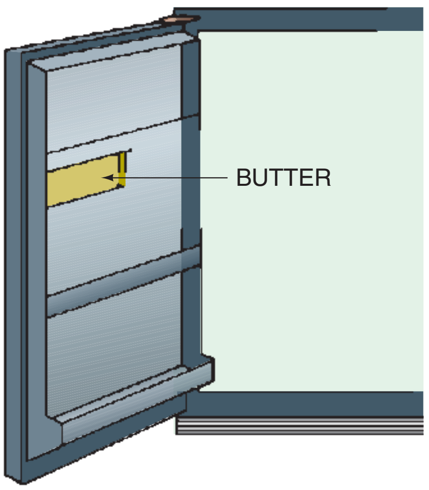


Figure 45–52 A butter warmer compartment.

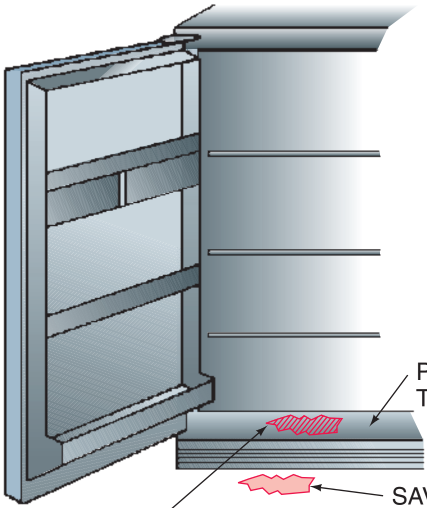


Figure 45–53 This refrigerator has a broken bottom rail.

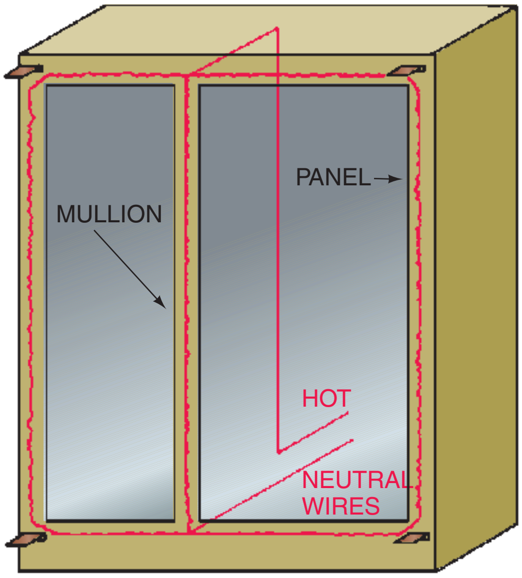


Figure 45–54 Mullion and panel heaters.

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 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.

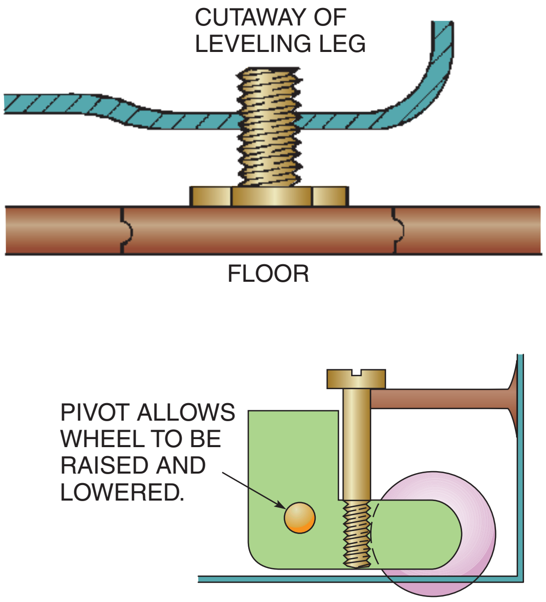


Figure 45–55 Leveling devices for feet or rollers.

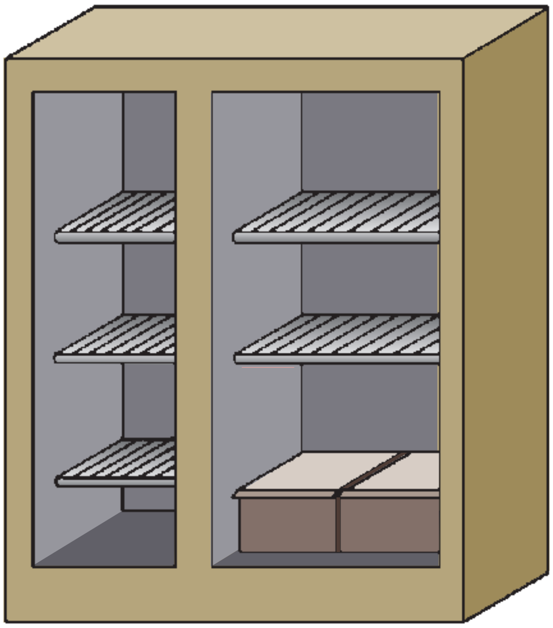


Figure 45–56 Side-by-side refrigerator compartments are narrower.

Figure 45–57 A water and ice dispenser on the outside. *Photo* ***(A)*** *by Bill Johnson. Photos* ***(B)*** *and* ***(C)*** *by John Tomczyk*

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.** 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 the following:

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

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.

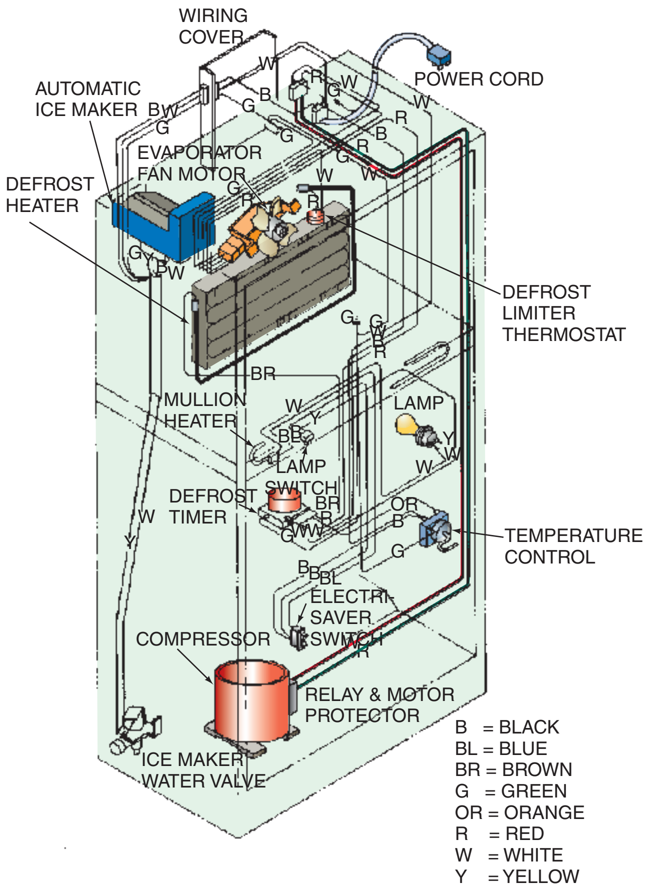


Figure 45–58 A pictorial wiring diagram. *Courtesy White Consolidated Industries, Inc.*

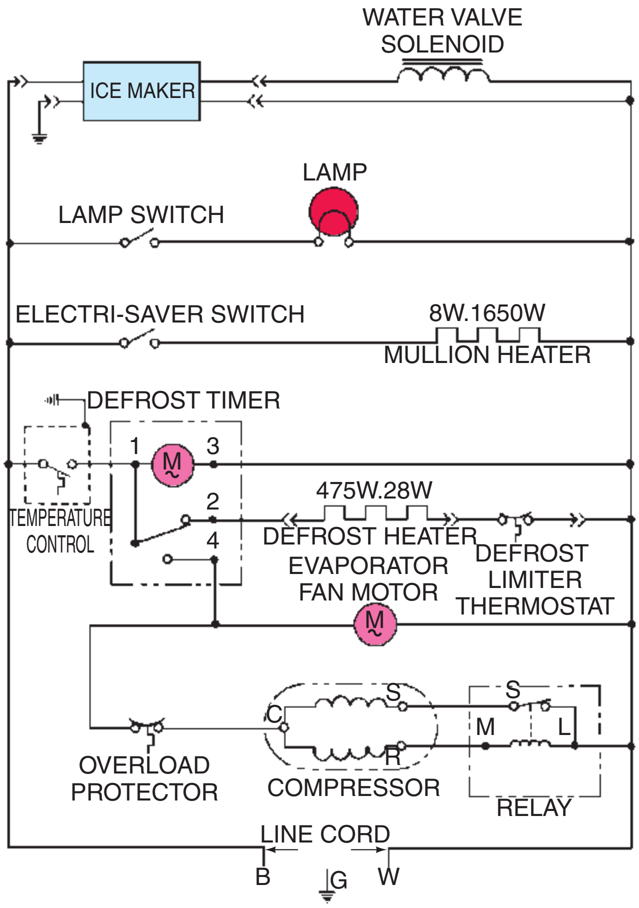


Figure 45–59 A line wiring diagram. *Courtesy White Consolidated Industries, Inc.*

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.

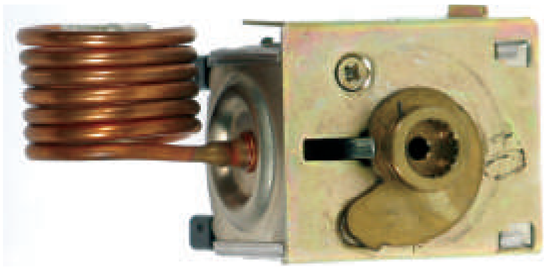


Figure 45–60 The thermostat or cold control. *Photo by Bill Johnson*

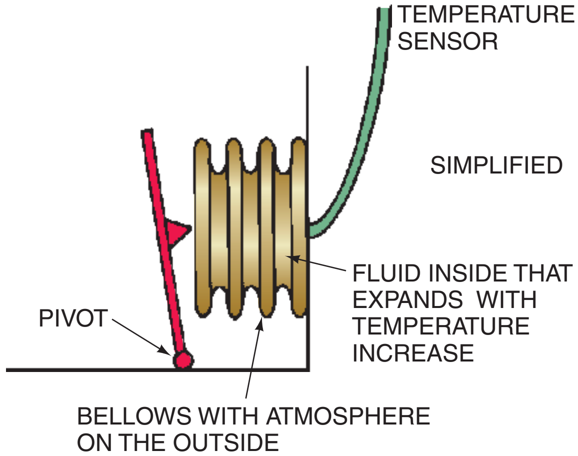
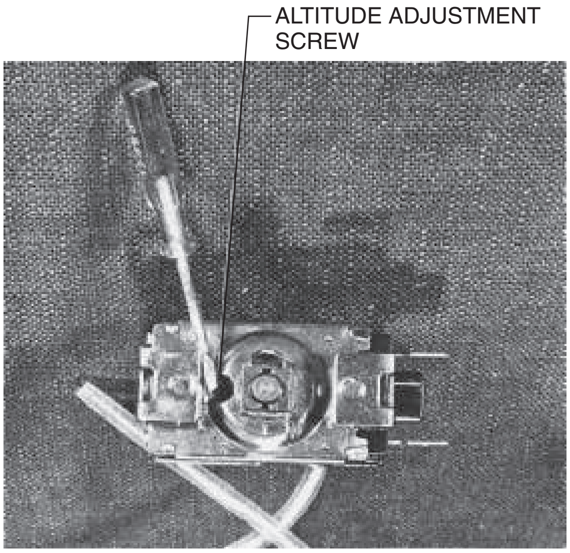


Figure 45–61 Sketch of a thermostat.



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.*

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 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 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

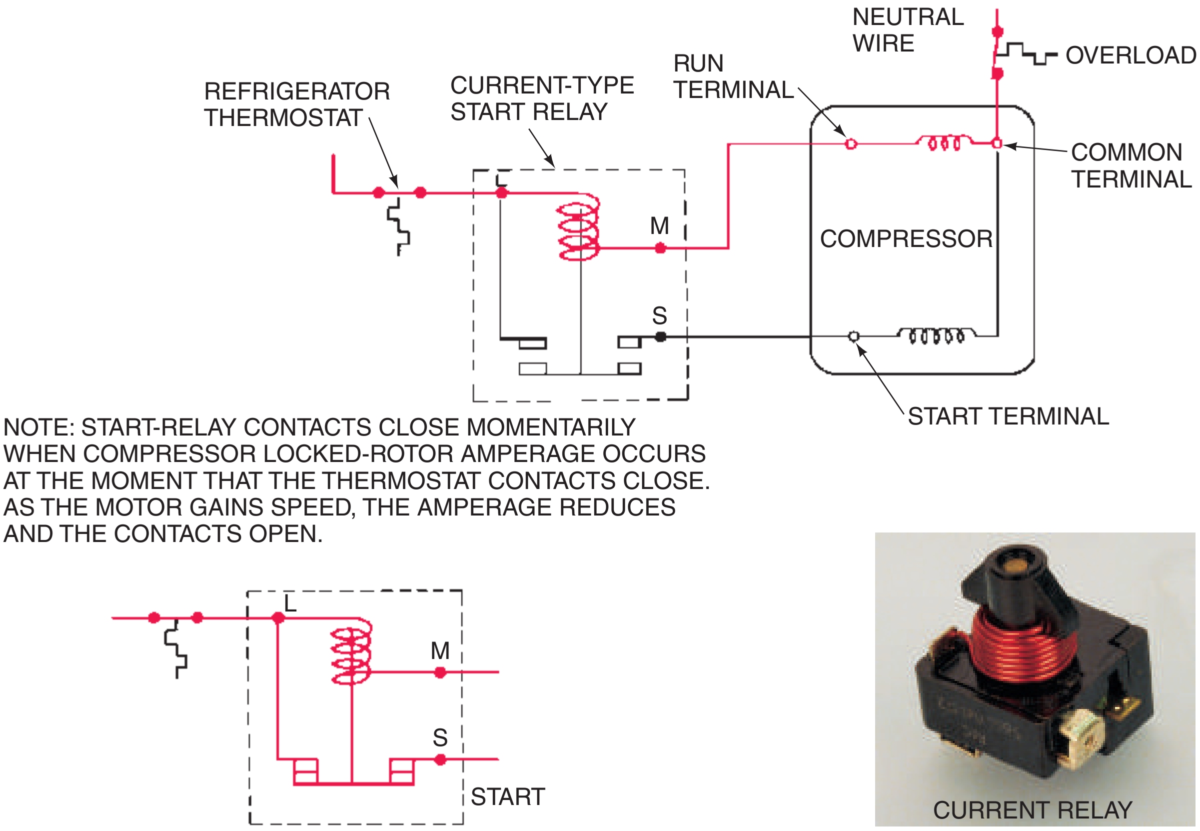


Figure 45–63 The refrigerator compressor start circuit using a current relay. *Photo by Bill Johnson*

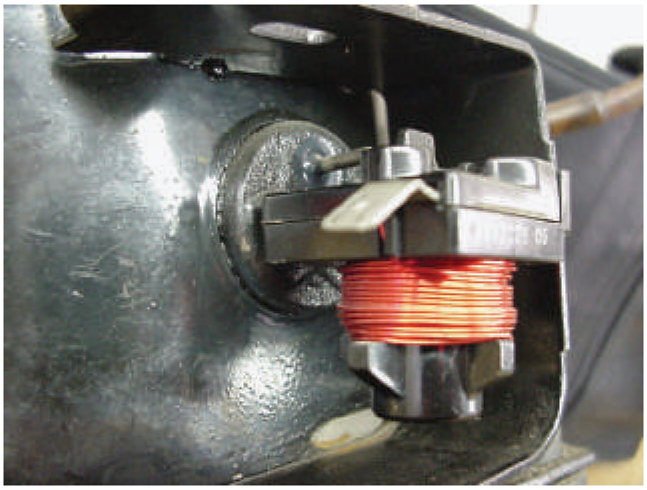


Figure 45–64 This compressor has a current relay that plugs onto the compressor terminals. *Photo by John Tomczyk, Courtesy Ferris State University*

fan stop, and the heaters are energized. This condition is 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 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

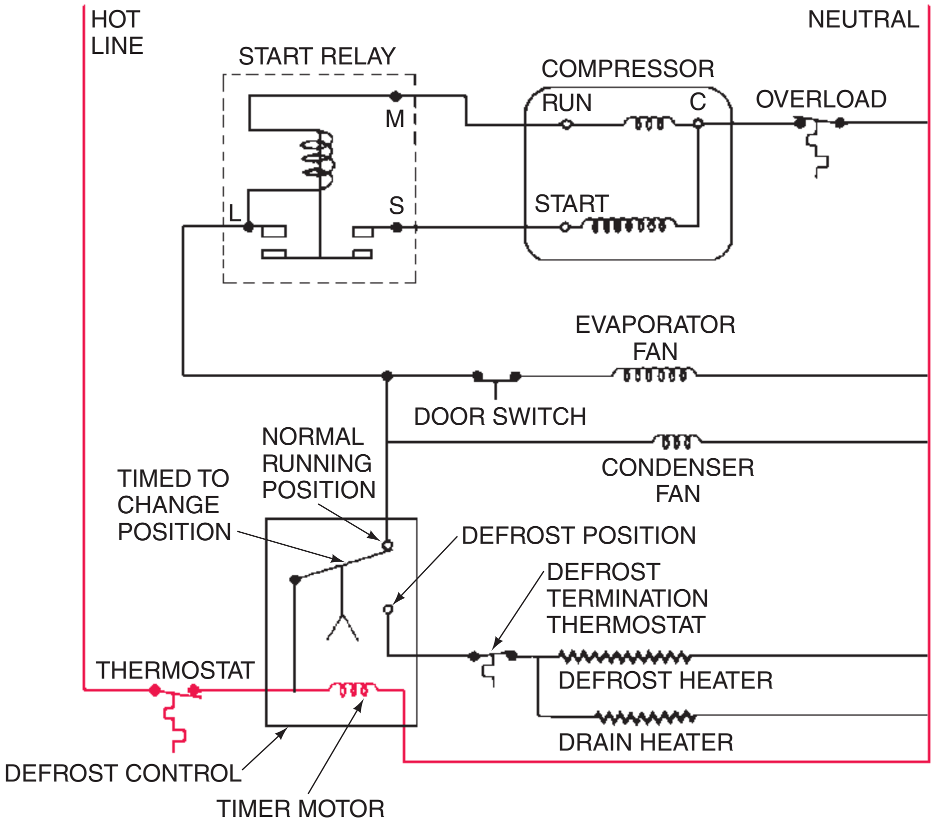


Figure 45–65 Timer wiring for refrigerator defrost.

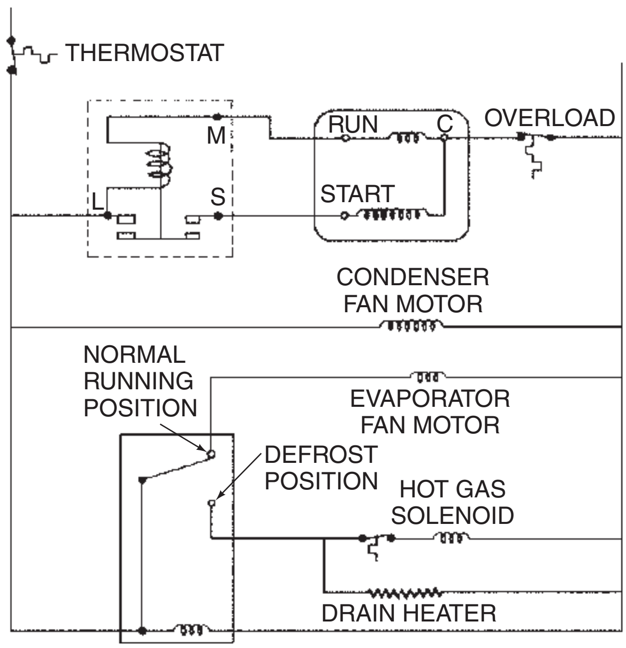


Figure 45–66 A wiring diagram for hot gas defrost.

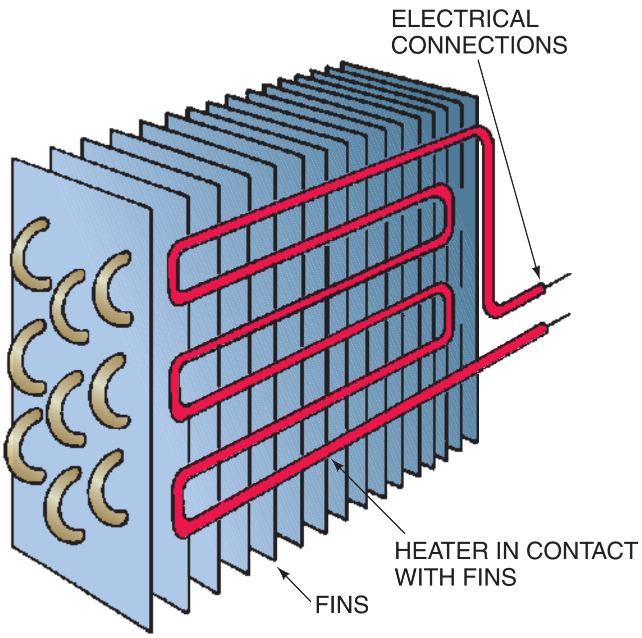


Figure 45–67 Electric heaters for defrost.

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.**

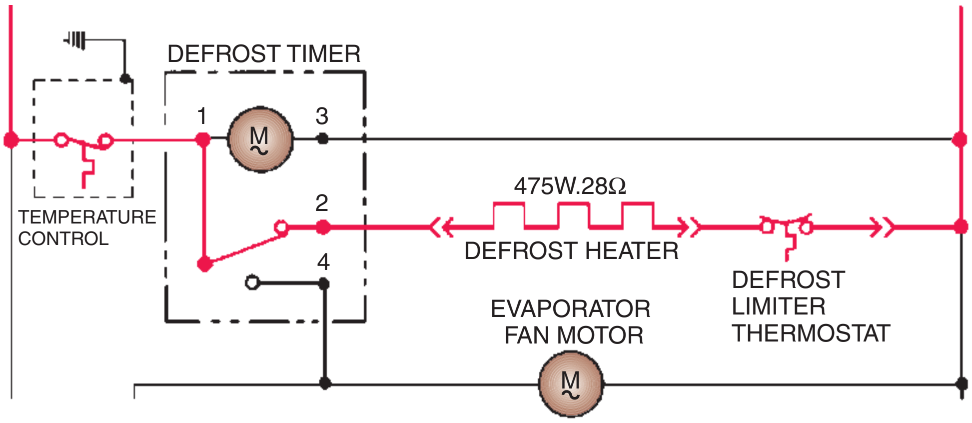


Figure 45–68 Electric heat defrost. *Courtesy White Consolidated Industries, Inc.*

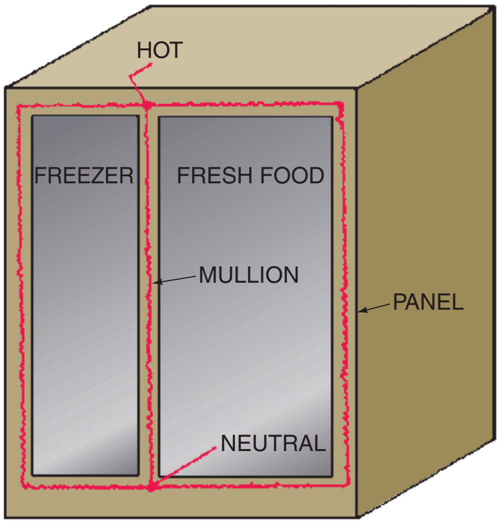


Figure 45–69 Heaters in a refrigerator showing their location.

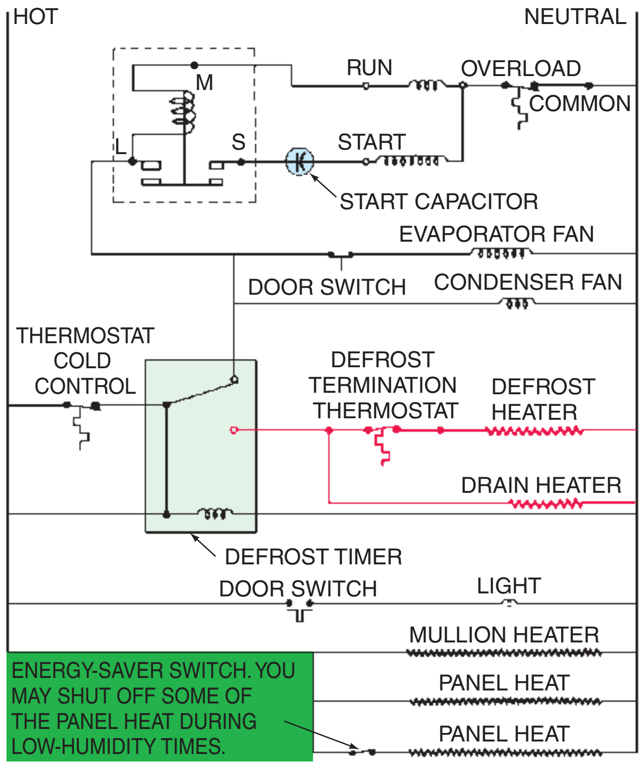


Figure 45–70 This wiring diagram shows the position of the energy-saver switch.

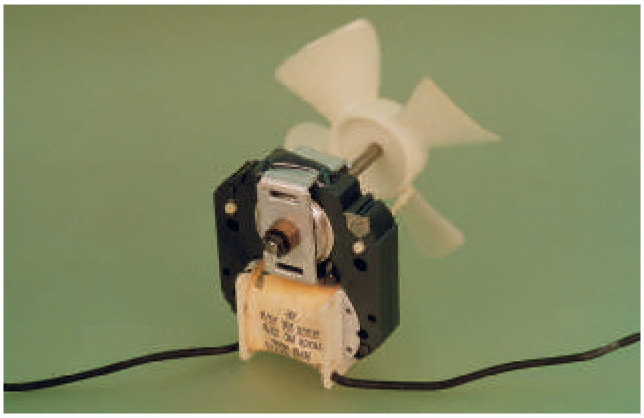


Figure 45–71 An evaporator fan motor. *Photo by Bill Johnson*

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

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

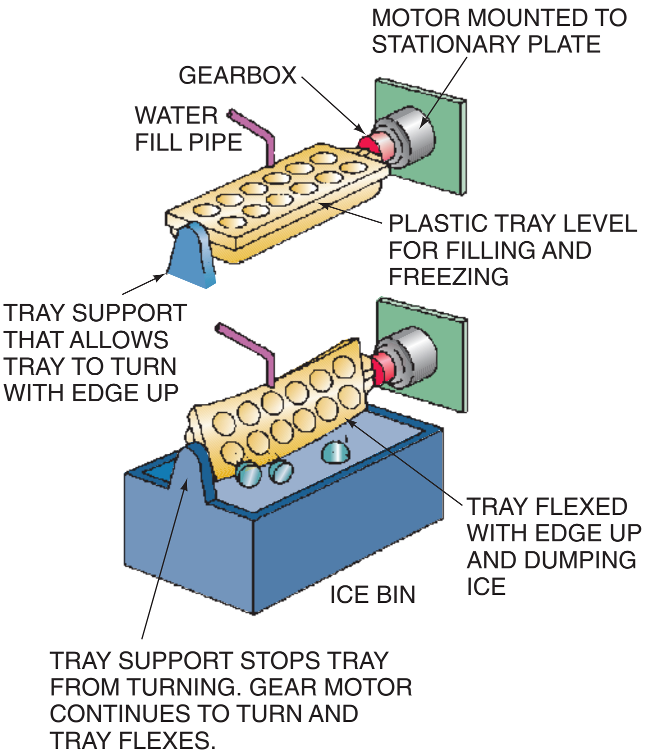


Figure 45–73 Water fills the tray and freezes. At the proper time, ice harvest is accomplished by twisting the plastic tray and dumping the ice into the ice bin.

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.**

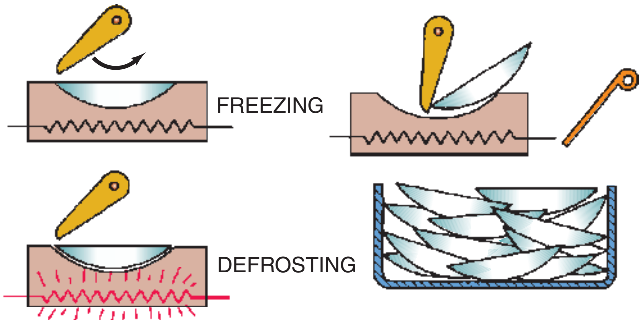


Figure 45–74 The water-filled tray freezes. When the control circuit determines that the water is frozen, the heater energizes. Then the fingers push the ice out of the tray to the storage bin. When the bin is full, the bail switch is moved to the right and will not return; production stops.

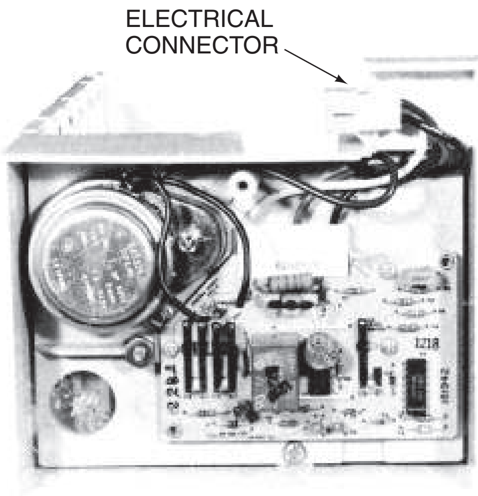


Figure 45–75 An electronic circuit board for an ice maker. *Courtesy White Consolidated Industries, Inc.*

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.**

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 magnetic 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.**

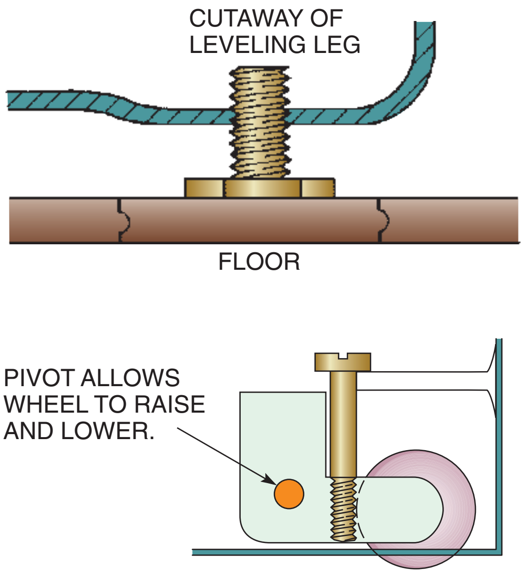


Figure 45–76 Refrigerator leveling devices.

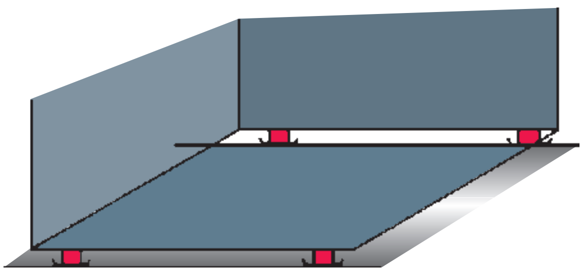


Figure 45–77 All four feet or wheels must be touching the floor.

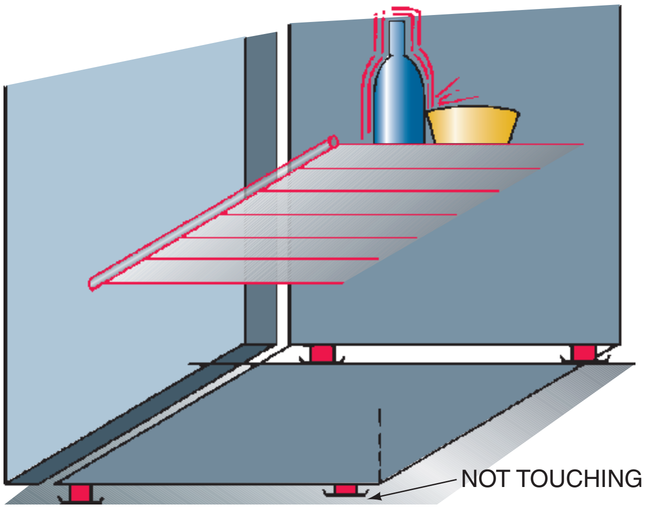


Figure 45–78 If all four contact points are not touching the floor or spacers with equal pressure, vibration will cause noise.

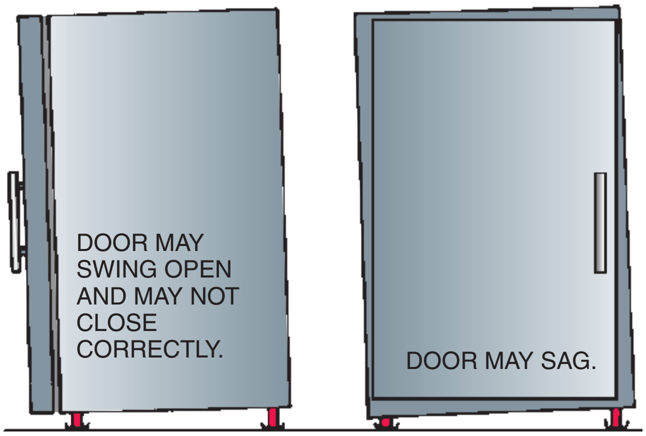


Figure 45–79 If the box is not leveled per the manufacturer's instructions, the doors may not function correctly.

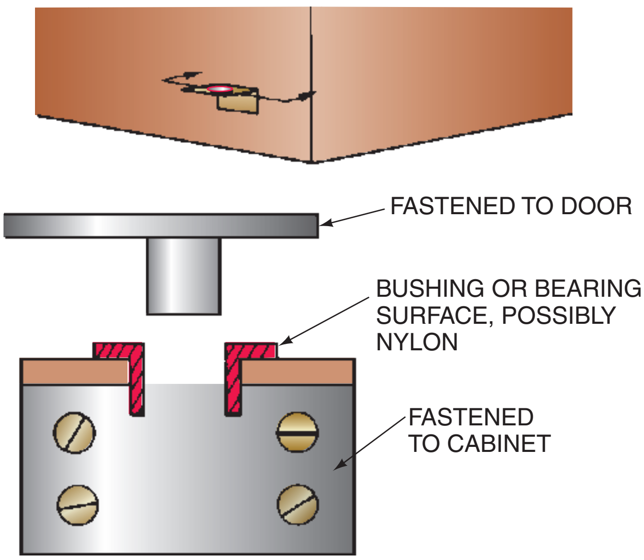


Figure 45–80 Hinges may have bearing surfaces to make door opening easier.

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.**

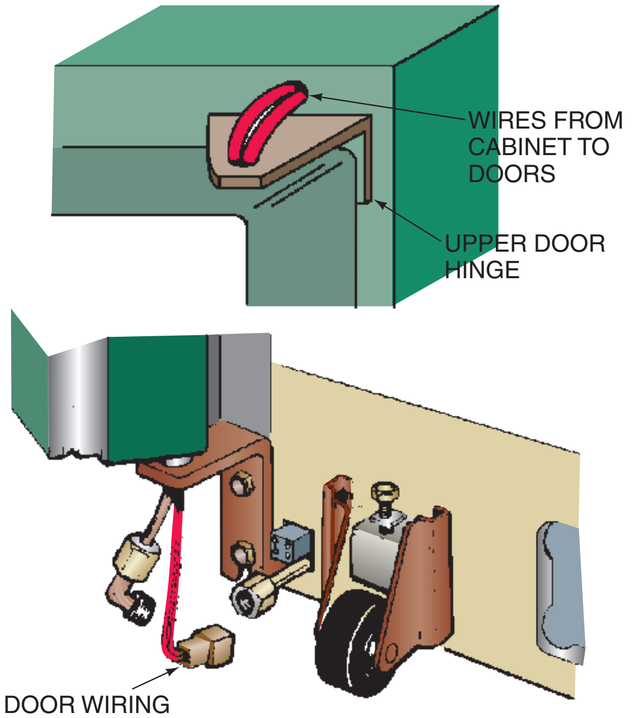


Figure 45–81 Power circuits and tubing for water may be connected to the door through the hinges. *Courtesy White Consolidated Industries, Inc.*

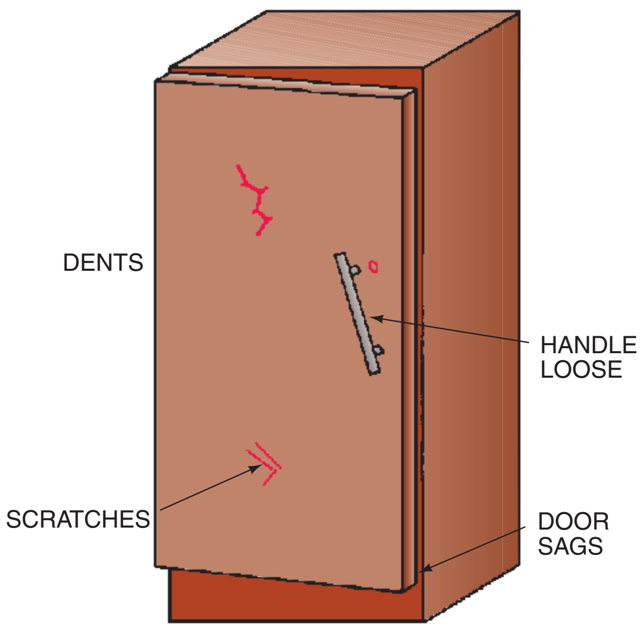


Figure 45–82 A door distorted from use or abuse.

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 for determining system problems without the use of 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

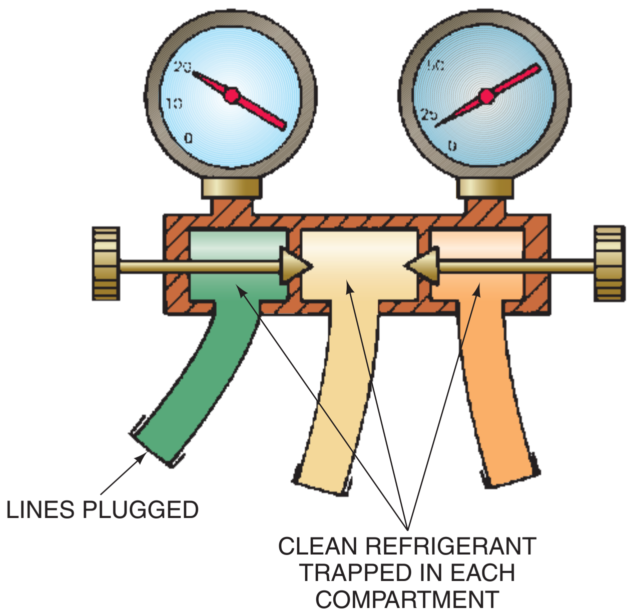


Figure 45–83 A clean, leak-free set of gages.

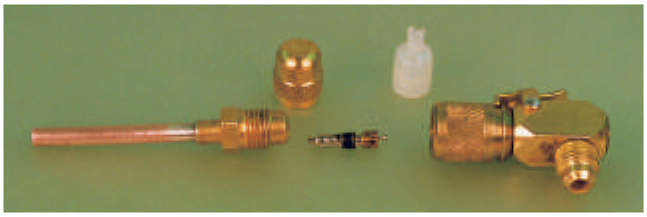


Figure 45–84 Remove the Schrader valve depressors from gage lines and use the special fitting on the right to depress the valve cores. *Photo by Bill Johnson*

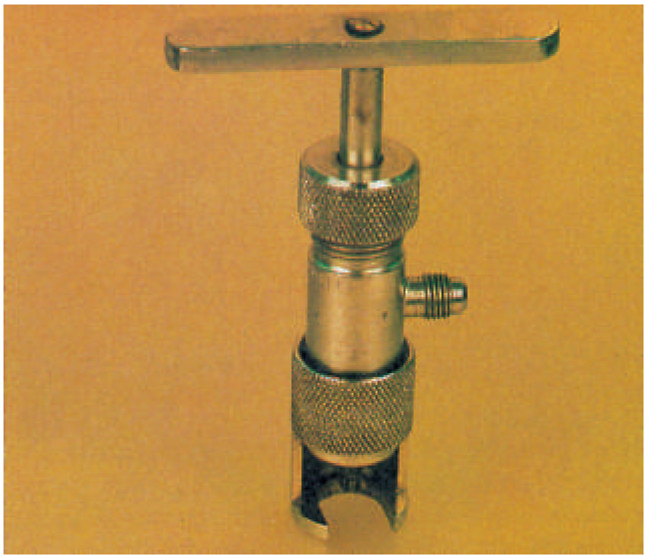


Figure 45–85 A service valve assembly. *Photo by Bill Johnson*

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 valve size 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 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 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.**

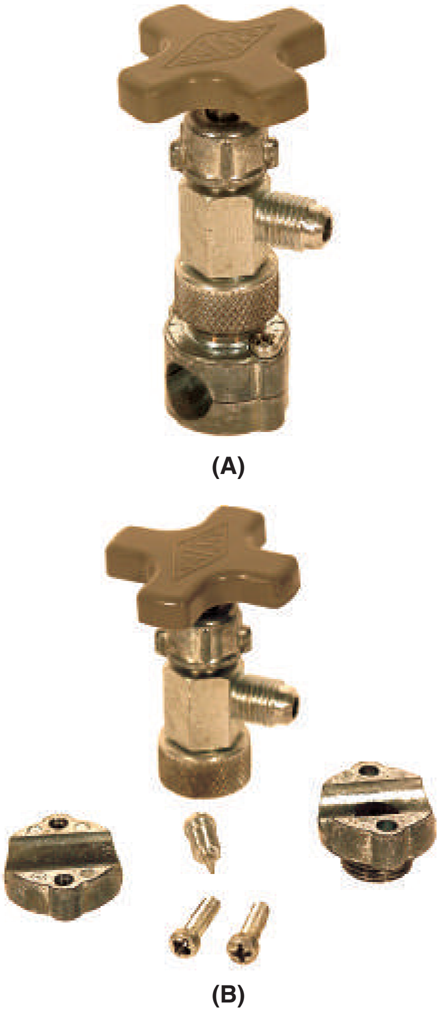


Figure 45–86 Line tap valves for access to refrigerant lines. ***(A)*** *Photo by Bill Johnson.* ***(B)*** *Courtesy J/B Industries*

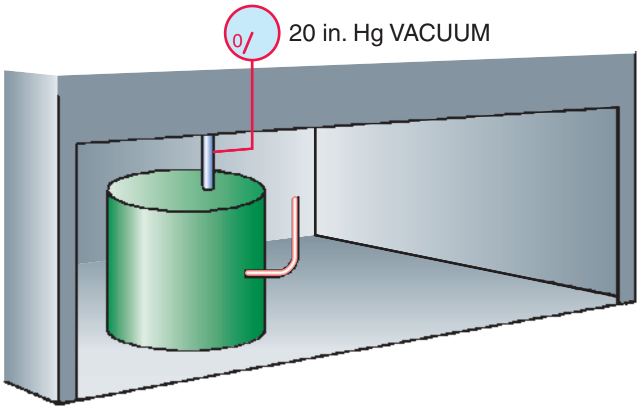


Figure 45–87 If the unit is operating in a vacuum, air may be pulled into the system when gages are installed.

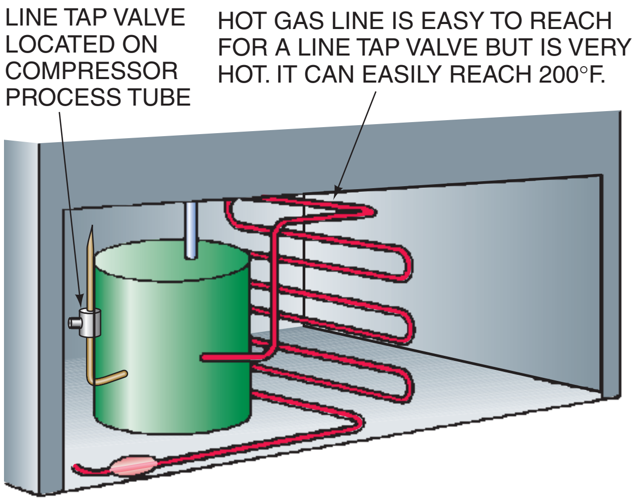


Figure 45–88 Locate the high-pressure line tap valve on the liquid line, not the hot gas line.

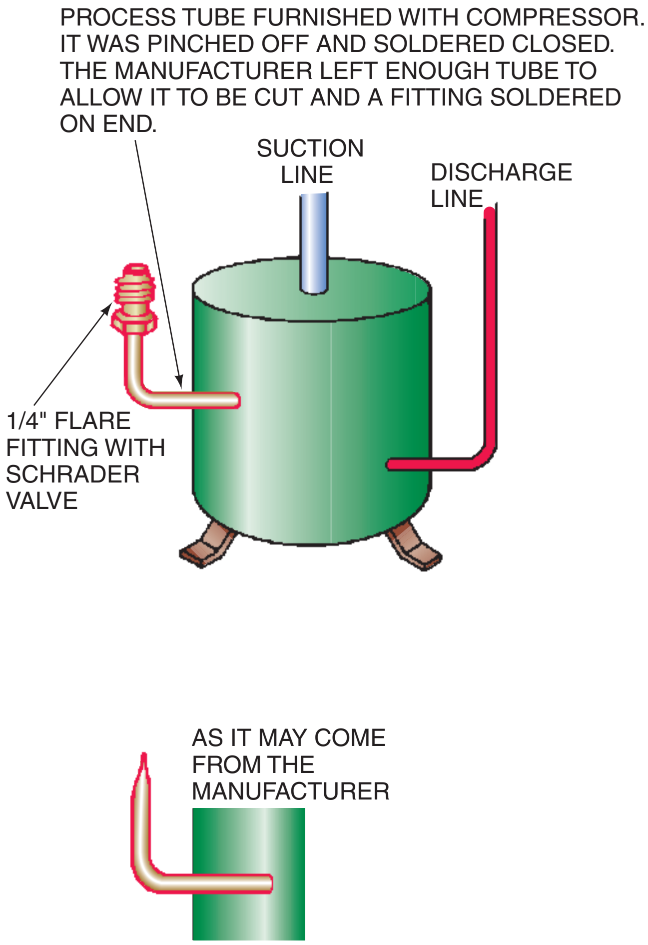


Figure 45–89 Fittings may be soldered on the process tube.

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.

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

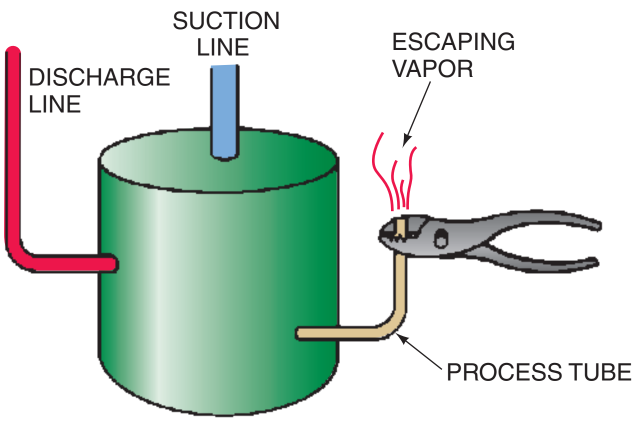


Figure 45–91 SAFETY PRECAUTION: You cannot use pliers to pinch off a line.

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 pressures equalize, much of the refrigerant in the condenser moves to

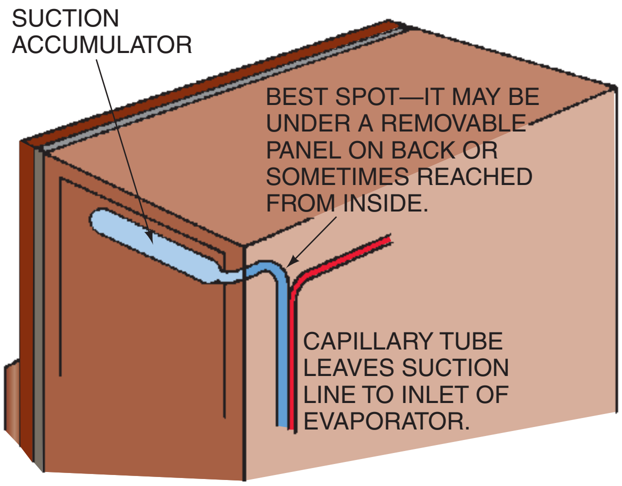


Figure 45–92 Location of the cold spot on the suction line for checking the refrigerant charge.

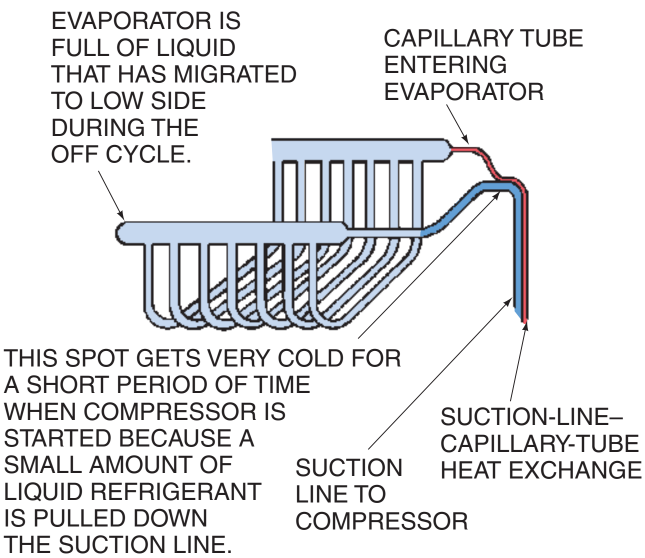


Figure 45–93 Performing the suction touch test for correct refrigerant charge.

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

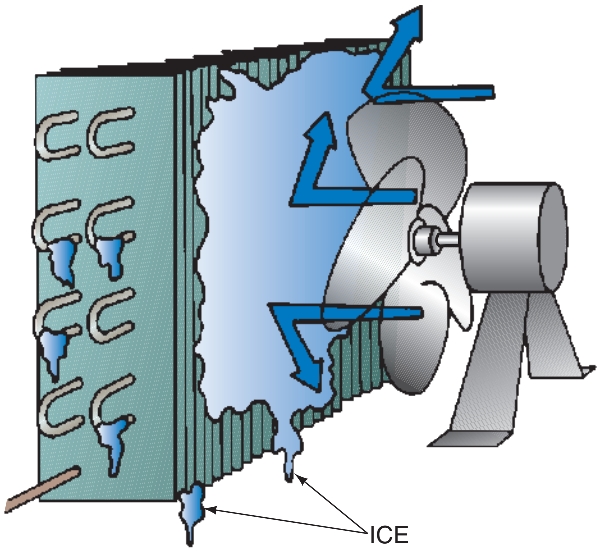


Figure 45–94 Ice buildup on the evaporator.

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*

♻ 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.**

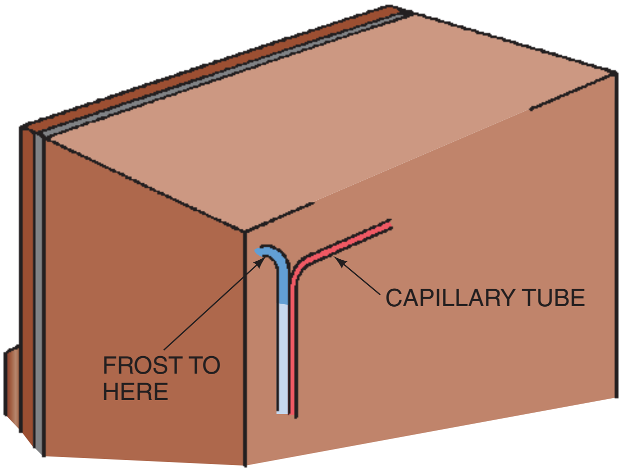


Figure 45–96 Checking the refrigerator charge using the frost-line method.

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.** ♻

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.

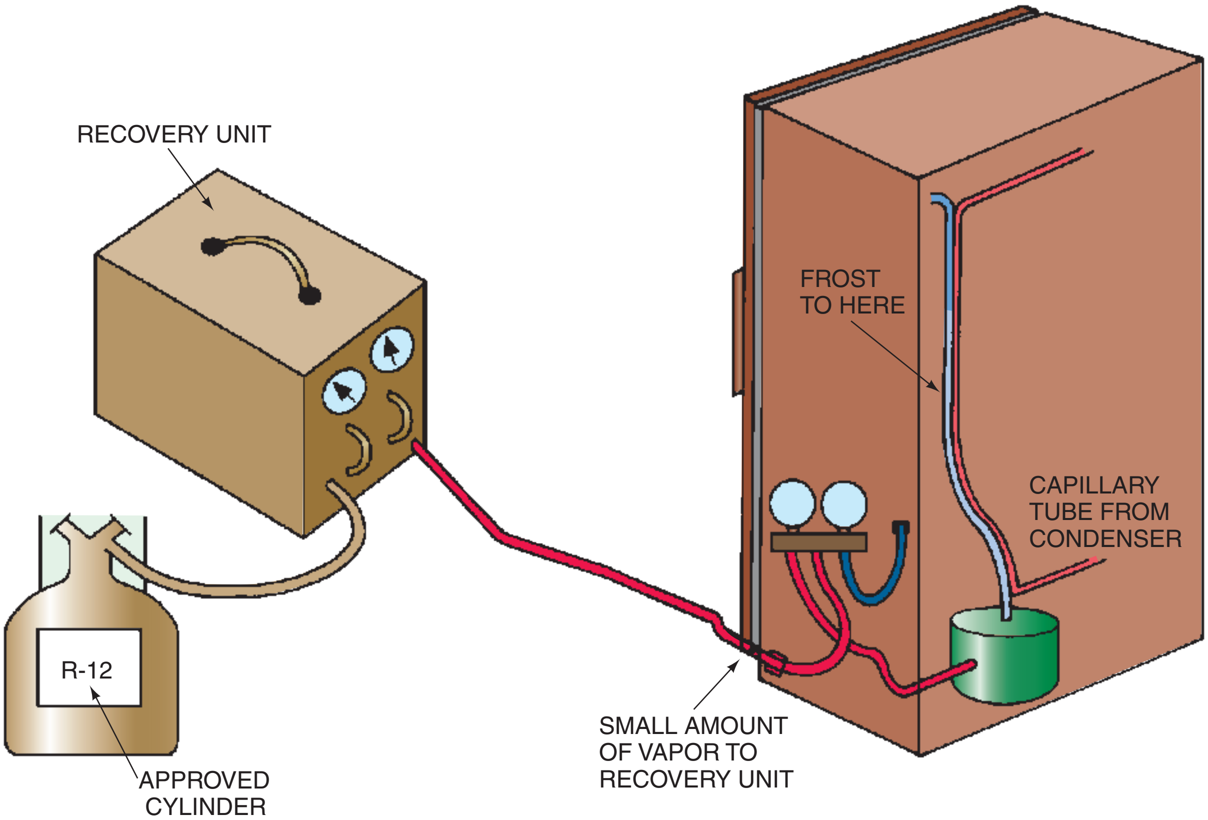


Figure 45–97 The frost line has moved toward the compressor; a small amount of vapor is recovered through the low-side gage.

NOTE: Many units will operate in a vacuum for a period of time after start-up. This will occur until the refrigerant 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 between 114 and 135 for R-134a, **Figure 45–98.** Refer to the temperature/pressure chart in Unit 3, **Figure 3–40.** 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 pulldown 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.

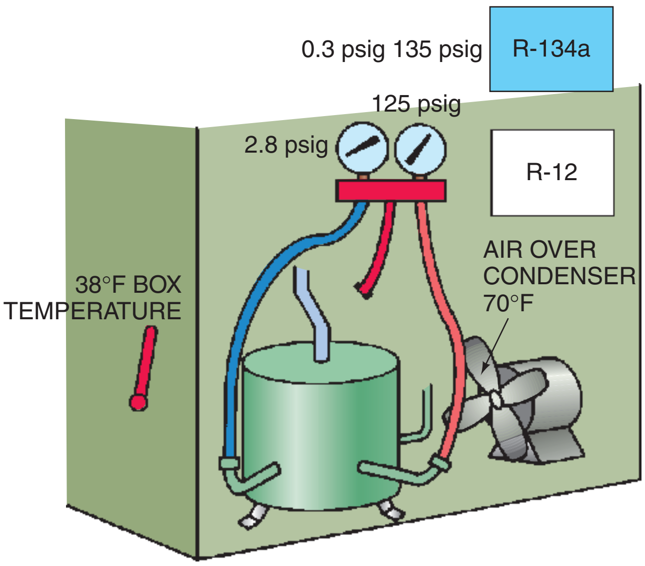


Figure 45–98 A typical head pressure.

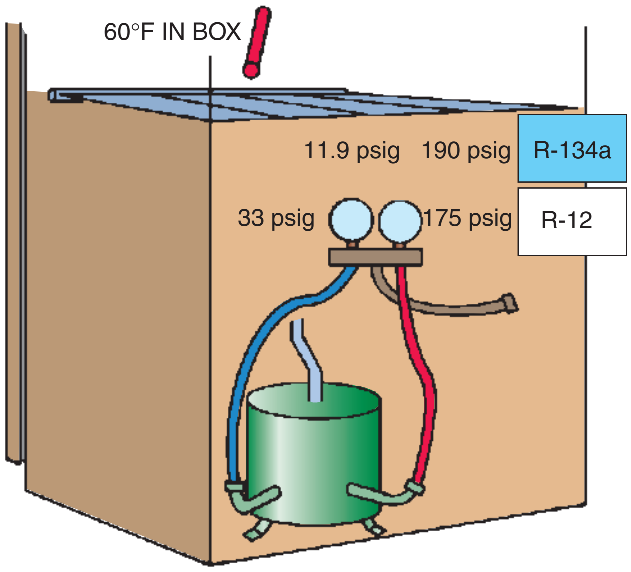


Figure 45–99 Head pressure under an abnormal load.

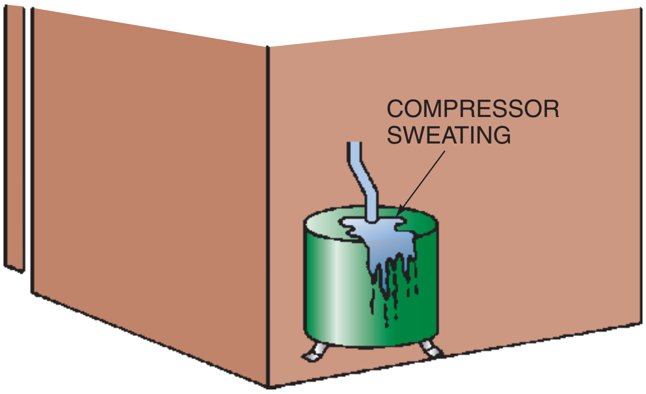


Figure 45–100 If the compressor is sweating around the suction line, there is too much refrigerant.

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*

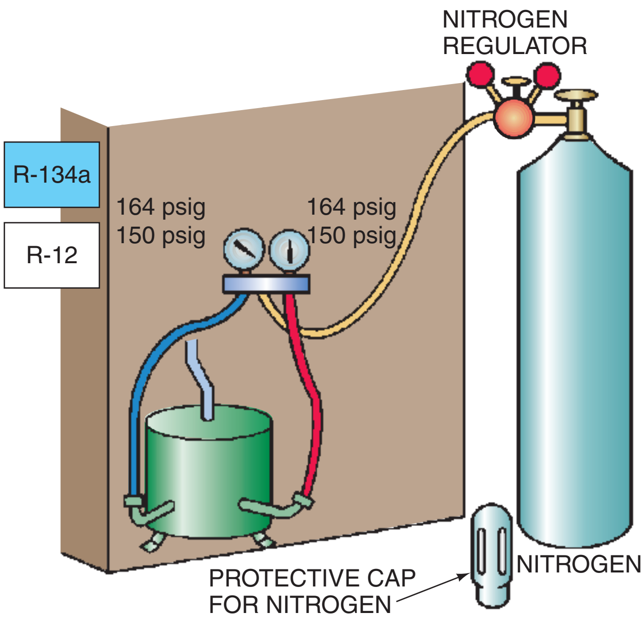


Figure 45–102 Nitrogen may be used to create more pressure for leak checking.

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.**

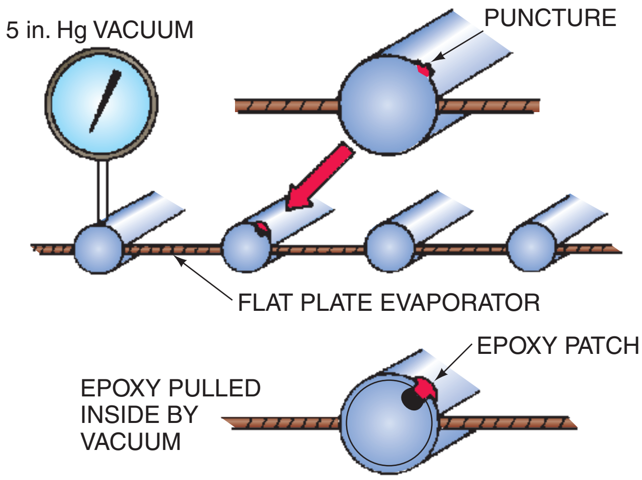


Figure 45–103 A slight vacuum may be used to pull a small amount of epoxy into the puncture.

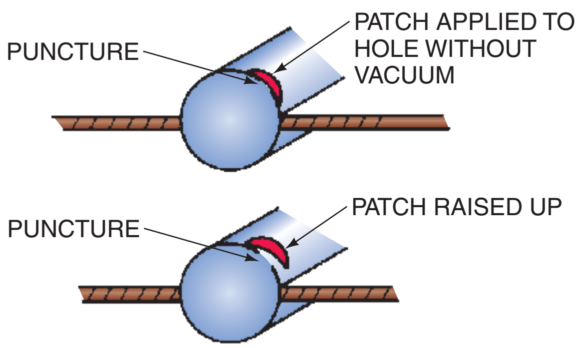


Figure 45–104 The pressure inside may push the patch off the puncture under some circumstances. This may occur during storage when the low-side pressure is high.

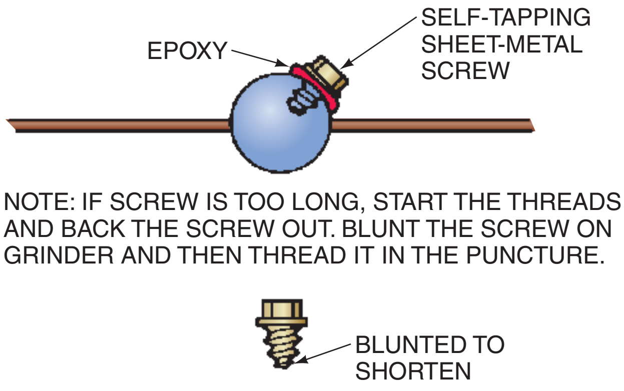


Figure 45–105 A screw may be used in some cases to hold the epoxy in the puncture hole.

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.

Leaks may occur in the connection where the copper suction line is attached to the aluminum tubing leaving the

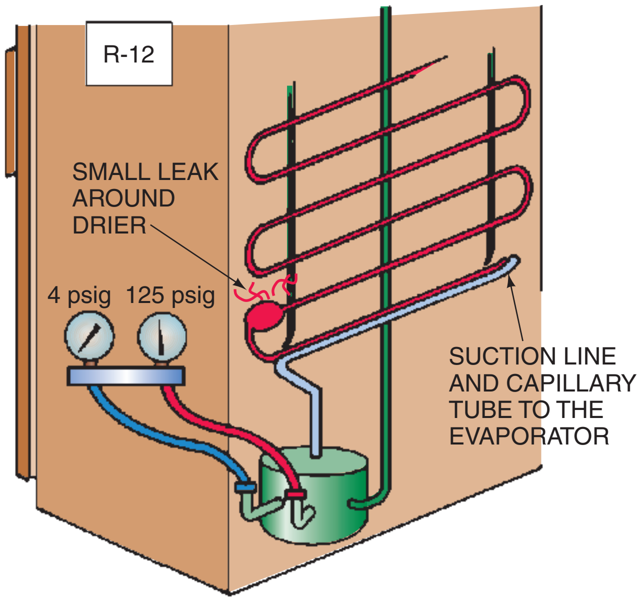


Figure 45–106 A small leak in the high-pressure side of the system will cause a greater refrigerant loss than a leak on the low-pressure side.

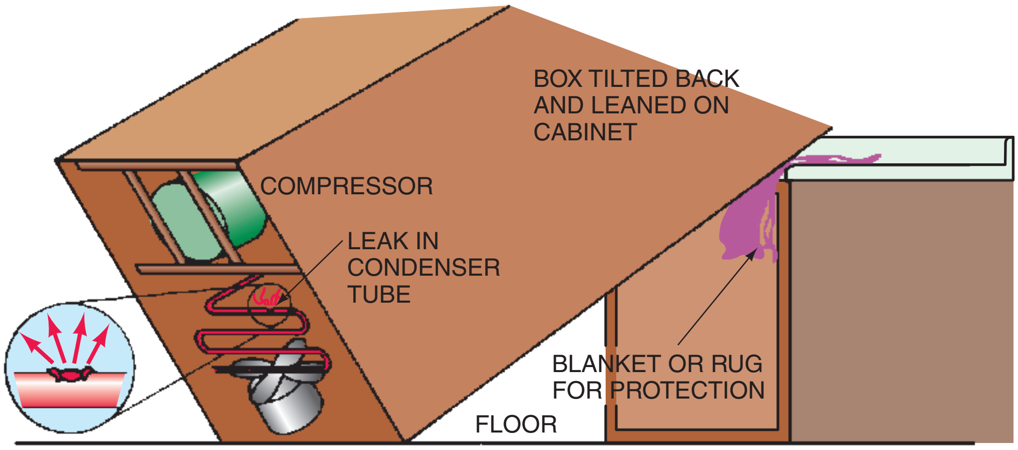


Figure 45–107 A refrigerator may be tilted to one side or to the back to service the condenser under the box.

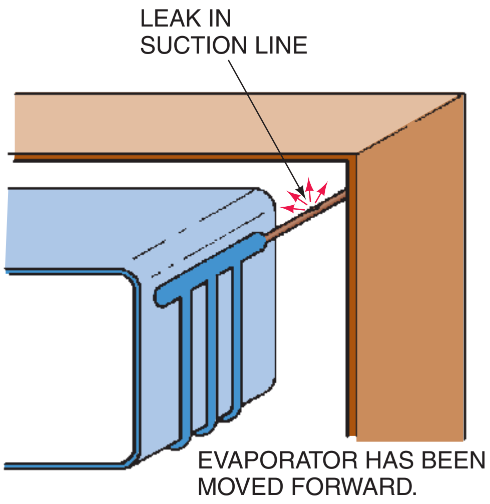


Figure 45–108 A piping leak on the suction line inside the box.

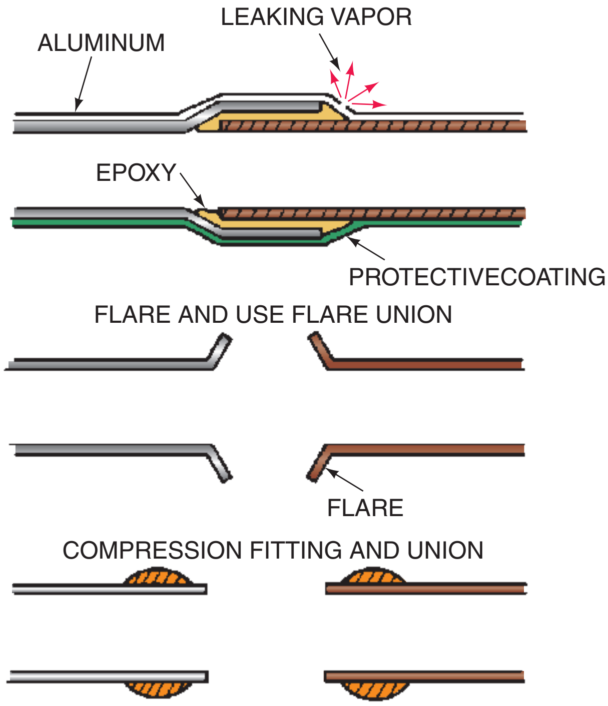


Figure 45–109 Procedures for repairing a leak in the connection between the copper suction line and the aluminum tubing leaving the evaporator.

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 box

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

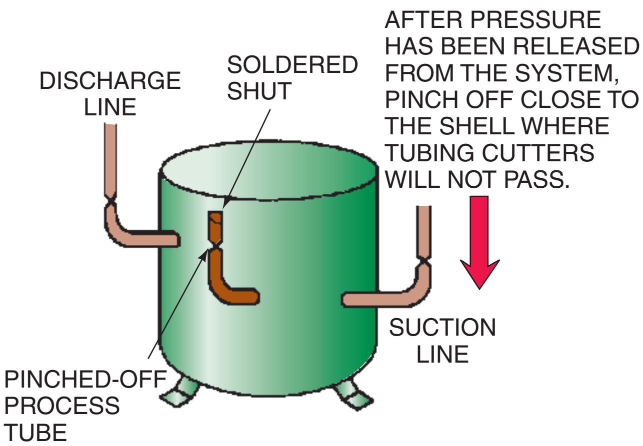


Figure 45–111 Pinch the old lines close to the compressor shell using side-cutting pliers.

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.**

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

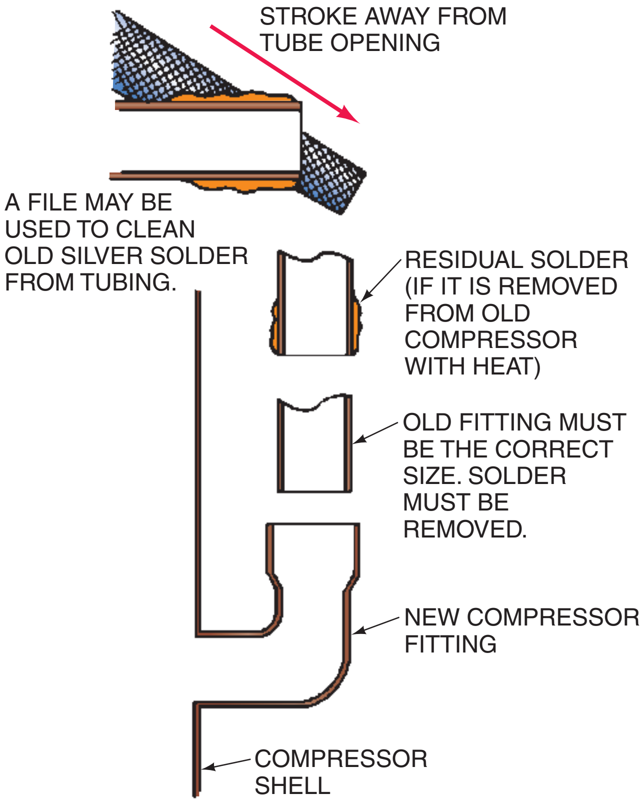


Figure 45–112 The old tubing must be cleaned of all old solder; a file may be needed.

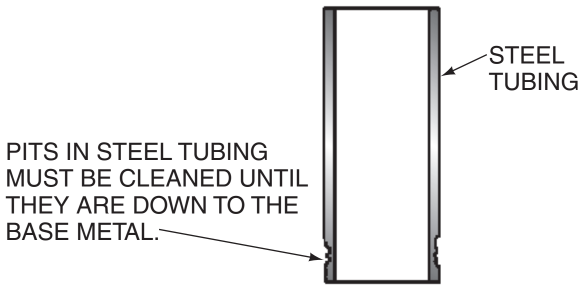


Figure 45–113 All pits in steel tubing must be cleaned.

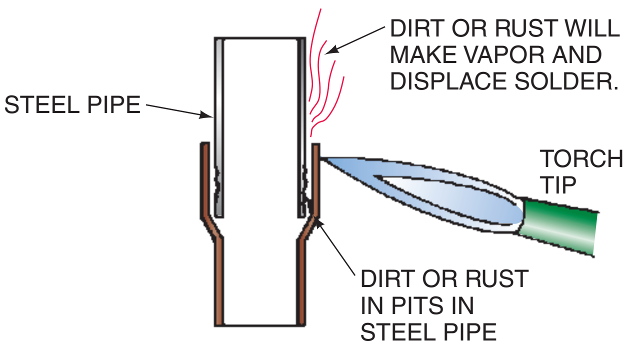


Figure 45–114 Dirt trapped in pits will expand when heated and cause leaks.

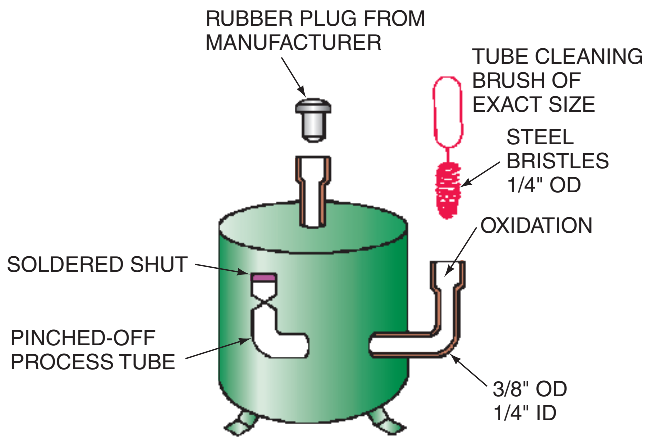


Figure 45–115 Remove the plugs from the compressor lines and clean the tubing ends.

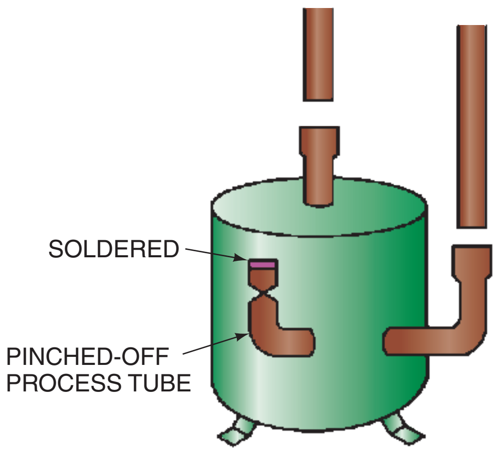


Figure 45–116 Do not apply flux until the lines are being fastened together for the last time before soldering.

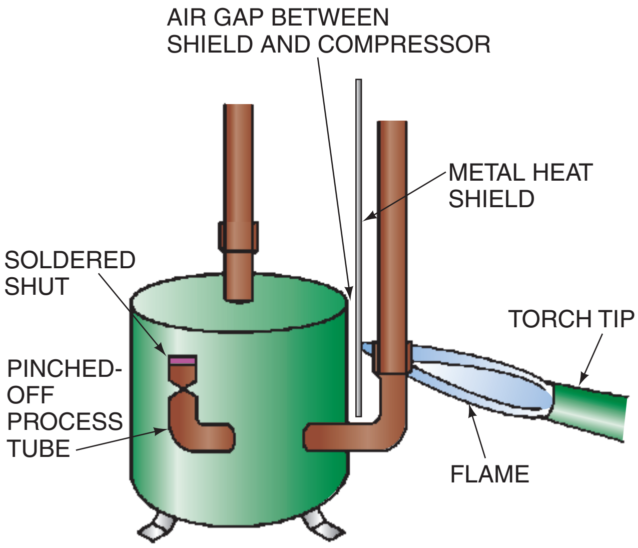


Figure 45–117 SAFETY PRECAUTION: When soldering, a shield may be used to protect the surrounding components and cabinet from heat.

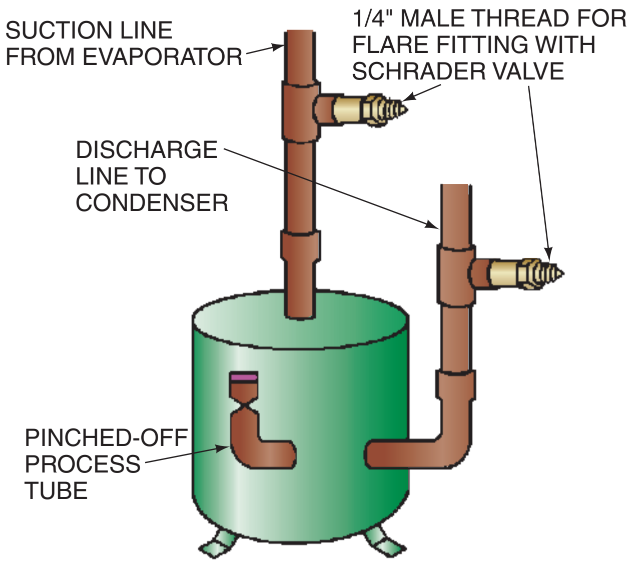


Figure 45–118 A "tee" fitting may be soldered in the suction and discharge lines for service connection while the system is open.

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.

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.

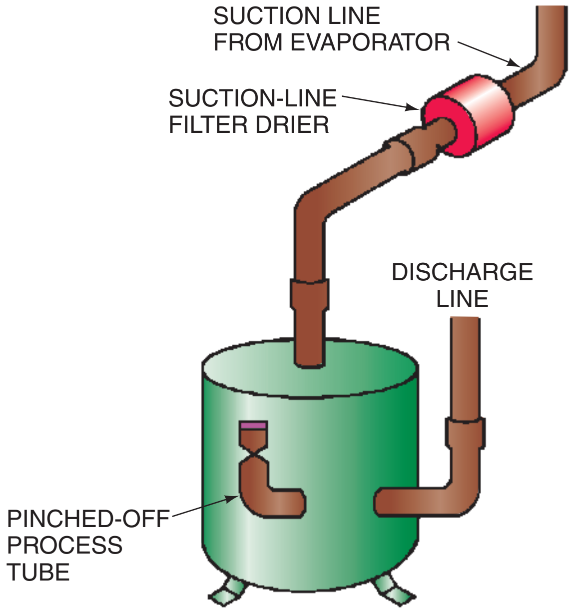


Figure 45–119 A suction-line drier added to the low side will not require extra charge because the refrigerant is in the vapor state.

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.

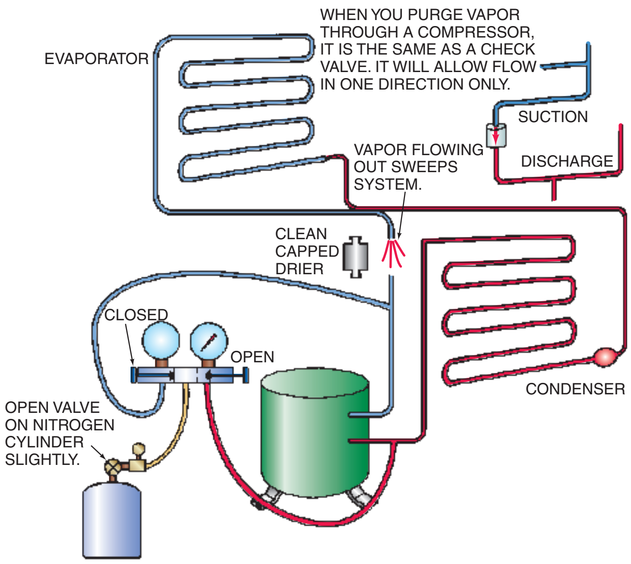


Figure 45–120 Purging or sweeping a system.

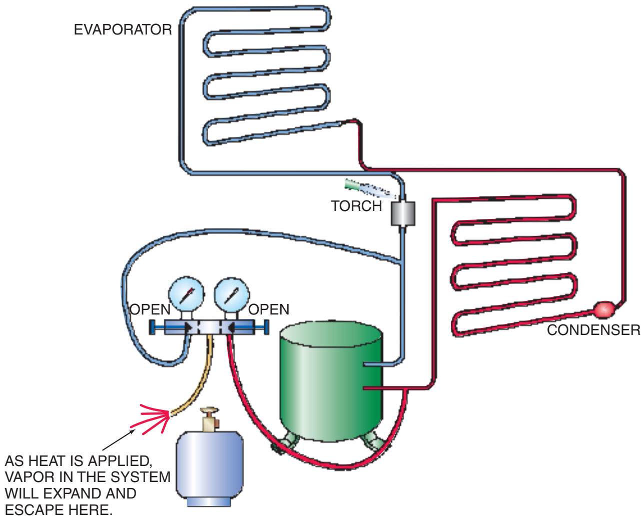


Figure 45–121 Be sure to open gages before attempting to solder the drier in the suction line.

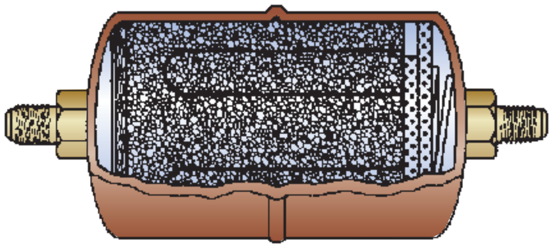


Figure 45–122 A drier with flare fittings may be a better choice to avoid soldering. *Courtesy Mueller Brass Co.*

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, 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 it will move from the evaporator through the suction line to the compressor crankcase. When the compressor is restarted, there may be moisture 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

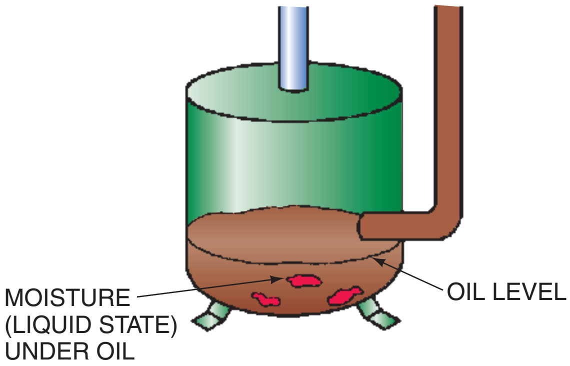


Figure 45–123 Moisture may be trapped under the oil in the compressor.

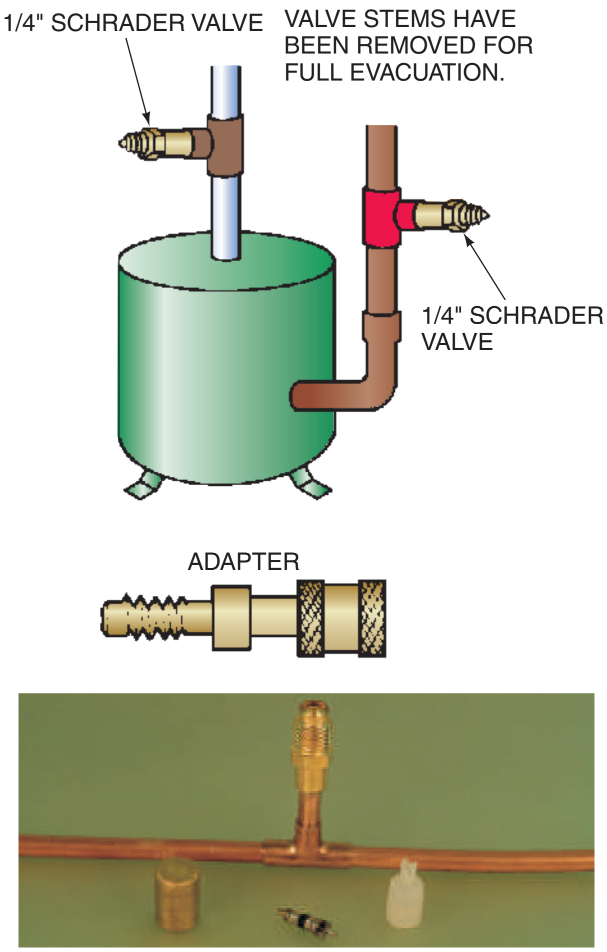


Figure 45–124 Full-size gage connections must be installed to remove moisture. *Photo by Bill Johnson*

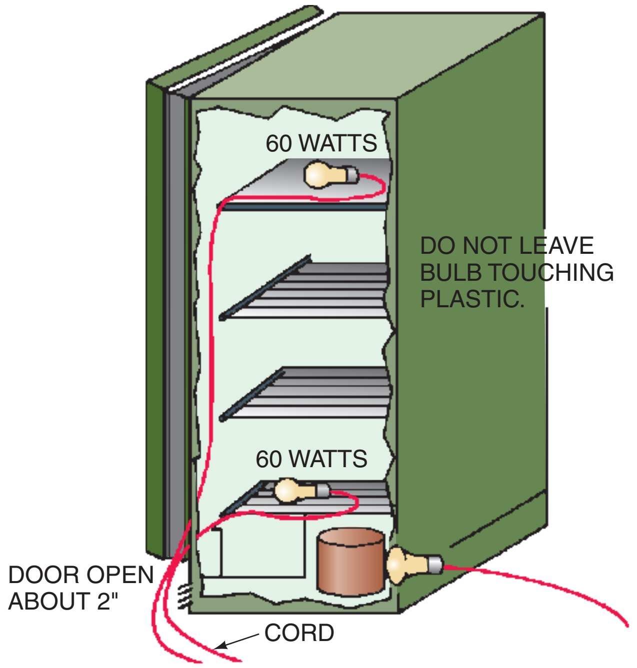


Figure 45–125 Placing light bulbs in a refrigerator to heat the refrigerant circuit and not overheat the plastic.

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 hours. 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 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 has 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.

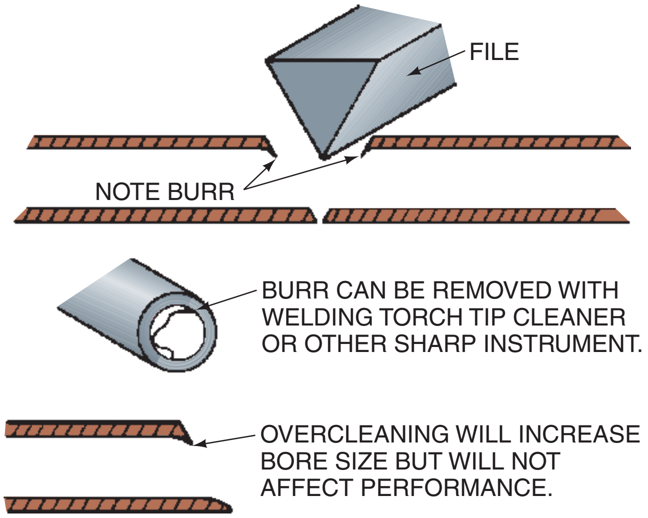


Figure 45–126 Use a file to cut a capillary tube to the correct length.

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 tubing one size larger, **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 has become 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,

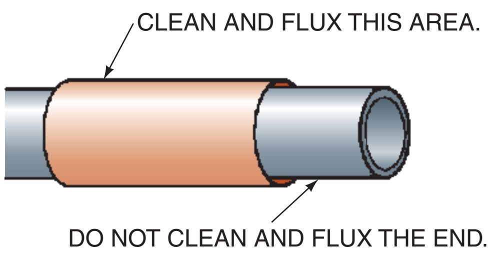


Figure 45–127 Application of flux to a capillary tube to prevent solder from entering the tube.

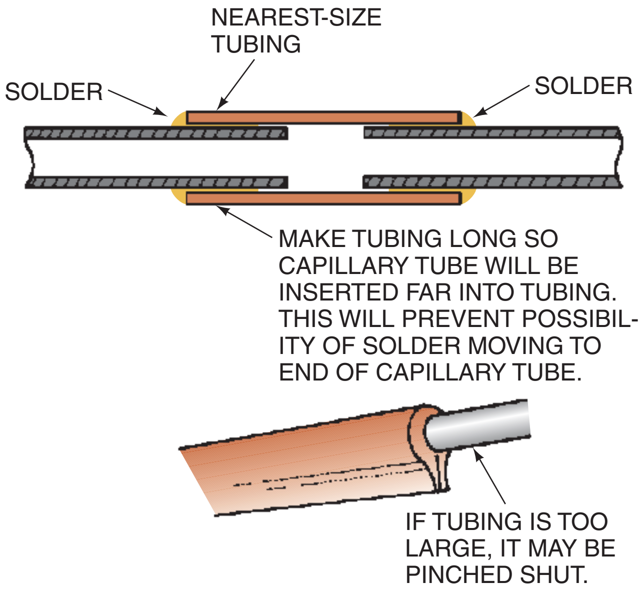


Figure 45–128 Repairing a broken capillary tube.

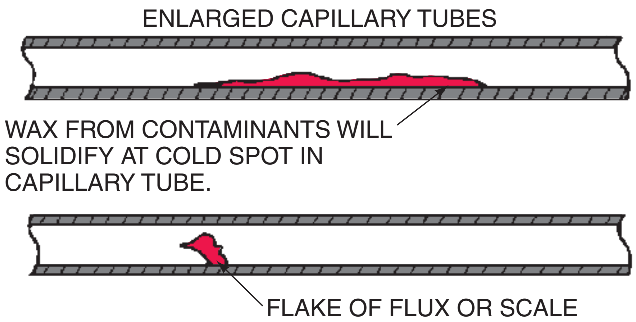


Figure 45–129 Wax or a small particle may enter and lodge in the capillary tube.

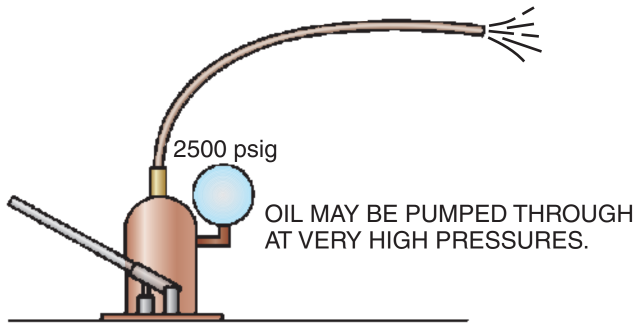


Figure 45–130 A capillary tube–cleaning pump may be used.

and observe the pressures. Of course this means putting the system back to normal working order with a leak check and evacuation. 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.**

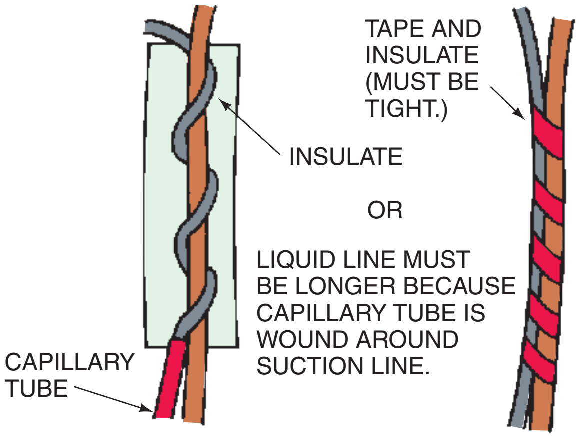


Figure 45–131 You may pass the capillary tube close to the suction line under insulation and get some heat exchange.

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 touch test mentioned earlier in this unit.

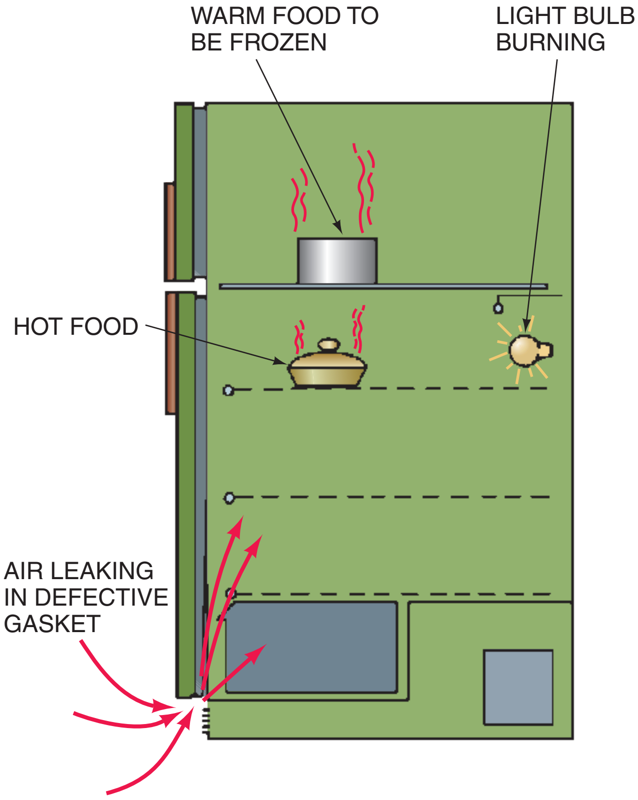


Figure 45–132 Extra load on a refrigerator may be caused by defective gaskets, hot food placed in the box, or a light bulb burning all the time.

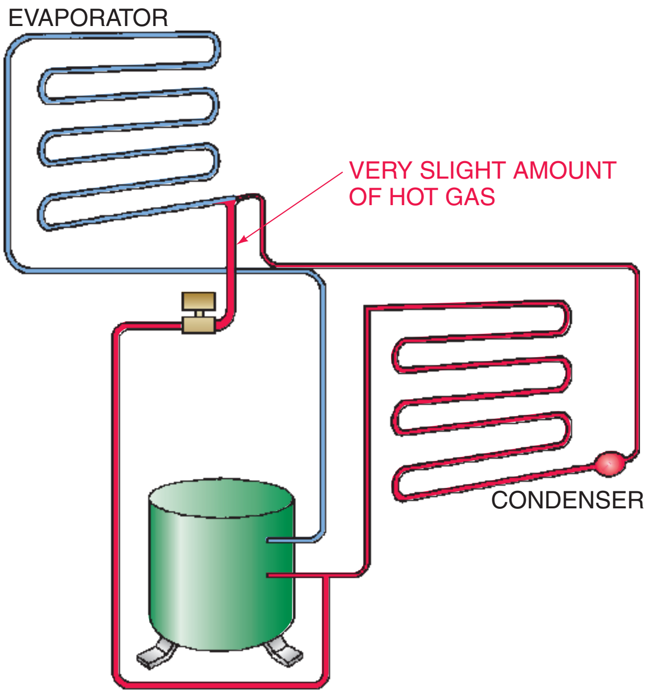


Figure 45–133 A leaking hot gas solenoid will cause a false load on a refrigerator.

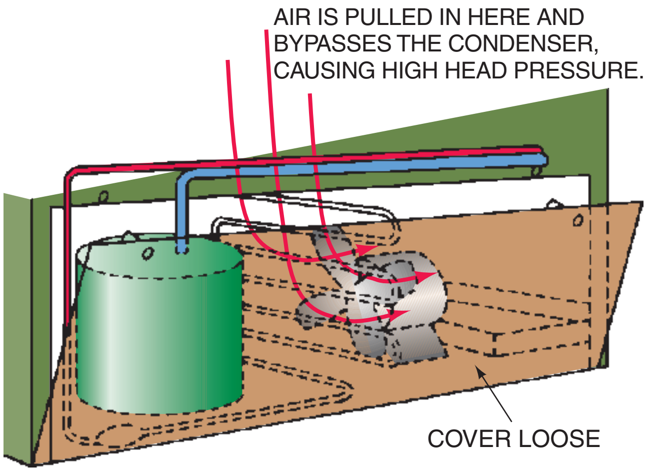


Figure 45–134 Make sure that all baffles are in place in the condenser area for correct airflow.

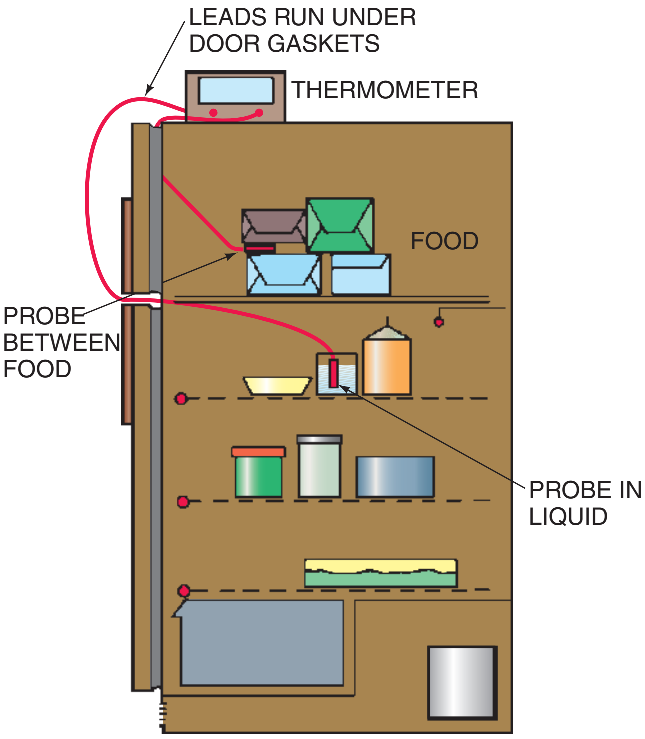


Figure 45–135 A thermometer with leads may be used to check the compartment temperatures.

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 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

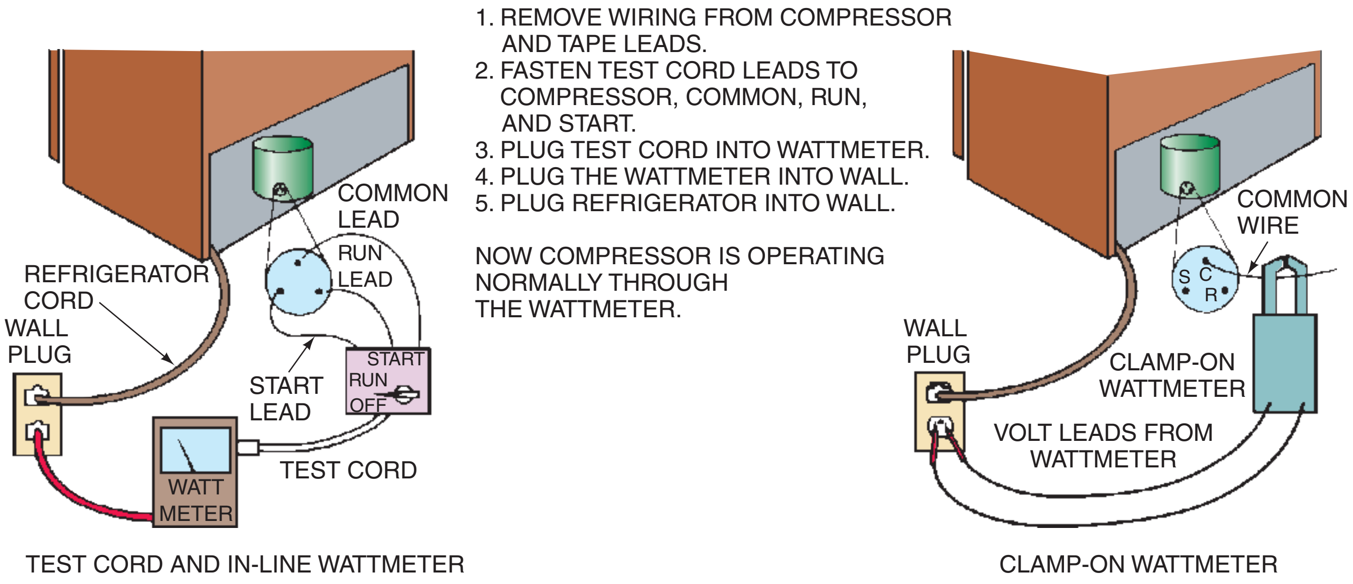


Figure 45–136 A wattmeter may be used to check the compressor to make sure that it is working to capacity. The correct wattage must be known for this procedure. The two common types of wattmeters are plug-in and clamp-on. The plug-in type requires that the compressor be isolated. A test cord is used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

capacity loss is ensured. Forced-draft condensers must have all cardboard partitions in place, or air may recirculate across the condenser and cause 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 when 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 (if 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 tells 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 the technician feels confident the problem has been corrected.

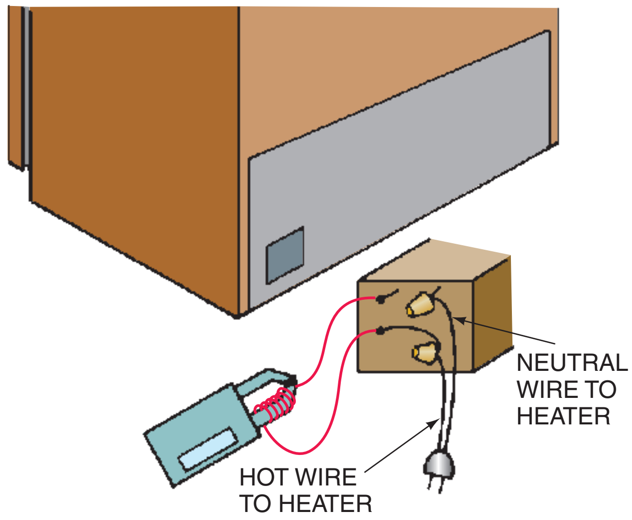


Figure 45–137 Wrapping the heater wire around the ammeter jaws to amplify the reading.

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 that 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.

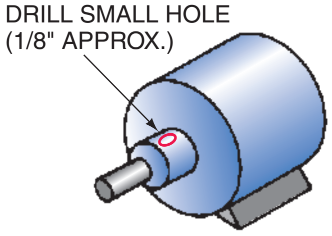


Figure 45–138 The motor housing may be drilled and penetrating oil forced into the bearings for a temporary repair. **The only permanent repair is to replace the motor.**

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 that 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

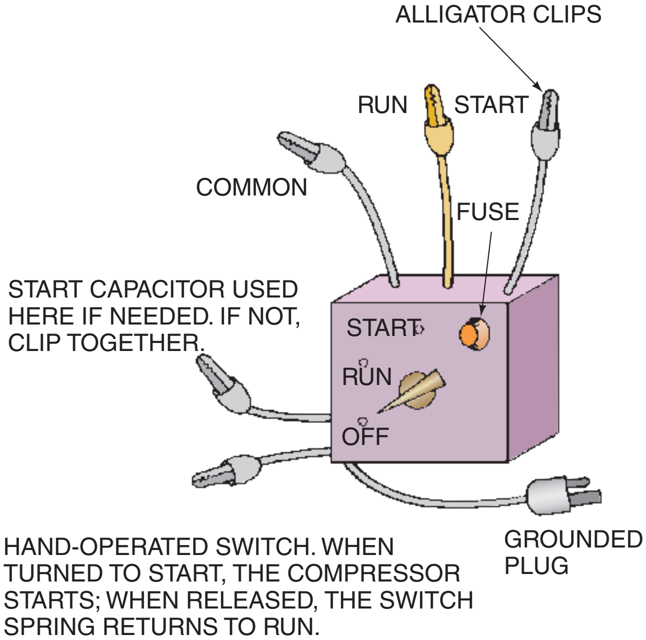


Figure 45–139 A hermetic starting test cord.

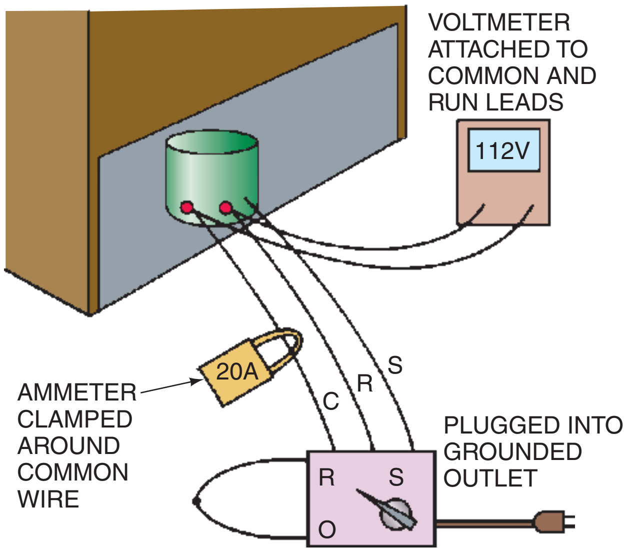


Figure 45–140 Voltage and amperage readings are recorded when the compressor is started.

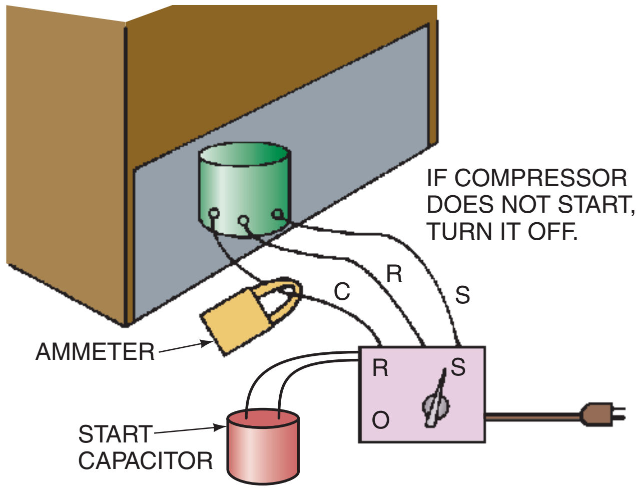


Figure 45–141 When stuck, a start capacitor may be placed in the start windings to give the compressor extra torque for starting.

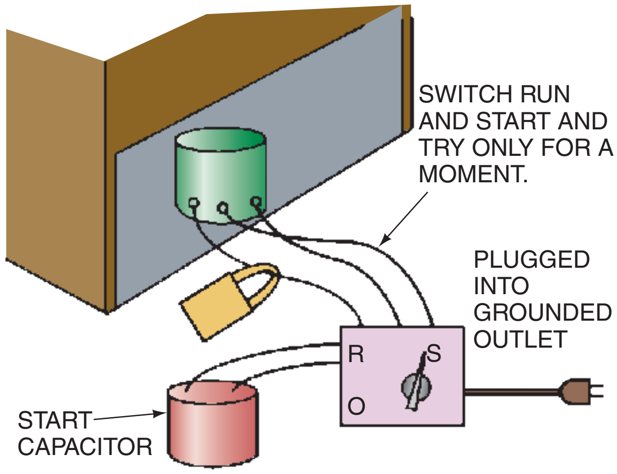


Figure 45–142 The run and start wires may be reversed to reverse the motor for a moment. The motor must not run for more than a few seconds in the reverse rotation.

places a start capacitor in the start circuit of the test cord and tries to start the compressor; again, it does not start, **Figure 45–141.** The run and start wires are reversed, **Figure 45–142.** This will allow the technician to start the compressor in reverse rotation. The compressor starts. It is stopped quickly because it cannot run in this mode for long without causing damage. The leads are reversed and the compressor is tried again. It starts correctly this time. The technician unplugs the test cord and fastens the compressor start circuit back to the compressor. The ammeter is clamped around the common wire. When the refrigerator is plugged in, the compressor starts and runs with normal amperage.

The technician has explained the procedure to the customer. The technician is quick to point out that something would not allow the compressor to restart when it stopped. It could be a particle stuck in the cylinder or internal friction due to wear. There is no way of knowing. It may stop again. The customer is told not to put food into the box until the next day to allow the box to cycle a few times during the night. If the compressor stops again, the box should be unplugged and the technician called again.

The technician copies all data from the compressor nameplate and draws a diagram of the compressor lines and mount in case a substitute compressor must be obtained. The customer wants this refrigerator repaired. All information is copied from the refrigerator nameplate before pushing the refrigerator back to the wall and leaving.

The next morning, the customer calls. The box is off again, just as suspected. The technician goes by the supply house and obtains an exact replacement compressor. This is best because it will fit exactly. A suction-line drier is also obtained.

When the technician arrives, the refrigerator hand truck is fastened to the refrigerator from the side so the unit will go through the door. The strap around the doors keeps the doors closed during movement. The unit is moved to the garage, and the technician starts. ♻ The charge is recovered from the system. ♻

A torch, fire extinguisher, gages, gage ports for the process tubes, refrigerant, scales, and wrenches are carried into the garage while the charge is being recovered. The compressor suction and discharge lines are snipped off close to the compressor connectors. The oil cooler lines are also cut. The old compressor is removed. The new compressor is set in place for a trial fit of all lines; it is a perfect fit.

The compressor is removed and the lines on the refrigerator are cut off square on the ends using a tubing cutter, **Figure 45–143.** They can be reached with the compressor out of the way. The ends are now cleaned with proper nonconducting sand tape. The plugs are removed from

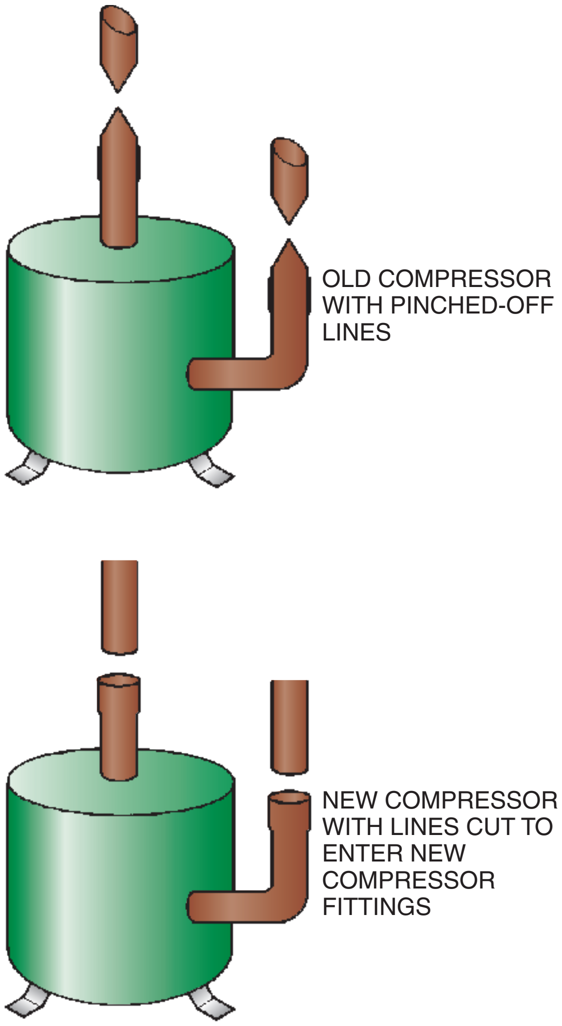


Figure 45–143 The pinched lines of the compressor must be cut off before inserting the new compressor connections.

the compressor lines and it is set in place. The lines are fitted to the compressor. Process tubes are 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 the technician knows that 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 is starting 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

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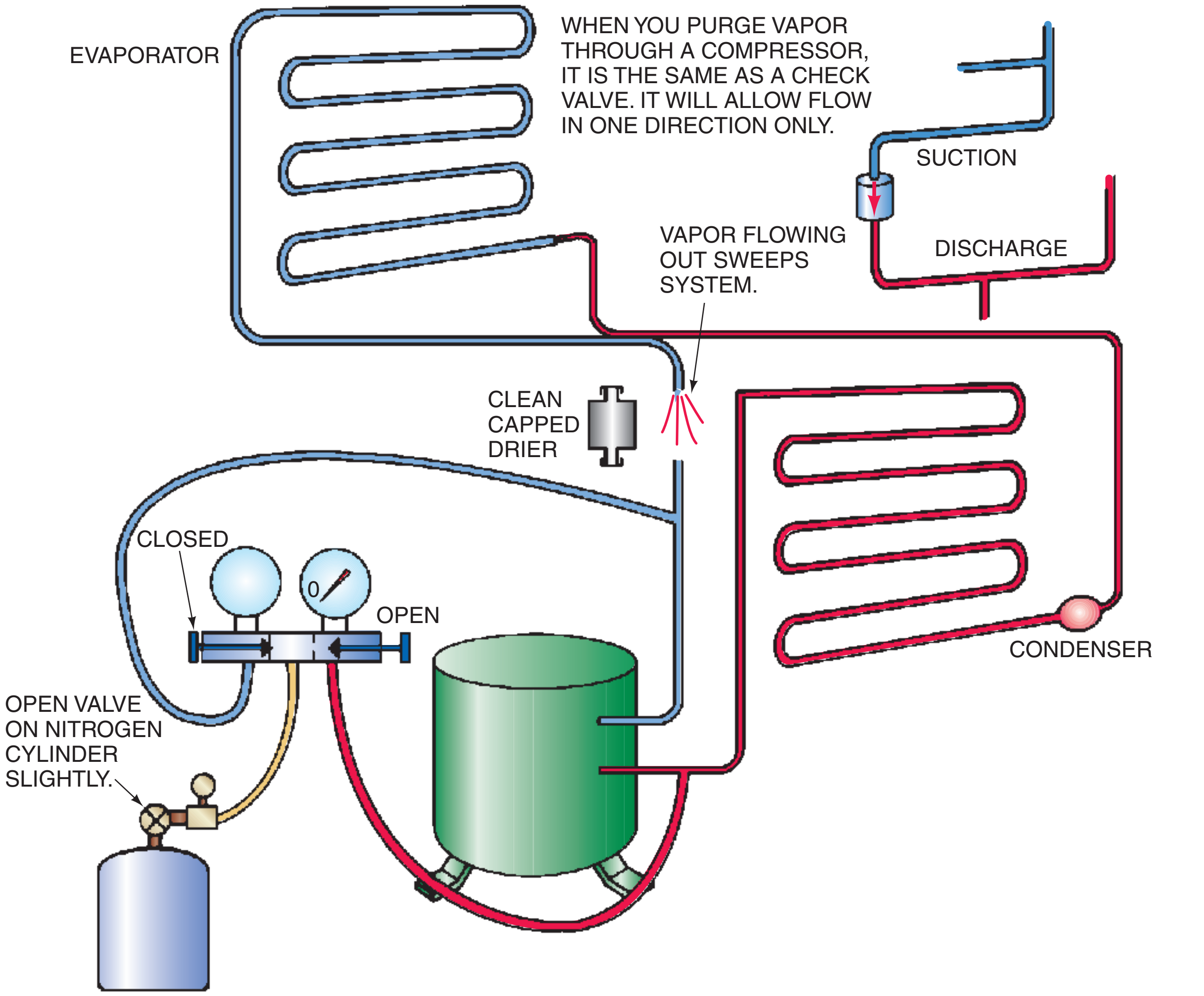

Figure 45–144 Sweeping or purging the system before soldering the drier in the line.

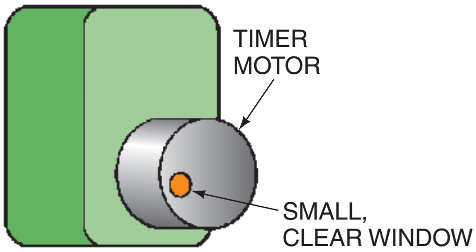

Figure 45–145 A small window may be provided for checking timer rotation.

for observing rotation of the timer motor, **Figure 45–145.** The 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

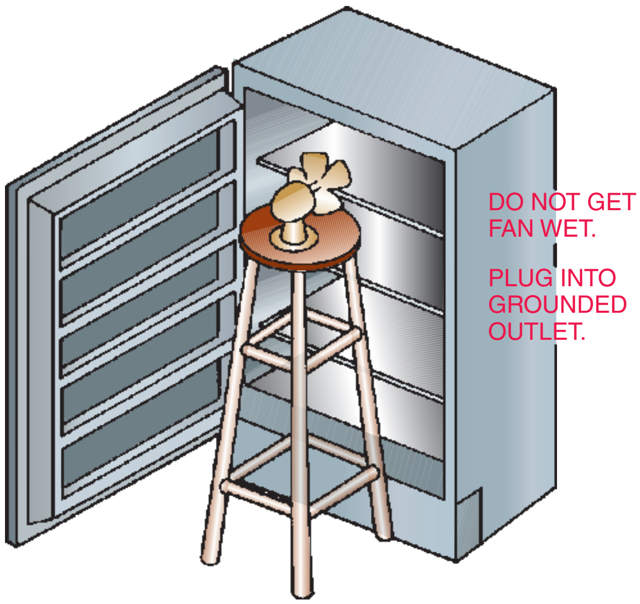

Figure 45–146 A room fan may be used for rapid defrost.

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 that 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.

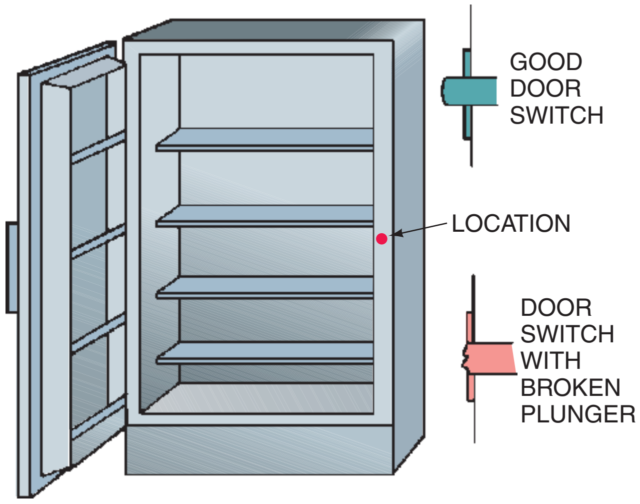

Figure 45–147 The plunger is missing from the door switch.

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 that 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 the refrigerator would not cool, the tenant 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

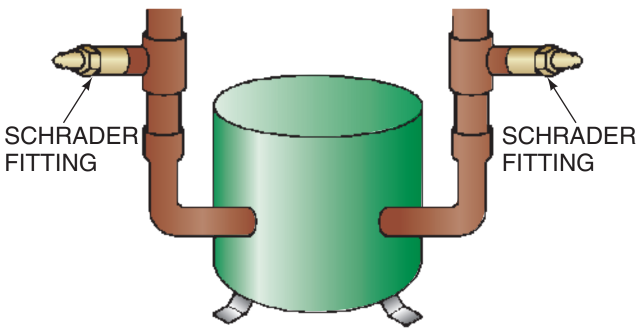

Figure 45–148 Process tubes soldered in the suction and discharge lines offer the best service access.

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 more epoxy 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.

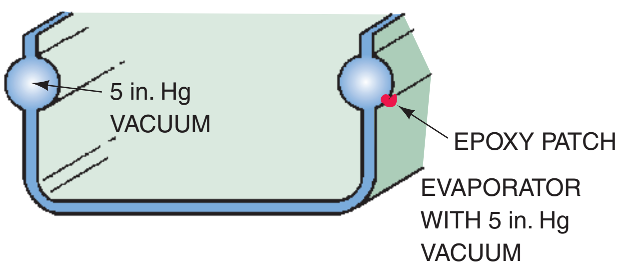

Figure 45–149 The vacuum is used to pull a small amount of epoxy into the evaporator puncture.

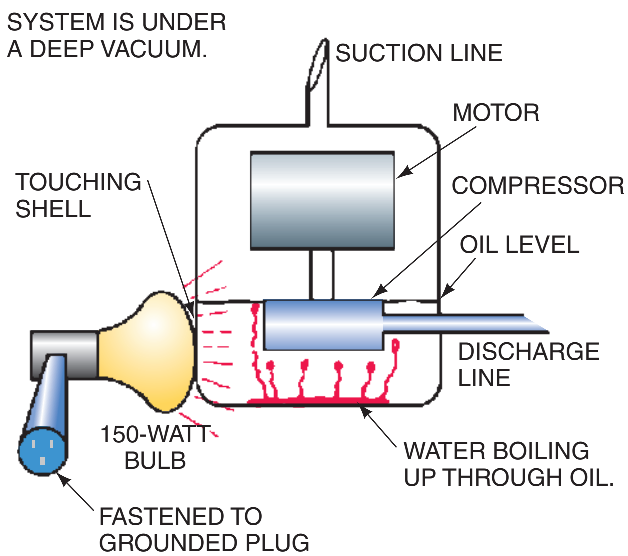

Figure 45–150 Heat is applied to the compressor to boil any moisture from under the oil.

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 hours; 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 hours. 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 that 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 the technician touches 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.**

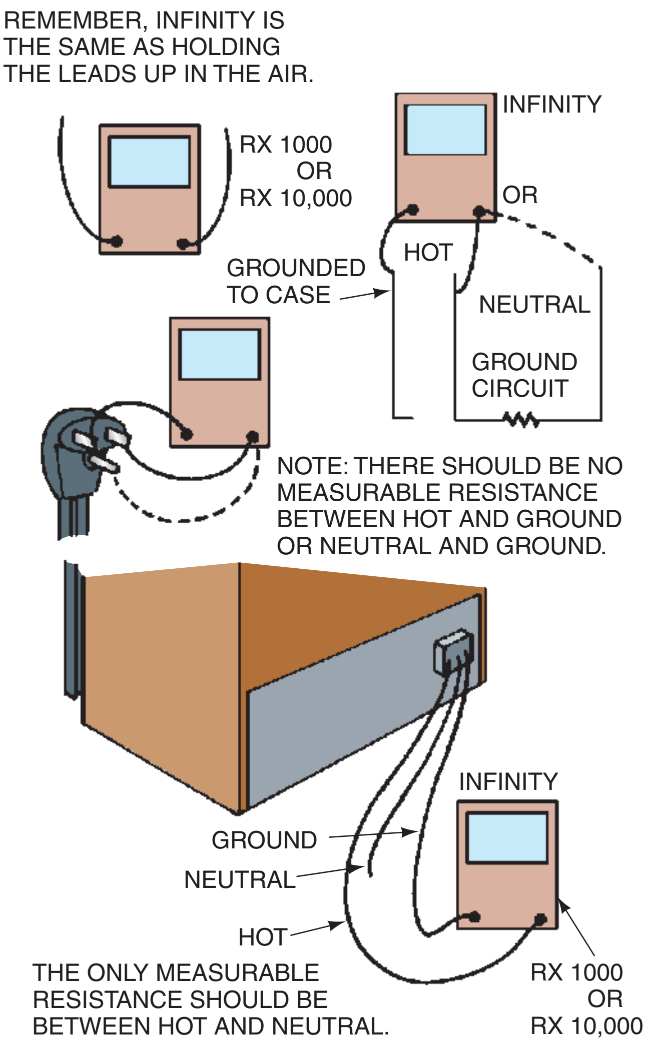

Figure 45–151 Checking the unit for a grounded circuit using the appliance plug.

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.

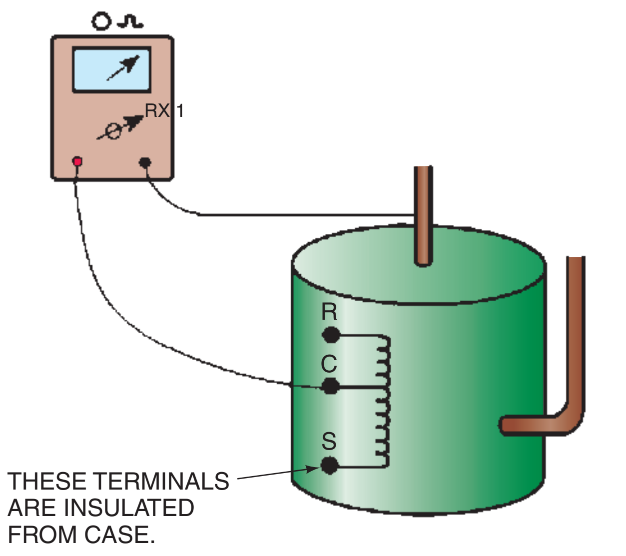

Figure 45–152 Using the compressor frame or lines to check for an electrical ground circuit.

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 how a system is totally sealed after an evacuation.** The

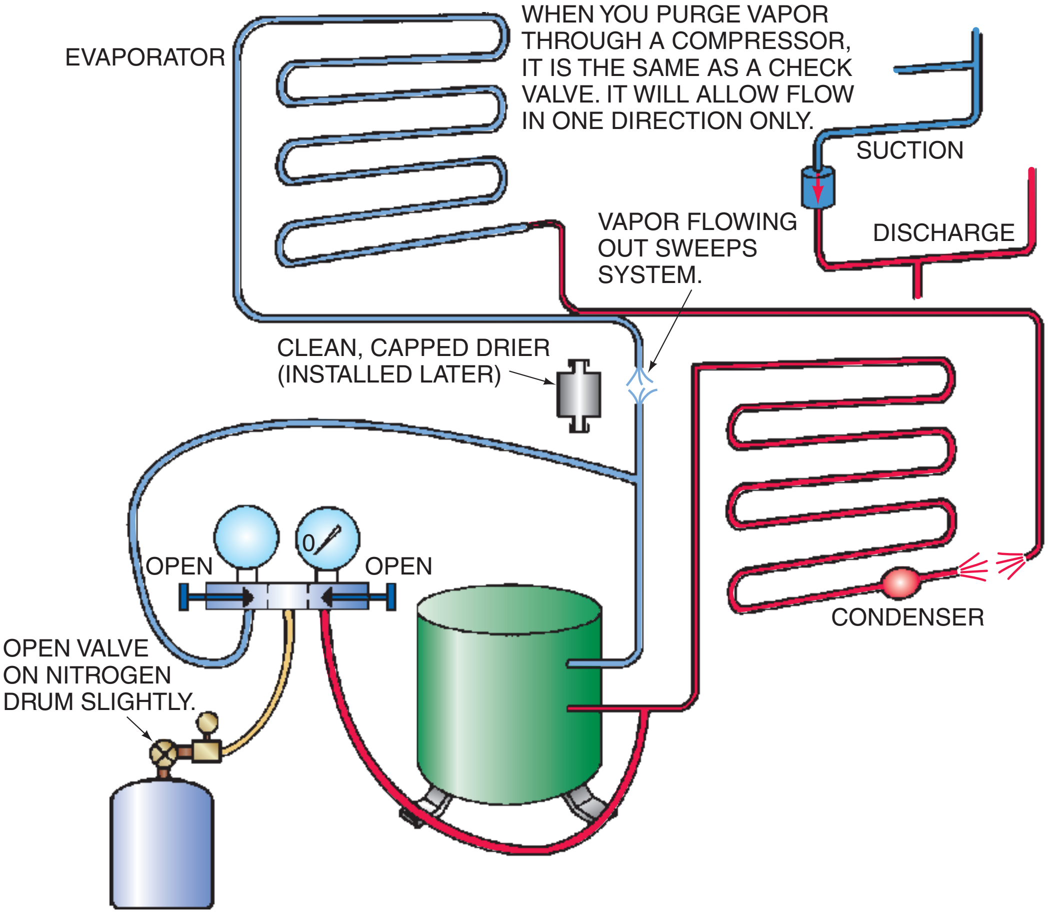

Figure 45–153 Purging the system at the suction-line drier connection before soldering the drier in the line.

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 of 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 pulldown of the box, **Figure 45–154.** The box is allowed to stay plugged in for 24 hours to operate on its own and then is transported back to the customer.

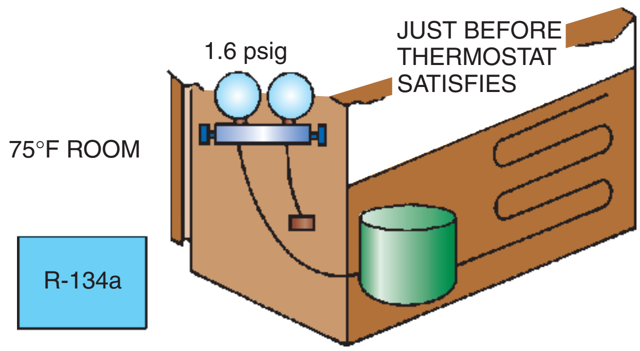

Figure 45–154 Typical pressure while the box is pulling down.

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.

- Evaporators may be manually defrosted or have an automatic defrost feature.
- Many compressors have a suction line, a discharge line, a process tube, and two oil cooler lines, all protruding from the shell.
- Many compressors in refrigerators do not have service ports.
- Most domestic refrigerators use the capillary tube metering device.
- Current model refrigerators have a magnetic strip gasket with a compression seal around the door or doors.
- The space-temperature thermostat controls the compressor.
- Most cabinet frost and moisture prevention heaters are small, electrically insulated wire heaters that are mounted against the cabinet walls near the door openings.
- The fans used for forced-draft condensers and evaporators are typically prop-type with shaded-pole motors.
- Ice makers are located in the low-temperature compartment and freeze water into ice cubes.
- The service technician should not routinely apply gages to a domestic refrigerator system. Explore all other troubleshooting techniques before applying gages.
- A very small amount of refrigerant lost from a refrigerator will affect the performance. Very small leaks may be found only with the best leak detection equipment.
- An epoxy may be used to seal a leak in an aluminum evaporator.
- Tubing in condensers is usually made of steel. These leaks should be repaired with the appropriate solder.
- When a leak has been repaired, a triple evacuation should be pulled on the entire system.
- Under certain conditions capillary tube metering devices may be repaired.
- ♻ Refrigerant should be recovered and never exhausted into the atmosphere. ♻

REVIEW QUESTIONS

1. The typical temperature inside the fresh-food compartment in a domestic refrigerator is
- **A.** 25°F to 30°F.
- **B.** 30°F to 35°F.
- **C.** 35°F to 40°F.
- **D.** 40°F to 45°F.

2. The single compressor in a household refrigerator operates under conditions for the lowest box temperature, which is typically
- **A.** −20°F to −10°F.
- **B.** −10°F to +5°F.
- **C.** +5°F to +15°F.
- **D.** +15°F to +25°F.

3. What are the two types of evaporators found in household refrigerators?

4. List two sources of heat that may be applied for evaporator defrost.

5. Domestic refrigerator compressors may be the reciprocating or ________ type.

6. Welded ________ sealed compressors are normally used in household refrigerators.

7. Condensers in these refrigerators are all ________ cooled.

8. Frost accumulates on the evaporators of these refrigerators because
- **A.** they are generally located within a house.
- **B.** they are generally located in high-humidity areas.
- **C.** they are low-temperature appliances.
- **D.** there is a heat exchange with the suction line.

9. The capillary tube metering device is usually fastened to the ________ for a heat exchange.
- **A.** suction line
- **B.** compressor discharge line
- **C.** liquid line

10. The refrigerant flow through the fixed-bore capillary tube metering device is determined by the bore of the tube and the ________ of the tube.

11. Special heaters called ________ heaters are often located around the doors to keep the door facing above the dew point temperature to avoid sweating.
- **A.** defrost
- **B.** condensate
- **C.** mullion or panel
- **D.** oil

12. Two types of wiring diagrams are the ________ and the ________ diagrams.

13. The defrost cycle in a domestic refrigerator may be terminated by two methods: ________ and ________.

14. The hot gas defrost uses the heat from the ________ to melt the ice from the coil.
- **A.** compressor
- **B.** evaporator
- **C.** condenser
- **D.** metering device

15. The refrigerator cabinet will sweat if it is not kept
- **A.** above the dew point temperature.
- **B.** below the dew point temperature.
- **C.** within the psychrometric tolerance.
- **D.** within the tolerance of the filter drier.

16. Two fans are provided on refrigerators when forced draft is used: one for the ________, and one for the ________.

17. Refrigerators currently being manufactured in the United States are using refrigerant ________.

18. Typical head pressures should correspond to a condensing temperature ________°F higher than room temperature at design operating conditions.
- **A.** 5–15
- **B.** 15–25
- **C.** 25–35
- **D.** 35–45

19. The adjustment device used for low atmospheric pressure conditions is called the ________ thermostatic adjustment control.
- **A.** positive temperature coefficient
- **B.** altitude
- **C.** dual-voltage
- **D.** condenser coil

20. What happens to the temperature of the refrigerant in the compressor discharge line when the head pressure increases?

UNIT 47 Room Air Conditioners

OBJECTIVES

After studying this unit, you should be able to

- describe the various methods of installing window air-conditioning units.
- discuss the variations in the designs of window and through-the-wall units.
- list the major components in the refrigeration cycle of a window cooling unit.
- explain the purpose of the heat exchange between the suction line and the capillary tube.
- describe the heating cycle in the heat pump or reverse-cycle room air conditioner.
- describe the controls for room air-conditioning (cooling) units.
- describe the controls for room air-conditioning (cooling and heating) units.
- discuss service procedures for room air conditioners.
- list the procedures to be followed to determine whether or not to install gages.
- state the proper procedures for charging a room air conditioner.
- list the types of expansion valves that may, under some conditions, be substituted for the capillary tube.
- state the components that may require electrical service.

SAFETY CHECKLIST

✔ Wear back brace belts when lifting or moving any appliance.

✔ Lift with your legs, keeping your back straight. Whenever possible use appropriate equipment to move heavy objects.

✔ Observe proper electrical safety techniques when servicing any appliance or system. Ensure that electrical power to the unit is off except when needed for troubleshooting.

✔ Wear goggles and gloves when transferring refrigerant into or out of a room air-conditioning unit.

✔ When performing service on window units, make sure that all loose clothing and hair are secured because they could become entangled in rotating fans and shafts.

47.1 AIR CONDITIONING AND HEATING WITH ROOM UNITS

Room air conditioning is the process of conditioning the air in rooms, usually one at a time, with individual units. This term applies to both heating and cooling.

Room air-conditioning equipment is constructed of components that have already been discussed in detail. When a particular component or service technique is mentioned, you will be referred to the appropriate part of the text for the needed details. Systems and components characteristic to room units are discussed in this unit.

Single-room air conditioning can be accomplished in several ways, but each involves the use of package (self-contained) systems of some type. A common type is the room air-conditioning window unit for cooling only, **Figure 47–1.** This type of unit has been expanded to include electric strip heaters in the airstream with controls for heating and cooling, **Figure 47–2.** Adequate air circulation between

Figure 47–1 A window unit for cooling. *Courtesy Friedrich Air Conditioning Co.*

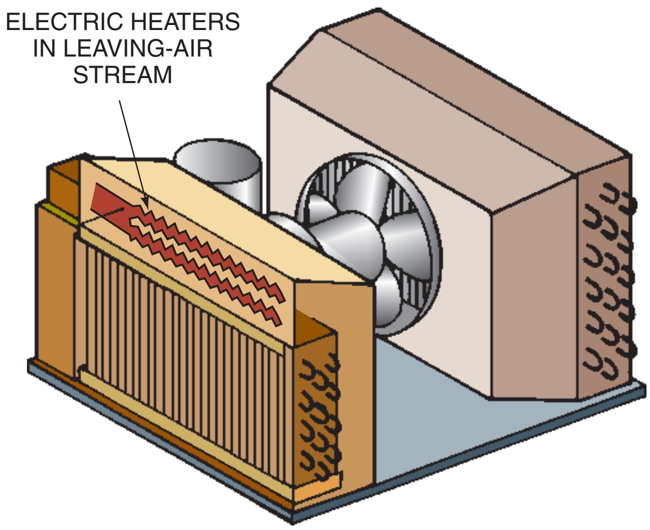

Figure 47–2 A window unit with heat added.

rooms enables many owners to use a room unit for more than one room.

47.2 ROOM AIR CONDITIONING, COOLING

Cooling-only units may be either window or through-the-wall types, **Figure 47–3.** They are much the same, typically having only one double-shaft fan motor for the evaporator and the condenser. The capacity of these units may range from about 4000 Btu/h (1/3 ton) to 24,000 Btu/h (2 tons). Some units are front-air discharge and some are top-air discharge, **Figure 47–4.** Top-air discharge is more common for through-the-wall units with the controls being located on top. These top-air discharge units are installed frequently in motels in which individual room control is desirable. The controls are built-in so the unit may be serviced in place or changed for a spare unit and repaired in the shop.

Window and wall units are designed for easy installation and service. Window units have two types of cases. One type is fixed to the chassis of the unit, and the other is a case that fastens to the window opening and in which the chassis slides in and out, **Figure 47–5.** Older units were all slide-out-type cases; in the smaller, later-date units the case is built on the chassis.

(A)

(B)

Figure 47–3 **(A)** Window and **(B)** through-the-wall-type units. *Courtesy Friedrich Air Conditioning Co.*

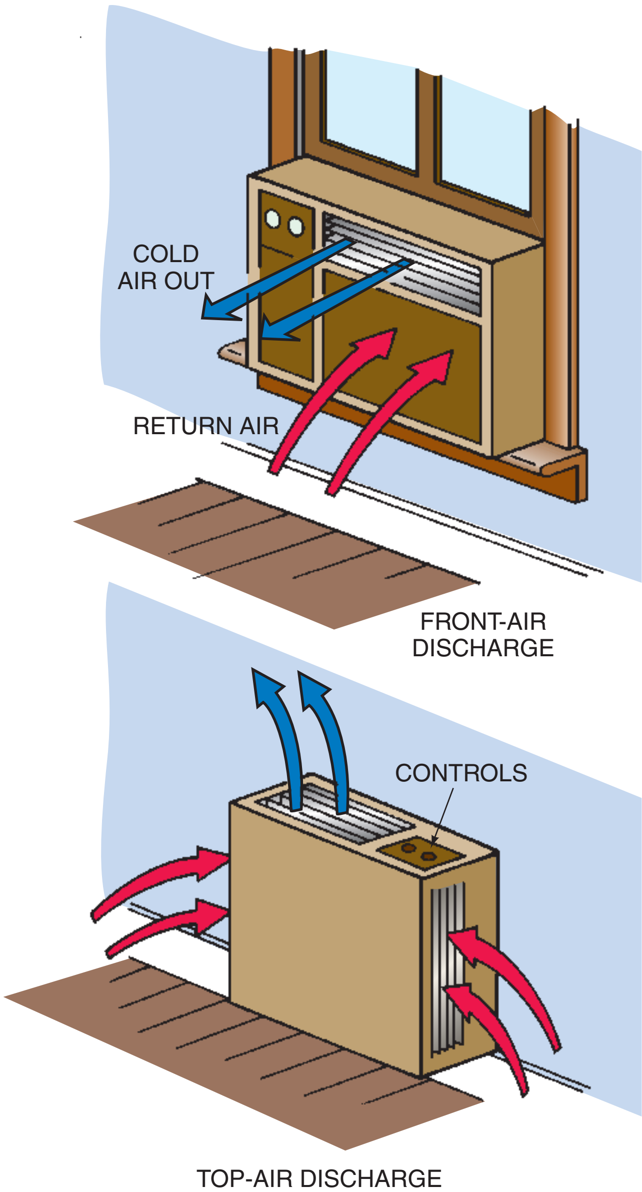

Figure 47–4 Some room units are front-air discharge, and some are top-air discharge.

The case design is important from a service standpoint. For units that have the case built on the chassis, the entire unit including the case must be removed for service. On units with a slide-out chassis, the chassis may be pulled out from the case for simple service.

One special application unit manufactured by several companies is a roof-mount design for travel trailers and motor homes, **Figure 47–6.** This unit may be seen in some service station attendant booths because it is up out of the way. It will not get run over and does not take up wall space. The case on this unit lifts off the top, **Figure 47–7.** The controls and part of the control circuit are serviced inside next to the air discharge, **Figure 47–8.**

The manufacturer's design objectives for room units are efficiency of space and equipment and a low noise level.

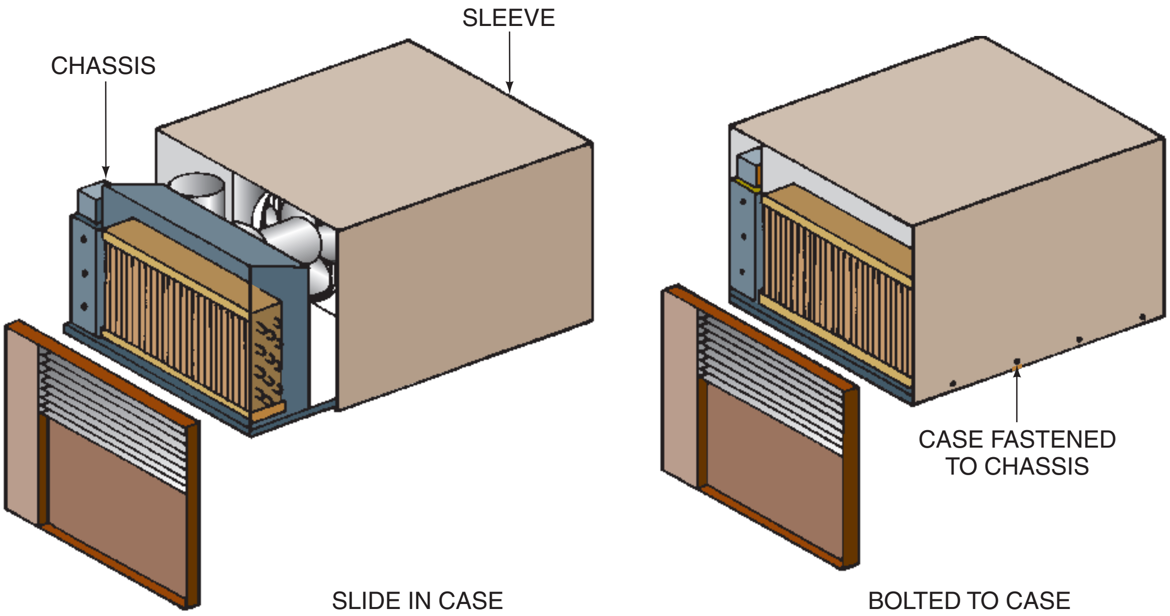

Figure 47–5 Some window units are of the slide-out design, and in some, the cover is bolted to the chassis.

Figure 47–6 A roof-mount unit for recreational vehicles. Sometimes these are used in small stand-alone buildings. *Photo by Bill Johnson*

Figure 47–7 The case lifts off the roof-mount unit. *Photo by Bill Johnson*

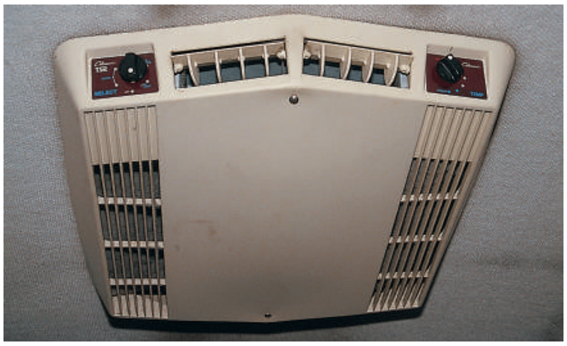

Figure 47–8 Part of the control circuit is located inside, under the front cover. *Photo by Bill Johnson*

Most units are as compact as current manufacturing and design standards will allow. Most components are as small and efficient as possible. The intent is to get the most capacity from the smallest unit.

47.3 THE REFRIGERATION CYCLE, COOLING

You should have a full understanding of Unit 3, "Refrigeration and Refrigerants," before attempting to understand the following text. The most common refrigerant that has been used for room units is R-22. However, environmentally friendly alternative refrigerants are replacing R-22 because of its chlorine content and ozone depletion potential. This refrigerant will be the only one discussed here. When a refrigerant of another type is encountered, the temperature/pressure chart in Unit 3 may be consulted for the difference in pressure. The operating temperatures will be the same.

The refrigeration cycle consists of the same four major components as those described in Unit 3: an evaporator to absorb heat into the system, **Figure 47–9;** a compressor to

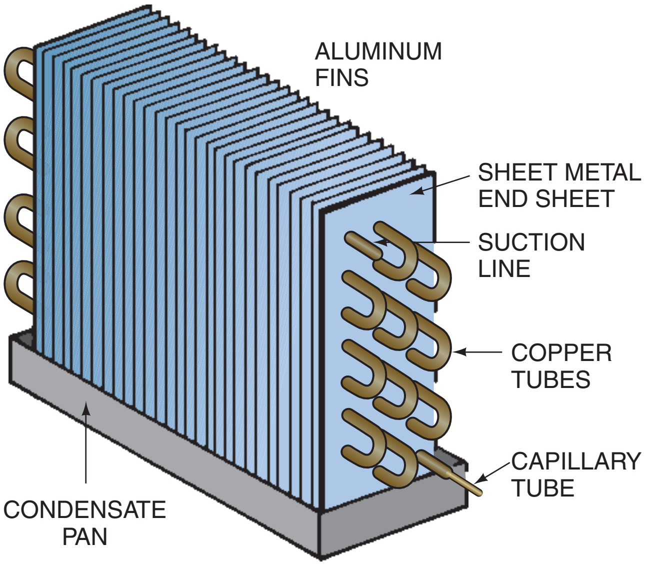

Figure 47–9 A room unit evaporator.

Figure 47–10 A room unit compressor. *Courtesy Bristol Compressors Inc.*

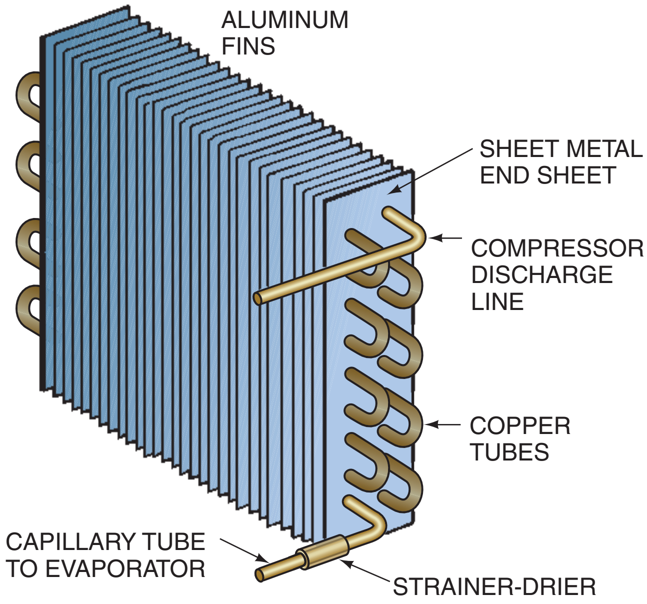

Figure 47–11 A room unit condenser.

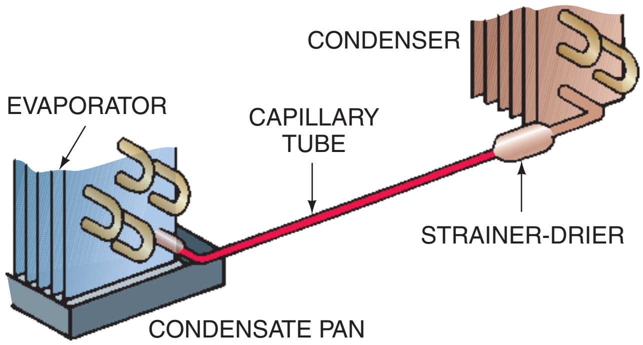

Figure 47–12 A room unit capillary tube.

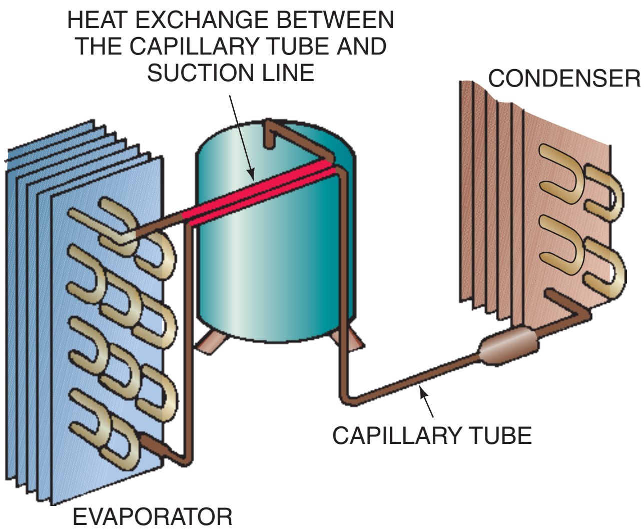

Figure 47–13 A suction-to-capillary-tube heat exchange.

pump the heat-laden refrigerant through the system, **Figure 47–10;** a condenser to reject the heat from the system, **Figure 47–11,** and an expansion device to control the flow of refrigerant, **Figure 47–12.** This is done by maintaining a pressure difference between the high-pressure and low-pressure sides of the system. Many units have a heat exchange between the metering device (capillary tube) and the suction line, **Figure 47–13.** The complete refrigeration cycle may be seen in **Figure 47–14.**

Cooling units are considered high-temperature refrigeration systems and must operate above freezing to prevent condensate from freezing on the coil. Typically the evaporators boil the refrigerant at about 35°F. Central air conditioners normally boil the refrigerant at 40°F. Room units boil the refrigerant much closer to freezing, so more care must be taken to prevent freezing of the evaporator.

The evaporator is typically made up of copper or aluminum tubing with aluminum fins. The fins may be straight or spine type. All fin types are in close contact with the copper tubing for the best heat exchange.

The evaporator may have only a few refrigerant circuits or it may have many. They may take many different paths, such as two, three, or four circuits that may be in line with the airflow (series) or that operate as multiple evaporators, **Figure 47–15.** Each manufacturer has designed its own and tested it to perform to its specifications.

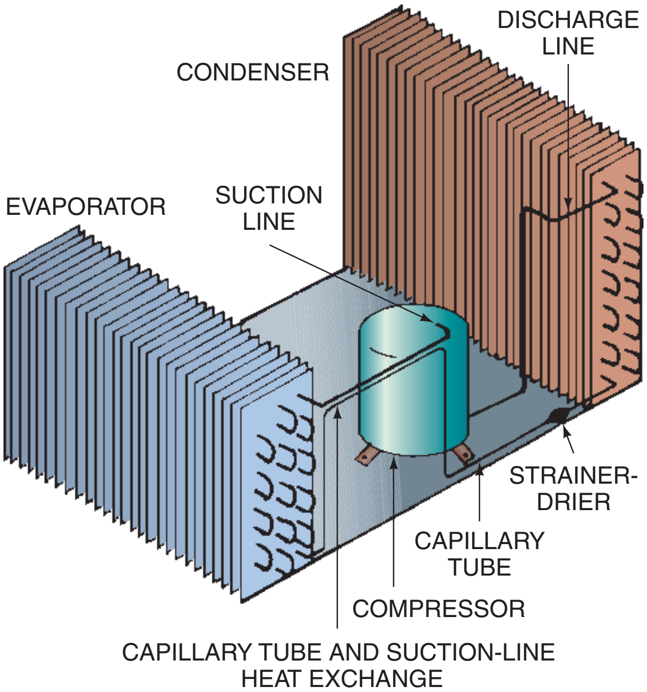

Figure 47–14 Refrigeration cycle components.

The evaporators are small and designed for the maximum obtainable heat exchange. Fins that force the air to move from side to side and tubes that are staggered to force the air to pass in contact with each tube are typical, **Figure 47–16.**

The evaporator typically operates below the dew point temperature of the room air for the purpose of dehumidification, so condensate forms on the coil. It drains to a pan beneath the coil, **Figure 47–17.** The condensate is generally drained back to the condenser section and evaporated. **Figure 47–18** shows a typical evaporator with temperatures and pressures.

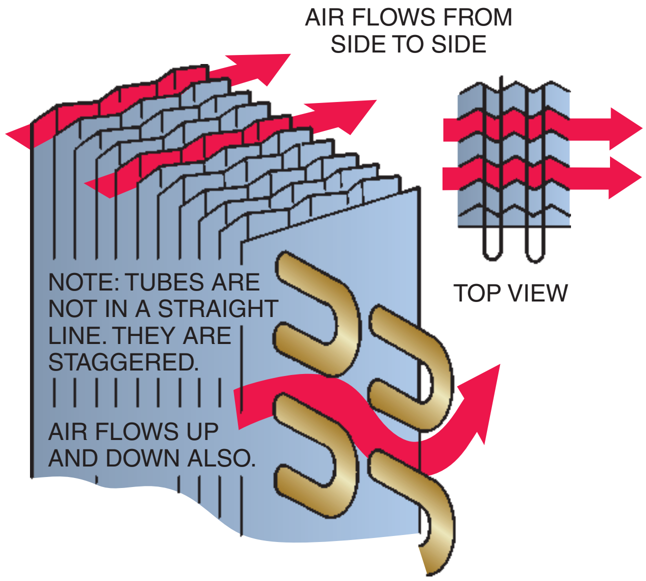

Figure 47–16 Some fins force the air to have contact with the fins and tubes.

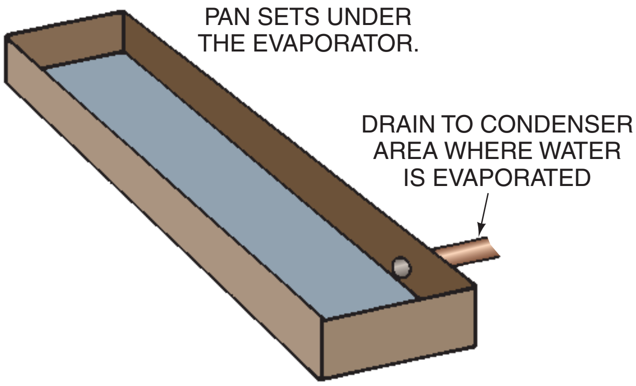

Figure 47–17 A condensate pan.

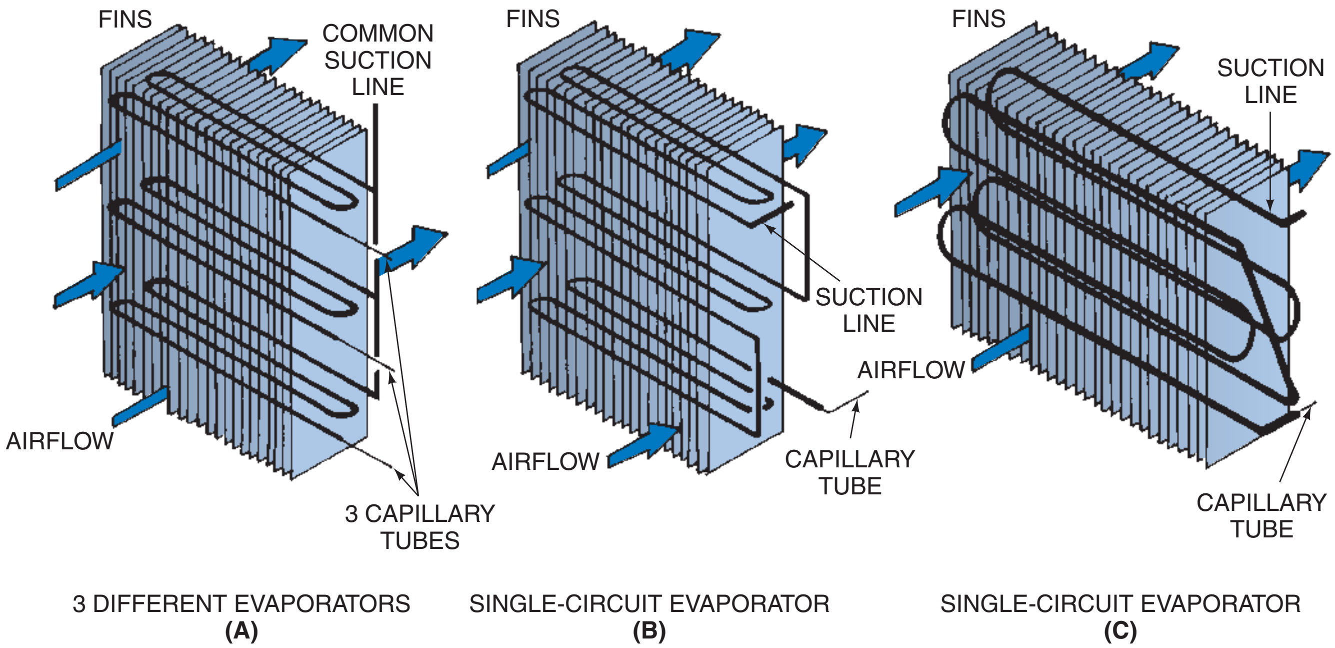

Figure 47–15 Some typical evaporator circuits.

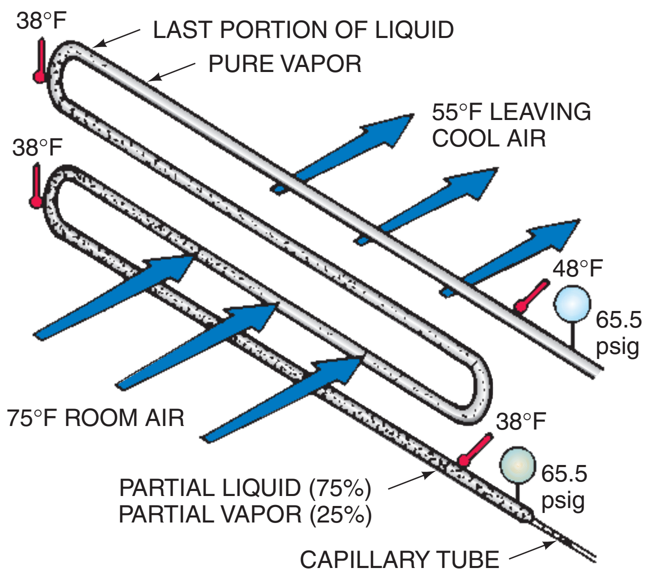

Figure 47–18 A typical evaporator with pressures and temperatures.

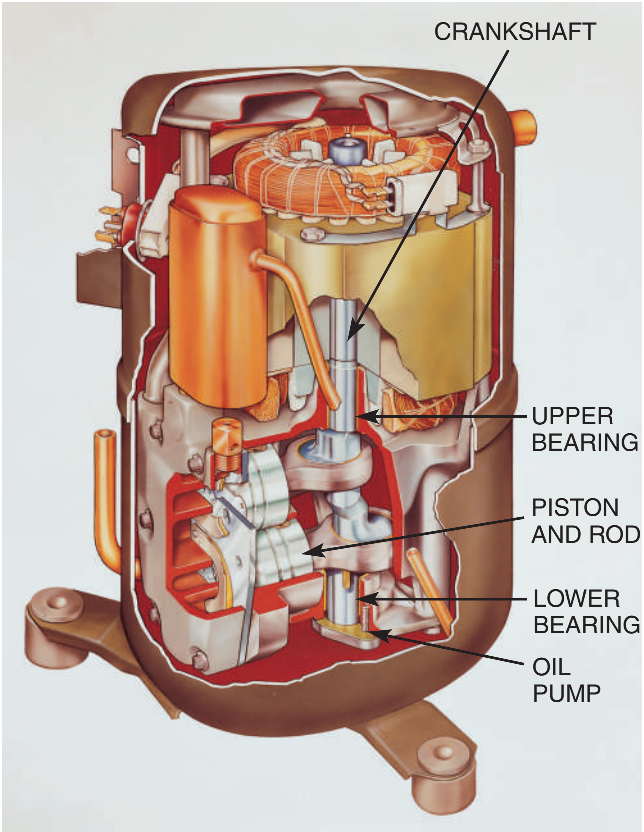

Figure 47–19 A hermetically sealed compressor. *Courtesy Tecumseh Products Company*

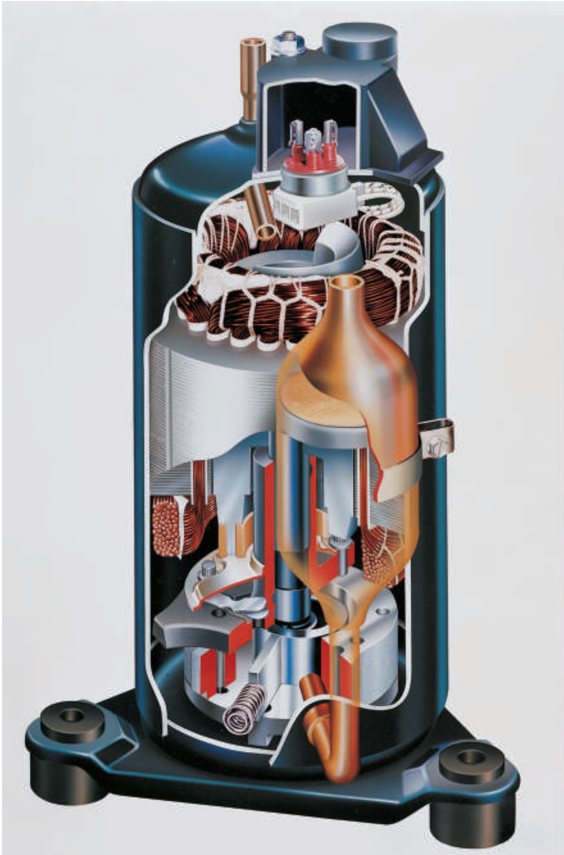

Figure 47–20 A rotary compressor. *Reprinted with permission of Motors and Armatures, Inc.*

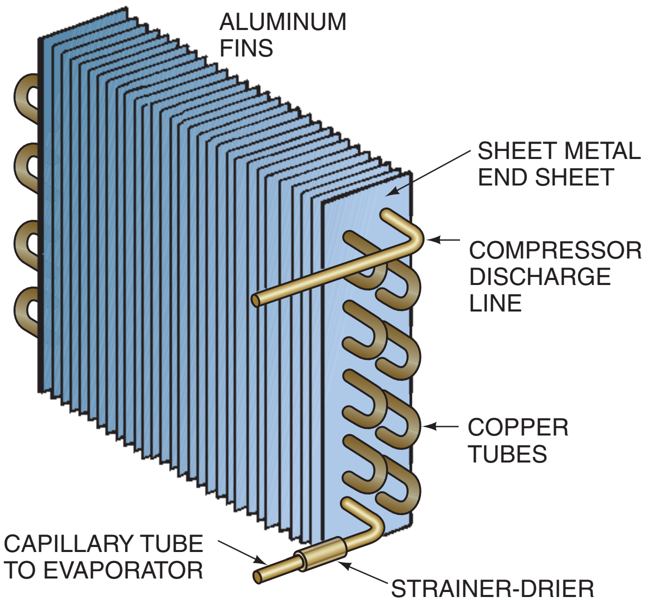

Figure 47–21 A finned-tube condenser.

The compressor for room units is a typical hermetically sealed air-conditioning compressor, **Figure 47–19.** The compressor may be reciprocating, **Figure 47–19,** or rotary, **Figure 47–20.** Compressors are described in detail in Unit 23.

Condensers are typically finned tube with copper or aluminum tubes and aluminum fins, similar to the evaporator, **Figure 47–21.** The condenser serves two purposes–it condenses the heat-laden vapor refrigerant inside the tubes and evaporates the condensate from the evaporator section. This is generally accomplished by using the heat from the discharge line and a slinger ring on the condenser fan, **Figure 47–22.** Evaporating the condensate keeps the unit from dripping and improves the efficiency of the condenser.

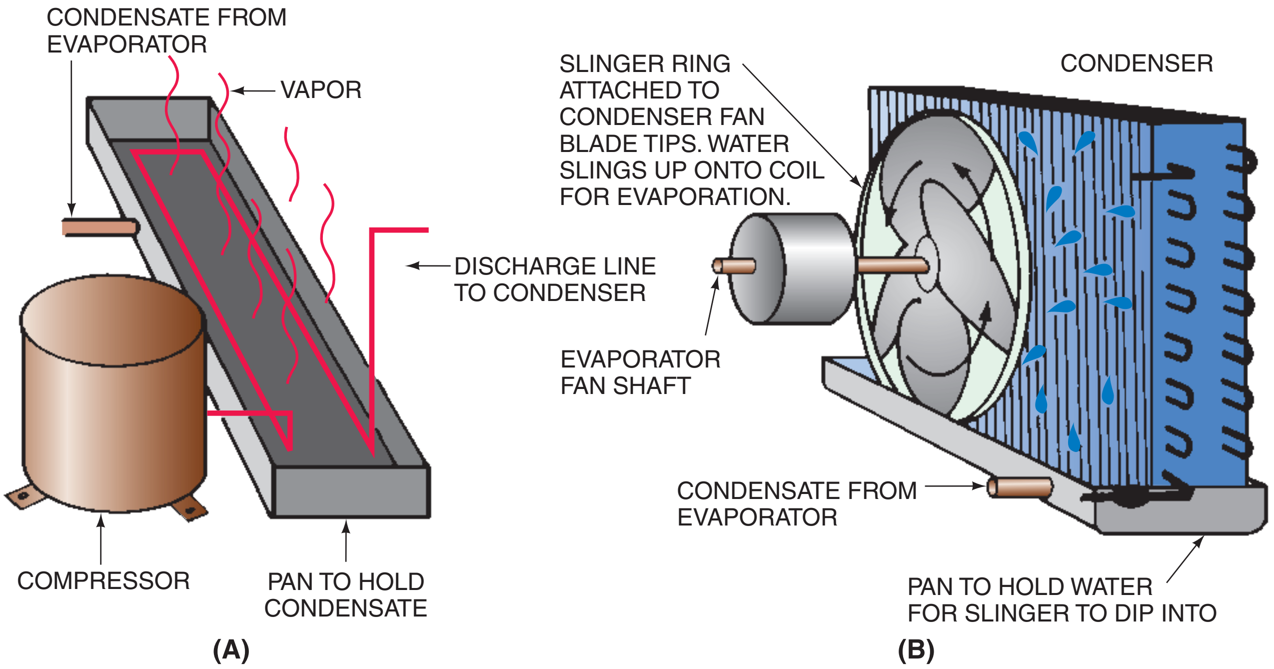

Figure 47–22 Moisture evaporated with the **(A)** compressor discharge line or **(B)** slinger.

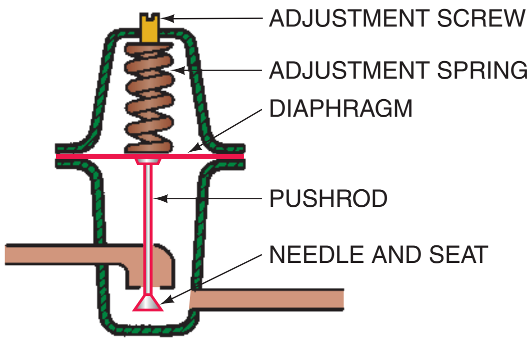

Figure 47–23 Some units use the automatic expansion valve.

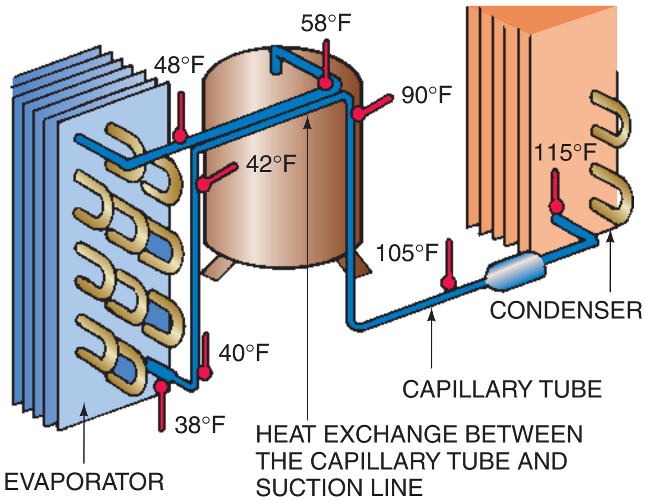

Figure 47–24 Typical temperatures along the capillary tube and suction-line heat exchange.

The capillary tube is the type of metering device in units manufactured during the past several years. Some early units used the automatic expansion valve, **Figure 47–23.** The automatic expansion valve has the advantage of controlling the pressure, which in turn controls the coil temperature. Coil freezing could be prevented by controlling the pressure. Unit 24 describes the automatic expansion device. Because more capillary tubes exist than any other expansion device for room air conditioners, it will be the one discussed in this text.

Most room units are designed to exchange heat between the capillary tube and suction line. This exchange adds some superheat to the suction gas and subcools the refrigerant in the first part of the capillary tube. The pressure and temperature of the refrigerant reduces all along the tube, **Figure 47–24.** The tube is colder at the outlet (where it enters the evaporator) than at the inlet (where it leaves the condenser). When this capillary tube is attached to a suction line, it has a net result of warming the compressor. The increase in subcooling of the capillary tube may also help the manufacturer get more capacity from the evaporator coil.

47.4 THE REFRIGERATION CYCLE, HEATING (HEAT PUMP)

Some window and through-the-wall units have reverse-cycle capabilities similar to the heat pumps discussed in Unit 43. They can absorb heat from the outdoor air in the winter and reject heat to the indoors. This is accomplished with a four-way reversing valve. The four-way reversing valve is used to redirect the suction and discharge gas at the proper time to provide heat or cooling, **Figure 47–25.** Check valves are used to ensure correct flow through the correct metering device at the proper time. A study of Unit 43 will help you to understand the basic cycle because the same principles are used.

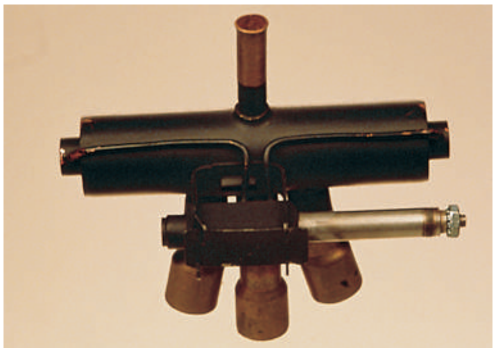

Figure 47–25 The four-way reversing valve for a heat pump. *Photo by Bill Johnson*

The following is a typical cycle description. There are many variations, depending on the manufacturer. Follow the description in **Figure 47–26.**

During the cooling cycle, the refrigerant leaves the compressor discharge line as a hot gas. The hot gas enters the four-way valve and is directed to the outdoor coil where the heat is rejected to the outdoors. The refrigerant is condensed to a liquid, leaves the condenser, and flows to the indoor coil through the capillary tube. The refrigerant is expanded in the indoor coil where it boils to a vapor, just like the cooling cycle on a regular cool-only unit. The cold heat-laden vapor leaves the evaporator and enters the four-way valve body.

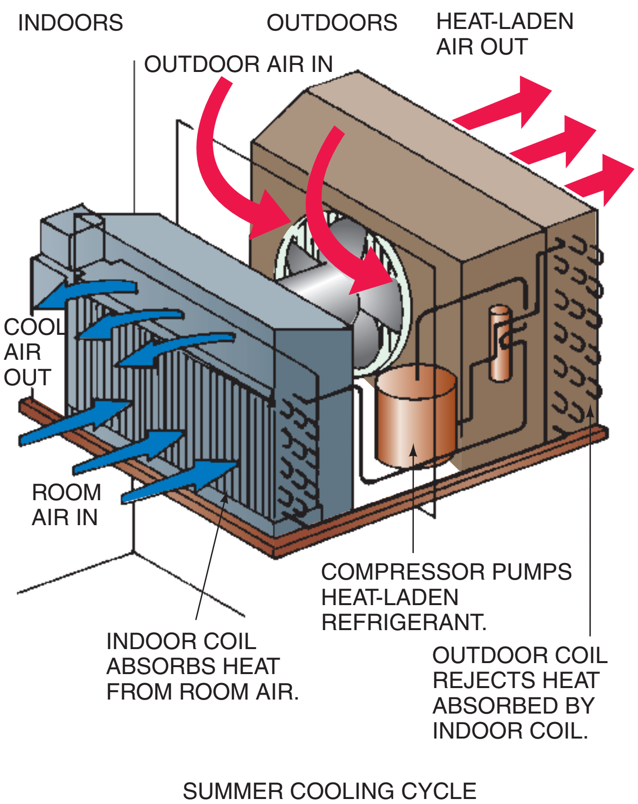

Figure 47–26 The refrigeration cycle and description—cooling.

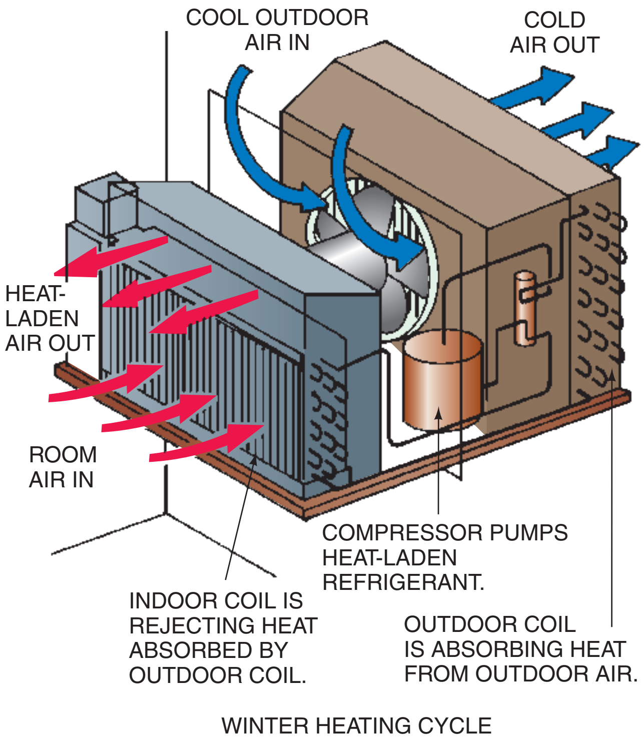

Figure 47–27 The refrigeration cycle and description—heating.

The piston in the four-way valve directs the refrigerant to the suction line of the compressor where the refrigerant is compressed and the cycle repeats itself.

The heating cycle may be followed in **Figure 47–27.** The hot gas leaves the compressor and enters the four-way valve body as in the previous example. However, the piston in the four-way valve is shifted to the heating position, and the hot gas now enters the indoor coil. It now acts as the condenser and rejects heat to the conditioned space. The refrigerant condenses to a liquid and flows out the indoor coil through the capillary tube to the outside coil. The refrigerant is expanded and absorbs heat while boiling to a vapor. The heat-laden vapor leaves the outdoor coil and enters the four-way valve where it is directed to the compressor suction line. The vapor is compressed and moves to the compressor discharge line to repeat the cycle.

A few things to keep in mind for any heat pump follows. The compressor is not a conventional air-conditioning compressor. It is a heat pump compressor. It has a different cylinder displacement and horsepower. The compressor must have enough pumping capacity for low-temperature operation. The unit evaporator also operates at below freezing during the heating cycle, and frost will build up on the evaporator. Different manufacturers will handle this frost in different ways; you will have to consult their literature. A defrost cycle may be used to defrost this ice. Another point to remember is that the capacity of a heat pump is less in colder weather so supplemental heat will probably be used. Electrical strip heat is the common heat. It may also be used to prevent the unit from blowing cold air during the defrost cycle.

47.5 INSTALLATION

There are two types of installation for room units, both cooling and cooling-heating types. These are the window installation and the wall installation. The window installation may be considered temporary because a unit may be removed and the window put back to its original use. The wall installation is permanent because a hole is cut in the wall and must be patched if the unit is removed. When a unit becomes old and must be changed for a new one in a window installation, a new unit to fit the window would probably be available. A new unit may not be available to fit the hole in a wall.

Window installations are for either the double-hung window or the casement window, **Figure 47–28.** The double-hung window is the most popular because there are more double-hung windows. Window units may be installed in other types of windows, such as picture window locations or jalousie windows, but these require a great deal of carpentry skill. A special unit is manufactured for casement window installation, **Figure 47–29.**

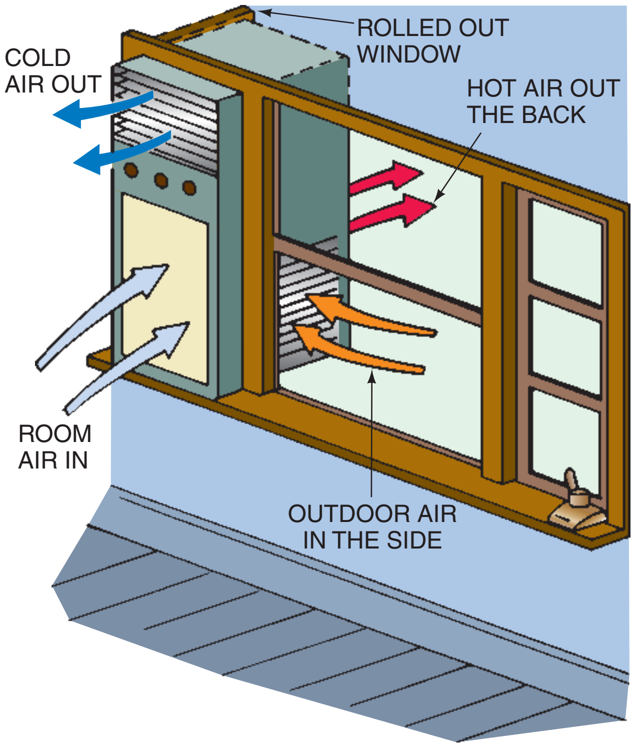

Figure 47–29 A window unit installed in a casement window.

(A)

(B)

Figure 47–28 Window units are for either **(A)** double-hung or **(B)** casement windows. *Courtesy Friedrich Air Conditioning Co.*

Every installation should follow some general guidelines. The inside part of the installation requires that the proper electrical outlet be located within the length of the cord furnished with the unit. Extension cords are not recommended by manufacturers. The proper electrical outlet must match the plug on the end of the cord, **Figure 47–30.** Window units may be either 115- or 208/230-V operation and should be on a circuit by themselves.

When 115-V operation is chosen, it is usually to prevent having to install an electrical circuit. Often this choice is made without investigating the existing circuit as it may already have some load on it. For example, a 115-V electrical outlet may be part of the lighting circuit and have a television and several lamps on the same circuit. The addition of a

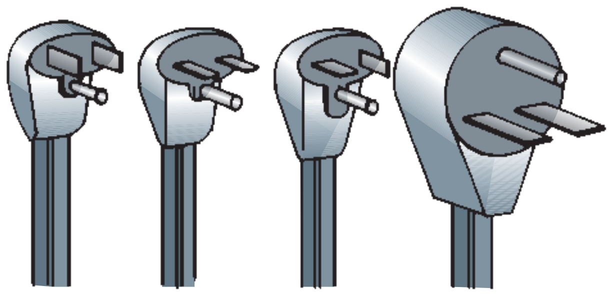

Figure 47–30 The proper outlet must be used to match the plug.

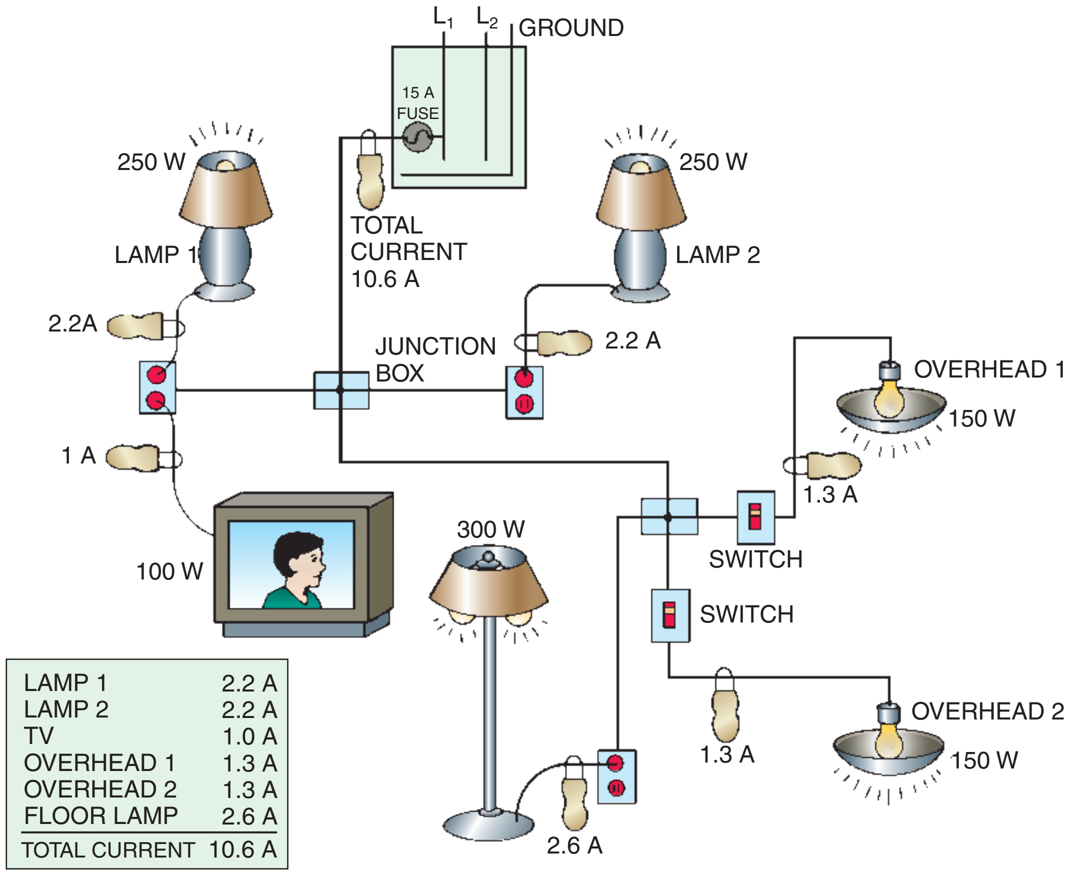

Figure 47–31 The circuit already has a load without the addition of the window unit.

window air conditioner of any size may overload the circuit, **Figure 47–31.**

An investigation of the electrical circuit to see what extra capacity is available is necessary. This may be accomplished by turning on all the lights in the room nearest the outlet intended for use. The adjacent room's lights may also be turned on. Then turn off the breaker that controls the outlet. The current load of the lights may be totaled by adding them mathematically or using an ammeter on the wire to the circuit. If the circuit is already using 10 A and it is a 15-A circuit, a window unit consuming 6 A will overload the circuit. A typical 5000 Btu/h unit will pull about 7 A when 115 V is used. An inexperienced homeowner who buys a unit at the department store and installs it may be in trouble. If the unit will run on a slightly overloaded circuit, the television picture may roll over every time the unit compressor starts, **Figure 47–32.**

Other considerations on the inside of the room are the best window to use and the air direction. A window that will give the best total room circulation may not be the best choice because it may be next to the easy chair in a den, by the bed in a bedroom, or behind the dining table, **Figure 47–33.** Some people will purchase a large window unit for several rooms. The unit must be able to circulate the air to the adjacent rooms, or the thermostat will shut the unit off and cool only one room. A floor fan may be used to move the air from the room with the unit, **Figure 47–34.**

Through-the-wall units in motels usually seem to be located on the outside wall, under the window and where the chair or chairs and table are located. This is the best practical place for the unit, but not necessarily the best for the occupants. However, there may be no other place in a small room than on an outside wall, **Figure 47–35.**

A unit located where air will recirculate, for example behind drapes, will be a problem in any installation. Air will continually recirculate to the return air grille and be cold enough to satisfy the thermostat, shutting the unit off. Some small units have no thermostat, only an ON-OFF switch. These may freeze the evaporator solid with ice, **Figure 47–36.**

Typically, the airflow should be directed upward, as cold air will fall, **Figure 47–37.** This will also keep the supply air from mixing with the return air and freezing the evaporator or satisfying the thermostat.

The window must be wide enough for the unit to be installed in and must raise far enough for the unit to set on the window ledge, **Figure 47–38.**

Smaller window units are of a size that when they are placed on the window ledge, they will almost balance. The center of gravity of the unit is near the center of the unit, **Figure 47–39.**

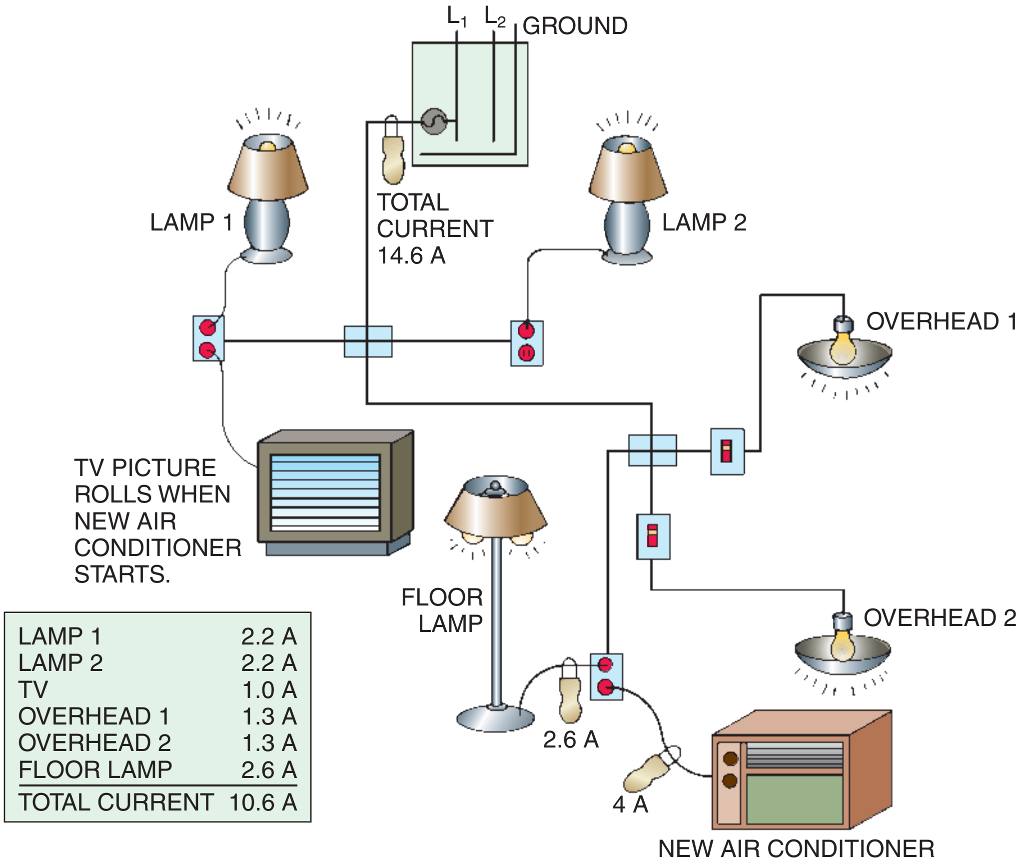

Figure 47–32 When a unit is on an overloaded circuit, the television picture may roll over when the compressor starts.

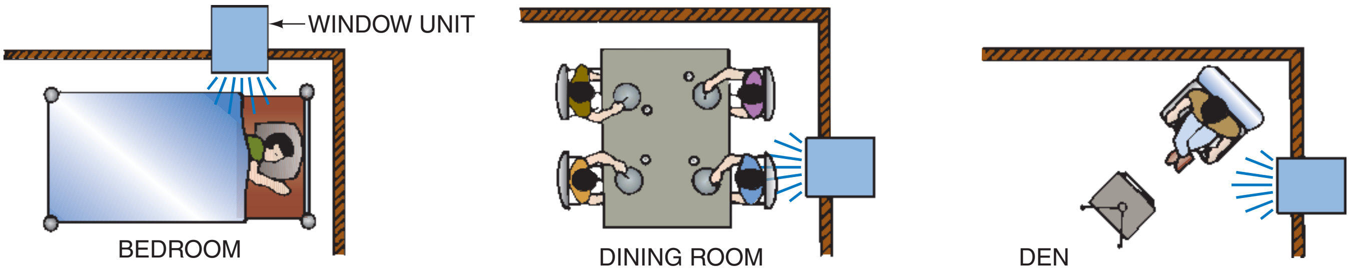

Figure 47–33 Some bad locations for window air conditioners.

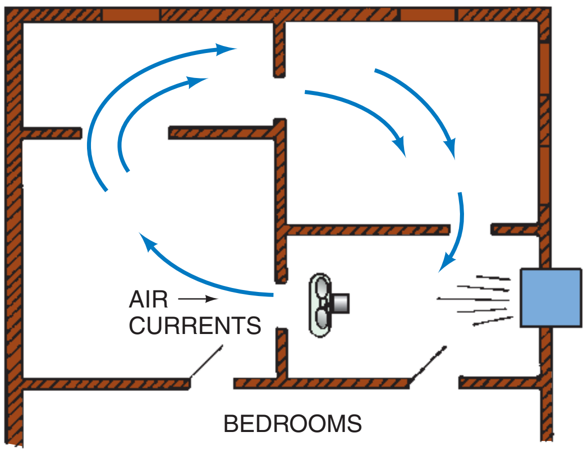

Figure 47–34 A floor fan may be used to circulate air to adjacent rooms.

In larger units, the compressor is located more to the rear causing the unit to have a tendency to fall out the window unless half of the unit is extended into the room. This, of course, is not desirable. Most manufacturers provide a brace kit to support the back of the unit, **Figure 47–40.** The bracket takes the pressure off the upper part of the window and places the load on the bracket.

When the unit is placed in the window, it never completely fills the window. A kit is provided with each new unit to aid in neatly filling the hole. This kit may be telescoping side panels or panels to match the unit color that may be cut to fit. When the window is partly raised to accommodate the window unit, the space between the movable window parts must be insulated. Usually a foam strip is furnished for this purpose, **Figure 47–41.**

Directions are included with each new unit. However, in some instances the unit may be removed; the braces and

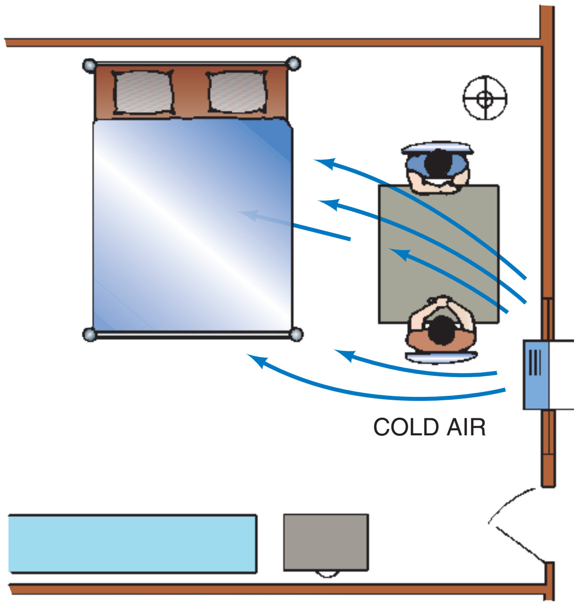

Figure 47–35 The outside wall may not be the best location for comfort, but it is the only place in most rooms.

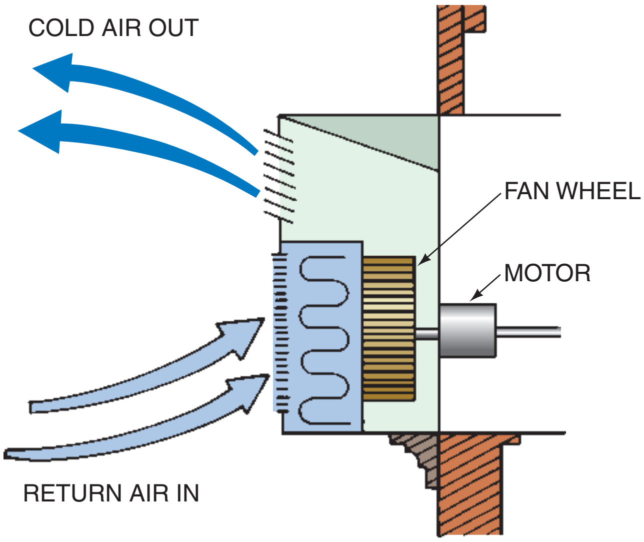

Figure 47–37 Cold air should be directed upward for best distribution.

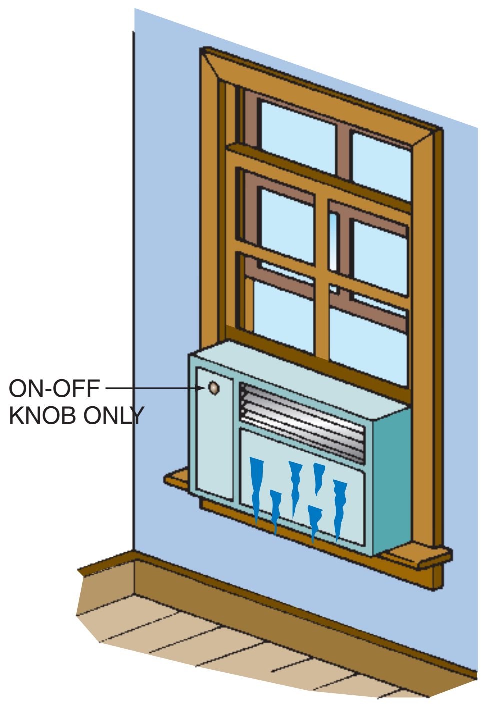

Figure 47–36 Some small units have no room thermostat, only an ON-OFF switch. If left on, the evaporator may freeze.

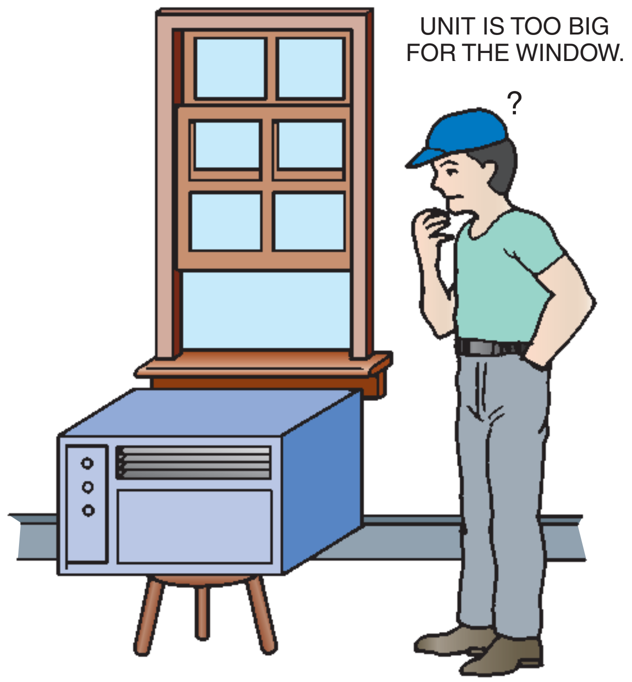

Figure 47–38 The window must open wide enough for the unit to fit.

window kit may be misplaced; and when reinstalled without braces and a proper window kit, a poor installation may result. Some awkward installations can be seen because of this. Units that are installed and not properly braced will vibrate, sometimes called window shakers, **Figure 47–42.** The unit, properly braced, will be typically slanted slightly to the rear for proper condensate drainage. When the weight is supported by the back, it relieves the pressure on the window and reduces the vibration.

Most units evaporate the condensate, but some allow it to drain out the back. This condensate should drain to a proper location, such as a flower bed, on the grass, or in a gutter, **Figure 47–43.** Some are installed so that the condensate drips on the sidewalk. This is not good as algae may form, and the walkway will become slick, **Figure 47–44.**

The unit must be installed in such a manner that air can circulate across the condenser and not recirculate. It must be

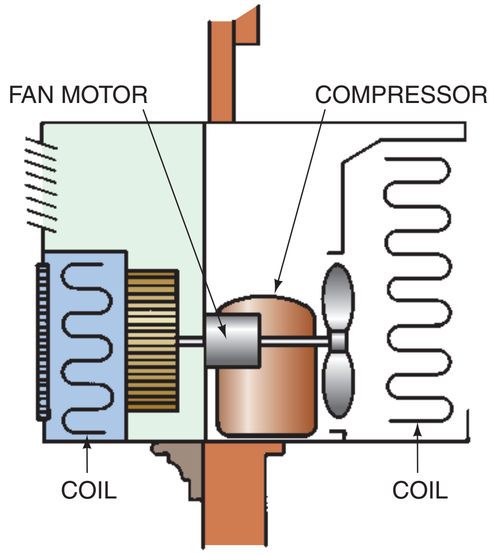

Figure 47–39 The center of gravity of a typical window unit is near the center.

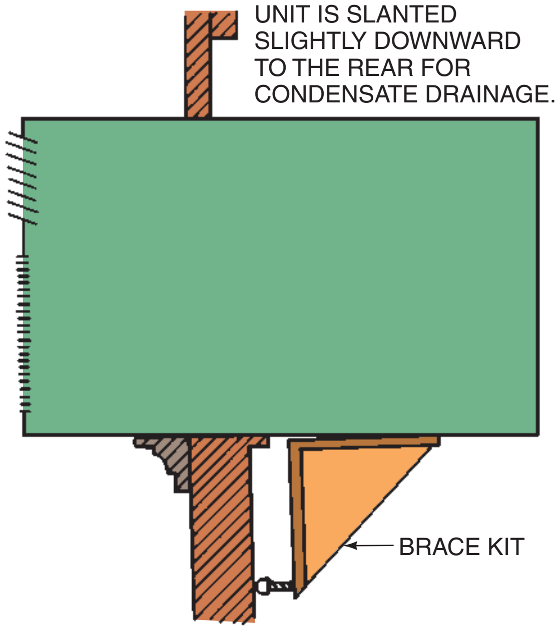

Figure 47–40 Larger units may be located farther to the rear so they do not protrude into the room. A brace kit should be used.

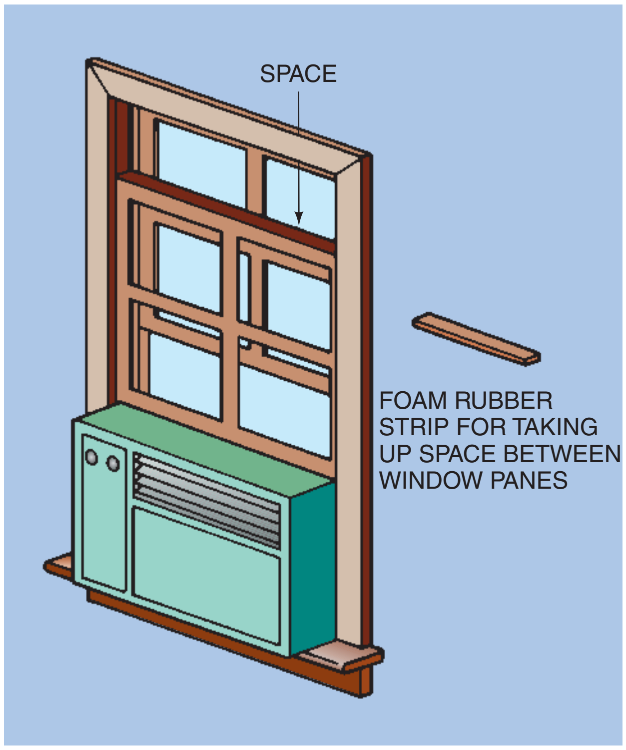

Figure 47–41 A foam strip for the top of the window.

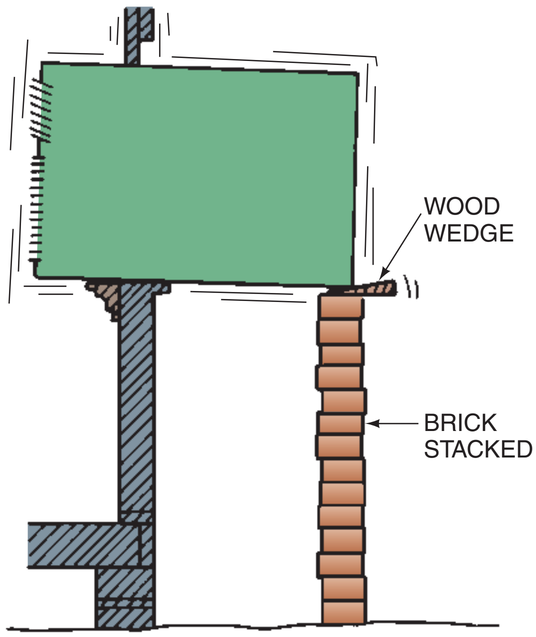

Figure 47–42 An awkward installation because the bracket kit is lost.

allowed to escape the vicinity and not heat the surroundings. Window units have been located with the condenser in a spare room, such as in a business, **Figure 47–45.** This is poor practice because the unit heats the air, and high operating conditions will occur.

Recirculation will cause high head pressure and high operating cost, **Figure 47–46.** Obstructions must not be located close to the air discharge.

Casement window installations require a special unit. This unit is narrow and tall to fit the rollout portion of the casement window. If the window is double, a regular window unit may be installed by cutting out part of the fixed portion of the window, **Figure 47–47.** This requires some skill. When this type of installation is performed, all stress must be on the window sill. If the unit is removed, another

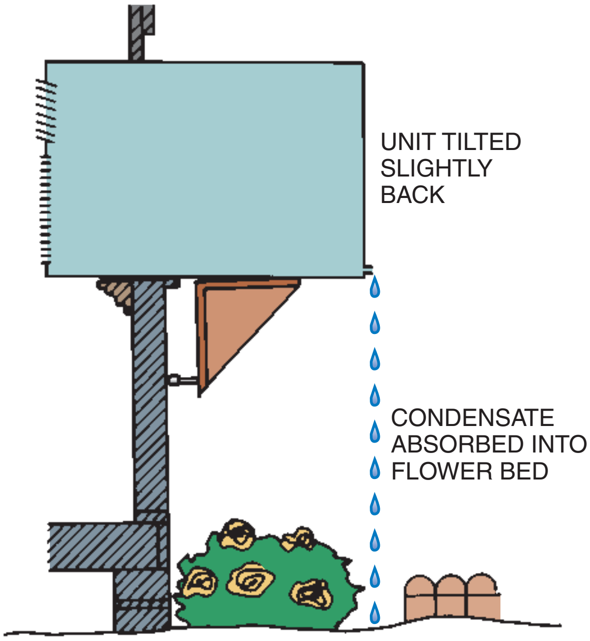

Figure 47–43 The condensate should drain to the proper place.

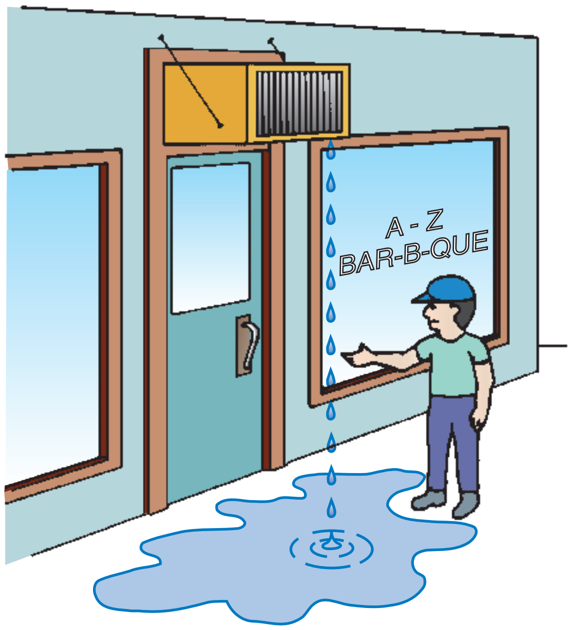

Figure 47–44 Condensate on a walkway can be dangerous.

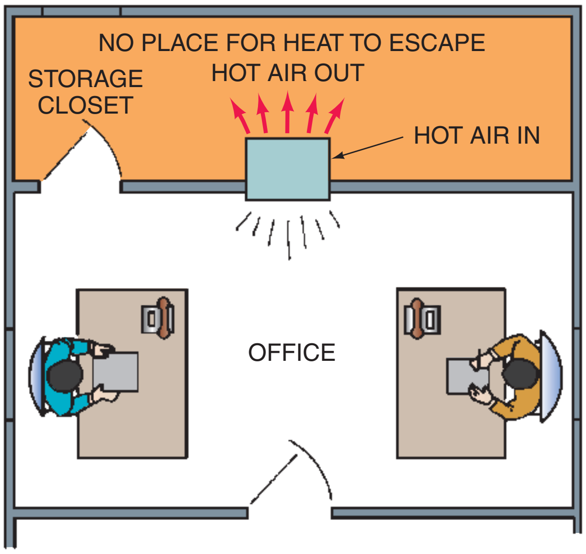

Figure 47–45 The heat must be able to escape from around the unit. Units with the condenser in an adjacent room will not operate efficiently.

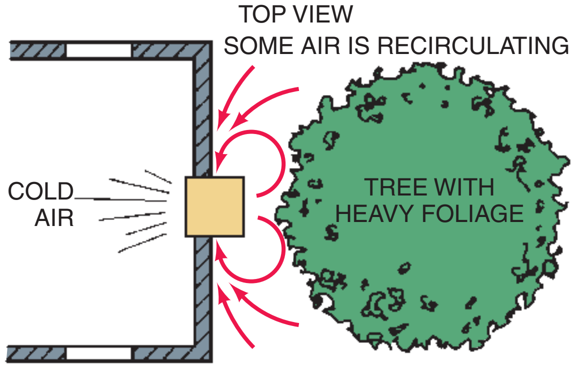

Figure 47–46 Recirculated air will cause high head pressure.

repair job must be performed for the window to be used, **Figure 47–48.**

Through-the-wall units typically protrude into the room only a slight amount with the bulk of the unit on the outside, **Figure 47–49.** When these units are installed in a motel, the outdoor portion protrudes into the walkway slightly. If condensate is not completely evaporated, it will run across the walkway and cause a hazard.

Through-the-wall units may be installed while the building is under construction. This is accomplished by installing wall sleeves and covering the openings until the unit is set in place, **Figure 47–50.** The wiring is run to the vicinity of the unit, and the unit is connected when installed. It is important that holes of the correct size be cut. The wall sleeve should be purchased from the manufacturer in advance to ensure this.

47.6 CONTROLS FOR ROOM UNITS, COOLING

Room units for cooling only are typically plug-in appliances furnished with a power cord. All controls are furnished with the unit. There is no wall-mounted remote thermostat as in central air conditioning. The room thermostat sensor is located in the unit return airstream, **Figure 47–51.** A typical room unit may have a selector switch to control the fan speed

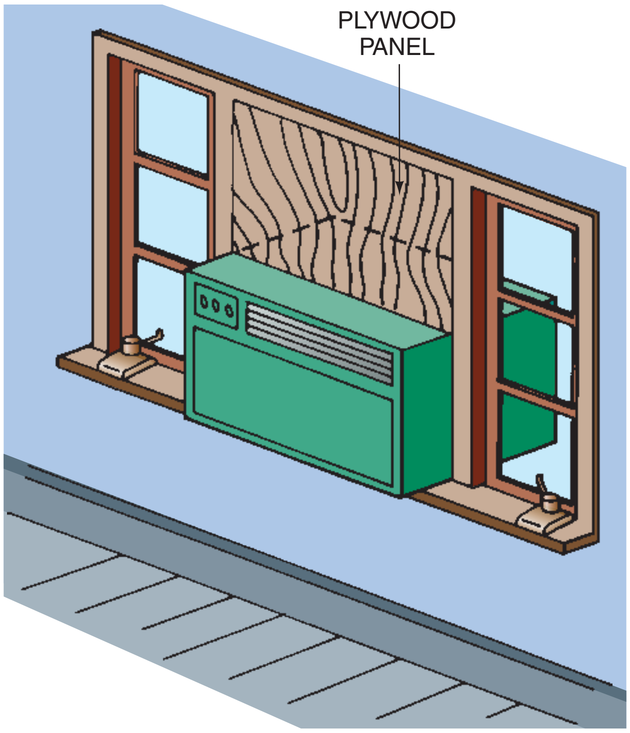

Figure 47–47 A regular window air conditioner is sometimes installed in the fixed portion of the casement window unit between the rollout sections.

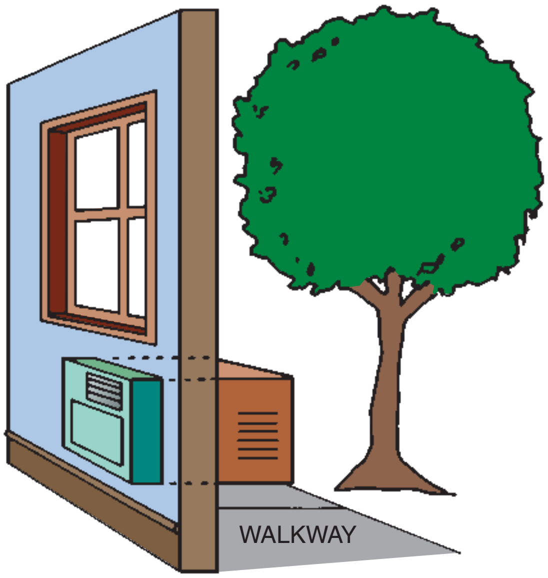

Figure 47–49 Most of the through-the-wall unit is located on the outside of the wall.

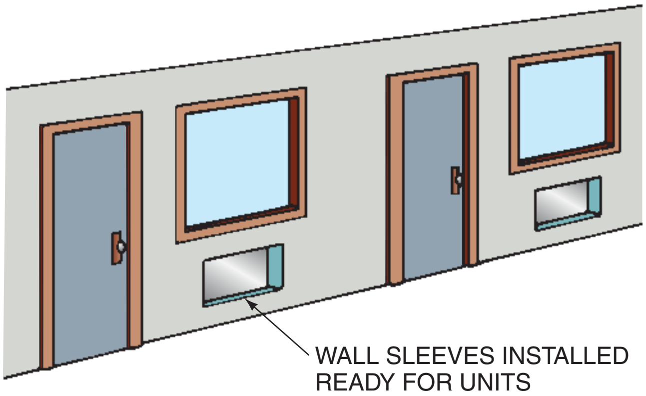

Figure 47–50 Wall sleeves may be installed in advance of the unit.

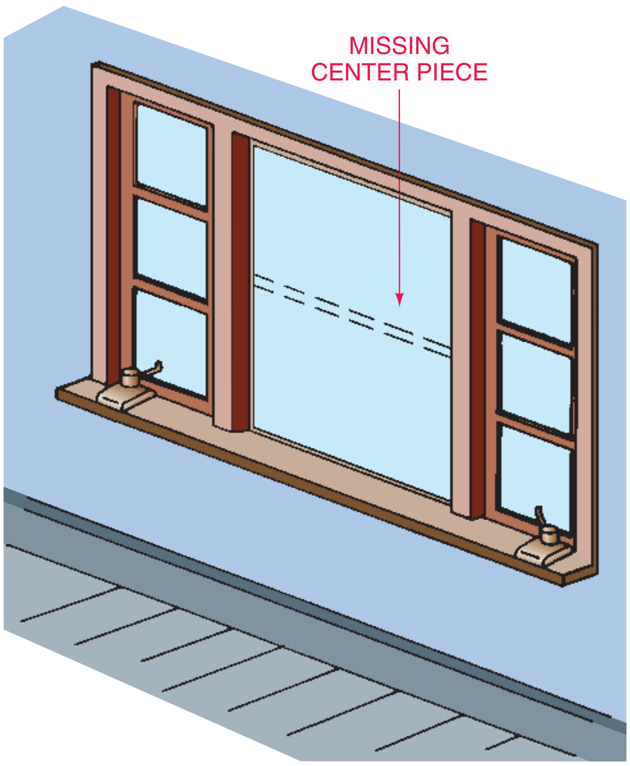

Figure 47–48 If the unit is moved, the window must be repaired.

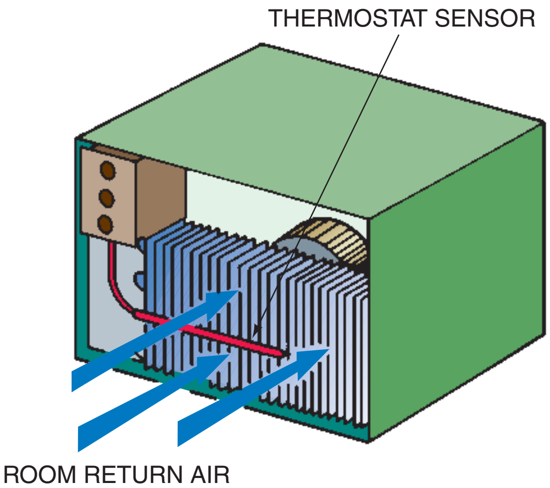

Figure 47–51 The thermostat is located in the return airstream.

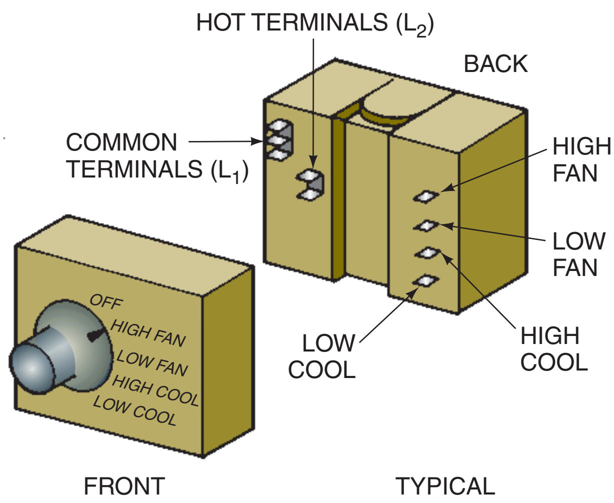

Figure 47–52 A typical selector switch for a room unit.

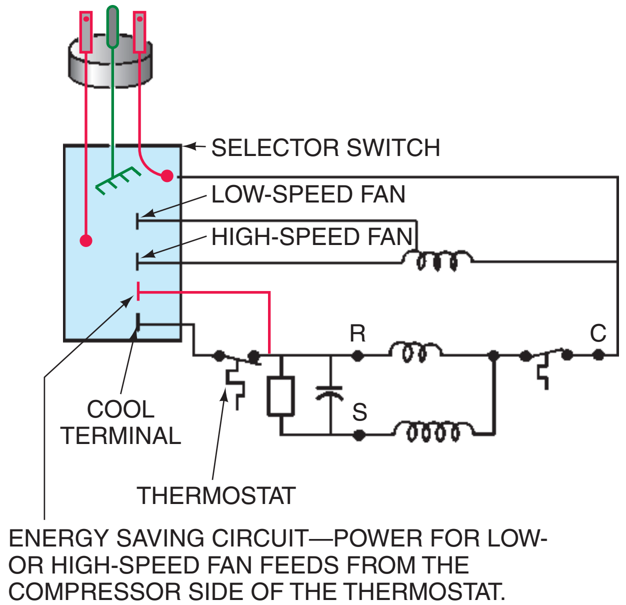

Figure 47–54 Some units cycle the fan for power savings.

and provide power to the compressor circuit, **Figure 47–52.** The selector switch may be considered a power distribution center. The power cord will usually be wired straight to the selector switch for convenience. Therefore it may contain a hot, grounded neutral, and a frame safety (green) ground wire for a 115-V unit. A 208/230-V unit will have two hot wires and a grounded neutral, **Figure 47–53.** The ground or neutral wire for 115-V service is routed straight to the power-consuming devices. The other hot wire is connected directly to the other side of the power-consuming devices. Many combinations of selector switches will allow the owner to select fan speeds, high and low cool, exhaust, and fresh air. High and low cool is accomplished with fan speed. Because the unit has only one fan motor, a reduction in fan speed slows both the indoor and the outdoor fan. This reduces the capacity and the noise level of the unit. A slight power savings is also achieved, **Figure 47–54.** Some newer units have electronic controls with remotes, cool and fan speed options, and 24-hour on-off timers.

The exhaust and fresh-air control is a lever that positions a damper to bring in outdoor air or exhaust indoor air, **Figure 47–55.**

The selector switch sends power to various circuits (including the compressor start circuit) to start the compressor.

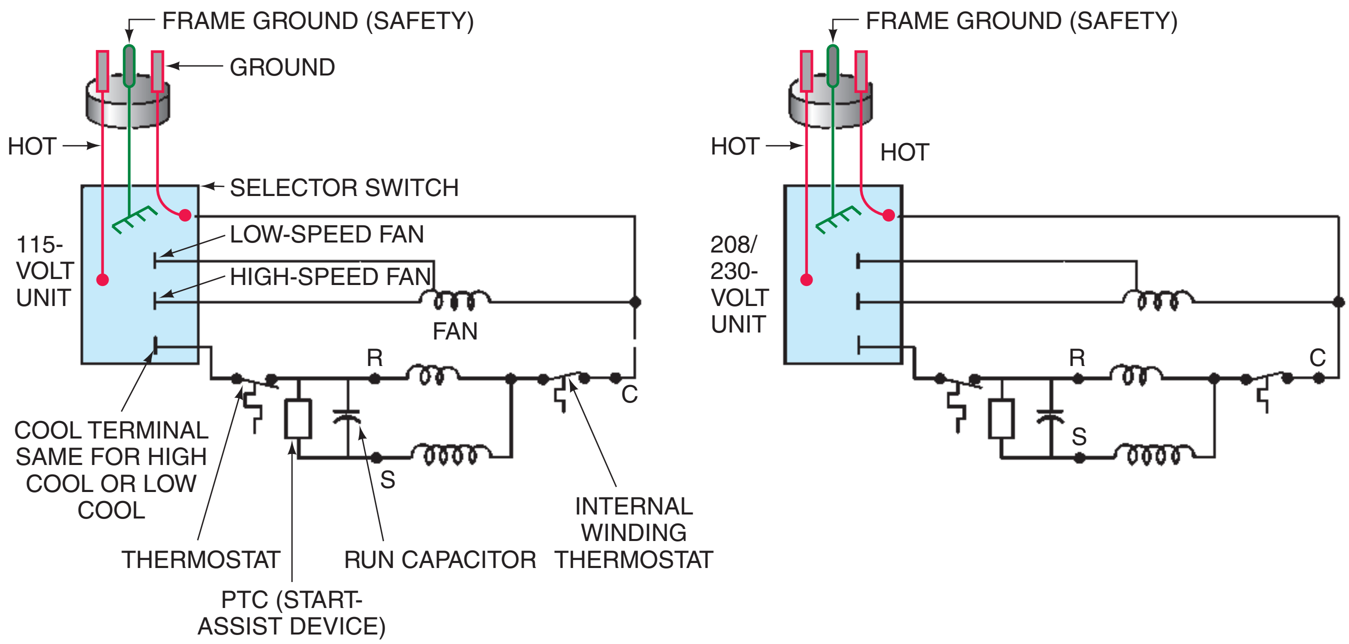

Figure 47–53 Typical selector switch terminal designations for 120- and 208/230-V units.

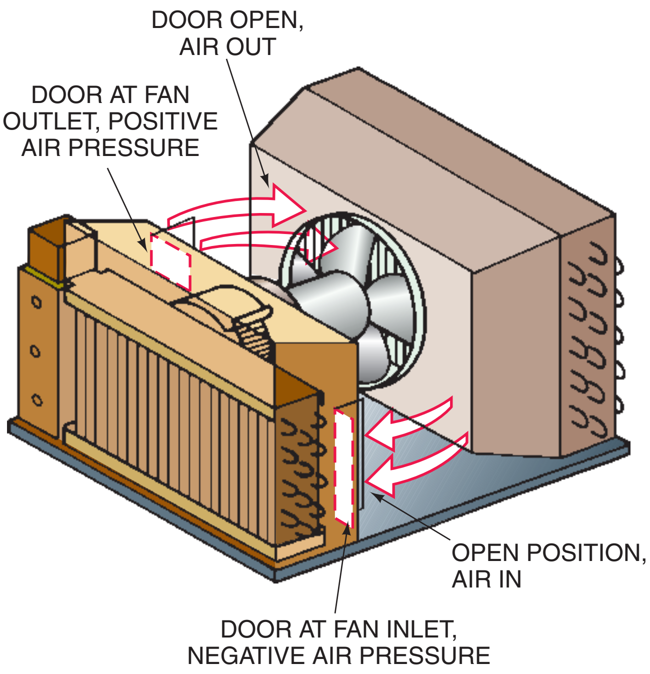

Figure 47–55 Exhaust and fresh air is accomplished with a damper operated from the front of the unit.

Motor starting was discussed in Unit 19, "Motor Controls," and will not be further discussed here. **Figure 47–56** shows some selector switch and compressor diagrams with explanations.

47.7 CONTROLS, COOLING AND HEATING UNITS

Combination cooling and heating units may be either plug-in appliances or through the wall. Through-the-wall units usually have an electrical service furnished to the unit. The cooling controls for cooling and heating units are the same as previously discussed in the cooling cycle. Typically a selector switch changes the unit from cooling to heating. When the unit has electric strip heat, the selector switch merely directs the power to the heating element through the thermostat, **Figure 47–57.** If the unit is a heat pump, it will have a selector switch to select heating or cooling. The cooling cycle should be a typical cycle with the addition of the four-way valve. In the heating cycle, defrost may have to be considered.

Many newer units with strip heat have electronic controls. Usually these units have a thermostat that controls the heating elements for constant room temperature. They may have digital touch pad controls with remotes and a 24-hour on-off timer, **Figure 47–58.**

47.8 MAINTAINING AND SERVICING ROOM UNITS

Maintenance of room units basically involves keeping the filters and coils clean. The motor is typically a permanently lubricated motor in the later models. Older models may need lubrication. If the filter is not maintained, the indoor coil will become dirty and cause the unit to operate at low suction pressures. While in the cooling mode, the coil is already operating at about 35°F. If the coil temperature drops any at all, ice will begin to form. Some manufacturers provide freeze protection that will shut the compressor off and allow the indoor fan to run until the threat of freezing is over. This may be done with a thermostat located on the indoor coil or a thermostat mounted on the suction line, **Figure 47–59.**

Service may involve mechanical or electrical problems. Mechanical problems usually concern the fan motor and bearing or refrigerant circuit problems. All room units have a critical refrigerant charge, and gages should be installed only after there is some proof that they are needed. The system will normally be sealed and require line tap valves or the installation of service ports on the process tubes for gages to be installed. Line tap valves and their use is discussed in Unit 45. **Figure 47–60** shows an example of a line tap valve. NOTE: Be sure to follow the valve manufacturer's instructions.

A bench test at the workshop is often performed on room units. The technician should perform the following test before installing gages when a low charge is suspected. Because the condenser and the evaporator are in the same temperature air, the condenser airflow may need to be reduced to move any refrigerant from the condenser due to low head pressure. A full explanation of condenser operation and charging under low ambient conditions is discussed in Unit 29. Refer to **Figure 47–61** while reading the following:

- Remove the unit from its case.
- Make sure that air flows through the coils. For temporary testing, cardboard may be positioned over places where panels force air to flow through the coils.
- Start the unit in high cool.
- Let the unit run for about 5 min and observe the sweat on the suction line. It should come close to the compressor. The evaporator should be cold from bottom to top.
- Cover a portion of the condenser to force the head pressure to rise. If the room is cool, a portion of the charge may be held in the condenser. The condenser airflow may be blocked to the point that the air leaving it is hot, about 110°F.
- With the head pressure increased, allow the unit to run for 5 min; the sweat line should move to the compressor. If the humidity is too low for the line to sweat, the suction line should be cold. The evaporator should be cold from bottom to top. If only part of the evaporator is cold (frost may form), the evaporator is starved. This may be a result of a restriction or the unit has a low charge.
- If the compressor is not pumping to capacity and the charge is correct, the coil will not be cold anywhere, only cool. An ammeter may be clamped on the common wire to the compressor and the amperage compared to the full-load amperage of the compressor. If it is very low, the compressor may be pumping on only one of two cylinders.

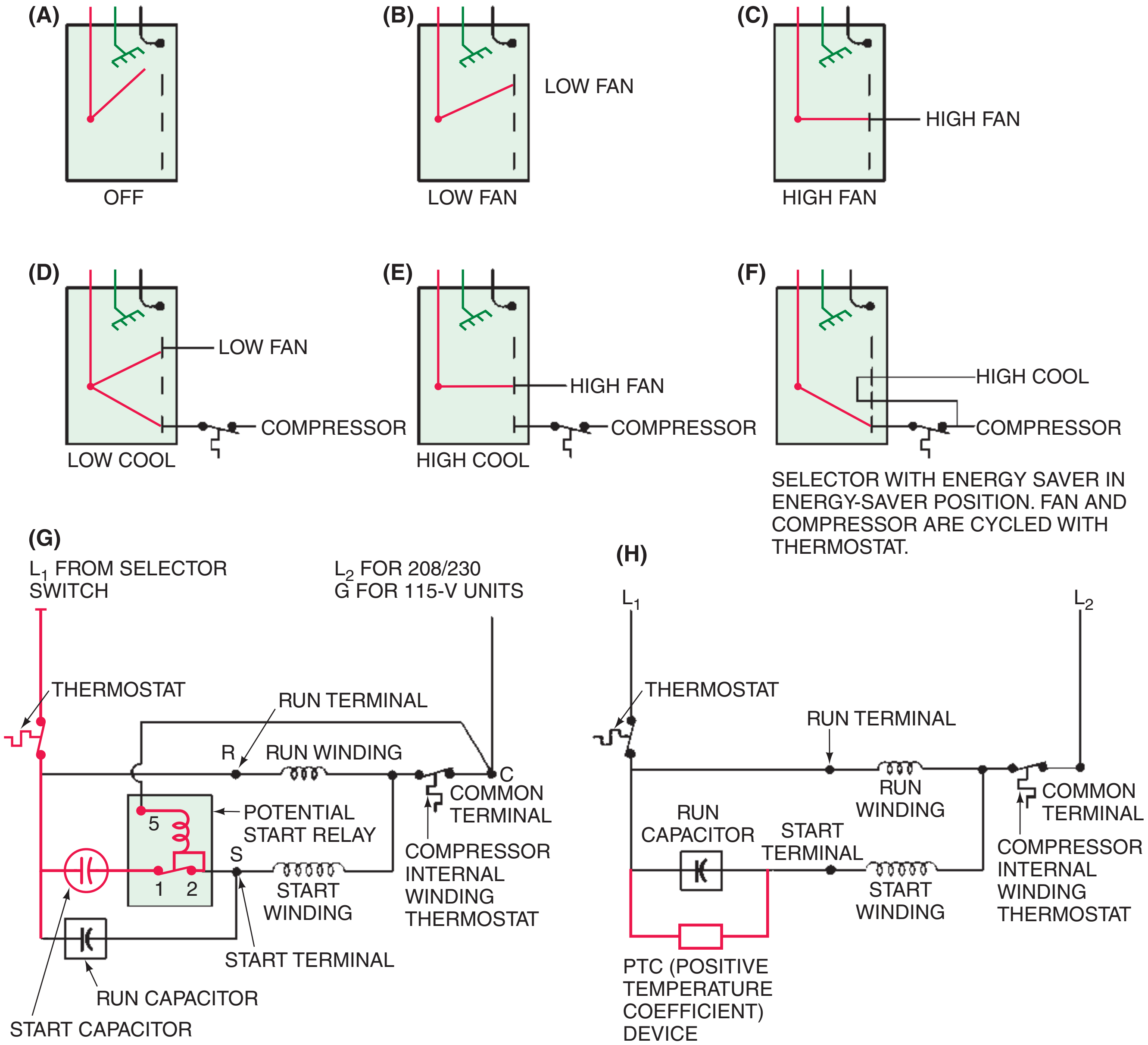

Figure 47–56 Some selector switch wiring diagrams and compressor starting diagrams.

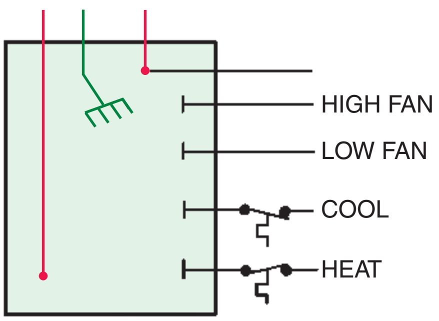

Figure 47–57 The selector switch directs the power to the heating or cooling circuits.

When the previous test indicates that the charge is low, because the suction line is not cold or sweating, gages should be installed.

When the charge is low, the leak should be found. If the unit has never had a line tap or service port installed and has operated for a long period of time without a problem, it can be assumed that the leak has just occurred. It is not good practice to just add refrigerant and hope. An electronic leak detector may be used. Turn the unit off and allow the pressures to equalize. Make sure there is enough refrigerant in the unit to properly leak check, **Figure 47–62.** If the system temperature and pressure relationship indicates there is no liquid present, there is so little refrigerant in the system that what is left could be considered trace refrigerant for leak-checking purposes. If the leak cannot be found with the unit off, dry nitrogen may be used to increase the pressure to the lowest working pressure of the unit. This would be the

Figure 47–58 A window air-conditioning unit with heat strips, electronic controls, timer, and remote. *Courtesy Heat Controller, Inc.*

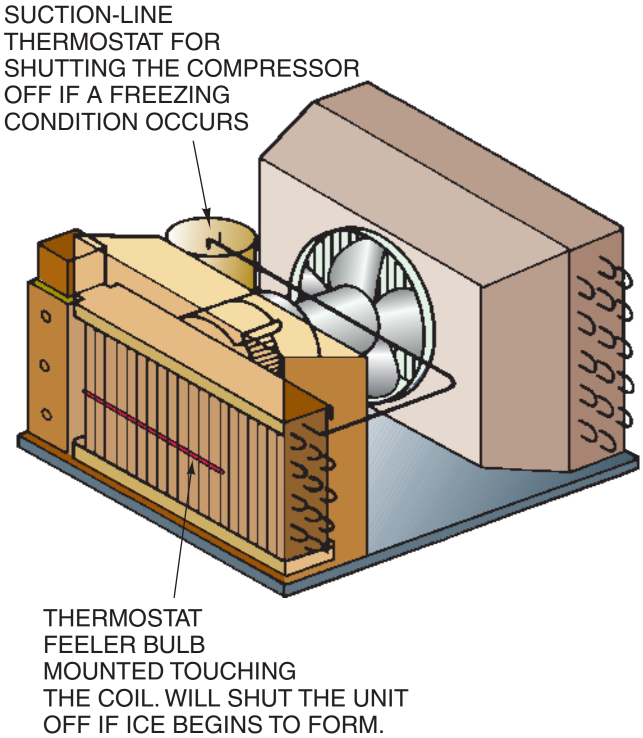

Figure 47–59 Protection from freezing for a room unit.

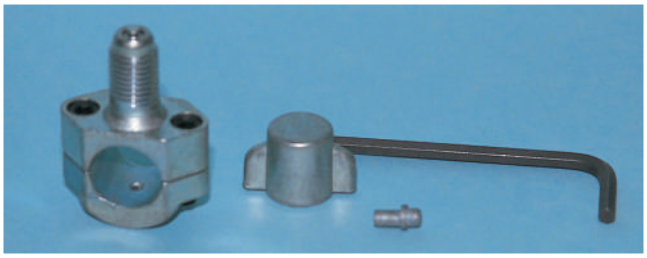

Figure 47–60 A line tap valve. *Photo by Bill Johnson*

evaporator working pressure and may be 150 psig; check the nameplate to be sure. When the leak check is completed, the nitrogen and trace refrigerant will have to be exhausted, the system evacuated, and a new charge added. This venting of trace refrigerant is allowed.

♻ The correct method to charge a unit is to remove and recover the remaining charge, evacuate the unit, and measure in the correct charge printed on the nameplate. ♻ SAFETY PRECAUTION: Do not start the unit with a nitrogen charge in it as high pressure will occur, and the motor will quickly overheat due to lack of cooling. Technicians should use accurate scales similar to the one in **Figure 47–63** to measure the charge. At times the technician may want to adjust the charge rather than start from the beginning. A charge may be adjusted by using the following method, which, together with **Figure 47–64,** illustrates the procedure:

- Install suction and discharge gage lines.
- Purge the gage lines and connect to the correct refrigerant cylinder.
- Make sure that air is passing through the evaporator and the condenser coils; cardboard may be used for temporary panels.
- Start the unit in high cool.
- Watch the suction pressure and do not let it fall below atmospheric pressure into a vacuum; add refrigerant through the suction gage line if it falls too low.
- Adjust the airflow across the condenser until the head pressure is 260 psig and corresponds to a condensing temperature of 120°F for R-22. Refrigerant may have to be added to obtain the correct head pressure.
- Add refrigerant vapor at intervals with the head pressure at 260 psig until the compressor suction line is

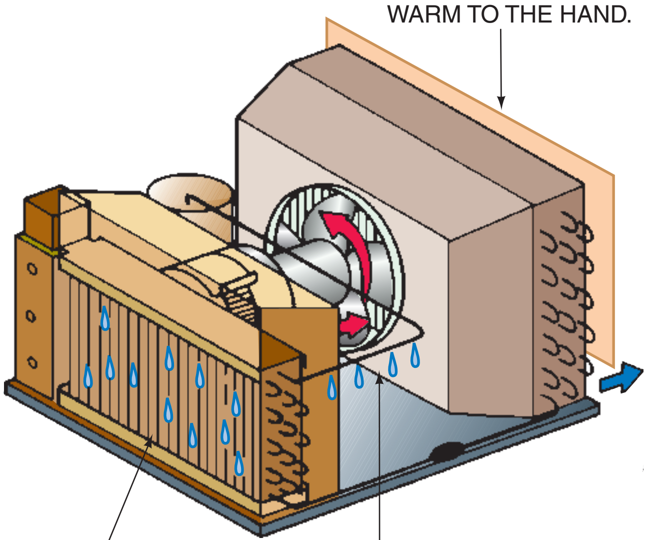

Figure 47–61 Testing for a low charge before installing gages.

Figure 47–63 Charging scale. *Courtesy Robinair Division, SPX Corp.*

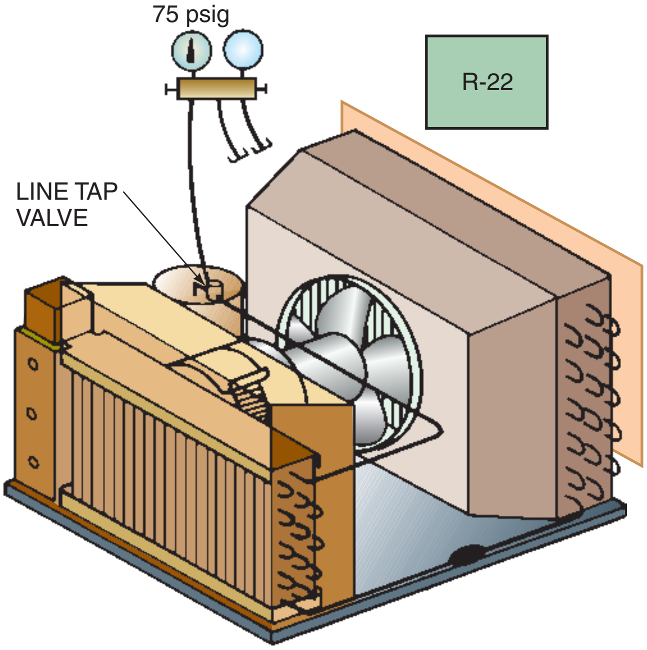

Figure 47–62 Make sure that there is enough refrigerant in the unit for leak-checking purposes.

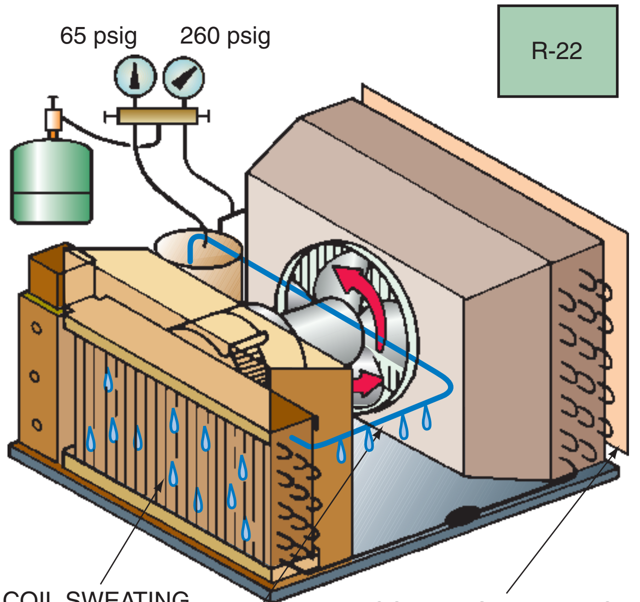

Figure 47–64 Charging a unit by sweat line.

sweating to the compressor. As refrigerant is added, the airflow will have to be adjusted over the condenser, or the pressure will rise too high. You should also note that the evaporator coil becomes colder toward the end of the coil as refrigerant is added.

- The correct charge is verified after about 15 min of operation at 260 psig and by a cold (probably sweating) suction line at the compressor. The suction pressure should be about 65 psig and the compressor should be operating at near full-load amperage.

When a system must be evacuated, the same procedures are used as those discussed in Unit 8. The larger the evacuation ports, the better. Unit 45 has a complete evacuation procedure for refrigerators; this same procedure would apply here.

The capillary tube may be serviced in much the same manner as the capillary tube maintenance described in

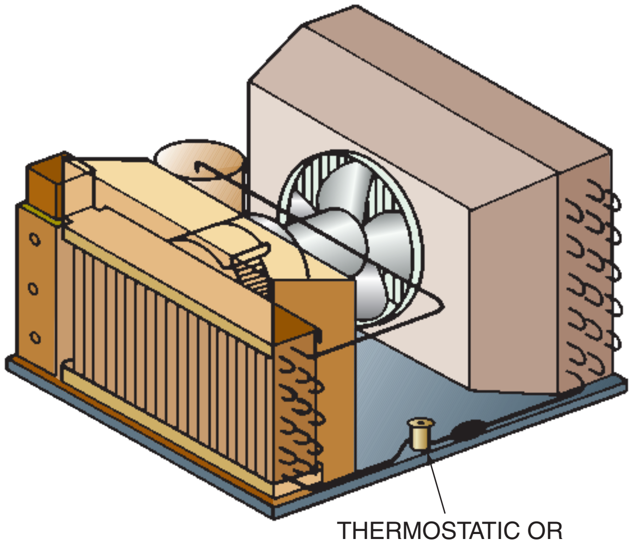

Figure 47–65 A technician may sometimes install a thermostatic or automatic expansion valve instead of replacing a capillary tube.

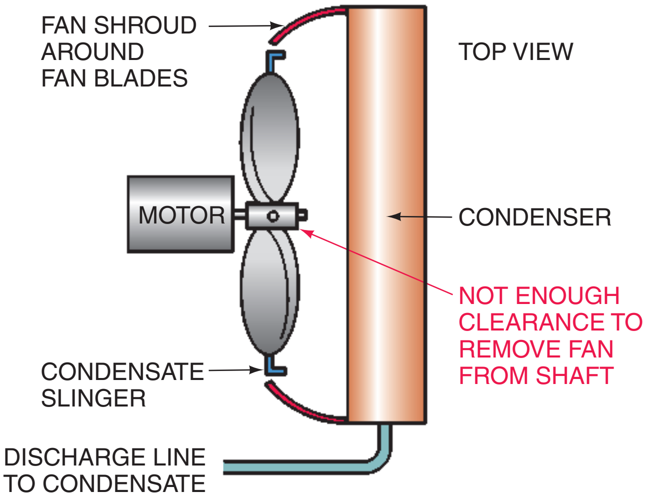

Figure 47–66 Often the condenser fan is hard to remove from the shaft because of the clearance between the condenser and fan.

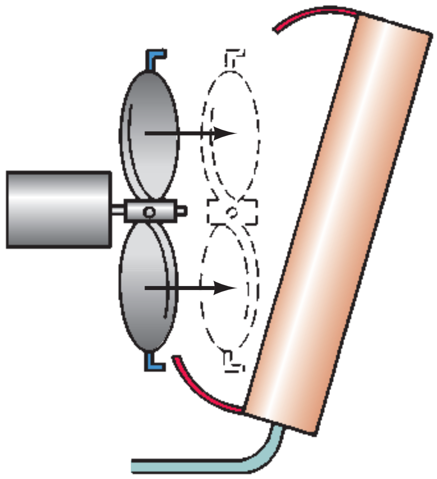

Figure 47–67 The condenser may be moved back or the fan motor may be raised in order to remove the fan blade.

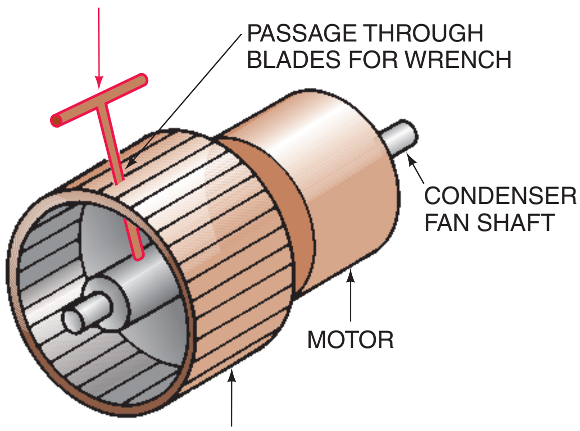

Figure 47–68 An Allen-head setscrew may be loosened by placing a long Allen wrench through the blades.

Unit 45. At times a capillary tube may need to be changed. If the head pressure rises and the suction pressure does not and refrigerant will not fill the evaporator coil, there is a restriction. The capillary tube-to-suction line heat exchange for a room air conditioner presents the same problem as with a refrigerator. It may not be worth the time to make the change. Some service technicians may install a thermostatic or automatic expansion valve instead of trying to change a capillary tube, **Figure 47–65.** In this case you must make sure the compressor has a starting relay and capacitor or it may not start. Thermostatic and automatic expansion valves do not equalize during the off cycle. This is a workable situation for a room unit, but not a refrigerator.

Fan motor removal may be difficult in many units. The units are so compact that the fans and motor are in close proximity to the other parts. The evaporator fan is normally a centrifugal type (squirrel cage design) and the condenser fan is typically a propeller type. The condenser fan shaft usually extends to a point close to the condenser coil. Often there is not room to slide the propeller fan to the end of the shaft, **Figure 47–66.** Either the fan motor must be raised up or the condenser coil moved, **Figure 47–67.** The evaporator fan wheel is normally locked in place with an Allen-head setscrew that must be accessed through the fan wheel with a long Allen wrench, **Figure 47–68.** When a unit is reassembled after fan motor replacement, it is often difficult to align everything back together correctly. The unit should be placed on a level surface, such as a workbench, **Figure 47–69.**

Electrical service requires the technician to be familiar with the electrical power supply. All units are required to be grounded to the earth. This involves running a green wire to every unit from the grounded neutral bus bar in the main control panel, **Figure 47–70.** Many units are operating today that do not have this ground and these units will operate correctly because the wire is not there to help the unit operate. It is a

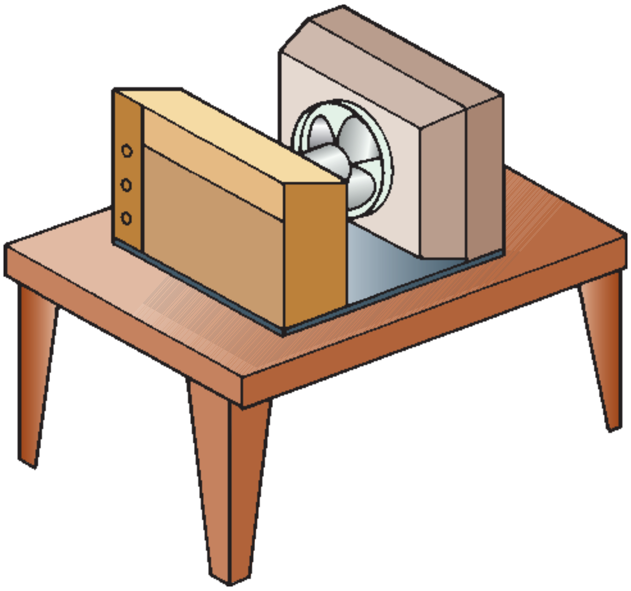

Figure 47–69 For proper alignment, the unit should be placed on a level surface while the fan and blades are being installed.

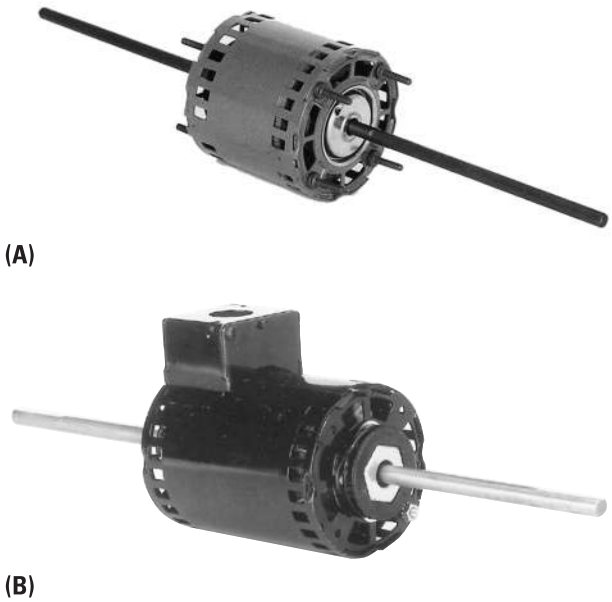

Figure 47–71 Fan motors. **(A)** Shaded pole. **(B)** Permanent split capacitor. *Courtesy Dayton Electric Manufacturing Co.*

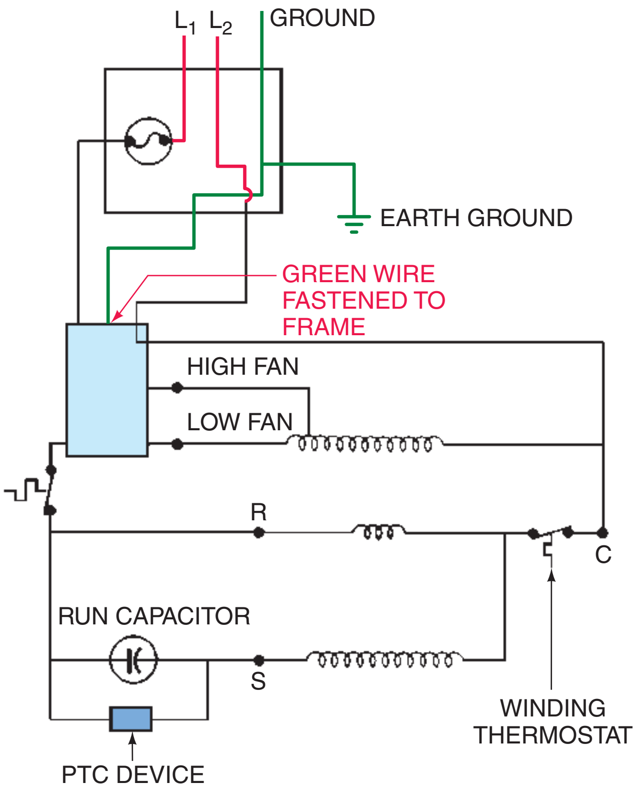

Figure 47–70 This wiring diagram shows where the green ground wire terminates in the main control panel.

safety circuit to protect the service technician and others from electrical shock hazard.

The electrical service must be of the correct voltage and have adequate current-carrying capacity. The example described in Section 47.5, "Installation," in this unit is typical of what will happen if the circuit is not planned.

Electrical service may involve the fan motor, the thermostat, the selector switch, the compressor, and the power cord. The fan motor will be either a shaded pole or a permanent split-capacitor type, **Figure 47–71.** These motors are discussed in detail in Section 4.

The thermostat for room units is usually mounted with the control knob in the control center and the remote bulb in the vicinity of the return air. These thermostats are the line-voltage type discussed in Unit 13, "Introduction to Automatic Controls." They are typically slow to respond. This is somewhat overcome because most units operate with the fan running continuously anytime the selector switch is set for cooling or heating. Therefore, the thermostat has a moving airstream over it at all times. Some systems may have an energy-saving feature that allows the thermostat to cycle the fan. In this case the thermostat will not provide precise control.

The thermostat passes power to the compressor start circuit and may be treated as a switch for troubleshooting purposes. If it is suspected that the thermostat is not passing power to the compressor start circuit, you may unplug (shut off the power and lock the circuit out if wired direct) the unit and remove the plate holding the thermostat. The plate may be moved forward far enough to apply voltmeter leads to the thermostat terminals. Turn the power back on. Turn the selector switch to the high-cool position and observe the voltmeter reading. If there is a voltage reading, the thermostat contacts are open, **Figure 47–72.**

The selector switch may be defective similar to the thermostat and the trouble may be found in a similar way. The panel that holds the thermostat usually has the selector switch mounted on it. If it is suspected that the selector switch is not passing power, turn the power off and remove the panel. Secure it in such a manner that the unit may be started. The selector switch is checked in a slightly different manner,

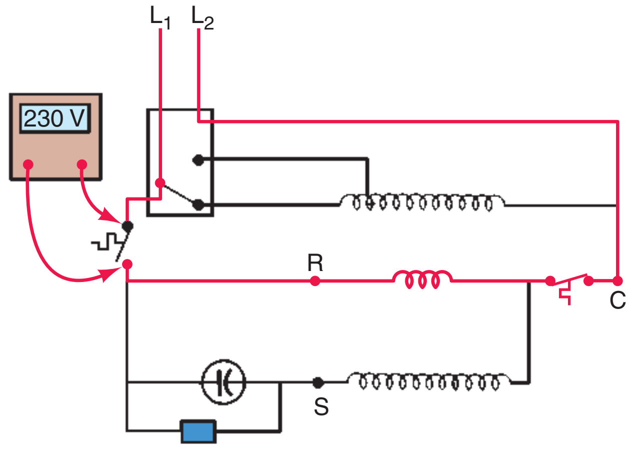

Figure 47–72 If the meter reads voltage, the thermostat contacts are open.

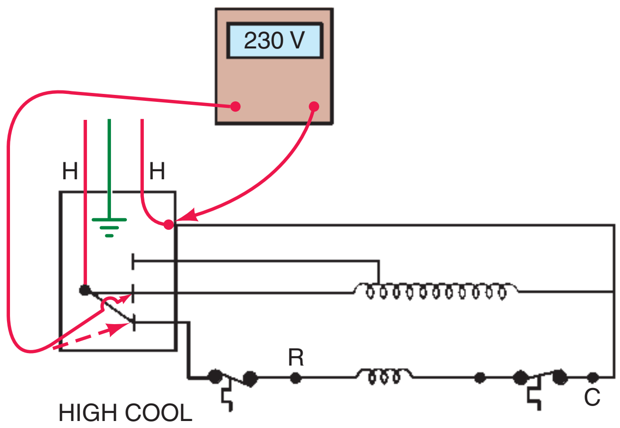

Figure 47–73 Using a voltmeter for checking a selector switch.

using the common terminal and the power lead. For example, attach one lead of a voltmeter to the common lead and the other to the circuit to be tested—high cool, **Figure 47–73.** Resume the power supply and turn the selector switch to the HIGH-COOL position. Full line voltage should be indicated on the meter. If not, check the hot lead entering the selector switch. If power enters, but does not leave, the switch is defective.

Compressor electrical problems may be in either the starting circuit or the compressor itself. Room units use single-phase power. They use the potential relay or the positive temperature coefficient device (PTC) described in Unit 17, "Types of Electric Motors," for starting the compressor. Electrical troubleshooting and capacitor checks are discussed in Unit 20, "Troubleshooting Electric Motors." A review of these units will help you to understand motors and their problems.

Power cord problems usually occur at the end of the cord, where it is plugged into the wall plug. Loose connections occurring because plugs do not fit well or the plug or power cord has been stepped on and partially unplugged are the big problems. The power cord should make the best connection

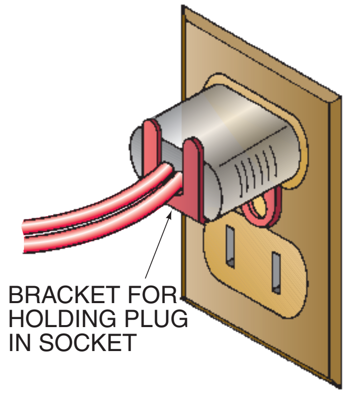

Figure 47–74 A power cord may need support.

possible at the wall outlet. Sometimes the cord may need support to keep the strain off the connection, **Figure 47–74.** If the cord becomes hot to the point of discoloration or the plug swells, the plug should be changed. The wall receptacle may need inspection to make sure that damage has not occurred inside it. If the plastic is discolored or distorted, it should be changed or installing a new plug will not help and the problem will recur.

HVAC GOLDEN RULES

When making a service call to a residence:

- Try to park your vehicle so that you do not block the customer's driveway.
- Always carry the proper tools and avoid extra trips through the customer's house.
- Ask the customer about the problem. The customer can often help you solve the problem and save you time.

Added Value to the Customer

Here are some simple, inexpensive procedures that may be added to the basic service call.

- Clean or replace the air filters.
- Advise the customer about proper operation; for example, tell them not to allow conditioned air to recirculate into the return air.
- If removal of the unit is necessary, obtain the proper assistance and use dropcloths to prevent dirt from the unit from falling on the floor.

47.9 SERVICE TECHNICIAN CALLS

SERVICE CALL 1

A customer in an apartment calls and says that the window unit in the dining room, used to serve the kitchen, dining room, and living room, is freezing solid with ice every night. The tenants both work during the day. They shut the unit off in the morning and turn it on when they get home from work. The air temperature is 80°F inside and outside by the time they turn the unit on. *The problem is that the head pressure is too low during the last part of the cycle, starving the evaporator and causing it to operate below freezing.*

The apartment house technician arrives late in the afternoon, at which point the tenants arrive home to survey the situation. The tenants show the technician how the thermostat is set each night. The technician explains that the outdoor temperature is cooler than the temperature in the apartment by the time the unit is turned on. It is explained that a better approach may be to leave the unit on LOW COOL during the day, and to raise the thermostat setting several degrees, letting the unit run some during the day. A call back a few days later verifies that the unit is performing well using this approach. The unit had no problem; it was lack of operator knowledge.

SERVICE CALL 2

A customer calls to indicate that the air conditioner in the guest bedroom is not cooling the room. The coil behind the filter has ice on it. This sounds like a low-charge complaint. *The problem is that the drape is partially hanging in front of the unit, causing the air to recirculate. The supply air louvres are also pointing downward.*

The technician in this apartment house goes to the installation and notices that the drape hangs in front of the unit. The technician explains that the drape will have to be kept out of the airstream. The air discharge is pointed down also, causing the air to move toward the return air inlet. This is adjusted. Just to be sure that the unit does not also have a low charge, the technician pulls the unit out of the case and places it on a small stool so it can be started. The technician notices that when the unit is started, air blows out of the top of the blower compartment and bypasses the indoor coil—so a piece of cardboard is placed over the fan compartment to force the air through the coil. The unit is started and the condenser is partially blocked to force the head pressure higher. After the unit has run for a few minutes, the suction line starts to sweat back to the compressor. If the unit had a low charge, the coil would form ice on the bottom portion because there would not be enough refrigerant to fill the coil. If the coil were dirty or the airflow blocked, the coil might ice all over, even to the compressor. The compressor might sweat excessively because the refrigerant wouldn't be boiled to a vapor, and liquid would enter the compressor. This unit has never had gages installed, so it has the original charge and it is still correct. The unit is stopped and pushed back into its case in the window. The filter is cleaned. The unit is started and left operating normally.

SERVICE CALL 3

A customer calls and reports that a new unit just purchased and installed is not cooling so it has been turned off. *The problem is a leak in the high-pressure side of the system.*

The technician arrives and starts the unit. The compressor runs, but nothing else happens. The technician turns the unit off and slides it out of its case onto a stool and restarts the compressor. It is obvious the unit has problems so the technician goes to the truck, brings back a hand truck, and takes the unit to the truck and to the shop.

The unit is moved to a workbench. A line tap valve is installed on the suction process tube. When the gages are fastened to the line tap valve, no pressure registers on the gage. The system is out of refrigerant.

The technician allows R-22, the refrigerant for the system, to flow into the unit. A leak cannot be heard, so an electronic leak detector is used. A leak is found on the discharge-line connection to the condenser. The refrigerant is recovered from the unit. The process tube is cut off below the line tap valve connection. A 1/4-in. flare connection is soldered to the end of the process tube and a gage manifold connected to the low side; the leak is repaired on the discharge line with high-temperature silver solder.

When the torch is removed from the connection, the gage manifold valve is closed to prevent air from being drawn into the system when the vapor inside cools and shrinks. When the connection is cooled, refrigerant is allowed into the system and the leak is checked again. It is not leaking. A small amount of refrigerant and air is purged, and the system is ready for evacuation.

The vacuum pump is attached to the system and started. While the system is being evacuated, the electronic scales are moved to the system and prepared for charging. Because the service connection is on the low-pressure side of the system, the charge will have to be allowed into the system in the vapor state. The cylinder is a 30-lb cylinder. This should be enough refrigerant to keep the pressure from dropping during charging. The unit calls for 18.5 oz of refrigerant. When the vacuum is reached, 29 in. Hg on the low-side gage, the vacuum pump is disconnected and the hose connected to the refrigerant cylinder; the gage line is purged of air. The correct charge is allowed into the system.

If the charge will not move into the system, the technician may start the compressor to lower the low-side pressure where refrigerant will move from the cylinder into the system. NOTE: DO NOT allow the system to operate in a vacuum. If it tries to go into a vacuum, shut the compressor off for a few minutes. When the correct charge is established, the unit is started. It is cooling correctly.

The technician takes the unit back to the customer and places it in the window. The unit is started and operates correctly.

SERVICE CALL 4

A customer in a warehouse office calls and reports that the window unit cooling the office is not cooling to capacity. A quick fix must be performed until a new unit can be installed. *The problem is a slow leak.*

The technician arrives and looks at the unit. The unit definitely has a low charge; the evaporator coil is only cold halfway to the end. The unit is pulled out of the case and set on a stool. The technician points out that the unit is old and needs replacing. The customer asks if there is anything that can be done to the unit to get them through the day.

A line tap is fastened to the suction line and a gage line connected; the suction pressure is 50 psig. The unit has R-22; this is an evaporator temperature of 26.5°F. The unit is showing signs of frost on the bottom of the coil. This is an old unit, so refrigerant is added to adjust the charge. The unit is on a stool in the room, where it is about 80°F. The condenser airflow is blocked until the leaving air is warm to the hand. Refrigerant is added until the suction line is sweating to the compressor. The gages are removed and the unit is placed back in the case. The leak was not found. The company requests that a new unit be installed tomorrow. ♻ When the old unit is discarded, the refrigerant will have to be recovered before it is scrapped. ♻

SERVICE CALL 5

A new unit sold last month is brought to the shop for the technician to repair. The service repair order reads, "no cooling." *The problem is that the compressor is stuck and will not start.*

The technician checks to make sure the selector switch is in the OFF position and plugs the unit into the correct wall plug, 230 V. This workbench is made for servicing appliances so it has an ammeter mounted in it. The technician turns the fan to HIGH FAN; the fan runs. The selector switch is then turned to LOW FAN and the fan still runs. The amperage is normal, so the technician turns the selector switch to HIGH COOL, keeping a hand on the switch. The fan speeds up but the compressor does not start. The thermostat is not calling for cooling. The thermostat is turned to a lower setting and the compressor tries to start. The ammeter rises to a high amperage and does not fall back. The technician turns the unit off, before the compressor overload reacts. The unit is turned off and the power cord disconnected.

The technician then removes the unit from the case and looks for the compressor terminal box. The cover is removed and a test cord is installed on common-run-start, **Figure 47–75.** The test cord is attached to a power supply on the bench. An ammeter is still in the circuit on the test bench. The technician tries to start the compressor with the test cord by turning the selector switch to start and then releasing the selector knob, per directions. It will not start; the compressor is stuck and must be changed.

♻ The technician installs a line tap valve on the suction process tube and starts to recover the refrigerant. While the refrigerant is being recovered slowly, a new compressor, a 1/4-in. flare fitting for the process tube, and a

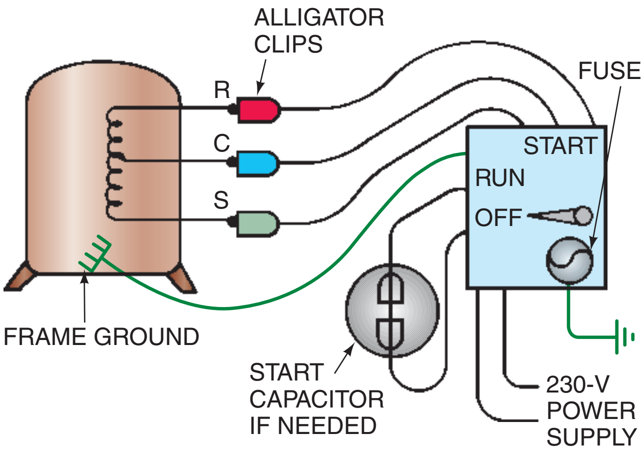

Figure 47–75 A test cord is fastened to common-run-start on the compressor.

suction-line drier are brought from the supply room. The technician removes the compressor hold-down bolts. When the refrigerant has been recovered, the technician uses an air-acetylene torch with a high-velocity tip and removes the suction and discharge lines. ♻ The old compressor is set out and the new one set in place. The suction line is altered to install the suction-line drier, but it is not installed yet. The compressor discharge line is soldered in place. The process tube was cut off below the line tap connection and the 1/4-in. flare fitting is installed on the process-tube connection. The suction line is soldered to the compressor and the suction-line drier is soldered into the line. A gage line is fastened to the 1/4-in. flare connection. A small amount of R-22 is added to the system (to 5 psig), then nitrogen is used to pressure the system to 150 psig and a leak check is performed on all fittings; the unit is leak free.

The small amount of refrigerant vapor and nitrogen is purged and the vacuum pump is fastened to the gage manifold and started. When the vacuum pump has obtained a deep vacuum according to the mercury manometer, the correct charge is weighed into the unit. The compressor wiring is reconnected while the vacuum pump operates so the unit is ready to start. The technician plugs in the cord and turns the selector switch to HIGH COOL; the compressor starts. The unit is allowed to run for 30 min and it operates satisfactorily. The process tube is pinched off and cut off below the 1/4-in. flare fitting. The process tube is closed on the end and soldered shut.

SERVICE CALL 6

A unit for an apartment is brought into the apartment workshop with a tag saying "no cooling." *The problem is that the start relay is defective—a burned coil.*

The technician sets the unit on the workbench and checks the selector switch, which is in the OFF position. The unit is plugged into the correct power supply, 230 V.

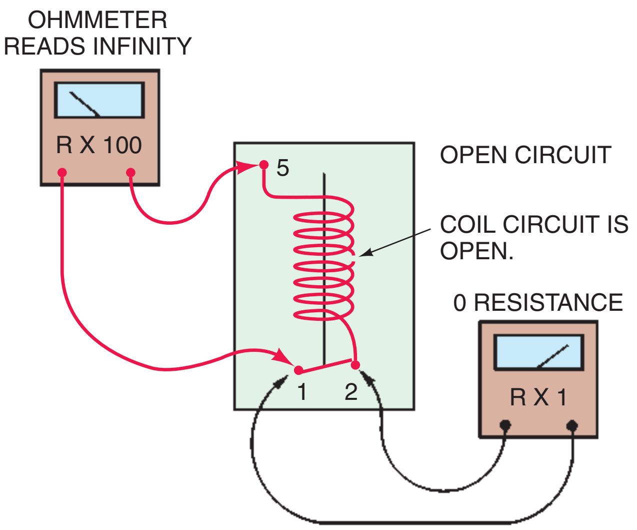

Figure 47–76 A start relay is checked with an ohmmeter.

This workbench also has a built-in ammeter. The technician turns the selector to the HIGH FAN setting; the fan runs as it should. It is switched to LOW FAN and the fan still runs fine, at low speed. The technician then turns the selector switch to HIGH COOL, hand still on the switch. The fan speeds up to high, but the compressor does not start. The ammeter reads very high, 25 A. The technician turns the unit off before the compressor overload protector reacts.

The unit is turned off, unplugged, and removed from its case. The compressor motor terminal wires are removed and a test cord connected. The test cord is plugged in. The technician turns the test cord to start, then releases the knob (as per directions), and the compressor starts. This narrows the problem to the compressor start circuit. The compressor is turned off because it is running by itself, no fan.

The technician removes the terminals from the start relay and checks the coil circuit from terminals 2 to 5; it has an open circuit, **Figure 47–76.** The relay coil is defective, keeping the unit in start. The capacitors are checked as explained in Unit 19, "Motor Controls," and they are satisfactory.

The relay is changed and the compressor is wired back into the circuit. The unit is plugged in again and the selector switch turned to HIGH COOL. The compressor starts and runs. The amperage is normal when compared with amperage indicated on the nameplate.

SERVICE CALL 7

A customer calls to report that a window unit servicing the den and kitchen has tripped the breaker. This is a fairly new unit, six years old. The owner is told to shut the unit off and to not reset the breaker. *The problem is that the unit has a grounded compressor.*

The technician arrives and decides to give the unit an ohm test before trying to reset the breaker and start the unit. The ohmmeter selector switch is set to R × 1 and the meter is zeroed. The technician unplugs the unit and fastens one ohmmeter lead to each of the hot plugs on the 230-V plug, **Figure 47–77.** The unit selector switch is turned to HIGH COOL. There is a measurable resistance; all appears to be well. Before plugging the unit in, one more ohm test is necessary for the complete picture, a ground test. The ohmmeter is set at 0 on the R × 1000 scale and one lead is moved to the ground terminal. The meter reads 0 resistance; there is a ground in the unit somewhere, **Figure 47–78.** It could be the fan motor or the compressor. The unit is pulled from its case. The compressor terminals are disconnected. One lead of the meter is

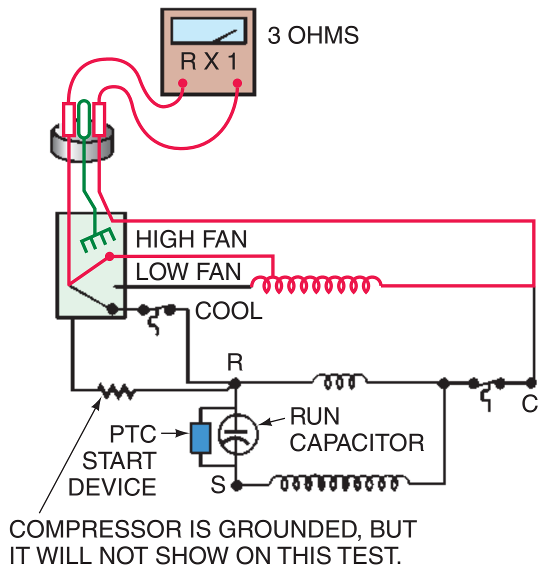

Figure 47–77 The unit has a ground circuit according to the ohmmeter.

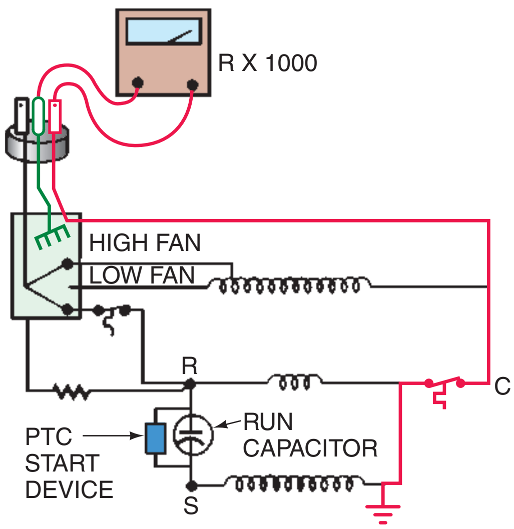

Figure 47–78 The ground circuit is through the compressor.

touched to the discharge line and the other to the common terminal; the meter reads 0 resistance. The compressor has the ground circuit.

The customer is informed of the problem and given the price of repairing the unit. The customer decides to have it repaired because the repair cost is much less than purchasing a new unit.

The technician moves the unit to the truck and takes it to the shop. ♻ The technician decides to recover the refrigerant from the unit to an approved cylinder for contaminated refrigerants. It may be burned and contaminated. ♻

The technician obtains a liquid-line drier, a suction-line drier, a 1/4-in. "tee" fitting for the liquid line, a compressor, and a 1/4-in. fitting for the process tube. When the refrigerant is removed from the unit, the technician cuts the compressor discharge line at the compressor with diagonal pliers. Then the suction line is cut with a small tube cutter and the compressor is removed from the unit. A "tee" fitting is installed in the liquid line. A gage line is fastened to the "tee" fitting and nitrogen is purged through the unit, **Figure 47–79.** This will push much of the contamination from the unit.

The technician sets the new compressor in place and solders the discharge line to the new compressor. The suction line is cut to the correct configuration for the suction-line drier. The liquid line is now cut, just before the strainer entering the capillary tube, and the new small drier is installed. The suction-line drier and the 1/4-in. fitting for the process tube are soldered in place. The gages are fastened to the process port and the "tee" fitting in the liquid line. The unit is pressured with a small amount of R-22 (to 5 psig) and nitrogen is added to push the pressure up to 150 psig. The unit is then leak checked with an electronic leak detector. After the unit is leak checked, the trace refrigerant and nitrogen are purged from the system.

The vacuum pump is connected after the leak check and started. While the unit is being evacuated, the capacitors and relay are checked. Both capacitors, run and start, are good. The relay has a measurable resistance in the coil and the contacts look good.

The charge for the unit is 18 oz, plus the capacity of the small liquid-line drier is 1.9 oz = 19.9 oz total (this information should be packed in the drier directions but all manufacturers do not furnish it). When a 500-micron vacuum is obtained according to the micron gage the charge is added in the following manner.

The charge is in a charging cylinder, as explained in Unit 9. This charging cylinder has plenty of refrigerant and a liquid valve. The high-pressure gage line is connected to the liquid line on the unit, and the charge is allowed to enter the system through the liquid line in the liquid state, **Figure 47–80.** When the complete charge is inside the unit, the liquid-line valve is pinched off and soldered shut.

The unit is started and allowed to run while the technician is monitoring the suction pressure and amperage. The unit is ready to be returned to the customer.

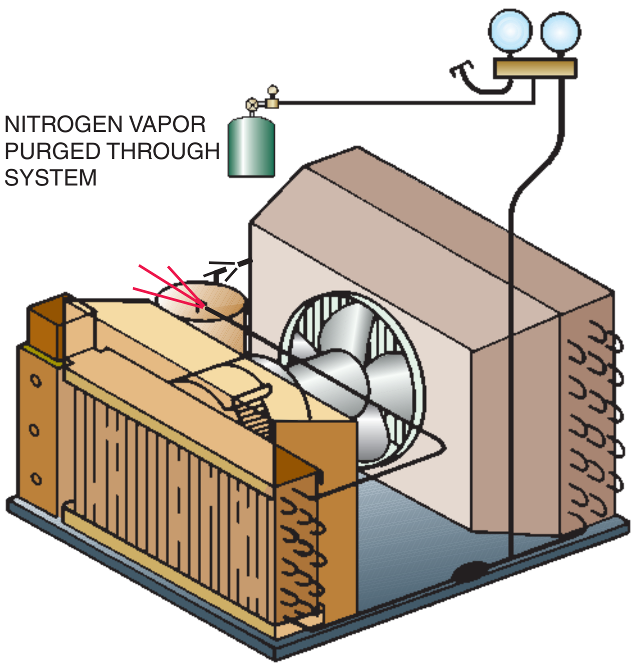

Figure 47–79 The system is purged using the "tee" fitting installed in the liquid line.

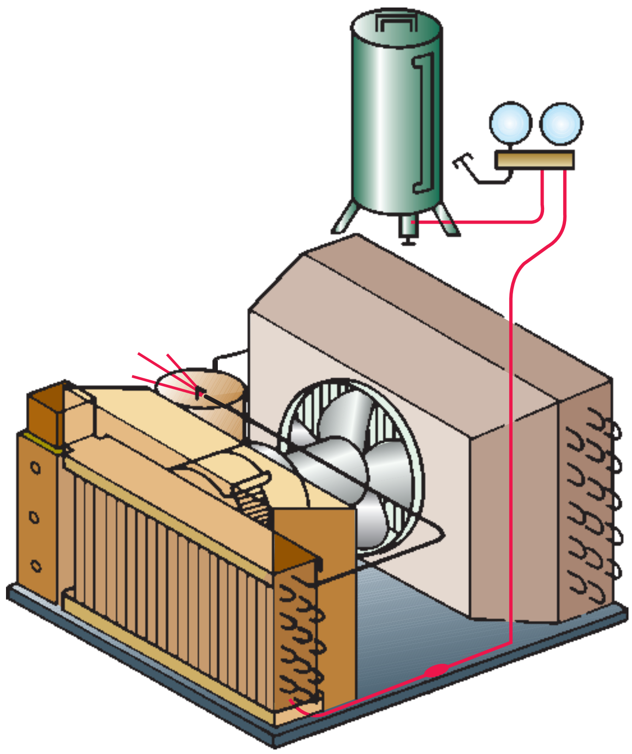

Figure 47–80 Liquid is charged into the system; this saves time.

SUMMARY

- Room air conditioners may be designed to be installed in windows or through the wall.
- These units may be designed for cooling only, cooling and heating with electric strip heat, or cooling and heating with a heat pump cycle.
- The four major components in the cooling cycle for these units are the evaporator, compressor, condenser, and metering device.
- Most units are designed to produce a heat exchange between the capillary tube and the suction line. This adds superheat to the suction line and subcools the refrigerant in the capillary tube.
- The heat pump cycle uses the four-way valve to redirect the refrigerant.
- The heat pump compressor is different from one found in a cooling-only unit. It must have enough pumping capacity for low-temperature operation.
- Before installing a unit, the technician should make sure that the electrical service is adequate.
- When installing these units, ensure that there is no possibility of direct recirculation of air through the unit.
- The selector switch is the primary control for room air-conditioning units.
- The primary maintenance for these units involves keeping the filters and coils clean.
- Gages should be installed for service only when it is determined that it is absolutely necessary.
- Electrical service may involve the fan motor, thermostat, selector switch, compressor, and power cord.

REVIEW QUESTIONS

1. A typical room air-conditioning unit has ________ (one or two) fan motors.
2. The most common refrigerant used in the past for window units is
   - **A.** R-12.
   - **B.** R-22.
   - **C.** R-134a.
3. Most units utilize a heat exchange between the capillary tube and the
   - **A.** suction line.
   - **B.** hot discharge line.
   - **C.** high-side liquid line.
4. Typically room air-conditioning unit evaporators boil the refrigerant at
   - **A.** 15°F.
   - **B.** 25°F.
   - **C.** 35°F.
   - **D.** 45°F.
5. True or False: Typically window air conditioners utilize automatic defrost.
6. The evaporator tubing is normally made of ________ or ________.
7. The evaporator normally operates ________ the dew point temperature.
   - **A.** at
   - **B.** below
   - **C.** above
8. Compressors in these units are ________ sealed compressors.
9. The refrigerant in the capillary tube is ________ at the outlet than at the inlet.
   - **A.** warmer
   - **B.** colder
   - **C.** the same temperature
10. Room units that use the heat pump cycle absorb heat from outdoors in the winter and reject the heat indoors by using a ________ reversing valve.
    - **A.** two-way
    - **B.** three-way
    - **C.** four-way
    - **D.** five-way
11. True or False: A window-unit heat pump compressor is the same as a conventional window-unit air-conditioning compressor.
12. The room temperature sensor is located in the ________ airstream.
    - **A.** return
    - **B.** supply
13. A 208/230-V unit will have ________ hot wire(s) and a ground.
    - **A.** one
    - **B.** two
    - **C.** three
14. Describe the operation of the exhaust and fresh-air control.
15. Preventive maintenance primarily involves ____________________.
16. Why should gages be installed only after there is evidence that they are needed?
17. A head pressure of 260 psig with R-22 corresponds to a temperature of: (Use the temperature/pressure relationship chart, **Figure 3–15.**)
    - **A.** 100°F.
    - **B.** 110°F.
    - **C.** 120°F.
    - **D.** 130°F.
18. In a normally operating window unit, the suction pressure should be approximately 65 psig, which converts to ________°F.
19. During the heat pump heating cycle, the hot gas from the compressor discharge line is directed to the:
    - **A.** indoor coil.
    - **B.** outdoor coil.
20. What are two methods used to evaporate condensate from the evaporator?