

Heating and Cooling

E S S E N T I A L S



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Jerry Killinger has extensive experience installing and servicing air conditioning, refrigeration, and heating systems. He has worked with industrial, commercial, and residential systems ranging from heat pumps to boilers to cooling towers to refrigerated food cases to solid-state environmental control equipment. Jerry has over 20 years' experience teaching traditional vocational classes as well as various seminars and workshops. He has conducted numerous seminars on refrigeration, air conditioning, and electricity for industrial maintenance personnel at facilities of major manufacturers across the United States.

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Cover image courtesy of Lennox International

exposed for prolonged periods to moisture-laden atmospheric air. Blowing the system out with an inert gas (nitrogen or carbon dioxide) removes most of the air from the system but does not remove moisture and air from trapped areas. Filter-driers remove small amounts of moisture and contaminants.

Evacuating a system

Before evacuation, the system's internal pressure must be reduced to atmospheric (0 psig). The vacuum pumps used to evacuate systems are not designed to handle pressures above atmospheric.

Proper evacuation of a system is performed with a two-stage, rotary-type vacuum pump. The vacuum pump draws all vapor (gas) out of the system, reducing its internal pressure to a very low vacuum. The vacuum causes any moisture to boil, allowing it to be removed as a gas.

The amount of time required to properly evacuate a system is strictly a matter of judgment; a large system requires more time on the vacuum pump than a small system. Time must be allowed for the pump to pull a vacuum in all parts of the system and for moisture to work its way out of the oil in the compressor crankcase.

A large quantity of moisture in a system cannot boil into a vapor immediately upon lowering the pressure (just as an open pan of water does not immediately flash into a vapor upon reaching the boiling temperature of 212°F or 100°C). The boiling process requires time for the molecules to rearrange themselves in a new pattern. The boiling process must continue until all the molecules are rearranged. Stopping the vacuum pump too soon will leave moisture in the system.

Evacuation of the refrigeration system should be performed using a vacuum pump of the proper size. Vacuum pumps are rated in cfm (cubic feet per minute). The following are suggested minimum vacuum pump ratings for systems of different sizes:

- ☐ Up to 7 tons — 1.2 cfm
- ☐ Up to 21 tons — 3.0 cfm
- ☐ Up to 35 tons — 5.0 cfm
- ☐ Up to 70 tons — 10.0 cfm
- ☐ Up to 105 tons — 15.0 cfm

The time required for a vacuum pump to remove moisture and air from a system depends upon several factors:

- ☐ Size of the system.
- ☐ Amount of water present in the system.
- ☐ Capacity of the vacuum pump being used.
- ☐ Size and length of the connecting lines.

Pulling a good vacuum on the system is not sufficient; the vacuum pump must have time to do its work. The gauge reading reveals pressure at the pump, but it seldom shows actual vacuum at the farthest point

of the system. The exact amount of time required to evacuate and **dehydrate** (dry out) a given system cannot be predicted because many factors are involved.

The speed of moisture removal can be increased by applying a heat lamp to the compressor crankcase during the vacuum-drawing process. Severe moisture problems may require the use of heat lamps on other system components as well. See **Figure 15-1**.

15.1.3 Contaminants

In addition to moisture and air, contaminants such as soldering fluxes, metal chips, wax, acid, oil sludge, dirt, black oxides, and rust can harm refrigeration systems. With hermetic and semi-hermetic compressors, the motor windings are exposed to contaminants in the system. Care is required to avoid contamination. Contaminants cause serious damage to the motor windings.

Sludge is caused by a chemical breakdown of oil that combines with other materials, such as carbon, metals, oxides, or salts. These compounds form a dark, gummy mass that blocks valves, oil ports, screens, and filters. Sludge problems can be traced to high compressor discharge temperatures and the presence of contaminants, including air.

Air in the system causes high discharge pressure (and high temperature). *Atmospheric air* is a source of oxygen and moisture. Oxygen and moisture contribute to breakdown of the oil-refrigerant mixture. The breakdown forms **acids**, which are corrosive chemical compounds. Acids are more corrosive in the presence of moisture than in a dry system, reacting quickly with metal parts and contributing (among other effects) to the formation of sludge. Therefore, it is important to keep systems as clean and dry as possible.

When contaminants are in a system, ordinary operating temperatures will produce corrosion. Oxygen from the moisture and air combine to form **red iron oxide** (rust). This leads, in turn, to the formation of iron salts and more water if acid is present.

Soldering fluxes also cause metal salts to form. Methyl alcohol (used as an antifreeze) can react with aluminum and cause corrosion. Moreover, poor brazing practice can introduce flux (acid) into the system.

Contamination during brazing

Brazing procedures can cause **black oxides** to form on the inside and outside of copper tubing. Oxides forming on the outside of tubing cause no harm, but those forming on the *inside* are easily washed from the tubing surface when the system is in operation. The oxides are then free to circulate with the refrigerant and oil. These oil-borne oxides are exposed to high temperatures at the compressor discharge and cause decomposition of the oil and refrigerant (sludge).

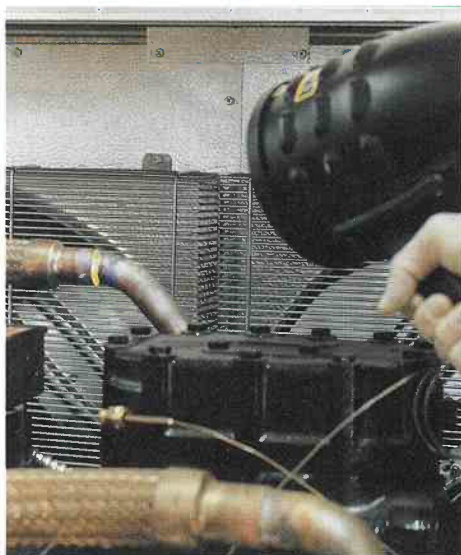


Figure 15-11. An aid in troubleshooting refrigeration systems is a leak-detection method that uses a fluorescent tracer dye and an ultraviolet light source. The dye is added to the refrigerant oil, and the system is allowed to operate for a time. Leakage shows up as a bright yellow stain under ultraviolet light. (H.B. Fuller Company)

Dyes are particularly effective in locating low-level leaks that cannot be found by other detectors. Furthermore, the equipment owner can see evidence of a leak, and the dye remains in the system for future detection.

It is important to allow adequate time between injecting the dye and inspecting for leaks. Time is needed for the dye to circulate and for very small leaks to produce a visible stain. The dye method cannot be used on tubing runs between walls and other enclosed spaces since the tubing cannot be observed.

15.2.8 Standing Pressure Test

Once leaks have been located and repaired, and if time permits, the system should be checked with a **standing pressure test** to determine whether all leaks were found.

If the leak-testing procedure does not involve a refrigerant, an inert gas should be used to raise the system pressure to the proper leak-testing level of 150 psig or 300 psig (1035 kPa or 2070 kPa). Note and record the system pressure and ambient temperature; then, backseat the service valves, and remove the gauge manifold (to prevent leakage). The system is now pressurized and sealed. After several hours (overnight, if possible), reconnect the gauge manifold, open the service valves, and record new pressure readings and ambient temperature. If the pressures remain constant according to ambient, the system has no leaks. Pressure loss indicates an undetected leak remains.

If the system contains a refrigerant rather than an inert gas, it should be fully charged to bring it to full operating pressure. With the system turned off, note and record the pressure and ambient temperature. Seal the system by backseating the service valves and removing the gauge manifold. Recheck the system pressures and ambient after several hours (or overnight) to determine whether all leaks were detected.

15.3 Refrigerant Cylinders

Cylinders used to store and transport refrigerants are made from either steel or aluminum and are available in a number of standard sizes. All but the smallest of cylinders must have a pressure relief device to protect against excessive pressure buildup. The U.S. Department of Transportation (DOT) requires a relief valve or a fusible plug in any refrigerant cylinder more than 12" (30 cm) tall and 4 1/2" (11 cm) in diameter. On large steel cylinders, a fusible plug is normally located in the concave cylinder base. Depending upon whether a cylinder is used for a corrosive or a noncorrosive refrigerant, it must be inspected every five or 10 years.

15.3.1 Steel Cylinders

Large cylinders containing 100 lbs. to 150 lbs. (45 kg to 68 kg) of liquid refrigerant are convenient when servicing systems that require large quantities of refrigerant. They also are less costly than smaller cylinders on a per-pound basis. Suppliers usually require a sizable deposit to ensure return of the empty cylinder. A steel protective cap screws down over the valve at the top of the cylinders when they are being moved or are not in use. See **Figure 15-12**.

Steel cylinders are equipped with a dual valve that allows the technician to withdraw refrigerant as a vapor or, by means of a dip tube, as a liquid. There is no need to invert the cylinder (turn it upside down) to withdraw liquid refrigerant.

A refrigerant cylinder should *never* be completely filled with liquid — space must be left for **hydrostatic expansion** (swelling of the liquid) with increases in temperature. A cylinder is considered "full" when liquid occupies 85% of its interior space. The remaining 15% allows for expansion within a normal range of temperatures without danger of rupturing the cylinder. In case of temperatures that might cause expansion too great for the available space (and present the danger of a cylinder bursting), the fuse plug in the base of the cylinder or a special safety valve will open and vent refrigerant to relieve the pressure. See **Figure 15-13**.

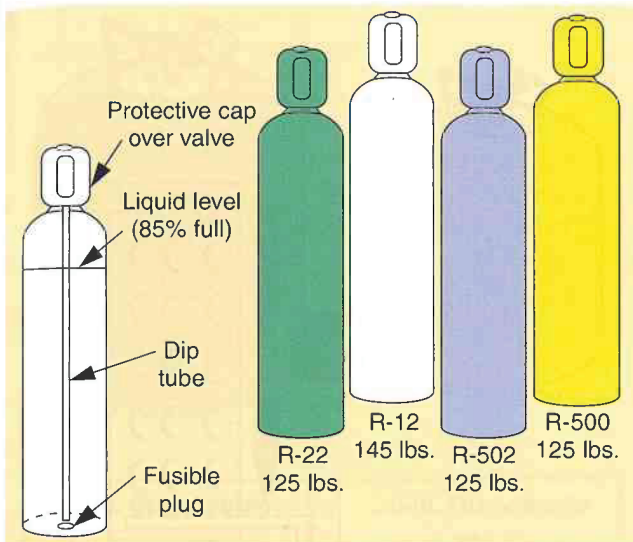


Figure 15-12. Large steel refrigerant cylinders are returned to the supplier for refilling after use. A dual valve permits the technician to select refrigerant as either liquid (through a dip tube) or vapor while keeping the cylinder upright. To protect against excessive pressure, a fusible plug is installed in the cylinder bottom.

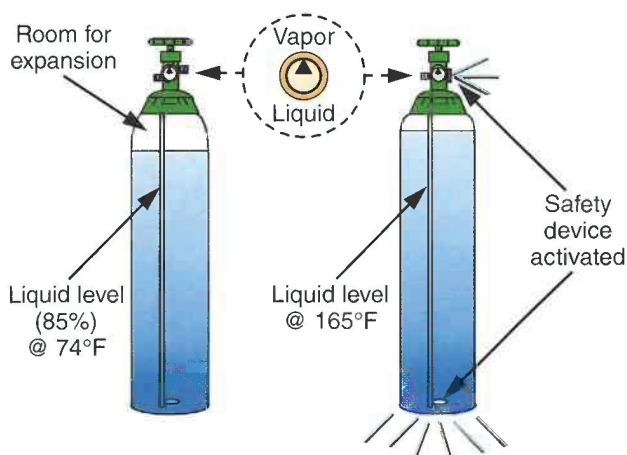


Figure 15-13. When a cylinder is filled, about 15% of its volume must be left for hydrostatic expansion of the liquid refrigerant. If the temperature of the cylinder increases to 165°F (74°C), fusible plugs will melt or a safety valve will open to relieve pressure and prevent bursting.

Saturated conditions exist inside the cylinder, so the contents behave according to the temperature-pressure chart for the specific refrigerant involved. The space above the liquid is occupied by a very dense refrigerant gas. A *balance point* is reached in which the pressure exerted on the liquid refrigerant by the gas molecules prevents any further *boiling off*, or changing of liquid to the gaseous state.

When the vapor valve at the top of the cylinder is opened, however, the gas molecules can escape. Pressure on the liquid is reduced, allowing it to boil

and produce a steady flow of refrigerant gas. The flow of gas continues until the valve is closed or all the liquid has changed to a gas.

The heat required for the change of state (“boiling off” of gas) is obtained from the remaining liquid and the metal cylinder. As gas is released, both the temperature and the pressure of the remaining liquid drops. A continuous release of gas actually causes frost to form on the outer cylinder wall. Cylinder pressure may drop so low that it creates a problem when charging refrigerant into a system in vapor form. The cylinder pressure *must* be higher than the system pressure for vapor to flow from the cylinder into the system. See **Figure 15-14**.

To increase cylinder pressure in such a situation, the contents may be carefully warmed. The best and safest way to increase pressure in the cylinder is to place the cylinder in a container of warm water (80°F to 110°F or 27°C to 43°C). Never heat a cylinder with a torch or use any other heating method that would produce a cylinder temperature greater than 125°F (52°C).

15.3.2 Disposable Cylinders

At one time, industry practice required technicians to transfer refrigerant from large steel cylinders to smaller, portable steel cylinders that held 25 lbs. to 30 lbs. (11 kg to 14 kg). Not only was this practice time-consuming and dangerous, it often resulted in contaminated refrigerant. The introduction of lightweight **disposable cylinders** has virtually eliminated the need to transfer refrigerants. These throwaway cylinders, **Figure 15-15**, are available in sizes ranging from 25 lbs. to 50 lbs. (11 kg to 23 kg).

Carrying handles on top of the cylinder also serve as protection against damage to the cylinder valve. The valve outlet is a 1/4" male flare fitting for easy connection to the gauge manifold. To withdraw refrigerant vapor, the cylinder is used in the upright position; to withdraw liquid, the cylinder is inverted. See **Figure 15-16**. Some cylinders are equipped with a dip tube and dual-stem valve and can remain upright for liquid charging.

WARNING: Federal law prohibits refilling disposable cylinders with refrigerant. Violators are subject to fines and jail terms. Although it is not illegal, using empty disposable cylinders to transport compressed air is unwise; moisture in compressed air could cause the thin metal of these cylinders to rust and eventually rupture.

15.3.3 Cylinders for Refrigerant Recovery

Since CFCs may no longer be vented into the atmosphere when installing and servicing refrigeration equipment, the use of recovery (returnable) cylinders with refrigerant recovery equipment has become widespread.

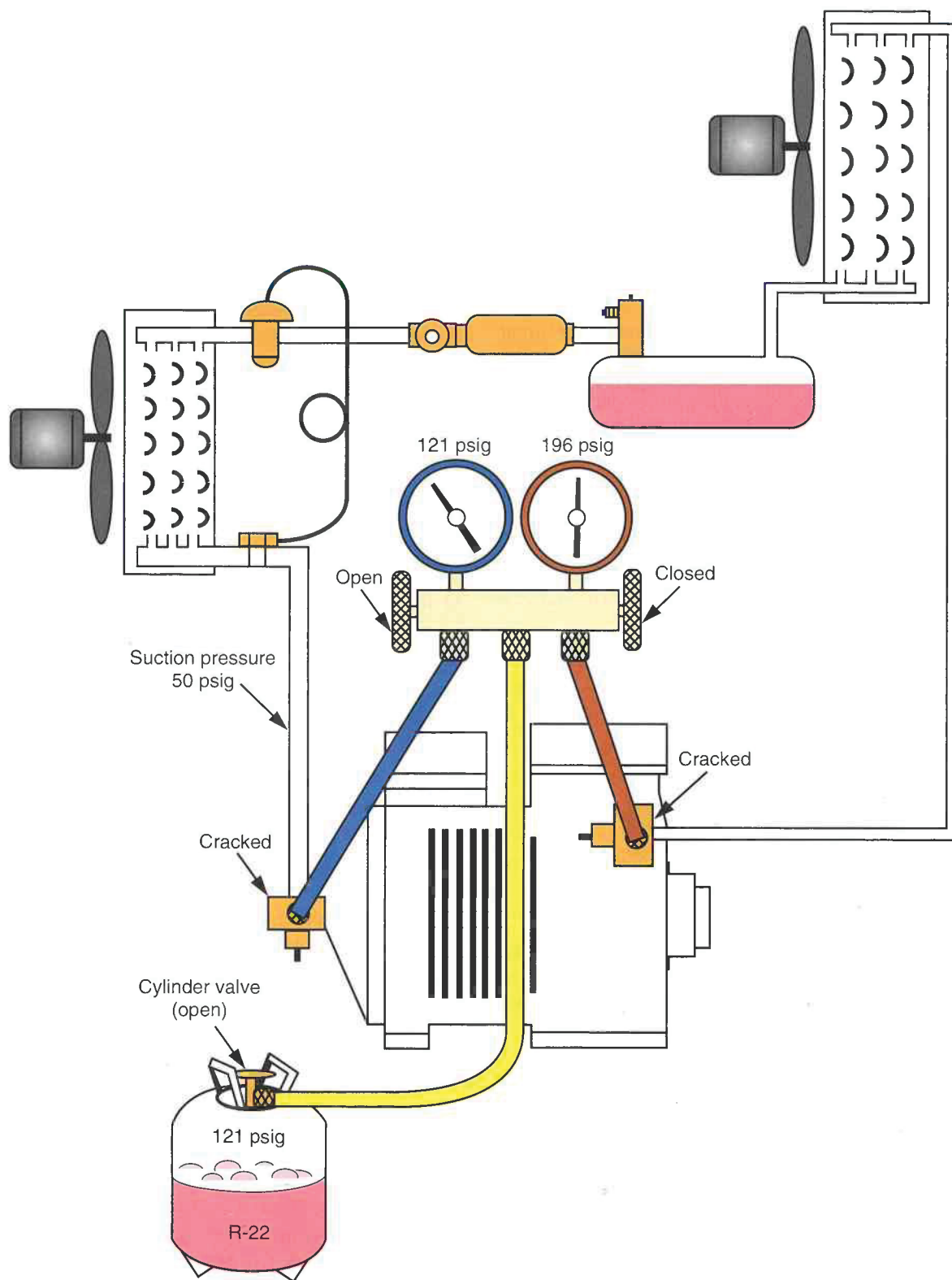
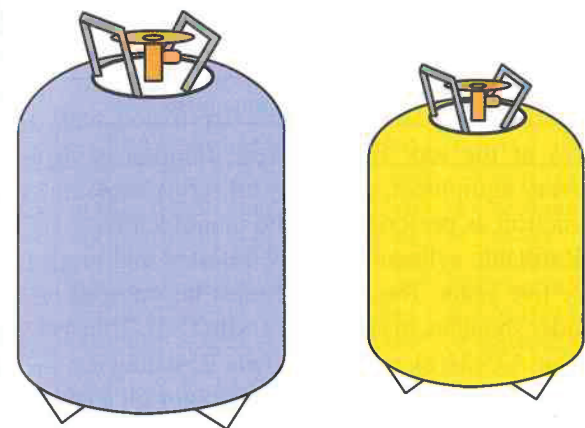


Figure 15-14. If cylinder pressure is lower than or equal to system pressure, charging will stop. For refrigerant to flow into the system, cylinder pressure must be higher. Pressure can be increased by carefully heating the cylinder.

**50-lb. Disposable**

R-12	White
R-22	Green
R-500	Yellow
R-502	Purple

30-lb. Disposable

R-12	White
R-22	Green
R-500	Yellow
R-502	Purple
R-11	Orange

Figure 15-15. Disposable cylinders are lightweight and intended to be discarded after use. An empty cylinder is considered hazardous waste until a hole is punched in it.

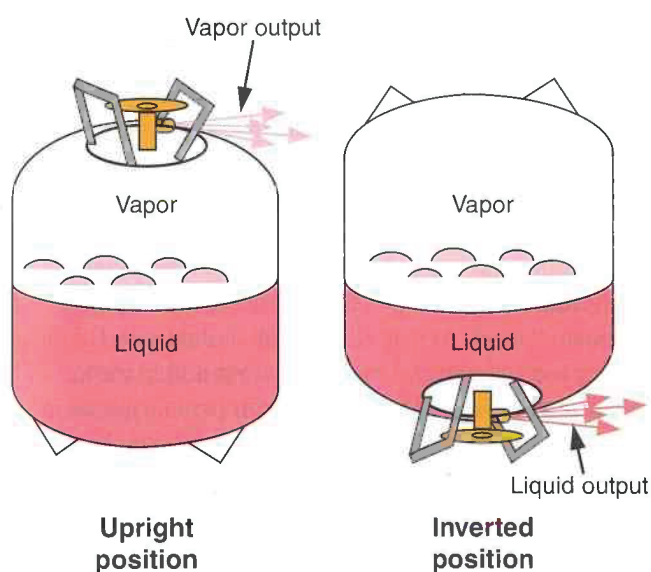


Figure 15-16. To obtain refrigerant in vapor form, the cylinder is in the upright position. Inverting it will provide refrigerant in liquid form.

Recovery cylinders are refillable, heavy-duty, certified pressure vessels meeting DOT specifications. **Figure 15-17** shows three recovery cylinders and one refillable cylinder. Federal law specifies that recovery cylinders must have gray bottoms with yellow shoulders and tops. Also, recovery cylinders must be inspected at regular intervals and repaired or replaced when damaged through handling.



Figure 15-17. Recovery cylinders have gray bottoms with yellow shoulders and tops. Refillable-type cylinders, like the one in the foreground, may have solid colors. (Amtrol)

Proper procedures must be followed when using cylinders. **The greatest danger to the technician and persons nearby is overfilling the cylinder with liquid refrigerant.** Even though the cylinders have pressure-relief devices, they can still rupture or violently discharge refrigerant if overfilled. The amount of liquid refrigerant a cylinder can safely hold is measured in pounds, which means quantities vary by the type of refrigerant (some weigh more than others for a given volume). Sufficient space must be allowed in the cylinder for hydrostatic expansion, **Figure 15-18**. Generally, 15% of the cylinder's volume should be left empty for expansion. The EPA is even more cautious, stipulating 20% of a recovery cylinder should be left empty for hydrostatic expansion.

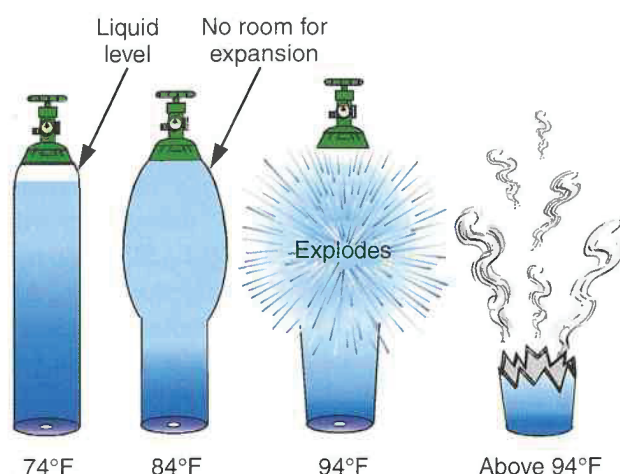


Figure 15-18. Sufficient room must be left in a cylinder for hydrostatic expansion of the liquid refrigerant. If little or no space is left, an increase in temperature will cause pressure to rise to the point where the cylinder explodes.

Cylinders must be clearly labeled to indicate the type of refrigerant inside; furthermore, they should always be refilled with the same type of refrigerant. Colored spray paint is often used for marking a cylinder with the number of the refrigerant it contains. Refilling an R-22 cylinder with R-134a could result in charging a system with the wrong refrigerant. Extreme care should be taken to prevent contamination of recovery cylinders.

Before reuse, recovered refrigerant should be recycled to separate oil and remove moisture, acids, and foreign particles. Preferably, the refrigerant should go through the *reclaiming* process, which brings it back to new product specifications.

15.3.4 Cylinder Safety

When working with refrigerants, the technician must practice safety on the job everyday. Safety-consciousness extends to the handling of cylinders that hold and transport refrigerants. Anytime a used refrigerant is transported, clearly label its container with a DOT classification tag to meet the requirements of the Code of Federal Regulation, Title 49. When moving a cylinder, be sure it is firmly strapped onto an appropriate wheeled device. *Never* roll a cylinder on its base or lay it down to roll it.

There are three major concerns when transferring refrigerants:

- ☐ Avoid contamination.
- ☐ Avoid venting to the atmosphere.
- ☐ Handle refrigerants safely.

Refrigerant cylinders must be the correct type and color and be properly marked.

The cylinder used for holding transferred refrigerants must first be evacuated to a vacuum of at least 28 in. Hg. Different refrigerants should not be mixed in a cylinder because no economical method exists to separate refrigerants.

Careless handling of cylinders can result in sudden releases of refrigerant that can cause frostbite, skin damage, or blindness. If skin contact occurs, soak the area in lukewarm water and seek medical attention at once.

A **returnable cylinder** must *never* be filled to more than 80% of the container volume. If the cylinder will be exposed to temperatures above 130°F (54°C), do not fill to more than 60% of the container volume. All liquids expand when heated. An expanding refrigerant liquid in an enclosed space determines the pressure in the cylinder. Overpressure safety devices provide some level of safety, but they do not eliminate all risk.

Weigh cylinders on an accurate scale, and inspect them carefully before filling. Do not use dented, rusted, gouged, or damaged cylinders. Examine the valve assembly for leakage, damage, or tampering. **Handle cylinders carefully. Do not drop them or bump**

them together. If the impact from a fall were to knock off a cylinder valve, the sudden release of refrigerant could turn the cylinder into a projectile. Store refrigerant cylinders in a vertical position with their valves at the top. Become very familiar with your recovery equipment, and apply all safety measures and instruction as prescribed by the manufacturer.

Refillable cylinders must be retested and recertified every five years. The test date must be stamped on the cylinder shoulder, in accordance with DOT Title 49 CFR Section 173.34(e) and 173.31(d). Retesting by visual inspection alone is not permitted. Do not fill a container that is out of date (five years or older). Outdated cylinders should be returned empty for retesting.

Disposable steel cylinders will oxidize and become so weakened by rust that the wall and seams can no longer tolerate pressure or contain gases. Discard disposable containers since they may never be used for recovery or refilling. Refrigerant returned for reprocessing in improper cylinders will not be accepted. The penalty for transporting a refilled disposable cylinder is a fine up to \$25,000 and five years imprisonment. Disposable refrigerant cylinders should be stored in a dry location to prevent corrosion. *Never* allow used cylinders with residual refrigerant to sit at a job site; saturated vapor pressure will exist if even the smallest amount of liquid is present. An abandoned cylinder could explode under direct heat from any source. Before discarding a disposable container, recover any refrigerant remaining in the container. Then, for maximum safety, break off the cylinder valve and puncture the container before disposal as scrap metal.

Never use an empty disposable cylinder as a compressed air tank. The inside of the cylinder is untreated steel. When filled with compressed atmospheric air, oxygen and moisture contained in the air will form rust on the inside of the tank. It is not a question of “*will* the cylinder burst?” but rather “*where* and *when*?”

15.4 Temperature-Pressure Relationships

Since pure and azeotropic refrigerants are stable, temperature-pressure relationships are also stable and predictable. For ease of reference and use, these relationships have been compiled into pressure-temperature or *saturation* charts. (Zeotropic blends do not exhibit stable temperature-pressure relationships. Refer to Chapter 14.)

Saturation charts provide a means to quickly convert temperature readings to pressure readings or vice versa. A technician can use a manifold gauge to obtain the pressure of the refrigerant, then, consult a pocket-size chart like the one in **Figure 15-19** to determine the corresponding temperature. Similarly, when

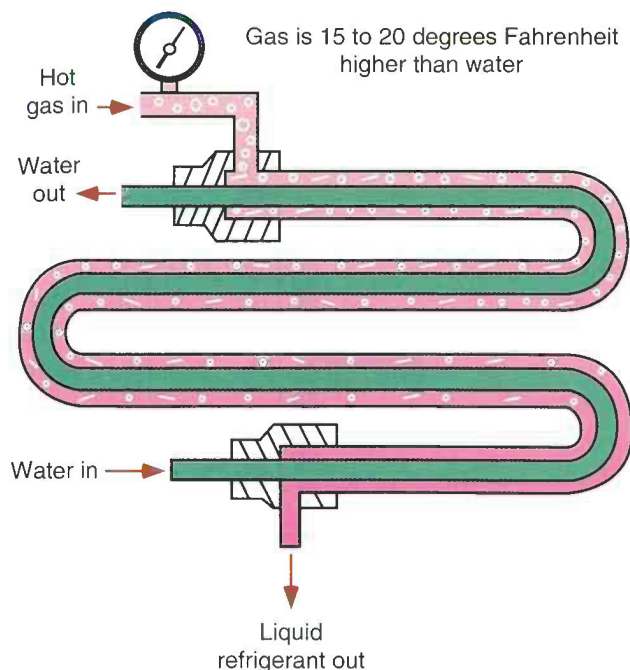


Figure 15-26. Water-cooled systems transfer heat efficiently by means of conduction, so the refrigerant in the condenser is only 15 to 20 degrees Fahrenheit higher than the water leaving the condenser.

15.5 Charging Refrigerant into a System

The term **charging**, in the context of a refrigeration or air conditioning system, means to add refrigerant. Systems use different kinds and amounts of refrigerant, and the amounts are critical at times. In some domestic systems, for example, a 1/2-ounce overcharge or undercharge can noticeably affect operation. In other systems, there is some room for error. For example, systems that use a liquid receiver can operate with an excess of refrigerant. As a rule, knowing when to *stop* adding refrigerant to a system is as important as knowing *how* to add refrigerant.

Refrigerant can be charged into a system as a *vapor* or as a *liquid*. Before it can be charged, a system must be tested for leaks, dehydrated, and evacuated. Then, a gauge manifold can be connected to the suction service valve and the discharge service valve. Both connections are important since they provide necessary pressure readings.

15.5.1 Vapor Charging

The most common mode of charging a system is to add refrigerant vapor to the low-pressure side (**vapor charging**) using the gauge port on the suction service valve. The center hose from the manifold is connected to a refrigerant cylinder, which must be in the *upright* position to permit vapor charging. The cylinder valve is then opened, transferring control to the

gauge manifold.

Cylinder pressure must be *higher* than suction pressure since refrigerant will not flow without a pressure difference. Sometimes, cylinder pressure must be carefully increased by warming the cylinder with hot water. **CAUTION:** Never use a torch to heat a refrigerant cylinder, and never raise cylinder temperature above 125°F (52°C). An explosion could result.

With both service valves in the cracked position, open the left (low-pressure side) manifold hand valve. Refrigerant vapor will travel from the cylinder, through the yellow (center) hose, through the left side of the manifold to the blue hose, and into the compressor through the suction service valve. See **Figure 15-27**.

If the system is turned off, refrigerant can be charged into *both* the high side and the low side by opening both hand valves on the manifold.

WARNING: When the system is running, *never* open the right (high-pressure side) manifold hand valve. Since the system's high-side pressure is greater than the cylinder pressure (refer to Figure 15-27), the system will pump into the cylinder. **This could contaminate the cylinder and cause the cylinder to rupture.** The high-pressure gauge is connected to the discharge service valve to allow monitoring of high-side pressures while charging.

Charging will take longer if it is done using Schrader valves rather than service valves. The passage for gas or liquid through a Schrader valve is much smaller than the passage through a service valve. Since the smaller passage restricts refrigerant flow, charging takes longer.

However, avoid charging too quickly; fast charging may cause discharge pressure to rise rapidly (it should not be allowed to exceed normal operating pressure). When charging with vapor, the process must be stopped periodically to check low-side operating pressure. The pressure should correspond to the conditions surrounding the evaporator.

Note: System operating pressures will not be normal until the system is fully charged and has achieved normal operating temperatures. Both high-side and low-side pressures will be too low if the system is *undercharged*. If the system is *overcharged*, the high-side pressure will be high. The low-side pressure will be high if the evaporator temperature is high.

Charging of small systems with hermetic compressors should always be done using the vapor method. Liquid refrigerant can easily damage hermetic compressors.

15.5.2 Liquid Charging

Charging a system with refrigerant in a liquid state is faster than vapor charging, since it is done with the

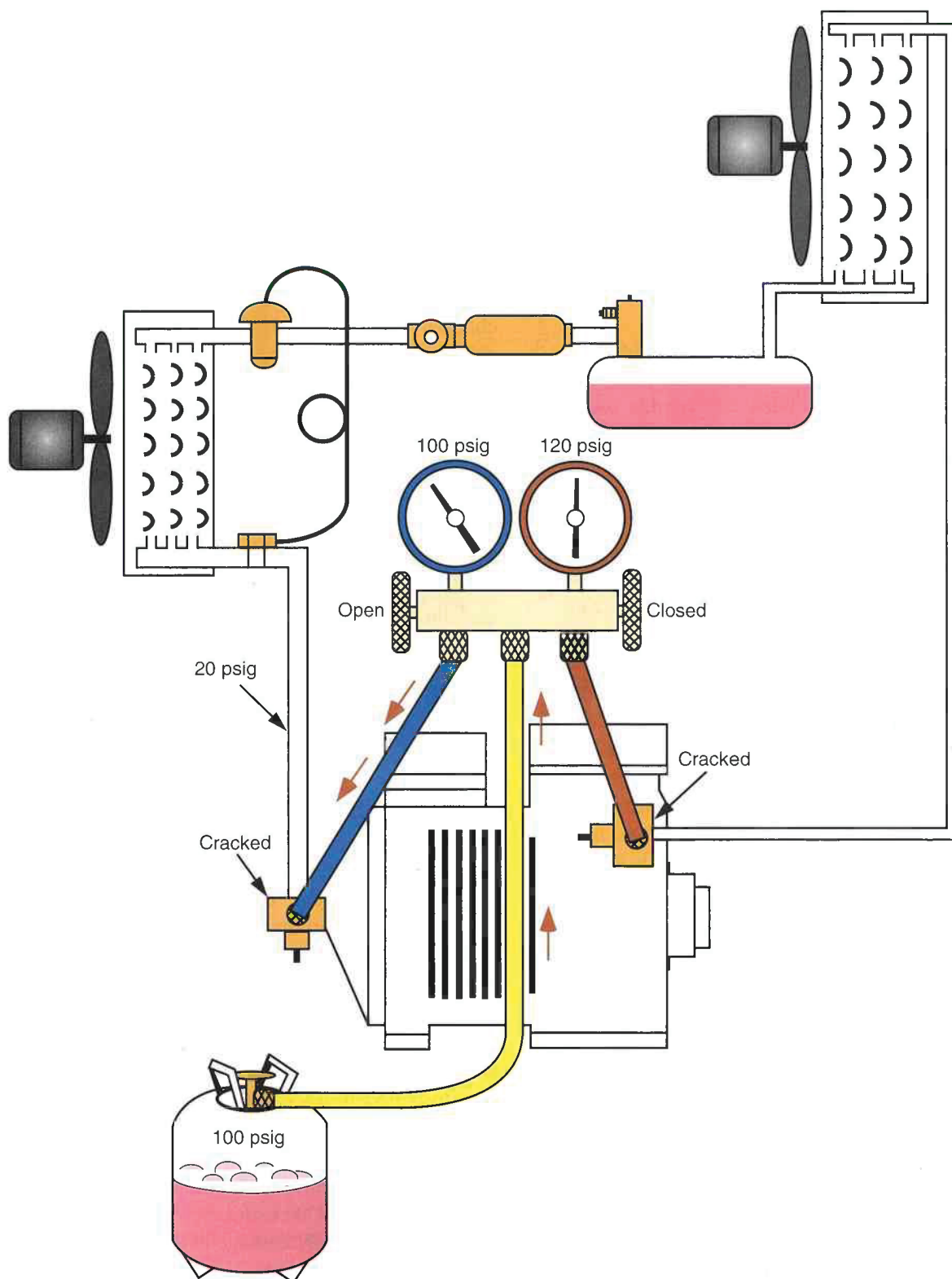


Figure 15-27. During vapor charging, the refrigerant vapor flows from the cylinder through the hoses to the compressor. Cylinder pressure must be higher than suction pressure so the refrigerant vapor flows into the system.

system operating; but it does require skill and experience. Since **liquid charging** can easily result in overcharging and cause compressor damage, it should be attempted only by experienced technicians. When liquid charging, the cylinder pressure remains constant since the liquid changes state to a vapor *inside the system*, rather than inside the cylinder. For liquid charging, the cylinder is usually inverted, as shown in **Figure 15-28**. Some cylinders, such as those used for refrigerant recovery, are equipped with a dip tube to allow liquid charging without inverting the cylinder.

Proper procedure for liquid charging entails *metering* the refrigerant into the low-pressure side of the system by adjusting the gauge manifold. The left

(low-pressure) manifold valve is cracked open so a pressure 10 psig to 15 psig (69 kPa to 104 kPa) higher than suction pressure is maintained. Frost will form on the manifold body and the hose connected to the suction service valve. Frost should not be allowed to reach the compressor body since it would indicate liquid refrigerant is present.

Because low-side pressure increases as refrigerant is added to the system, the left manifold valve should be closed at regular intervals to check pressure. When the valve is closed, frost disappears. After pressure is checked, the valve should be cracked open once again and the 10 psig to 15 psig (69 kPa to 104 kPa) pressure differential established.

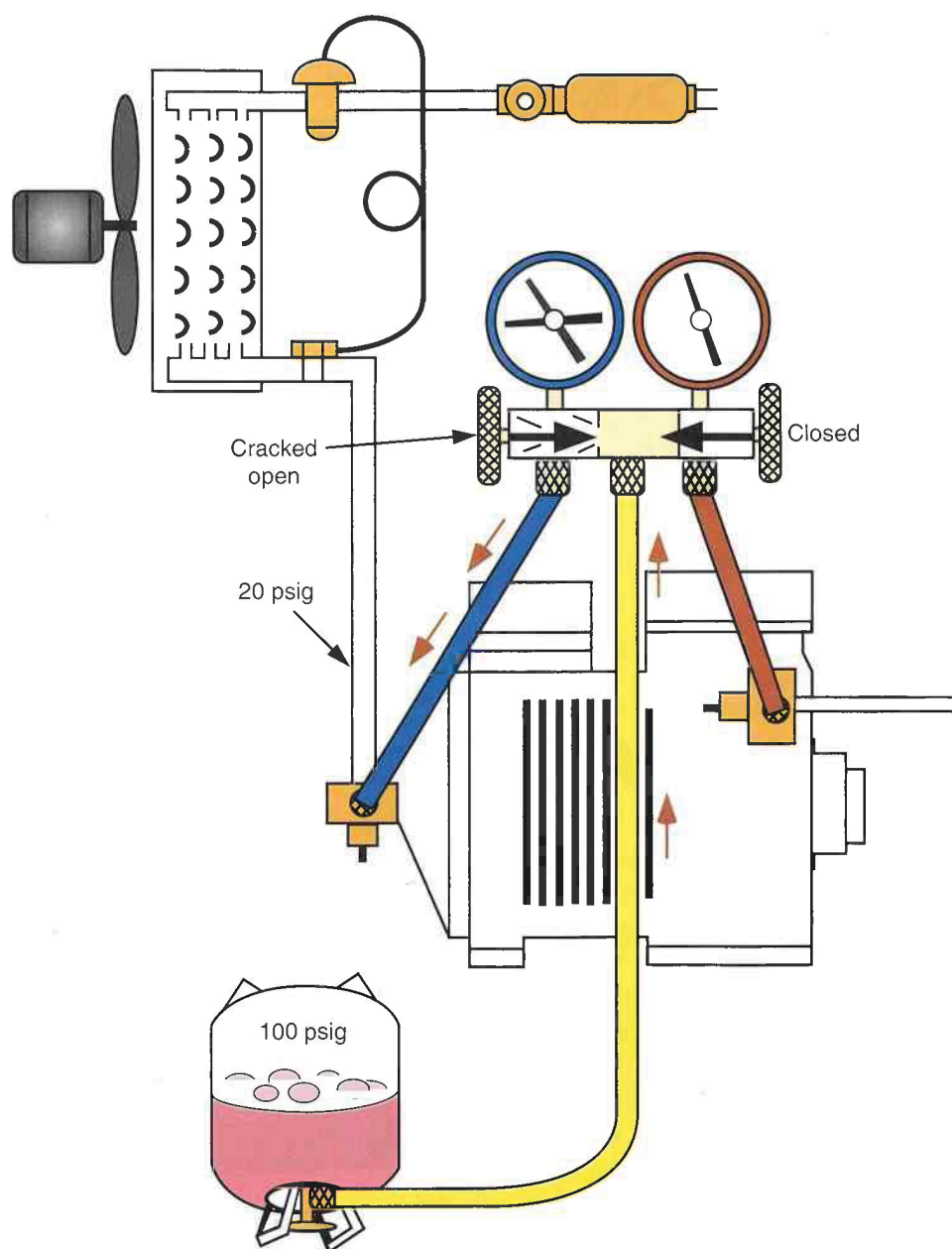


Figure 15-28. When liquid charging, the technician must be careful to prevent liquid refrigerant from entering and possibly damaging the compressor. Gauge pressure should be 10 psig to 15 psig above actual suction pressure. Some types of cylinders can be left upright for liquid charging.

Watch the high-side gauge to avoid excessive head pressure. Observe the sight glass for bubbles. When bubbles disappear from the sight glass and the two gauges register the correct pressure, the system is fully charged.

On larger systems, the liquid receiver service valve is usually used for charging. The valve is frontseated,

causing the system to pump down (evacuate the low side). When liquid is charged into the system through the LSRV valve, it travels to the expansion valve and the evaporator. The liquid becomes a vapor before it reaches the compressor. See **Figure 15-29**.

Systems with liquid receivers are slightly overcharged on purpose. The technician must determine

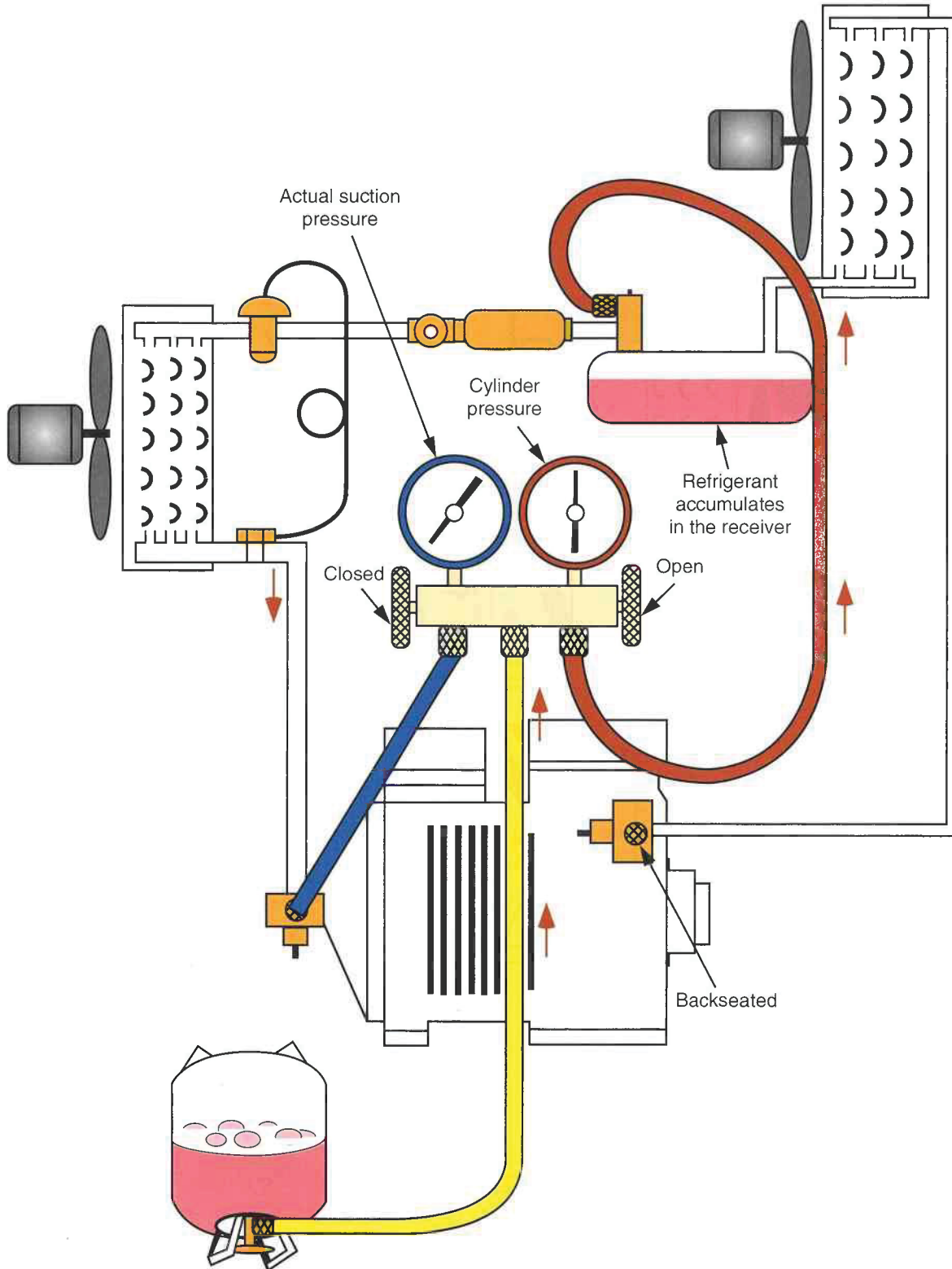


Figure 15-29. For larger systems, liquid charging is often done through the liquid receiver service valve.

how much liquid is being stored in the liquid receiver. (On very large systems, it may be big enough to hold the contents of three or four 30-pound cylinders of refrigerant). Periodically, charging should be stopped and the liquid line sight glass checked for bubbles. When bubbles stop appearing, the liquid line is full, and the receiver dip tube (outlet) is covered with liquid. Some additional refrigerant is added to the system, the amount determined by the technician's experience and judgment. The size of the receiver, and how much liquid it already contains, must be taken into account.

Charging by weight

Small, self-contained systems, such as window-mounted air conditioners, domestic refrigerators, and ice-making machines, are usually charged by weight of refrigerant. The recommended charge is stamped on the data plate of the equipment, making it quick and easy to measure an exact amount of refrigerant and charge the system. The system must be thoroughly evacuated before charging.

Electronic scales. Accurate, easy-to-use weighing devices are readily available for use by technicians, **Figure 15-30**. These **electronic scales** have displays that can be set to read zero when a full refrigerant cylinder is placed on them. The display shows the amount of refrigerant (in ounces) being withdrawn from the cylinder and charged into the system. When the desired refrigerant weight is reached, the manifold hand valve is closed to stop the process.



Figure 15-30. Electronic scales permit very accurate measurement of refrigerant while charging. The cylinder is placed on the scale pad, and the weight readout is adjusted to zero. As refrigerant is charged into the system, the readout will keep a running total in pounds and ounces. (TIF)

Graduated cylinder. A common method of measuring an exact refrigerant charge is using the **graduated cylinder**, **Figure 15-31**. Such cylinders are very accurate, and have scales for measuring three widely used refrigerants: R-12, R-22, R-502. The graduated scales can be rotated to align the desired one with the external viewing tube that shows the liquid level inside the cylinder.

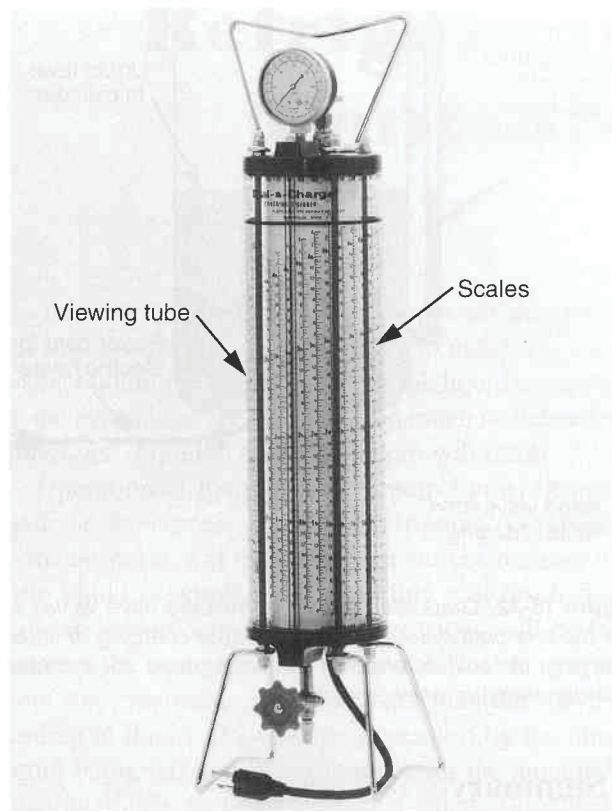


Figure 15-31. A graduated charging cylinder has scales for the most common refrigerants. The desired scale is rotated into position next to the viewing tube to read the cylinder liquid level. (Robinair Mfg. Corp.)

The graduated cylinder measures refrigerant by volume rather than weight. Since volume varies with temperature, the cylinder is equipped with a pressure gauge to permit selecting the proper scale. The cylinder is equipped with a top hand valve for vapor charging and a bottom hand valve for liquid charging. See **Figure 15-32**.

Before use, the graduated cylinder is charged with liquid refrigerant from a larger cylinder. The liquid level in the graduated cylinder, as shown by the viewing tube, should be slightly more than needed for the system being charged. The graduated cylinder is connected to the system through a gauge manifold; charging progress is monitored by watching the refrigerant level in the viewing tube. The graduated cylinder method allows precise charging.

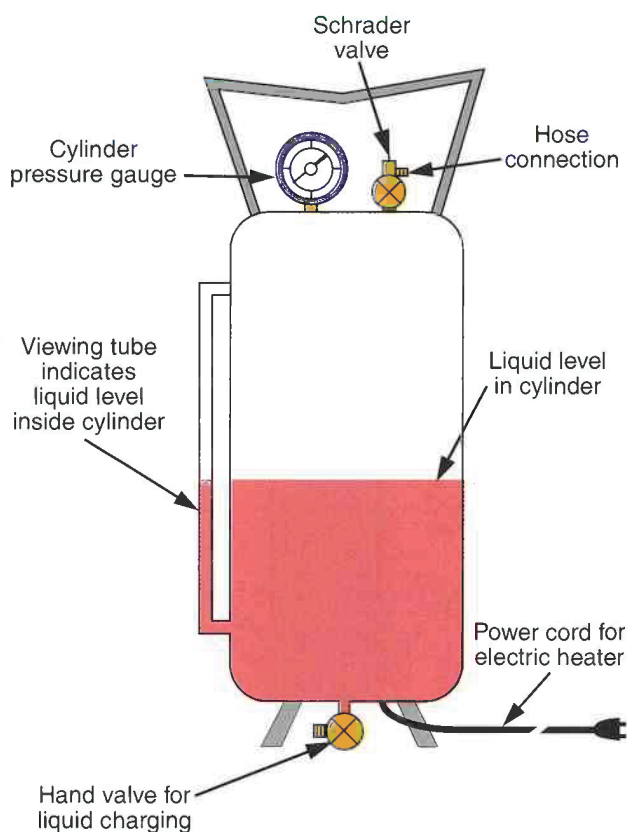


Figure 15-32. Graduated charging cylinders have valves at the top and bottom to permit either vapor charging or liquid charging. A built-in electric heater is used to increase cylinder pressure when necessary.

Summary

Knowing how to work safely and efficiently with refrigerants and high-pressure gases is very important. The information presented in this chapter is vital for properly installing, servicing, and troubleshooting refrigeration systems. The chapter explained many servicing and troubleshooting procedures and described several leak-detection methods. Charging methods for both vapor and liquid refrigerant were also described.

Test Your Knowledge

Please do not write in this text. Write your answers on a separate sheet of paper.

- Why is oxygen never used to pressurize a system?
- Leak detection using the _____ method is not reliable for detecting small leaks.
- List three acceptable methods of leak detection.
- Leak testing should be done with pressures between _____ psig and _____ psig.
- Name two inert gases commonly used to pressurize systems for leak detection.
- The halide torch can detect a leak as small as one ounce per _____.
- Why are refrigerant cylinders filled to only 85% of capacity?
- _____ cylinders should never be refilled.
- Temperature charts for three refrigerants are shown on manifold gauge faces. Name the refrigerants.
- Normally, controlling the temperature of the _____ around a product allows you to control the temperature of the product itself.
- The evaporator removes heat from the _____, which removed heat from the _____.
- In a refrigeration system, evaporator temperature should be about _____ degrees Fahrenheit colder than the entering air.
- Boiling refrigerant inside the evaporator is about _____ degrees Fahrenheit colder than the temperature of the evaporator itself.
- When a refrigeration system is turned off, is there a temperature difference between the air and the evaporator?
- In an air conditioning system, what is the temperature difference between the refrigerant and "air off" (the cooled air)?
- When a refrigeration system (such as one used for a walk-in cooler) is in operation, what is the evaporator temperature when the "air on" temperature is 36°F? What is the refrigerant temperature?
- The purpose of the condensing unit is to remove _____ from the refrigerant vapor so it changes state back to a _____.
- High-side pressure depends on the temperature of the _____ air passing through the condenser.
- How is proper head pressure determined for an air-cooled condenser?
- On a water-cooled condenser, head pressure should correspond to a temperature _____ to _____ degrees Fahrenheit higher than the temperature of the water leaving the condenser.
- List five causes of high head pressure.
- On an air-cooled system using R-502 as a refrigerant, what is the head pressure at an ambient air temperature of 80°F?
- On an air-cooled system using R-12 as a refrigerant, what is the head pressure at an ambient air temperature of 60°F?
- What is the most common means of charging a system?
- For _____ charging, the refrigerant cylinder often must be inverted.