# METHOD STATEMENT

FOR

# *DIRECT EXPANSION REFRIGERANT COPPER LINES INSTALLATION AND START UP*

Issue Record

| REV | DATE | DESCRIPTION | PREPARED | REVIEWED | UPLOAD DATE |
|---|---|---|---|---|---|
| 0 | 2021-09-16 | Issued for Approval | OLGA ULANOV | ROGER ABDO | |
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# 1 – SCOPE OF WORK:

This method statement covers the installation of refrigerant copper pipes, connections, testing and system start up for all direct expansion AC units (ex: Split AC units, etc….).

Installation of DX units shall be as per project specifications and approved drawings.

# 2- REFERENCES:

2.1- Project Specifications – Lot 33.
2.2- Approved Material Submittals.
2.3- Approved Shop Drawings.
2.4- ASHRAE 2000 – Systems and Equipments S05 and S45.
2.5- Residential Construction Academy – HVAC – 2005.

# 3 – Refrigerant Copper Pipes Installation:

3.1-**Material:** All Refrigerant Copper pipes which will be used in this project shall be of ***ACR Soft-Drawn Copper Tubing***. This type of tube is usually delivered in 20, 30, and 50 or even 100 ft Roll (as shown in fig 5-3) which will reduce the number of fittings because this type of pipes can be easily bent to any desired angle.

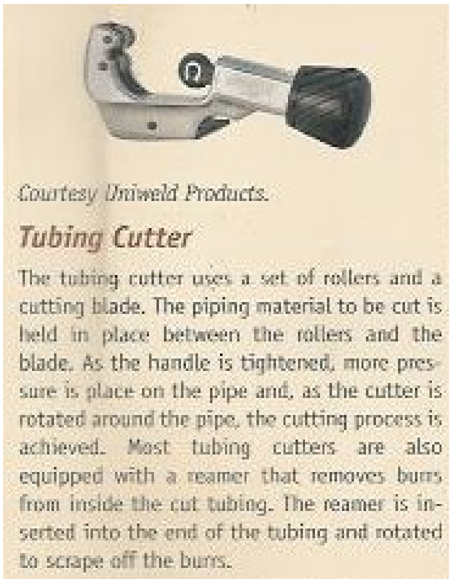
Figure 5–3 Soft-drawn copper tubing typically comes in 50-foot rolls.

Figure 5–4 Tubing should be unrolled carefully to avoid kinking the pipe. *Photo by Bill Johnson.*

## 3.2- Copper Pipes Operations:

3.2.1- ***Unrolling:*** the best way to unroll the copper pipe roll is to place the loose end on the ground and hold it in place with hand of foot (as shown in fig 5-4). Then, carefully unroll the tubing, keeping the roll on the ground as it's unrolled. Simply pulling the tubing off the coil will result in twisting the tubing, creating waves in the line and reducing the efficiency of the coil.

3.2.2- ***Cutting***: when copper piping is carrying refrigerant between the component parts of an air conditioning system, it's recommended that the tubing be cut with the tubing cutter (fig A-1).


Courtesy Uniweld Products.

**Tubing Cutter**

The tubing cutter uses a set of rollers and a cutting blade. The piping material to be cut is held in place between the rollers and the blade. As the handle is tightened, more pressure is place on the pipe and, as the cutter is rotated around the pipe, the cutting process is achieved. Most tubing cutters are also equipped with a reamer that removes burrs from inside the cut tubing. The reamer is inserted into the end of the tubing and rotated to scrape off the burrs.

Fig – A-1

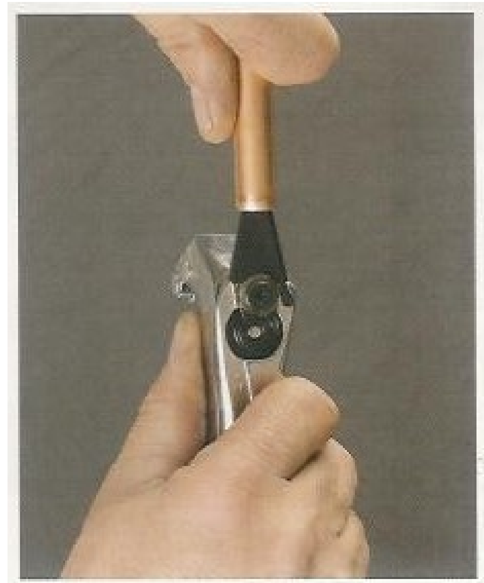


Fig – A-2

- Mark the pipe with pencil at the desired cutting point:
- Place the tubing cutter around the pipe and tighten the handle so that the cutting wheel is snug against the pipe surface at the pencil mark. The wheel should be tight enough to hold the cutter in place, but not so tight as to create and indentation in the pipe.
- Slowly rotate the tubing cutter around the pipe, 1 or 2 turns, until the pressure of the cutting wheel on the pipe is reduced.
- Tighten the adjusting handle 1/8 to ¾ turns to snug the cutting wheel against the pipe surface again.
- Repeat the tightening and turning of the cutter until the tubing is cut.

3.2.3- ***Bending:*** bending of soft drawn copper pipes could be achieved by using bending springs (Fig A-3). Simply place the bending springs over the tubing and bend the spring into the desired shape. The spring will evenly distribute the pressure, preventing the tubing from getting crimped.

Also bending can de done by using the tubing bender (Fig A-4). This type of bender facilitates the bending of tubing at precise locations and to the desired angle. Tubing bender is available in sizes ranging from ¼” to more than 7/8”.

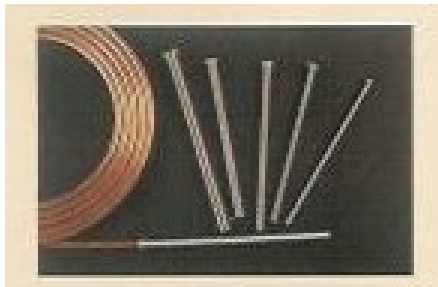


Fig A-3

Fig A-4

3.2.4- ***Swaging:*** it's the process by which two pieces of soft drawn copper tubing with the same diameter can be joined together by stretching the end of one of the sections. Once the end has been swaged or stretched, the unswaged end will fit on it.

Fig A-5

Fig A-6

To perform the swage, a flaring block (fig A-5), hammer, and proper size swaging tools (Fig A-6) are needed.

The following procedure must be followed for proper swaging of a copper pipe:

- Locate the proper hole in the flaring block. The proper hole is marked with the measurement that corresponds to the outside diameter of the tubing.
- Insert the section of soft drawn tubing to be swaged into the proper hole in the flaring block so that tubing extends a distance equal to the diameter of the tube plus about 1/8".make certain that the end of the tube to be swaged protrudes from the side of the block that has the beveled or angled edge (Fig A-7).

Fig A-7

- tighten the flaring block around the tubing, applying pressure and tightening the wing nuts equally to ensure that the 2 pieces of the block secure the tubing evenly.
- Insert the swaging tool (Fig A-6) into the tubing and strike the swaging tool firmly with a hammer (Fig A-8).

Fig A-8

- Rotate the flaring block ½ turn and strike the swaging tool again.
- Repeat the previous step until the swag has reached a length approximately equal to the diameter of the tubing.

3.2.5- ***Flaring***: the flare connection is used to join a section of soft drawn copper tubing to a male threaded flare fitting or system component. As the name suggest, flaring means that the end of the soft drawn tubing is flared to a 45-degree angle. This flared portion of tubing will rest against the male portion of the fitting being connected and will be held in place with a flare nut (Fig A-10). To perform the flaring process, a flaring block (Fig A-5) and a flaring yoke are needed (Fig A-9).

Fig A-9

Fig A-10

The following procedure must be followed for proper Flaring of a copper pipe:

- Cut the tubing to the desired length and ream.

- Place the flare nut over the end of the tubing with the threaded portion of the nut facing the end of the tubing (Fig A-10).
- Insert the section of soft drawn tubing to be swaged into the proper hole in the flaring block so that the tubing extends a distance about equal to the diameter of a nickel.
- Make certain that the end of the tube to be swaged protrudes from the side of the block that has the beveled or angled edge (Fig A-11).

Fig A-11 Fig A-12

- Tighten the flaring block around the tubing, applying pressure and tightening the wing nuts equally to ensure that the two pieces of the block secure the tubing evenly.
- Place the yoke around the block and position the cone over the opening of the tubing (Fig A-12).
- Turn the screw handle on the yoke until the cone comes in contact with the tubing. Tighten the screw handle an additional ¾ of a turn.
- Loosen the screw handle ¼ of a turn.
- Repeat the tightness process until the cone of the yoke is tight against the flaring block.
- Inspect the flare for cracks or other imperfections. If the flare is cracked, cut the flared end off and re-flare the tubing. Cracked flares will leak.

Fig A-13

***3.2.6-*** ***__Soldering:__*** soldering is a process that is frequently used to join a section of piping material to another piping section or a pipe fitting or system component. Materials that are commonly soldered are often made of either copper or brass. During the soldering process the pipe joint is heated to the desired temperature, usually in the 500º F range, and a filler material is introduced to the space between the pipe sections (Fig A-14).

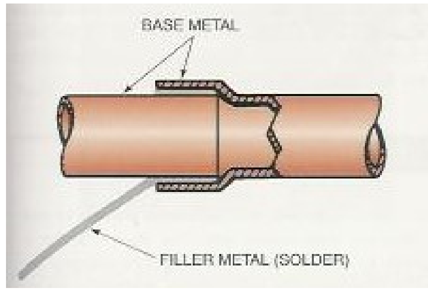



Fig A-14

The heat of the pipe causes the filler material to melt, filling the gap between the two sections. As the filler material cool, it hardens to seal the joint between the pipes. Different filler materials are used for different applications. Two commonly used filler materials:

*50/50 – 50% tin, 50% lead, used for lower pressure applications. Not to be used on potable water supplies.*

*95/5 – 95% tin, 5% antimony, used for higher pressure applications. provides greater joint strength.*

To perform the soldering process, pipe brushes, sand cloth or steel wool, a striker, solder, flux, flux brushes, refrigeration service wrench and a heat source such as air-acetylene torch kit are needed (Fig A-15).

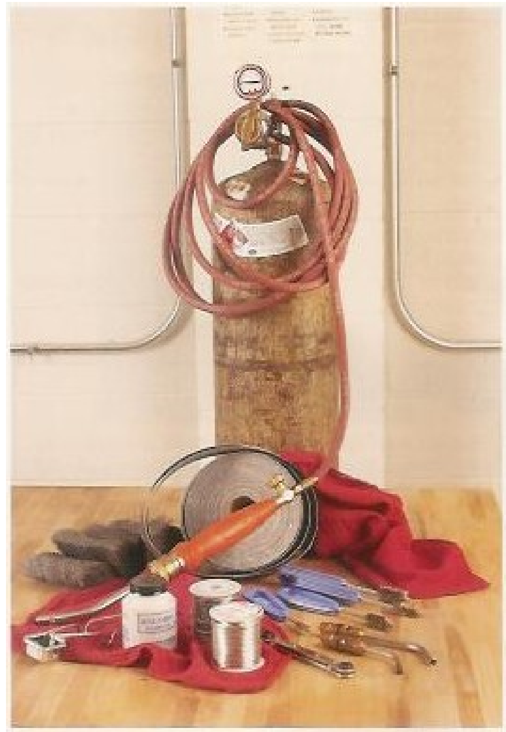


Fig A-15

For step by step soldering, the following procedure must be followed:

*Courtesy of The Mill-Rose Company.*

***Fitting Brushes***

These specialty brushes are designed to clean the interior surfaces of pipe fittings prior to soldering. Any dirt that accumulates inside the fitting will reduce the quality of the solder joint. Fitting brushes come in a variety of sizes to accommodate a wide range of fitting sizes. Simply insert the brush into the fitting and turn the brush until the interior is clean.

Fig A-16

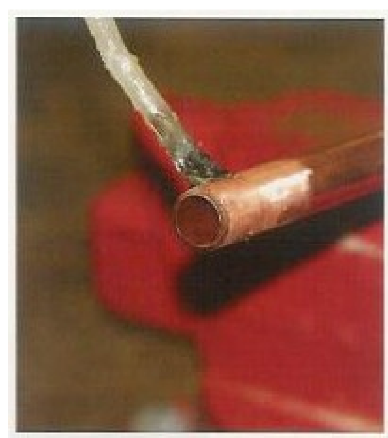


Fig A-17

- Properly cut and ream the section to be joined. Refer to cutting procedure section 3.2.2.
- Using sand cloth or steel wool and the correct size pipe brush, clean the male and female portions of the joint being soldered (Fig A-16).
- Using a flux brush, apply flux to the male portion of the joint (Fig A-17).
- Insert the male portion of the joint into the female end.
- Before connecting the acetylene regulator to the tank, quickly open and close the stem on the tank using the refrigeration service wrench. This will blow any particulate matter from the opening of the tank.

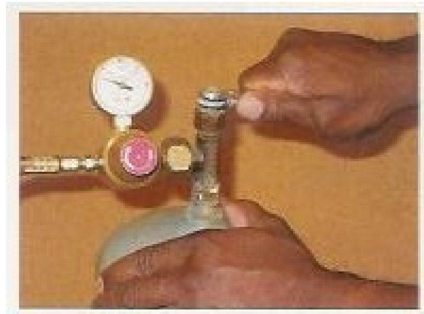
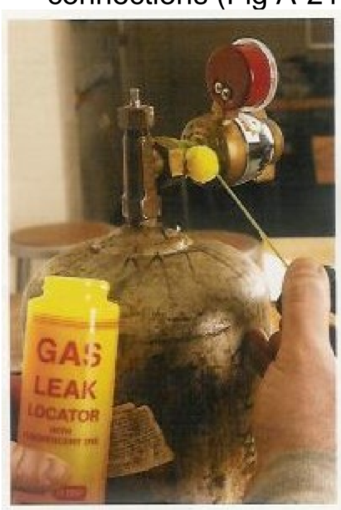



Fig A-18 Fig A-19 Fig A-20

- Mount the acetylene regulator and torch kit to the tank, making sure that the connections are tight (Fig A-18).
- Making certain that the valve on the torch handle is closed; open the stem valve on the acetylene tank ½ to 1 turn using the service wrench (Fig A-19). Flip the ratchet on the service wrench so the tank can be closed quickly in the event of emergency.
- Using a soap bubble solution, leak check the regulator, hose, and torch assembly, making certain that no acetylene is leaking from the kit. Tighten any leaking connections (Fig A-21).



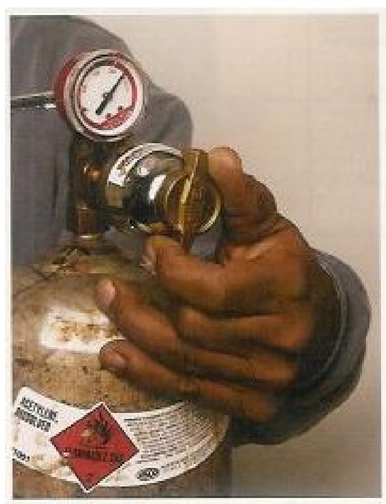



Fig A-21 Fig A-22 Fig A-23

- Set the regulator on the tank to the middle range to start. It can always be adjusted later on (Fig A-22).
- Open the valves on the torch handle most of the way and ignite the fuel with the striker (Fig A-20). The size of the flame and the amount of heat generated by the torch is directly related to the size of the torch tip used. Larger size pipe will require more heat and will therefore require a larger torch tip (Fig A-24).

Torch tip set

| ACETYLENE TORCH TIPS | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Tip Size | | | Gas Flow | | Copper Tubing Size Capacity | | | |
| | | | | | Soft Solder | | Silver Solder | |
| Tip No. | in. | mm | @ 14 psi $ft^3/hr$ | (0.9 Bar) $m^3/hr$ | in. | mm | in. | mm |
| A–2 | 3/16 | 4.8 | 2.0 | .17 | 1/8–1/2 | 3–15 | 1/8–3/8 | 3–10 |
| A–3 | 1/4 | 6.4 | 3.6 | .31 | 1/4–1 | 5–25 | 1/8–1/2 | 3–12 |
| A–5 | 5/16 | 7.9 | 5.7 | .48 | 3/4–1 1/2 | 20–40 | 3/8–3/4 | 10–20 |
| A–8 | 3/8 | 9.5 | 8.3 | .71 | 1–2 | 25–50 | 1/2–1 | 15–30 |
| A–11 | 7/16 | 11.1 | 11.0 | .94 | 1 1/2–3 | 40–75 | 3/4–1 1/2 | 20–40 |
| A–14 | 1/2 | 12.7 | 14.5 | 1.23 | 2–3 1/2 | 50–90 | 1–2 | 30–50 |
| A–32* | 3/4 | 19.0 | 33.2 | 2.82 | 4–6 | 100–150 | 1 1/2–4 | 40–100 |
| MSA–8 | 3/8 | 9.5 | 5.8 | .50 | 3/4–3 | 20–40 | 3/8–3/4 | 10–20 |

*Use with large tank only.
NOTE: For air conditioning, add 1/8 inch for type L tubing.

Fig A-24

- Adjust the flame using the regulator on the tank until the desired flame intensity is obtained (please refer to Fig A-24). A proper flame will have a bright blue inner cone and a lighter blue inner cone. The hottest portion of the torch flame is the tip of the inner cone.
- Apply heat to the joint, placing the tip of the inner cone on the surface of the joint. The flux will begin to melt and flow into the joint. Be sure to keep the flame moving to heat the entire joint. After heating the joint for a short period of time, apply the solder to the joint. The solder should me melted by the heat of the copper, not the heat of the torch flame. Is the solder does not immediately begin to flow, remove the solder and heat the joint a little more (Fig A-23).
- When the solder begin to flow, feed enough solder into the joint to completely fill it. You should use no more solder than is needed to fill the joint, using too much solder will result in buildup on the inside of the pipe. Using too little solder will result in leak *(the amount of soft solder used on any given joint should not exceed a length equal to twice the diameter of the pipe – molten solder will flow toward the source of heat. To help ensure that the solder flows into the joint, apply heat to the base of the female portion of the joint).*
- To extinguish the torch, simply close the valves on the torch handle. When the torch is no longer needed, close the stem on the acetylene tank and bleed off any acetylene from the hoses by opening the valve on the torch handle.
- While the joint is still hot, it's good practice to wipe the joint with a rag. This removes excess solder and improves the appearance of the solder joint. Applying a small amount to flux to the joint while the pipe is hot also helps clean the joint.

3.2.7- ***Brazing:*** brazing is another method used to join two sections of piping or to connect a pipe section to fitting or a system component. Brazing is called also silver soldering or hard soldering by many field personnel. It is the method of choice when there will be high pressure inside the piping circuit. Typically, air conditioning system installer use brazing techniques on the refrigeration circuit piping and soft soldering on other plumbing lines, such as condensate lines, if needed.

To perform the brazing process, a striker, refrigeration service wrench, brazing rod, and a heat source such as an air-acetylene torch kit are needed.

For step by step brazing, the following procedure must be followed:

- Properly cut and ream the section to be joined. Refer to cutting procedure section 3.2.2.
- Insert the male portion of the joint into the female end.
- Prepare and light the torch as explained in the soldering process.
- Apply heat to the joint, placing the tip of the inner cone on the surface of the joint. Molten brazing rods will flow toward the source of heat. To help ensure that the material flows into the joint, apply heat to the base of the female portion of the joint.
- After heating the joint until the pipes glow cherry red, apply the brazing rod to the joint. If the filler material does not immediately begin to flow, remove the rod and heat the joint a little more (fig A-25).

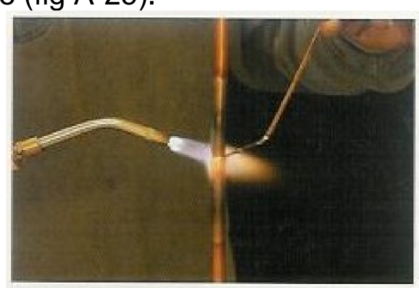


Fig A-25

- When the filler material begins to flow, feed enough into the joint to completely fill it. You should use no more materials than needed to fill the joint. Using too much solder will result in buildup on the inside of the pipe. Using too little solder will result in leak. The amount of filler material used on any given joint should not exceed a length equal to twice the diameter of the pipe.
- To extinguish the torch, simply close the valve on the torch handle. When the torch is no longer needed, close the stem on the acetylene tank and bleed off any acetylene from the hoses by opening the valve on the torch handle.

## 4- Refrigerant Copper Pipes Leak-Checking:

Once all of the installation works has been completed, the system is almost ready to be put into operation. There are, however, a few more important things to be done. On eof these is leak-checking the system to ensure that all solder and flare connections in the system were made properly. A leaking air conditioning system will not operate properly and will introduce refrigerant to the atmosphere. Therefore, leak-checking is a must prior to system startup, especially when refrigerant lines will eventually be sealed behind walls or ceilings. Accessing these solder joints will be extremely difficult once the walls and ceilings are finished.

The method that will be used on site for performing a leak-check on a system is the ***standing pressure test***:

- The pressure in the refrigerant piping circuit is brought up to approximately 150 psig using dry nitrogen (Fig A-27).
- The system is permitted to rest for approximately 5 to 10 minutes.
- The needle on the gauge is marked to indicate its exact position (Fig A-26).
- The system is then observed after 12 hours to ensure that the position of the needle has not moved.
- If the needle moves, there is a leak. If it does not, the system is tight and there is no leak.

*Courtesy of Robinair.*

**Gauge Manifold**

The gauge manifold is probably the most useful tool used by air conditioning service personnel. It is manufactured with two separate gauges: one for the high-pressure side of the system and one for the low-pressure side of the system. The low-side gauge is color-coded blue, and the high-side gauge is color-coded red. The handles on the gauge manifold control fluid flow between the center hose and the corresponding hoses on the manifold. It enables the technician to read both saturation temperatures and pressures within the system. The low-side gauge also provides a means by which the technician can read vacuum levels in the system during the evacuation process.

Fig A-26

**Nitrogen Tank and Regulator**

Nitrogen is typically the gas of choice for pressurizing and leak-checking air conditioning systems prior to system startup. The regulator is used to reduce the pressure leaving the tank to a useful pressure. The pressure in the nitrogen tank can be over 1,000 psi, so simply opening the tank will result in a large amount of gas leaving the tank, possibly causing damage to the system or personal injury. Adjusting the regulator will ensure that only the desired amount of gas is permitted to leave the tank. When working with pressurized vessels, always wear proper eye protection.

Fig A-27

## 4.1- Pressurizing the system:

When the pressure is initially introduced to the system, the manufacturer's test pressure should never be exceeded. Exceeding these pressures could result in damage to the equipment. The test pressure on atypical indoor unit is approximately 150 psig, so this pressure is safe under most conditions.

When bringing the system up for leak-checking purpose, nitrogen is the gas of choice because, after the leak test is complete, it can be safely released into the atmosphere. Small amount of refrigerant can be introduced along with the nitrogen to aid in the location of system leak if one exists.

## 4.2- Marking the gauge:

After the pressure has been introduced to the system, good field practice requires letting the system stand for a short period of time. This gives the gas time to settle and will ensure that the pressure in the system will not change due to this settling. Once the gas has settled, the face of the gauge should be marked, indicating the exact position of the needle (Fig A-26). By marking the gauge, any small movements in the needle's position will be easy to spot.

*Photo by Bill Johnson.*

***Soap Bubbles***

A soap bubble solution is a very effective way to check a pressurized system for leaks. The solution is simply brushed onto the piping circuit, primarily at solder joints. The formation of bub-

Fig A-28

### 4.3- System observation:

After the gauge has been marked, the system should be observed later to see if the needle has moved. The time that should be allowed to elapse is 12 hours. if a large leak is present, the pressure in the system will begin to drop rapidly. Smaller leaks, however, may require much more time to show up on the gauge.

If the pressure drops over time, a leak exists in the system. In this case, the solder and flare joints, if any, should be carefully inspected.

A liquid bubble type leak-detection solution should be used (Fig A-28). This solution shall be applied to all solder joints as well as to all flare connections and Shraeder Valve stems. The formation of bubbles on the surface of the piping indicates the presence of a leak; large bubbles indicate a small leak.

## 5- System evacuation:

Before refrigerant is added, the system must be properly evacuated. **Evacuation** is the process by which the pressure in a closed system is reduced, causing any moisture to boil off into a vapor. This vapor is removed from the system via the **vacuum pump**.

When evacuating a system, the technician should:

- Make certain that the system is evacuated from both the high and low pressure side.
- Make certain the vacuum pump is sized correctly for the system being evacuated.
- Change the vacuum pump oil frequently.

- ❖ Apply heat to the system to speed the evacuation process.
- ❖ Never operate a compressor while a system is in a deep vacuum.
- ❖ Use the largest valve ports possible to speed the evacuation process.

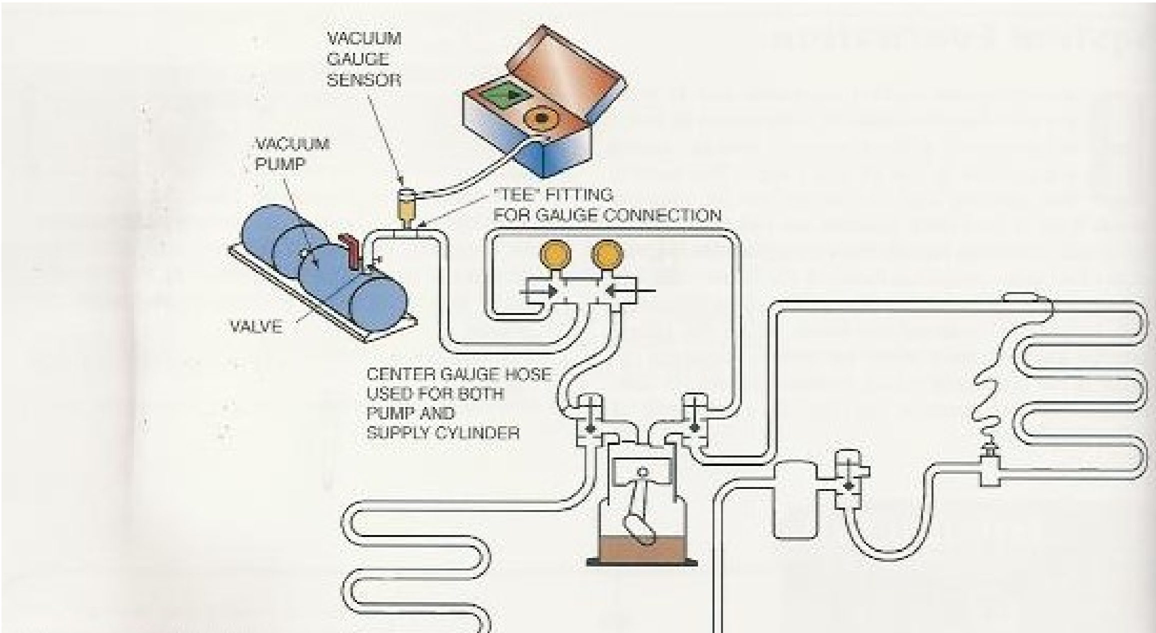



**Figure 6–1** Typical vacuum pump connection.

During the evacuation process, both the high and low pressure sides of the system should be connected to the vacuum pump. Thermostatic expansion valves and other components have small openings and orifices that will slow the evacuation process if the system is evacuated from only the high- and low-pressure side.

Figure 6-1 shows the vacuum pump and gauge connection on a central air conditioning system. Vacuum pump must be correctly sized for proper evacuation. For most residential applications, a 4-cfm pump is sufficient.

Heat can be added to system to speed up the evacuation process. This will help boil off any liquid moisture into vapor, which is much is much easier for the pump to remove. The best source of heat is heat lamp. If the technician suspects that moisture is present in the compressor crank case, heat should be applied directly to the crank case.

Using larger connectors and hoses can also speed up the evacuation process. Hoses with larger internal cross section areas designed especially for vacuum pump use can be purchased. These hoses have removable pin depressors and are commonly used in conjunction with a gauge adaptor that serves the purpose of depressing the pin on the Schraeder Valve. The Shraeder Valves commonly found on system service valves create a restriction even when they are in the open position. Field service valves (Fig A-29) can be used to remove the Schraeder pin for evacuation and replace the pins after the proper evacuation has been achieved.

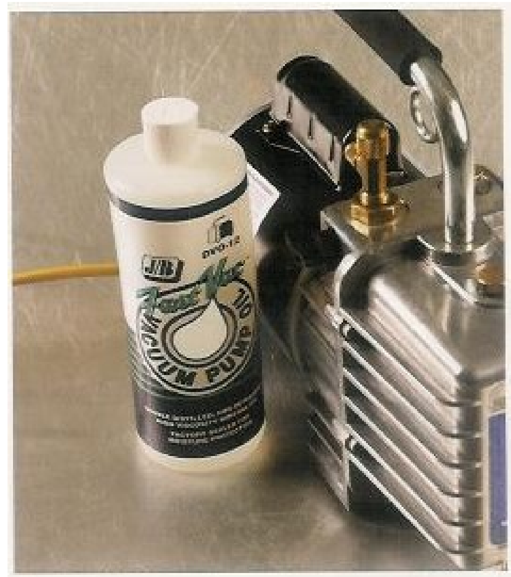


Fig A-29 Fig A-30

**5.1-Vacuum pump oil:**

The vacuum pump is used to help remove the moisture from an air conditioning system prior to adding refrigerant. When connected to the system, the vacuum pump pulls vapor from the system and discharge it into the atmosphere.

When using a vacuum pump, it's very common for the pump to become contaminated with whatever has been removed from the system. If the system contains acid, moisture, or other impurities, they will wind up on the interior surfaces of the pump. These impurities will ultimately find their way into the vacuum pump oil. When the oil becomes saturated with acid or moisture, the pump will not operate effectively and will not be able to pull the system to the desired level of vacuum.

Vacuum pump oil (Fig A-30) is designed with a very low boiling point. Using oil that has a highly boiling point will reduce the pumping capacity of the pump, increasing the amount of time required to properly evacuate the system.

Because the system contaminants will ultimately wind up in the oil, it's important to change the oil frequently. This means, at a minimum, the oil should be changed before each use when installing residential air conditioning system.

For step by step instructions on draining and replacing vacuum pump oil, below id the procedure:

- Make certain that the pump is warmed up.


Fig A-31

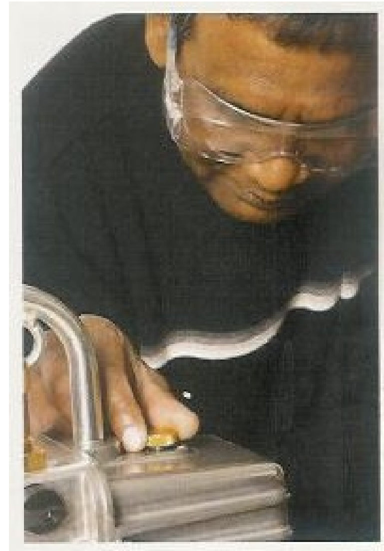


Fig A-32

- Remove the oil drain cap located at the bottom of one side of the pump and drain the oil into a container (Fig A-31).
- Properly dispose off the oil.
- Replace the drain cap.
- Remove the oil fill cap and begin to add oil to the pump (Fig A-32).


Fig A-33

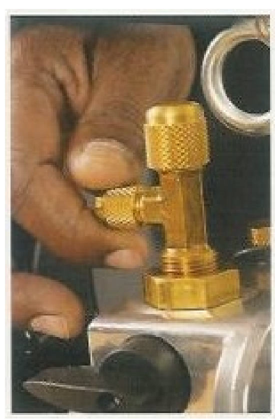


Fig A-34


Fig A-35

- Fill the pump with oil rated for vacuum pump use until the oil level is equal to the middle of the sight glass on the side of the pump (Fig A-33).
- Cap the inlet port of the pump (Fig A-34).
- Allow the pump to run for approximately one minute and check the oil level in the sight glass with the pump still operating.
- If the oil level is below level mark on the sight glass, slowly add more oil to the pump until the level of the oil is equal to the oil level mark.
- Replace the oil fill cap and tightly close the oil container (Fig A-35).

## 5.2 – Acceptable Level of Vacuum:

When the system is being evacuated and a vacuum is being pulled on the system, the reading on the gauge manifold will register values below 0 psig. The low side gauge will indicate a reading in the vacuum range from 0” Hg to 30” Hg. The high side needle will indicate a point lower than 0 psig as well, but this value can not be determined because there are no makings on the high side gauge in the vacuum region.

As the pressure in the system approaches a deep vacuum, close to 30” Hg, the reading on a compound gauge becomes less accurate and reliable. For this reason, vacuums are best measured in units called **microns**. The micron is the unit of linear measurement equal to 1/25,400 of an inch. It represents a measurement above an absolute pressure of zero, which represents a perfect vacuum of 29.92” Hg.


Fig A- 36

As the pressure in a system is reduced, the vacuum increases. At a gauge pressure of 28.9” Hg, the equivalent reading on a micron is 25,400.00 microns. The **micron gauge** (Fig A-36) is a test instrument that is designed to measure the vacuum in a system in microns, as opposed to inches of mercury. As the vacuum is increased to 29.8” Hg, the micron gauge will read approximately 250 microns. In a vacuum of 29.92” Hg, the micron gauge will read approximately 25 microns (perfect Vacuum).

**<u>5.3 – Calibrating the Gauge Manifold:</u>**

Before starting the evacuation process, technician has to make sure that Gauge manifold is calibrated and ready to be used. To calibrate the gauge manifold the following procedure must be followed:



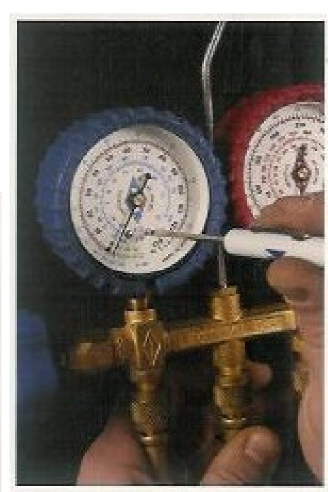


Fig A-37 Fig A-38 Fig A-39

- Remove the high and low side hoses from the blank ports of the gauge manifold (Fig A-37).
- Observe the position of the gauge needles.
- If both gauge needles point to 0 psig, the gauges are properly calibrated and no calibration is needed (Fig A-38).
- If one or both of the gauges do not point to 0 psig, remove the clear plastic cover from that gauge.
- Using a small straight slot, slowly turn the adjusting screw on the face of the gauge until the needle points to 0 psig (Fig A-39).
- Turning the screw clockwise will cause the needle to move counterclockwise and vice versa.
- Once the gauges have been calibrated, replace the plastic cover on the gauge.

**5.4- Evacuating an Air Conditioning System:**

The following procedures are used to evacuate an air conditioning system:

- Remove the high and low side hoses from the blank port on the gauge manifold and make certain that the gauges are calibrated.
- Calibrate gauges if needed (section 5.3).
- Connect the high side hose from the gauge manifold onto the high side service port on the condensing unit of the system (Fig A-40).

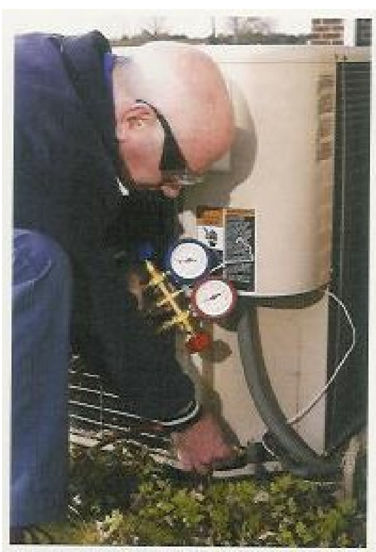


Fig A-40

Fig A-41

Fig A-42

- Connect the low side hose from the gauge manifold onto the low side service port on the condensing unit of the system (Fig A-41).
- Make certain that the oil level on the vacuum pump is correct.
- Connect the center hose from the gauge manifold to the inlet port of the vacuum pump.

Fig A-43

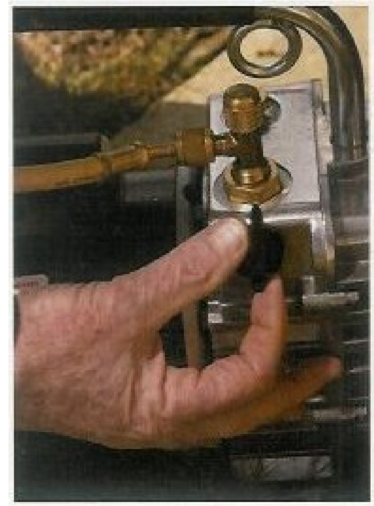


Fig A-44

- Make certain that both valves on the gauge manifold and the valve on the vacuum pump are in the closed position (Fig A-43).
- The power to the condensing unit must be disconnected.
- Turn the vacuum pump on.
- Slowly open the valve on the vacuum pump (Fig A-44).

Fig A-45

Fig A-46

- Open the high side valve on the gauge manifold (Fig A-45).
- Once the needle on the low side gauge falls below 5” Hg, slowly open the low side valve on the gauge manifold (Fig A-46).
- Allow the vacuum pump to operate until the desired vacuum is achieved.
- Once the desired vacuum has been reached, close both valves on the gauge manifold as well as the valve on the vacuum pump.
- Remove the hose from the pump inlet and turn the vacuum pump off.
- Open the valve on the vacuum pump for a few seconds and close it again.
- Cap the inlet port on the vacuum pump.
- Monitor the gauges to ensure that the system is maintaining the vacuum.
- If the gauge needles do not move, the system is properly evacuated.

- If the gauge needles rise slowly and stop at 0 psig, the system has a leak. Locate and repair the leak. Begin evacuation process again.
- If the gauge needles rise slowly and stop to some point in a vacuum, the evacuation process is not complete. Restart the evacuation process.

### 5.5 – System Holding Charge:

After the system has been properly leak-tested and evacuated, a refrigerant holding charge can be introduced to the system. In many cases, the outdoor unit comes pre-charged with enough refrigerants for the entire system, assuming a 25 foot refrigerant line run between the indoor and outdoor unit. If the run is longer than 25 foot, additional refrigerant will need to be added. If the run is less than 25 feet, refrigerant will need to be removed. Because this 25-foot is correct in only a general sense, the specific amount of refrigerant in the outdoor unit, if any, should be confirmed by the installation information provided with the new system.
For removing or introducing refrigerant to an air conditioning system, please refer to section **7.2 and 7.4**

## 6 – System Startup:

After the installation has been completed and all the above mentioned tests have been accomplished and succeeded, it’s time to start the system for the first time.

Ideally, the system should be started on a warm day, to help simulate the conditions under which it will most likely be operating. In the summer months this should not pose a problem.

The system should be started up in the cooling mode with the following conditions:

- A condenser saturation temperature of approximately 135º F.
- An indoor air temperature of approximately 75º F.

A number of factors must be considered when a system is started up for the first time:

- Air flow through the condensing unit.
- Air flow through the indoor unit.
- The high side pressure side of the system.
- The low side pressure of the system.
- Temperature differential across the evaporator coil.
- Evaporator and system superheat.
- Condenser subcooling.

### 6.1 – Air Flow through Indoor and Outdoor Unit:

On air conditioning systems, the airflow through both the evaporator and condenser coil must be correct. One way to ensure that the airflow is within design range is to take amperage readings of the fans motor.

Also, technician should avoid any obstructions around the condensing unit, which can result in reduced air flow through the condenser. Reducing the air flow through the coil will result in an improper refrigerant charge when initially charging the system, higher than normal operating pressures, and decreased cooling. Always make certain that all obstructions are removed from the area immediately around the condensing unit.

## 6.2 – System Pressures:

Once the proper airflow through both the indoor and outdoor units has been established, the operating pressure of the system can be evaluated. When checking the system's operating pressures, thinking in terms of saturation temperatures rather than pressures is more convenient.
The installed DX units in this project are of **DAIKIN** brand that run on R-410 A refrigerant (*50% R32 and 50% R125*), and **TRANE** that run on R-407 C refrigerant (*23% R32, 25% R125 and 52% R134a*). For physical properties of the above mentioned refrigerant (*such as saturation pressure, temperature etc…),* please refer to charts on pages 35, 36, 37, 38, 39 & 40.

### 6.2.1- high side pressure:

on a standard efficient system, the rule of thumb is that the refrigerant should condense at a temperature approximately equal to the outdoor ambient temperature plus about 30 to 35º F (*as per project specifications – Lot 33 - section 2.1.1, Port Harcourt ambient Temperature shall be taken 40º C = 104º F, so refrigerant should condense at 134 to 139º F*). If the condenser is a high efficiency model, the condenser saturation temperature may be as low as 20º F higher than the outdoor ambient temperature (*when ambient temperature is 104º F, condenser saturation temperature should be 124º to 129º F*).

The desired high side pressure can be determined by using the charts on pages 35, 36, 37, 38, 39 & 40.

For **R-407 C** the high side pressure should be in the range of **375 psig to 400 psig** for a standard efficiency condenser when the outside temperature is **104º F**, the condenser high side pressure should be **335 psig to 355 psig** for high efficiency model.

For **R-410 A** the high side pressure should be in the range of **525 psig to 550 psig** for a standard efficiency condenser when the outside temperature is **104º F**, the condenser high side pressure should be **475 psig to 500 psig** for high efficiency model.

### 6.2.2 – Low Side Pressure:

On an air conditioning system that is operating properly, the temperature of the evaporator coil should always be above freezing point. The design of the evaporator coil typically has the fins of the evaporator very close together to provide a larger heat transfer surface. Should frost begin to accumulate on the surface of the coil, it can easily become blocked with ice. This will greatly reduce the amount of airflow through the coil, resulting in reduced system effectiveness and efficiency.

In an air conditioning systems the coil may start to freeze when the temperature becomes close to 32º F. this temperature correspond to 116 psig R-410 A and 84 psig for R-407 C.
The temperature of an air conditioning evaporator coil is approximately 40º F, which correspond to an evaporator saturation pressure of **133 psig for R-410 A and 95 psig for R-407 C.**

## 6.3 – Temperature Differential across the Evaporator Coil:

Another factor that will help determine the refrigerant charge in an air conditioning system is the temperature differential across the evaporator coil. The **difference** between the supply and return air temperatures should be in the range of **17 to 20º F**.

*A temperature differential lower than 17 degrees indicate that the system may need to have more refrigerant added (section 7.4).*

*A temperature differential of more than 20º F indicates that refrigerant may need to be removed from the system (section 7.2).*

In addition to the refrigerant charge, humidity has also an effect on the evaporator's temperature differential. If the relative humidity of the indoor air is in the 50% range, then the 17 to 20º F differential is typical. During period of excessively high humidity, the differential will be lower and during period of very low humidity, temperature differential of greater than 20º F can be expected.

The following procedures must be followed to measure the temperature differential across the evaporator coil:

- Turn on the power on the air conditioning system and allow it to operate.

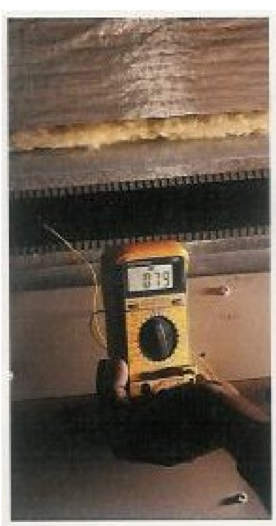


Fig A-47

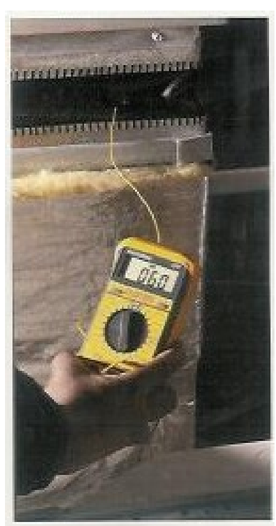


Fig A-48

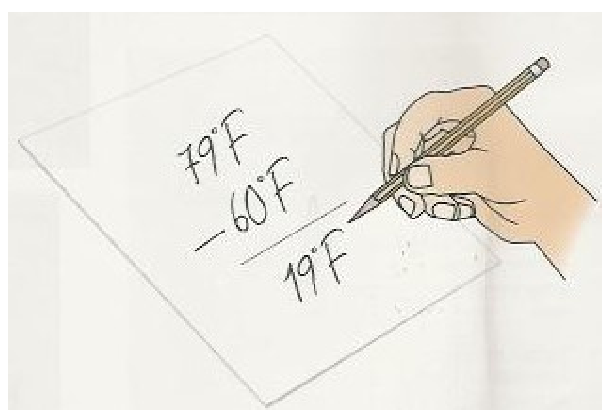



Fig A-49

- Using a high quality digital thermometer, take the temperature reading of the air in the return duct (if the unit is ducted, if no, read the temperature on the return terminal), just before it reaches the evaporator coil (Fig A-47).

- Using another thermometer, take the temperature reading of the air in the supply duct after it has passed through the evaporator coil (Fig A-48).
- Subtract the temperature of the supply air from the temperature of the return air to obtain the temperature differential across the evaporator coil (Fig A-49).

**6.4 – Evaporator Superheat:**

On systems operating with thermostatic expansion valves (which is our case), evaporator superheat shall be in the range of **12 to 20º F**.

*An evaporator superheat well below 12º F is an indication that the system may be overcharged*.

*An excessively high superheat indicates that the system may be undercharged. Improper superheat can also be caused by other system problems such as reduced evaporator air flow.*

The following procedure must be used to measure the superheat in an air conditioning system:

- Turn on the power to the air conditioning system and allow it to operate for approximately 15 minutes.
- Using a high quality digital thermometer, take the temperature reading of the suction line at the inlet of the condensing unit.


Fig A-50


Fig A-51

- Remove the low side hose from the blank port on the gauge manifold and make certain that the gauge is calibrated (Fig A-51).
- Calibrate gauge if needed.
- Connect the low side hose from the gauge manifold onto the low side service port on the condensing unit of the system (Fig A-51).

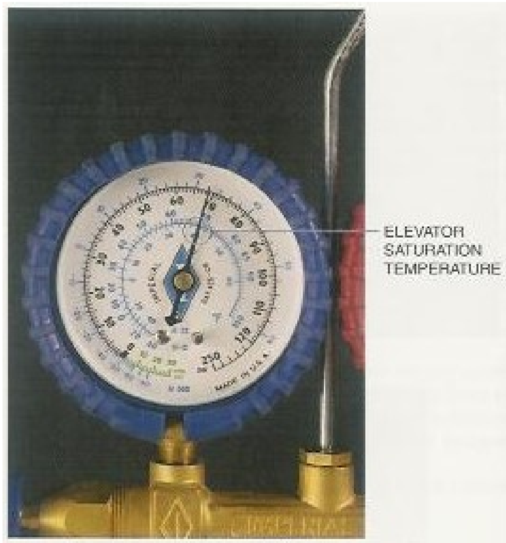



Fig A-52

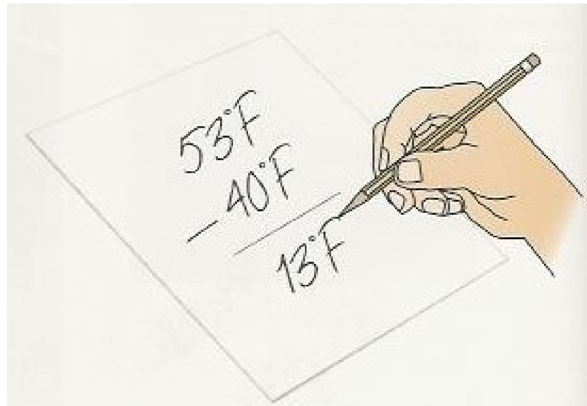



Fig A-53

- With the system operating, obtain the evaporator saturation temperature from the gauge or from the attached P-H Chart, by reading evaporator pressure and getting its corresponding saturation temperature on the P-H Chart (Fig A—52).
- Subtract the evaporator saturation temperature from the suction line temperature to obtain the system superheat.

**6.5 - Condenser Subcooling:**

To calculate the amount of subcooling that a condenser is operating with, two pieces of information are needed:

- The condenser outlet temperature.
- The condenser saturation temperature.

To calculate the condenser subcooling, we subtract the condenser outlet temperature from the condenser saturation temperature. **Condenser subcooling** should ideally be in the range of **10 to 20º F**.

*High subcooling is an indication that the system is overcharged, and low subcooling indicates that the system is undercharged.*

Should the condenser coil become blocked or the condenser fan motor become inoperable, the refrigerant in the condenser coil will not be able to condense effectively, causing the subcooling measurement to drop below acceptable levels.

The following procedure must be used to measure the subcooling in an air conditioning system:

- Turn on the power to the air conditioning system and allow it to operate for approximately 15 minutes.

Fig A-54

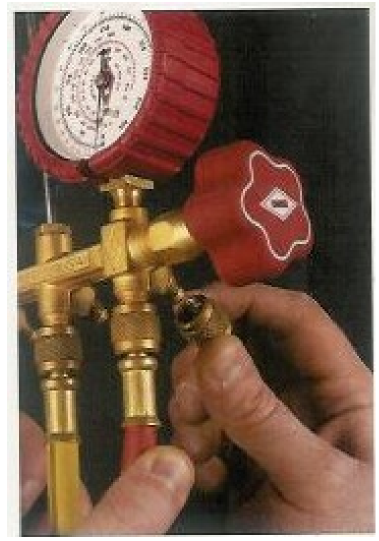


Fig A-55

- Using a high quality digital thermometer, take the temperature reading of the liquid line at the outlet of the condensing unit (Fig A-54).
- Remove the high side hose from the blank port on the gauge manifold and make certain that the gauge is calibrated (Fig A-55).
- Calibrate gauge if needed.
- Connect the high side hose from the gauge manifold onto the high side service port on the condensing unit of the system.
- With the system operating, obtain the condenser saturation temperature from the gauge (Fig – A-56), or by reading the pressure on the gauge and getting the saturation temperature from the refrigerant properties table or charts.
- Subtract the liquid line temperature from the condenser saturation temperature to obtain the system subcooling (Fig A-57).


Fig A-56

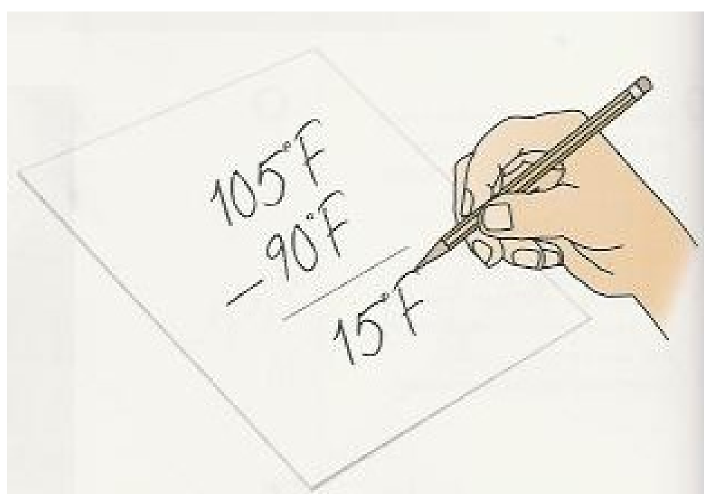


Fig A-57

## 7 – System Charging:

## 7.1- System Overcharge:

During the start up process, it may be determined that the system contains too much refrigerant. This may be the result of shorter refrigerant lines than the system holding charge was intended for a result of the technician adding too much refrigerant to the system. Symptoms of a system overcharge may include:

- ❖ High head pressure.
- ❖ High suction pressure.
- ❖ High condenser subcooling.
- ❖ Excessively low superheat.
- ❖ High condenser saturation temperature.
- ❖ High evaporator saturation temperature.
- ❖ High temperature differential across the evaporator coil.

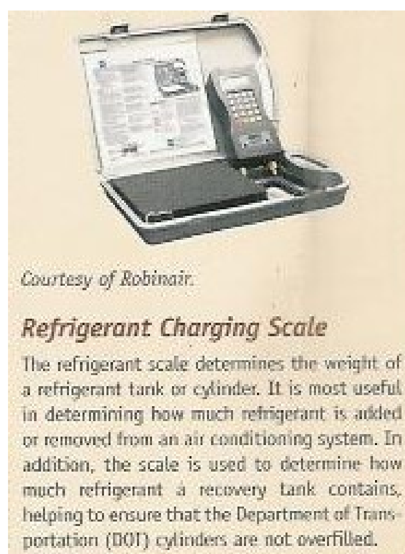
If the system is equipped with thermostatic expansion valve, the superheat in the evaporator will remain relatively constant, regardless of whether or not the system is charged properly.

If the system is equipped with another type of metering device, the evaporator superheat will be lower than desired if there is an overcharge of refrigerant.

## 7.2- Removing Excess Refrigerant from the System:

In the event that the system has an overcharge of refrigerant, the excess must be removed in accordance with the laws set forth by the **Environmental Protection Agency (EPA).**

***DOT – Approved Refrigerant Recovery Tanks.***
Fig A-58




***Refrigerant Charging Scale***
Fig A-59

Refrigerant must be removed from the system and stored in a DOT- Approved Cylinder (Fig A-58). The followings guidelines should de kept in mind when removing refrigerant from a system:

- ❖ Wear safety glasses when removing refrigerant from a system.
- ❖ Remove refrigerant in 4-ounce increment.
- ❖ Remove refrigerant from the high side of the system.
- ❖ Make certain that the recovery cylinder or tank that is being used to store the refrigerant has been properly evacuated prior to use (for evacuation procedure, refer to section 5.4).
- ❖ Give a system ample time to settle after each 4-ounce removal.
- ❖ Re-evaluate the system temperatures and pressure after each removal.
- ❖ Continue to remove refrigerant until the desired temperatures and pressures are reached.

The following procedure must be followed to remove refrigerant from an operating air conditioning system:

- ◘ Turn on the power to the air conditioning system and allow it to operate for approximately 15 minutes.
- ◘ Properly Evacuate a DOT-approved refrigerant cylinder (Fig A-58, for evacuation procedure, refers to section 5.4).
- ◘ Connect the centre hose of the gauge manifold to the valve on the refrigerant cylinder and place the cylinder on the refrigerant scale (Fig A-58 & 59).

Fig A-60


Fig A-61

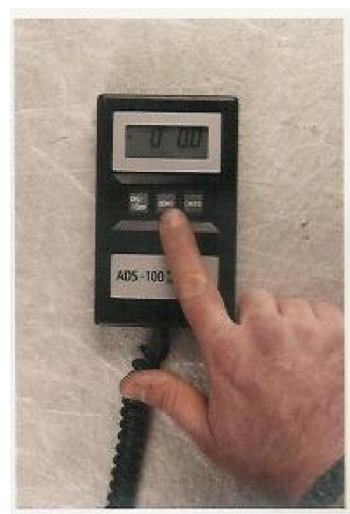


Fig A-62

- ◘ Open the high side valve on the gauge manifold. This will push refrigerant from the high side of the system through the centre hose (Fig A-60).
- ◘ Loosen the centre hose connection on the refrigerant cylinder for about 2 seconds to purge any air from the centre (Fig A-61).
- ◘ Tighten the centre hose connection on the refrigerant cylinder.
- ◘ Close the high side valve on the gauge manifold.
- ◘ Turn the refrigerant scale on (Fig A-59).
- ◘ Push the reset or zero button on the scale and hold it down until the scale reads zero (Fig A-62).
- ◘ Open the valve on the refrigerant cylinder.
- ◘ Slowly open the high side valve on the gauge manifold. Refrigerant will flow from the system into the refrigerant cylinder.
- ◘ Monitor the refrigerant scale.

- When the scale indicates that 4 ounces of refrigerant has been removed from the system, close the high side valve on the gauge manifold (Fig A-63).
- Allow the system to operate for approximately 5 to 10 minutes and re-evaluate the system charge.
- If the system is still overcharged, remove another 4 ounces of refrigerant from the system.
- Continue removing refrigerant from the system until the operating temperatures and pressures are within the desired range.

**N.B:** Never fill a refrigerant cylinder or tank to more than 80% of its capacity.

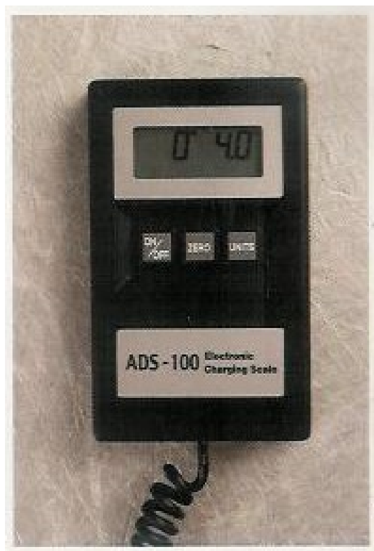



Fig A-63

## 7.3 – System Undercharge:

on air conditioning system in which the refrigerant lines are longer than the refrigerant holding charge or where the condensing unit is not shipped with a holding charge of refrigerant, additional refrigerant will have to be added to the system during the start up process. Symptoms of a system undercharge may include:

- Low head pressure.
- Low suction pressure.
- Low condenser subcooling.
- Excessively high superheat.
- Low condenser saturation temperature.
- Low evaporator saturation temperature.
- Low temperature differential across the evaporator coil.

## 7.4 – Adding Refrigerant to the system:

If refrigerant is to be added, it should be done in a slow, deliberate manner. The following guidelines should be followed when adding refrigerant:

- ❖ Refrigerant should be added to the system in vapour form, whenever possible.
- ❖ If a blended refrigerant is used (as in our case for R-407 C and R-410 A), introduce it slowly to the system as a liquid.
- ❖ Add refrigerant in 4 ounce increments.
- ❖ Allow the system to settle for approximately 5 to 10 minutes after each addition.
- ❖ Re-evaluate the pressures and temperatures before adding more refrigerant.
- ❖ Continue adding refrigerant in 4-ounce increments until the desired pressures and temperatures are reached.

**N.B:**

Blended refrigerant **must** be added to the system in the liquid state. Blended refrigerants are simply two or more refrigerants that are blended together to form another refrigerant such as R-410 A refrigerant (*50% R32 and 50% R125*) and R-407 C refrigerant (*23% R32, 25% R125 and 52% R134a*).
Charging a blended refrigerant in the vapor state will cause the refrigerants to separate, thereby changing its characteristics.

The following procedure must be followed to add refrigerant to an air conditioning system:

- ◘ Turn on the power to the air conditioning system and allow it to operate for approximately 15 minutes.

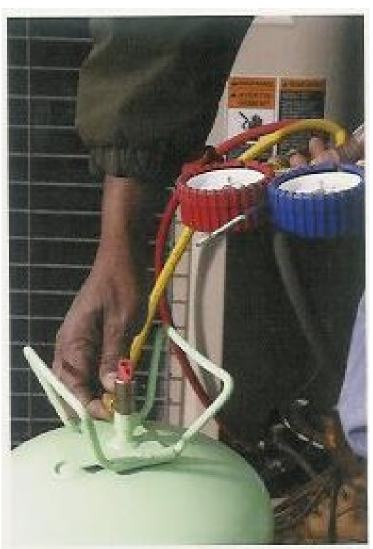


Fig A-64

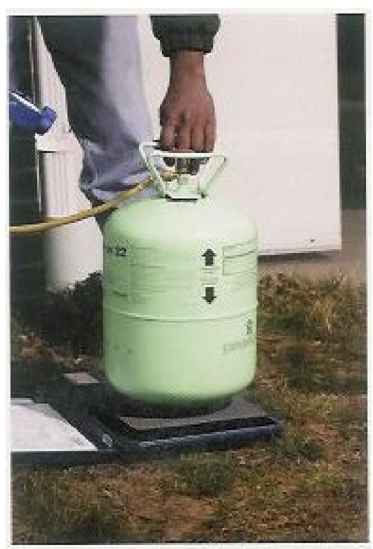


Fig A-65

Fig A-66

- ◘ Connect the centre hose of the gauge manifold to the valve on the refrigerant tank (Fig A-64).
- ◘ Place the tank on the refrigerant scale and open the valve on the refrigerant tank (Fig A-65).
- ◘ Loosen the centre hose connection on the gauge manifold for about 2 seconds to purge any air from the centre hose (fig A-66).
- ◘ Push the reset or zero button on the scale and hold it down until the scale reads zero (Fig A-67).

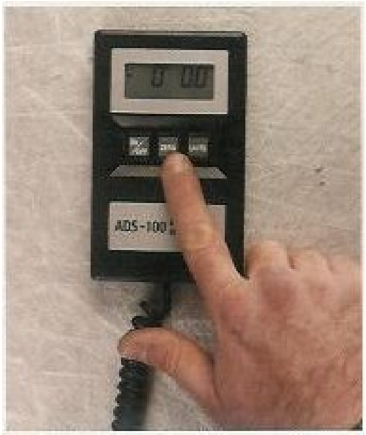


Fig A-67


Fig A-68

- Open the low side valve on the gauge manifold. This will introduce refrigerant to the system (Fig A-68).
- Monitor the refrigerant scale.
- When the scale indicates that 4 ounces of refrigerant has been introduced to the system, close the low side valve on the gauge manifold.
- Allow the system to operate for approximately 5 to 10 minutes and re-evaluate the system charge.
- If the system is still undercharged, introduce another 4 ounces of refrigerant into the system.
- Continue adding refrigerant to the system until the operating temperatures and pressures are within the desired range.

## 8 – Required Tools and Instruments:

- Copper pipes tubing Cutter (Fig A-1).
- Copper Pipes Tubing Bender (Fig A-4).
- Copper Pipes Bending Springs Set (Fig A-3).
- Flaring Block (Fig A-5).
- Swaging Tools Set (Fig A-6).
- Flaring Yoke (Fig A-9).
- Gas Welding Set (Fig A-15).
- Copper Fitting Brushes Set (Fig A-16).
- Soldering Flux and Flux Brush (Fig A-17).
- Adjustable Spanner (Fig A-18).
- Refrigeration Service Wrench Set (Fig A-20).
- Welding electrodes 95/5 - *95% tin, 5% antimony.*
- Gauge Manifold for R-407 C and R-410 A Refrigerant (Fig A-26).
- Nitrogen Tank and regulator (Fig A-27).
- Soap Bubbles (Fig A-28).
- Vacuum Pump 4 cfm or better 8 cfm (Fig A-30).
- Field Service Valve (Fig A-29).
- Vacuum pump oil (Fig A-33).
- Vacuum Gauge or Micron Gauge (Fig A-36).
- Digital Thermometer (Fig A-54).
- DOT- Approved Refrigerant Recovery Tank (Fig A-58).
- Refrigerant Charging Scale (Fig A-59).

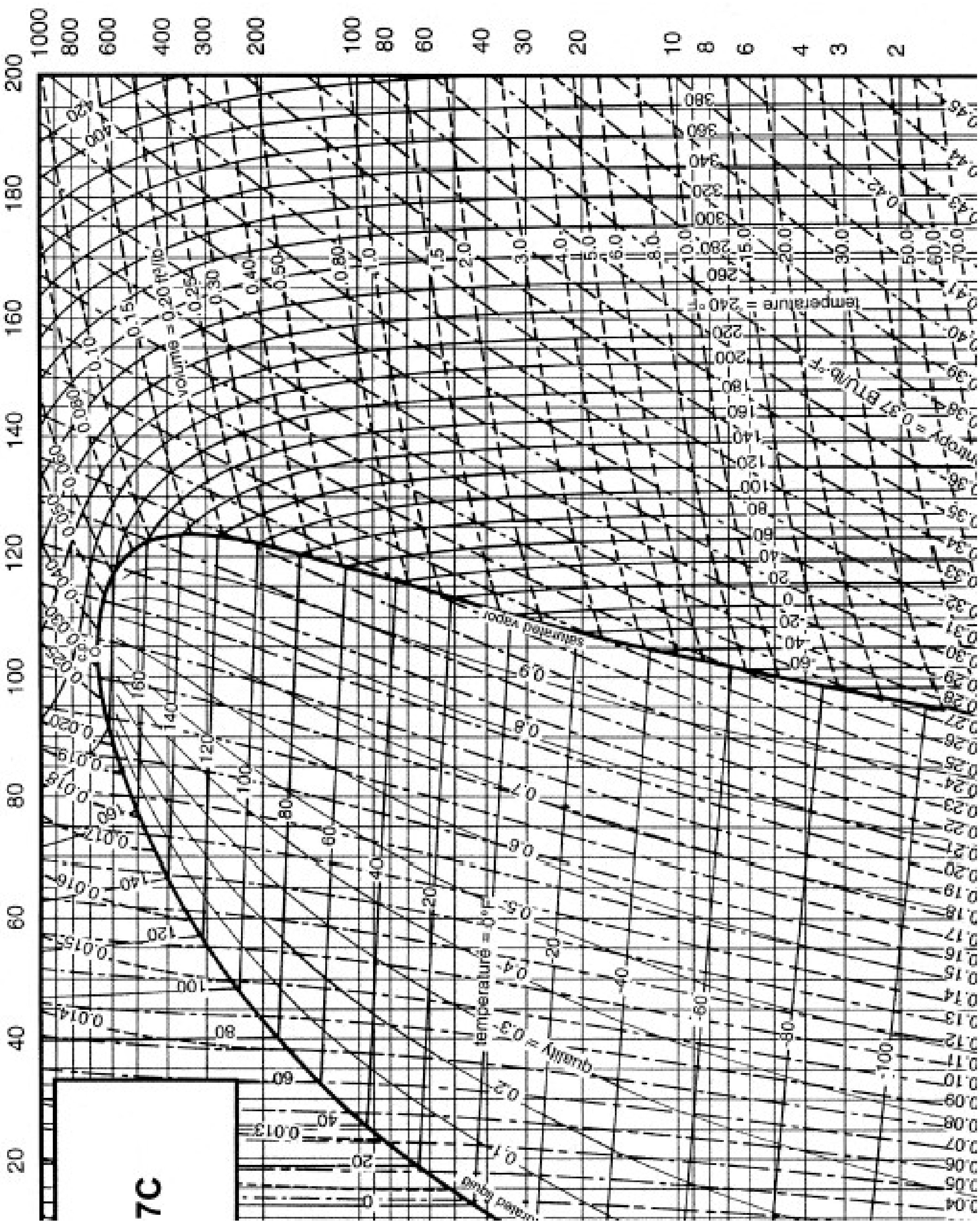
- Refrigerant R-407C & R410A.

## Refrigerant 410A [R-32/125 (50/50)] Properties of Liquid on the Bubble Line and Vapor on th

| Pres-sure, psia | Temp.*, °F | | Denisty, lb/ft³ | Volume, ft³/lb | Enthalpy, Btu/lb | | Entropy, Btu/lb·°F | | Specific Heat $c_p$, Btu/lb·°F | | $c_p/c_v$ | Vel. of Sound, ft/s | | Viscosity, $lb_m$/ft·h | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Bubble | Dew | Liquid | Vapor | Liquid | Vapor | Liquid | Vapor | Liquid | Vapor | Vapor | Liquid | Vapor | Liquid | Vapor |
| 1.00 | −135.75 | −135.69 | 92.11 | 47.5564 | −30.50 | 99.85 | −0.08227 | 0.32010 | 0.3135 | 0.1564 | 1.228 | 3466. | 518.2 | 1.4851 | 0.0193 |
| 1.50 | −126.58 | −126.52 | 91.19 | 32.5257 | −27.62 | 101.14 | −0.07352 | 0.31303 | 0.3137 | 0.1596 | 1.227 | 3373. | 524.1 | 1.3443 | 0.0199 |
| 2.00 | −119.70 | −119.64 | 90.50 | 24.8468 | −25.46 | 102.11 | −0.06710 | 0.30811 | 0.3140 | 0.1622 | 1.227 | 3305. | 528.3 | 1.2532 | 0.0203 |
| 2.50 | −114.12 | −114.06 | 89.93 | 20.1648 | −23.71 | 102.89 | −0.06199 | 0.30435 | 0.3144 | 0.1644 | 1.227 | 3250. | 531.6 | 1.1869 | 0.0206 |
| 3.00 | −109.40 | −109.34 | 89.45 | 17.0030 | −22.22 | 103.54 | −0.05773 | 0.30131 | 0.3147 | 0.1664 | 1.227 | 3204. | 534.3 | 1.1352 | 0.0209 |
| 4.00 | −101.65 | −101.58 | 88.66 | 12.9918 | −19.78 | 104.61 | −0.05083 | 0.29658 | 0.3155 | 0.1699 | 1.228 | 3130. | 538.5 | 1.0580 | 0.0214 |
| 5.00 | −95.34 | −95.28 | 88.00 | 10.5444 | −17.79 | 105.47 | −0.04532 | 0.29297 | 0.3162 | 0.1730 | 1.229 | 3070. | 541.7 | 1.0013 | 0.0218 |
| 6.00 | −90.00 | −89.93 | 87.45 | 8.8907 | −16.09 | 106.19 | −0.04071 | 0.29006 | 0.3169 | 0.1757 | 1.231 | 3019. | 544.3 | 0.9569 | 0.0221 |
| 7.00 | −85.33 | −85.26 | 86.96 | 7.6962 | −14.61 | 106.82 | −0.03674 | 0.28762 | 0.3175 | 0.1782 | 1.232 | 2975. | 546.5 | 0.9206 | 0.0224 |
| 8.00 | −81.18 | −81.11 | 86.52 | 6.7915 | −13.29 | 107.37 | −0.03323 | 0.28554 | 0.3182 | 0.1804 | 1.233 | 2937. | 548.3 | 0.8901 | 0.0226 |
| 10.00 | −74.00 | −73.92 | 85.76 | 5.5099 | −11.00 | 108.31 | −0.02724 | 0.28208 | 0.3194 | 0.1845 | 1.236 | 2870. | 551.3 | 0.8408 | 0.0231 |
| 12.00 | −67.89 | −67.81 | 85.10 | 4.6435 | −9.04 | 109.10 | −0.02222 | 0.27930 | 0.3206 | 0.1882 | 1.239 | 2814. | 553.6 | 0.8019 | 0.0234 |
| 14.00 | −62.54 | −62.46 | 84.52 | 4.0174 | −7.32 | 109.78 | −0.01788 | 0.27698 | 0.3217 | 0.1916 | 1.241 | 2764. | 555.4 | 0.7701 | 0.0238 |
| 14.70b | −60.83 | −60.74 | 84.33 | 3.8382 | −6.77 | 110.00 | −0.01649 | 0.27625 | 0.3221 | 0.1926 | 1.242 | 2749. | 556.0 | 0.7602 | 0.0239 |
| 16.00 | −57.78 | −57.69 | 84.00 | 3.5431 | −5.79 | 110.38 | −0.01404 | 0.27498 | 0.3228 | 0.1946 | 1.244 | 2721. | 556.9 | 0.7432 | 0.0241 |
| 18.00 | −53.46 | −53.37 | 83.53 | 3.1709 | −4.39 | 110.92 | −0.01059 | 0.27324 | 0.3238 | 0.1975 | 1.247 | 2681. | 558.2 | 0.7199 | 0.0243 |
| 20.00 | −49.51 | −49.42 | 83.09 | 2.8708 | −3.11 | 111.40 | −0.00746 | 0.27169 | 0.3248 | 0.2002 | 1.249 | 2645. | 559.3 | 0.6995 | 0.0246 |
| 22.00 | −45.86 | −45.76 | 82.68 | 2.6236 | −1.92 | 111.84 | −0.00458 | 0.27030 | 0.3257 | 0.2027 | 1.252 | 2612. | 560.1 | 0.6814 | 0.0248 |
| 24.00 | −42.46 | −42.36 | 82.30 | 2.4162 | −0.81 | 112.25 | −0.00192 | 0.26903 | 0.3267 | 0.2051 | 1.255 | 2581. | 560.9 | 0.6650 | 0.0250 |
| 26.00 | −39.28 | −39.18 | 81.94 | 2.2397 | 0.24 | 112.63 | 0.00056 | 0.26788 | 0.3276 | 0.2074 | 1.257 | 2552. | 561.5 | 0.6502 | 0.0252 |
| 28.00 | −36.28 | −36.18 | 81.60 | 2.0876 | 1.22 | 112.98 | 0.00288 | 0.26681 | 0.3284 | 0.2096 | 1.260 | 2525. | 562.1 | 0.6366 | 0.0254 |
| 30.00 | −33.45 | −33.34 | 81.27 | 1.9551 | 2.15 | 113.31 | 0.00507 | 0.26583 | 0.3293 | 0.2117 | 1.262 | 2499. | 562.5 | 0.6241 | 0.0255 |
| 32.00 | −30.76 | −30.65 | 80.96 | 1.8387 | 3.04 | 113.61 | 0.00714 | 0.26490 | 0.3302 | 0.2137 | 1.265 | 2475. | 562.9 | 0.6125 | 0.0257 |
| 34.00 | −28.20 | −28.09 | 80.67 | 1.7354 | 3.89 | 113.91 | 0.00910 | 0.26404 | 0.3310 | 0.2157 | 1.267 | 2451. | 563.2 | 0.6017 | 0.0259 |
| 36.00 | −25.75 | −25.64 | 80.38 | 1.6433 | 4.70 | 114.18 | 0.01097 | 0.26323 | 0.3318 | 0.2176 | 1.270 | 2429. | 563.5 | 0.5916 | 0.0260 |
| 38.00 | −23.41 | −23.29 | 80.11 | 1.5605 | 5.48 | 114.44 | 0.01275 | 0.26247 | 0.3326 | 0.2194 | 1.272 | 2408. | 563.7 | 0.5822 | 0.0262 |
| 40.00 | −21.16 | −21.04 | 79.84 | 1.4857 | 6.23 | 114.69 | 0.01445 | 0.26174 | 0.3334 | 0.2212 | 1.275 | 2387. | 563.9 | 0.5733 | 0.0263 |
| 42.00 | −19.00 | −18.88 | 79.59 | 1.4178 | 6.96 | 114.92 | 0.01609 | 0.26106 | 0.3342 | 0.2230 | 1.278 | 2367. | 564.0 | 0.5648 | 0.0264 |
| 44.00 | −16.91 | −16.79 | 79.34 | 1.3558 | 7.66 | 115.15 | 0.01766 | 0.26040 | 0.3349 | 0.2247 | 1.280 | 2348. | 564.1 | 0.5569 | 0.0266 |
| 46.00 | −14.90 | −14.77 | 79.10 | 1.2991 | 8.33 | 115.36 | 0.01918 | 0.25978 | 0.3357 | 0.2263 | 1.283 | 2330. | 564.2 | 0.5493 | 0.0267 |
| 48.00 | −12.95 | −12.82 | 78.87 | 1.2469 | 8.99 | 115.57 | 0.02064 | 0.25919 | 0.3365 | 0.2280 | 1.285 | 2312. | 564.2 | 0.5421 | 0.0268 |
| 50.00 | −11.07 | −10.94 | 78.64 | 1.1988 | 9.63 | 115.77 | 0.02205 | 0.25861 | 0.3372 | 0.2296 | 1.288 | 2295. | 564.2 | 0.5352 | 0.0269 |
| 55.00 | −6.59 | −6.46 | 78.10 | 1.0932 | 11.14 | 116.22 | 0.02538 | 0.25728 | 0.3390 | 0.2334 | 1.294 | 2254. | 564.1 | 0.5193 | 0.0272 |
| 60.00 | −2.42 | −2.29 | 77.58 | 1.0047 | 12.56 | 116.64 | 0.02848 | 0.25607 | 0.3408 | 0.2372 | 1.300 | 2216. | 563.9 | 0.5049 | 0.0275 |
| 65.00 | 1.49 | 1.63 | 77.10 | 0.9293 | 13.90 | 117.02 | 0.03137 | 0.25496 | 0.3426 | 0.2407 | 1.306 | 2180. | 563.6 | 0.4919 | 0.0274 |
| 70.00 | 5.17 | 5.32 | 76.63 | 0.8644 | 15.17 | 117.38 | 0.03408 | 0.25392 | 0.3443 | 0.2442 | 1.313 | 2146. | 563.1 | 0.4799 | 0.0277 |
| 75.00 | 8.66 | 8.81 | 76.19 | 0.8078 | 16.38 | 117.70 | 0.03665 | 0.25296 | 0.3460 | 0.2476 | 1.319 | 2114. | 562.6 | 0.4688 | 0.0279 |
| 80.00 | 11.98 | 12.13 | 75.77 | 0.7580 | 17.53 | 118.00 | 0.03907 | 0.25206 | 0.3477 | 0.2509 | 1.325 | 2083. | 562.0 | 0.4585 | 0.0281 |
| 85.00 | 15.14 | 15.30 | 75.36 | 0.7139 | 18.64 | 118.28 | 0.04138 | 0.25121 | 0.3494 | 0.2541 | 1.332 | 2054. | 561.4 | 0.4489 | 0.0284 |
| 90.00 | 18.17 | 18.32 | 74.96 | 0.6746 | 19.70 | 118.54 | 0.04358 | 0.25040 | 0.3511 | 0.2573 | 1.338 | 2026. | 560.7 | 0.4399 | 0.0286 |
| 95.00 | 21.06 | 21.22 | 74.58 | 0.6392 | 20.72 | 118.78 | 0.04569 | 0.24964 | 0.3527 | 0.2604 | 1.345 | 1999. | 560.0 | 0.4315 | 0.0288 |
| 100.00 | 23.85 | 24.01 | 74.21 | 0.6073 | 21.70 | 119.01 | 0.04771 | 0.24891 | 0.3544 | 0.2634 | 1.351 | 1973. | 559.2 | 0.4235 | 0.0290 |
| 110.00 | 29.12 | 29.28 | 73.49 | 0.5518 | 23.58 | 119.42 | 0.05152 | 0.24755 | 0.3577 | 0.2695 | 1.364 | 1923. | 557.6 | 0.4087 | 0.0294 |
| 120.00 | 34.03 | 34.20 | 72.82 | 0.5052 | 25.35 | 119.78 | 0.05506 | 0.24630 | 0.3609 | 0.2755 | 1.378 | 1876. | 555.8 | 0.3954 | 0.0297 |
| 130.00 | 38.65 | 38.82 | 72.17 | 0.4656 | 27.02 | 120.10 | 0.05838 | 0.24513 | 0.3642 | 0.2814 | 1.392 | 1832. | 554.0 | 0.3832 | 0.0301 |
| 140.00 | 43.00 | 43.18 | 71.55 | 0.4314 | 28.61 | 120.38 | 0.06151 | 0.24403 | 0.3675 | 0.2873 | 1.406 | 1790. | 552.0 | 0.3720 | 0.0305 |
| 150.00 | 47.13 | 47.31 | 70.95 | 0.4017 | 30.13 | 120.62 | 0.06447 | 0.24299 | 0.3708 | 0.2932 | 1.421 | 1751. | 550.0 | 0.3617 | 0.0308 |
| 160.00 | 51.05 | 51.23 | 70.37 | 0.3755 | 31.59 | 120.84 | 0.06729 | 0.24201 | 0.3742 | 0.2992 | 1.436 | 1712. | 548.0 | 0.3520 | 0.0311 |
| 170.00 | 54.79 | 54.98 | 69.80 | 0.3523 | 32.99 | 121.03 | 0.06997 | 0.24106 | 0.3776 | 0.3052 | 1.452 | 1675. | 545.9 | 0.3430 | 0.0315 |
| 180.00 | 58.37 | 58.56 | 69.25 | 0.3315 | 34.35 | 121.19 | 0.07254 | 0.24016 | 0.3811 | 0.3112 | 1.468 | 1640. | 543.7 | 0.3345 | 0.0318 |
| 190.00 | 61.80 | 61.99 | 68.72 | 0.3129 | 35.65 | 121.34 | 0.07500 | 0.23929 | 0.3846 | 0.3174 | 1.484 | 1606. | 541.5 | 0.3265 | 0.0321 |
| 200.00 | 65.10 | 65.29 | 68.19 | 0.2961 | 36.92 | 121.46 | 0.07737 | 0.23844 | 0.3882 | 0.3237 | 1.502 | 1573. | 539.3 | 0.3189 | 0.0324 |
| 220.00 | 71.34 | 71.54 | 67.18 | 0.2668 | 39.34 | 121.64 | 0.08186 | 0.23682 | 0.3956 | 0.3366 | 1.538 | 1509. | 534.7 | 0.3049 | 0.0330 |
| 240.00 | 77.16 | 77.36 | 66.20 | 0.2423 | 41.65 | 121.76 | 0.08607 | 0.23528 | 0.4034 | 0.3503 | 1.577 | 1449. | 530.0 | 0.2921 | 0.0336 |

**Refrigerant 407C [R-32/125/134a (23/25/52)] Properties of Liquid on the Bubble Line and Vapor o**

| Pressure, psia | Temp.*, °F Bubble | Temp.*, °F Dew | Denisty, lb/ft³ Liquid | Volume, ft³/lb Vapor | Enthalpy, Btu/lb Liquid | Enthalpy, Btu/lb Vapor | Entropy, Btu/lb·°F Liquid | Entropy, Btu/lb·°F Vapor | Specific Heat $c_p$, Btu/lb·°F Liquid | Specific Heat $c_p$, Btu/lb·°F Vapor | $c_p/c_v$ Vapor | Vel. of Sound, ft/s Liquid | Vel. of Sound, ft/s Vapor | Viscosity, $lb_m$/ft·h Liquid | Viscosity, $lb_m$/ft·h Vapor |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.00 | −125.91 | −111.58 | 94.30 | 43.0639 | −26.04 | 93.36 | −0.06927 | 0.28125 | 0.2970 | 0.1565 | 1.182 | 3366. | 484.2 | 1.9459 | 0.0194 |
| 1.50 | −116.25 | −102.11 | 93.35 | 29.4288 | −23.17 | 94.74 | −0.06079 | 0.27589 | 0.2979 | 0.1596 | 1.181 | 3273. | 489.4 | 1.7307 | 0.0199 |
| 2.00 | −108.99 | −95.00 | 92.63 | 22.4684 | −21.00 | 95.79 | −0.05455 | 0.27221 | 0.2987 | 0.1620 | 1.181 | 3204. | 493.2 | 1.5942 | 0.0203 |
| 2.50 | −103.11 | −89.24 | 92.05 | 18.2270 | −19.24 | 96.63 | −0.04958 | 0.26941 | 0.2994 | 0.1641 | 1.180 | 3148. | 496.1 | 1.4962 | 0.0207 |
| 3.00 | −98.14 | −84.36 | 91.56 | 15.3639 | −17.75 | 97.34 | −0.04543 | 0.26717 | 0.3000 | 0.1658 | 1.180 | 3101. | 498.5 | 1.4209 | 0.0209 |
| 4.00 | −89.95 | −76.34 | 90.74 | 11.7335 | −15.29 | 98.51 | −0.03870 | 0.26373 | 0.3012 | 0.1688 | 1.180 | 3025. | 502.3 | 1.3095 | 0.0214 |
| 5.00 | −83.30 | −69.82 | 90.06 | 9.5196 | −13.28 | 99.46 | −0.03332 | 0.26113 | 0.3022 | 0.1714 | 1.181 | 2964. | 505.2 | 1.2290 | 0.0217 |
| 6.00 | −77.65 | −64.29 | 89.49 | 8.0243 | −11.57 | 100.26 | −0.02882 | 0.25905 | 0.3032 | 0.1737 | 1.182 | 2912. | 507.5 | 1.1666 | 0.0221 |
| 7.00 | −72.73 | −59.47 | 88.99 | 6.9445 | −10.07 | 100.96 | −0.02493 | 0.25733 | 0.3041 | 0.1757 | 1.182 | 2867. | 509.4 | 1.1161 | 0.0223 |
| 8.00 | −68.34 | −55.17 | 88.54 | 6.1270 | −8.74 | 101.58 | −0.02150 | 0.25587 | 0.3049 | 0.1776 | 1.183 | 2828. | 511.1 | 1.0739 | 0.0226 |
| 10.00 | −60.75 | −47.73 | 87.75 | 4.9691 | −6.41 | 102.64 | −0.01563 | 0.25348 | 0.3064 | 0.1809 | 1.185 | 2759. | 513.7 | 1.0063 | 0.0230 |
| 12.00 | −54.29 | −41.40 | 87.07 | 4.1866 | −4.43 | 103.54 | −0.01070 | 0.25158 | 0.3078 | 0.1839 | 1.187 | 2702. | 515.7 | 0.9537 | 0.0233 |
| 14.00 | −48.64 | −35.86 | 86.47 | 3.6213 | −2.68 | 104.32 | −0.00644 | 0.25000 | 0.3091 | 0.1866 | 1.189 | 2651. | 517.3 | 0.9110 | 0.0236 |
| 14.70b | −46.82 | −34.08 | 86.28 | 3.4596 | −2.12 | 104.56 | −0.00508 | 0.24951 | 0.3095 | 0.1875 | 1.189 | 2635. | 517.8 | 0.8978 | 0.0237 |
| 16.00 | −43.59 | −30.92 | 85.94 | 3.1932 | −1.12 | 105.00 | −0.00267 | 0.24867 | 0.3103 | 0.1890 | 1.191 | 2606. | 518.6 | 0.8751 | 0.0239 |
| 18.00 | −39.03 | −26.45 | 85.45 | 2.8573 | 0.30 | 105.62 | 0.00072 | 0.24751 | 0.3114 | 0.1914 | 1.193 | 2566. | 519.7 | 0.8443 | 0.0242 |
| 20.00 | −34.85 | −22.36 | 85.00 | 2.5866 | 1.61 | 106.19 | 0.00380 | 0.24649 | 0.3125 | 0.1935 | 1.194 | 2529. | 520.6 | 0.8174 | 0.0244 |
| 22.00 | −30.98 | −18.57 | 84.57 | 2.3635 | 2.82 | 106.70 | 0.00663 | 0.24558 | 0.3135 | 0.1956 | 1.196 | 2495. | 521.3 | 0.7936 | 0.0246 |
| 24.00 | −27.38 | −15.05 | 84.18 | 2.1764 | 3.95 | 107.18 | 0.00925 | 0.24476 | 0.3145 | 0.1975 | 1.198 | 2463. | 521.9 | 0.7723 | 0.0248 |
| 26.00 | −24.01 | −11.74 | 83.81 | 2.0172 | 5.02 | 107.62 | 0.01169 | 0.24402 | 0.3155 | 0.1994 | 1.200 | 2434. | 522.4 | 0.7530 | 0.0250 |
| 28.00 | −20.83 | −8.64 | 83.46 | 1.8800 | 6.02 | 108.04 | 0.01398 | 0.24333 | 0.3164 | 0.2012 | 1.202 | 2406. | 522.9 | 0.7355 | 0.0252 |
| 30.00 | −17.83 | −5.70 | 83.12 | 1.7605 | 6.98 | 108.43 | 0.01613 | 0.24270 | 0.3173 | 0.2029 | 1.204 | 2379. | 523.2 | 0.7193 | 0.0254 |
| 32.00 | −14.98 | −2.91 | 82.80 | 1.6555 | 7.88 | 108.79 | 0.01817 | 0.24212 | 0.3182 | 0.2045 | 1.206 | 2354. | 523.5 | 0.7044 | 0.0255 |
| 34.00 | −12.26 | −0.25 | 82.49 | 1.5624 | 8.75 | 109.14 | 0.02011 | 0.24158 | 0.3190 | 0.2062 | 1.208 | 2331. | 523.7 | 0.6906 | 0.0257 |
| 36.00 | −9.67 | 2.29 | 82.20 | 1.4793 | 9.58 | 109.47 | 0.02195 | 0.24107 | 0.3198 | 0.2077 | 1.210 | 2308. | 523.9 | 0.6778 | 0.0258 |
| 38.00 | −7.18 | 4.72 | 81.92 | 1.4047 | 10.38 | 109.78 | 0.02371 | 0.24059 | 0.3207 | 0.2092 | 1.212 | 2286. | 524.0 | 0.6657 | 0.0260 |
| 40.00 | −4.79 | 7.06 | 81.64 | 1.3372 | 11.15 | 110.08 | 0.02539 | 0.24014 | 0.3215 | 0.2107 | 1.214 | 2265. | 524.1 | 0.6544 | 0.0261 |
| 42.00 | −2.50 | 9.30 | 81.38 | 1.2760 | 11.89 | 110.36 | 0.02700 | 0.23972 | 0.3223 | 0.2122 | 1.216 | 2245. | 524.1 | 0.6438 | 0.0262 |
| 44.00 | −0.28 | 11.47 | 81.12 | 1.2202 | 12.60 | 110.64 | 0.02856 | 0.23932 | 0.3230 | 0.2136 | 1.218 | 2226. | 524.1 | 0.6337 | 0.0264 |
| 46.00 | 1.86 | 13.56 | 80.87 | 1.1690 | 13.30 | 110.90 | 0.03005 | 0.23893 | 0.3238 | 0.2150 | 1.220 | 2207. | 524.1 | 0.6241 | 0.0265 |
| 48.00 | 3.92 | 15.58 | 80.63 | 1.1220 | 13.97 | 111.15 | 0.03149 | 0.23857 | 0.3245 | 0.2163 | 1.222 | 2189. | 524.1 | 0.6151 | 0.0266 |
| 50.00 | 5.93 | 17.53 | 80.39 | 1.0786 | 14.62 | 111.39 | 0.03289 | 0.23822 | 0.3253 | 0.2177 | 1.224 | 2171. | 524.0 | 0.6064 | 0.0267 |
| 55.00 | 10.68 | 22.18 | 79.83 | 0.9835 | 16.17 | 111.96 | 0.03618 | 0.23741 | 0.3271 | 0.2209 | 1.229 | 2130. | 523.7 | 0.5865 | 0.0270 |
| 60.00 | 15.11 | 26.50 | 79.30 | 0.9037 | 17.63 | 112.48 | 0.03924 | 0.23668 | 0.3289 | 0.2240 | 1.234 | 2091. | 523.3 | 0.5686 | 0.0273 |
| 65.00 | 19.27 | 30.56 | 78.79 | 0.8358 | 19.01 | 112.95 | 0.04210 | 0.23601 | 0.3306 | 0.2271 | 1.239 | 2054. | 522.8 | 0.5524 | 0.0275 |
| 70.00 | 23.19 | 34.39 | 78.31 | 0.7772 | 20.31 | 113.40 | 0.04478 | 0.23540 | 0.3323 | 0.2300 | 1.244 | 2020. | 522.3 | 0.5376 | 0.0277 |
| 75.00 | 26.90 | 38.01 | 77.85 | 0.7263 | 21.55 | 113.81 | 0.04731 | 0.23483 | 0.3340 | 0.2329 | 1.249 | 1987. | 521.6 | 0.5239 | 0.0280 |
| 80.00 | 30.43 | 41.46 | 77.41 | 0.6814 | 22.73 | 114.19 | 0.04971 | 0.23429 | 0.3356 | 0.2357 | 1.255 | 1956. | 520.9 | 0.5113 | 0.0282 |
| 85.00 | 33.80 | 44.74 | 76.98 | 0.6417 | 23.87 | 114.55 | 0.05200 | 0.23379 | 0.3372 | 0.2384 | 1.260 | 1927. | 520.2 | 0.4996 | 0.0284 |
| 90.00 | 37.02 | 47.88 | 76.57 | 0.6062 | 24.96 | 114.89 | 0.05418 | 0.23332 | 0.3388 | 0.2411 | 1.265 | 1898. | 519.3 | 0.4886 | 0.0286 |
| 95.00 | 40.11 | 50.89 | 76.17 | 0.5744 | 26.01 | 115.21 | 0.05626 | 0.23287 | 0.3404 | 0.2438 | 1.270 | 1871. | 518.5 | 0.4783 | 0.0288 |
| 100.00 | 43.08 | 53.78 | 75.78 | 0.5456 | 27.02 | 115.51 | 0.05826 | 0.23245 | 0.3420 | 0.2464 | 1.276 | 1845. | 517.6 | 0.4686 | 0.0290 |
| 110.00 | 48.70 | 59.24 | 75.03 | 0.4956 | 28.96 | 116.07 | 0.06203 | 0.23165 | 0.3452 | 0.2516 | 1.287 | 1795. | 515.7 | 0.4508 | 0.0294 |
| 120.00 | 53.95 | 64.35 | 74.32 | 0.4537 | 30.78 | 116.56 | 0.06555 | 0.23092 | 0.3483 | 0.2567 | 1.298 | 1748. | 513.8 | 0.4347 | 0.0297 |
| 130.00 | 58.87 | 69.13 | 73.64 | 0.4180 | 32.50 | 117.01 | 0.06884 | 0.23024 | 0.3515 | 0.2618 | 1.309 | 1704. | 511.7 | 0.4201 | 0.0300 |
| 140.00 | 63.53 | 73.65 | 72.99 | 0.3872 | 34.14 | 117.41 | 0.07194 | 0.22960 | 0.3546 | 0.2669 | 1.321 | 1662. | 509.5 | 0.4066 | 0.0304 |
| 150.00 | 67.94 | 77.93 | 72.36 | 0.3604 | 35.71 | 117.78 | 0.07488 | 0.22899 | 0.3578 | 0.2720 | 1.333 | 1623. | 507.3 | 0.3943 | 0.0307 |
| 160.00 | 72.13 | 81.99 | 71.75 | 0.3368 | 37.21 | 118.11 | 0.07767 | 0.22841 | 0.3610 | 0.2771 | 1.346 | 1585. | 505.0 | 0.3828 | 0.0310 |
| 170.00 | 76.14 | 85.87 | 71.16 | 0.3159 | 38.66 | 118.41 | 0.08034 | 0.22785 | 0.3643 | 0.2823 | 1.359 | 1548. | 502.7 | 0.3720 | 0.0313 |
| 180.00 | 79.97 | 89.58 | 70.58 | 0.2972 | 40.06 | 118.68 | 0.08289 | 0.22731 | 0.3676 | 0.2875 | 1.373 | 1513. | 500.4 | 0.3619 | 0.0316 |
| 190.00 | 83.65 | 93.13 | 70.01 | 0.2804 | 41.41 | 118.93 | 0.08533 | 0.22679 | 0.3709 | 0.2928 | 1.387 | 1479. | 498.0 | 0.3525 | 0.0319 |
| 200.00 | 87.18 | 96.55 | 69.46 | 0.2653 | 42.72 | 119.15 | 0.08769 | 0.22628 | 0.3744 | 0.2982 | 1.401 | 1447. | 495.5 | 0.3435 | 0.0322 |
| 220.00 | 93.88 | 103.00 | 68.38 | 0.2389 | 45.23 | 119.53 | 0.09215 | 0.22529 | 0.3815 | 0.3094 | 1.432 | 1385. | 490.5 | 0.3269 | 0.0328 |
| 240.00 | 100.14 | 109.02 | 67.33 | 0.2167 | 47.61 | 119.83 | 0.09633 | 0.22433 | 0.3890 | 0.3211 | 1.465 | 1326. | 485.5 | 0.3119 | 0.0334 |


7C
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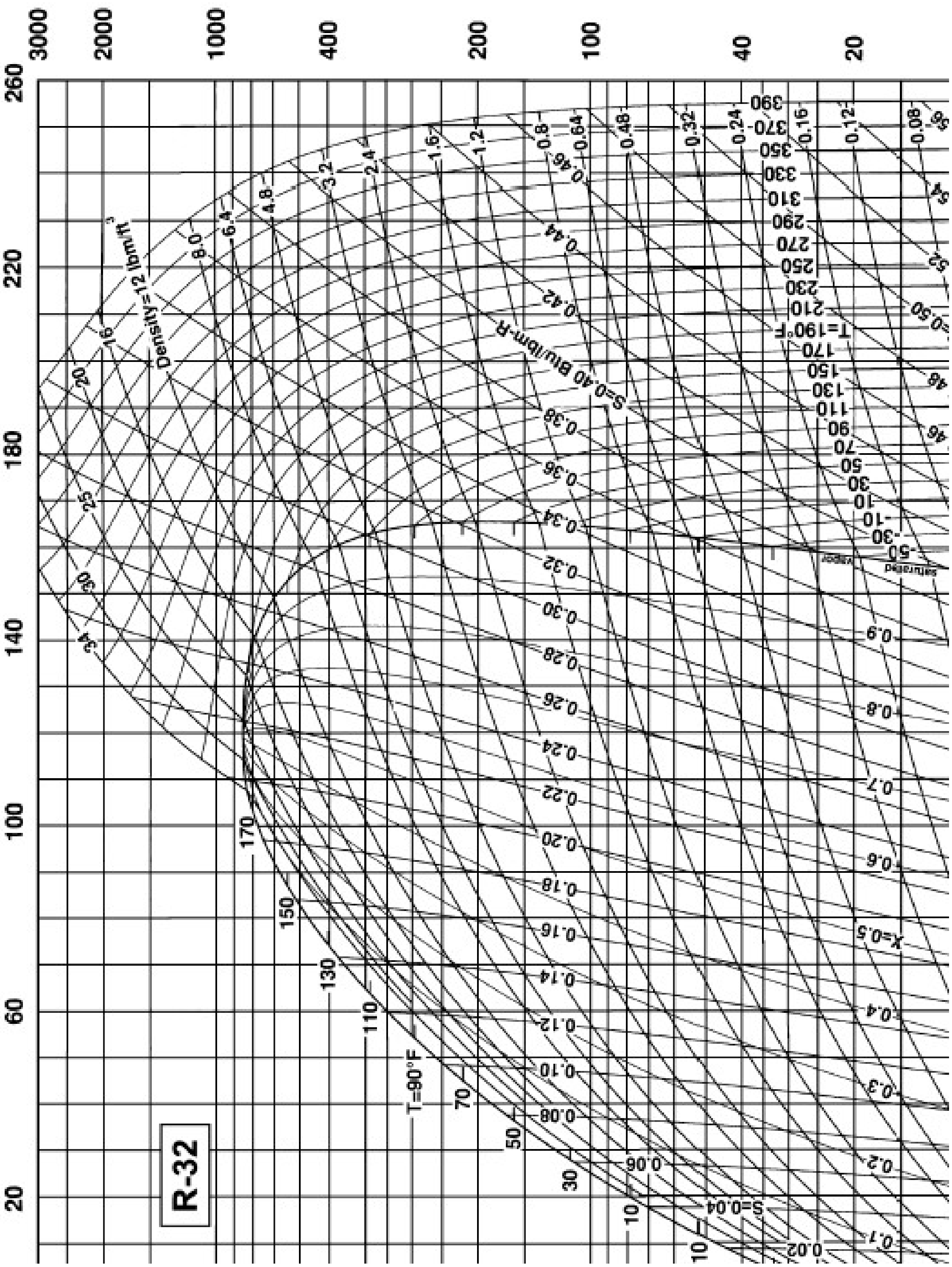
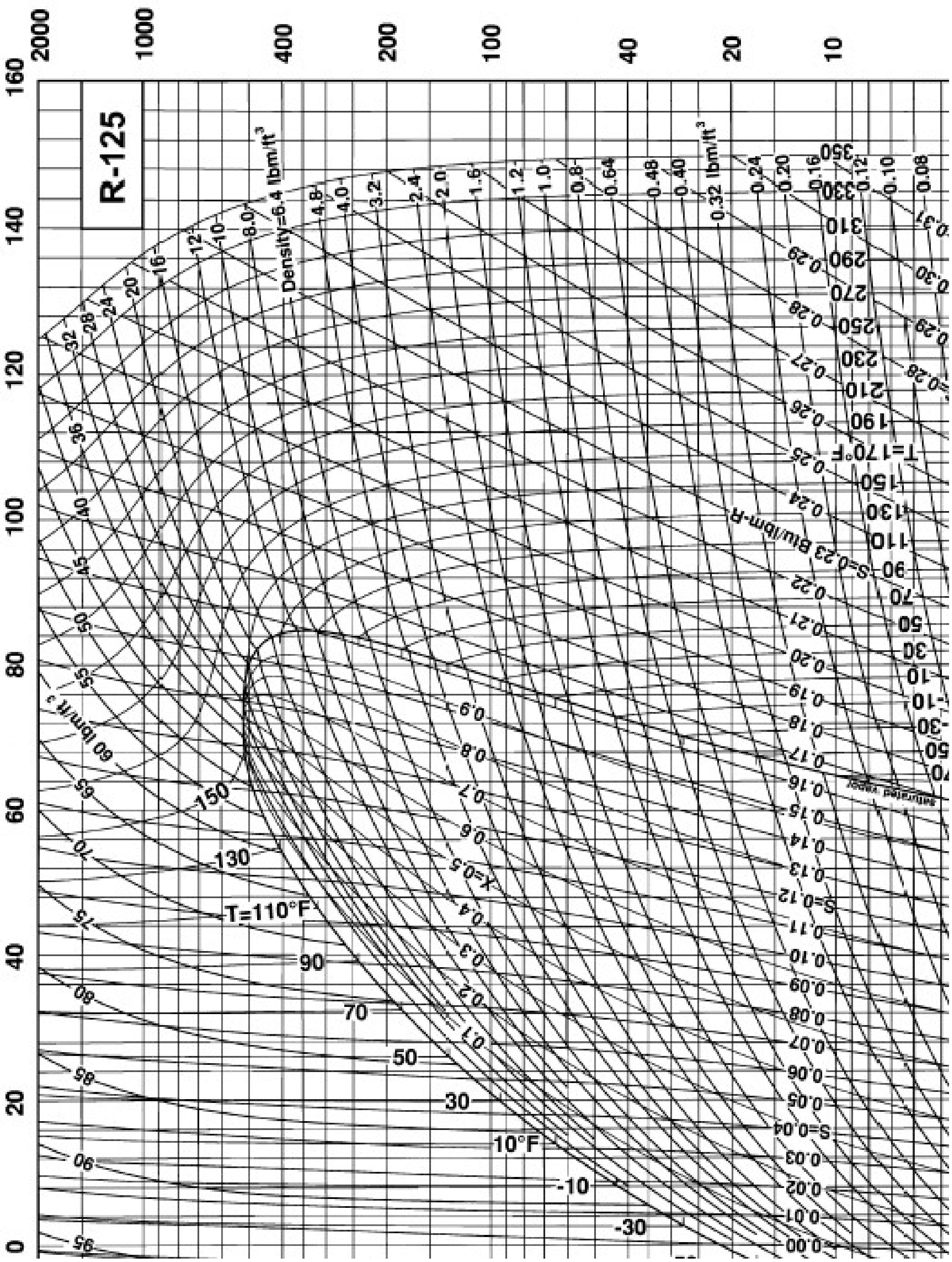
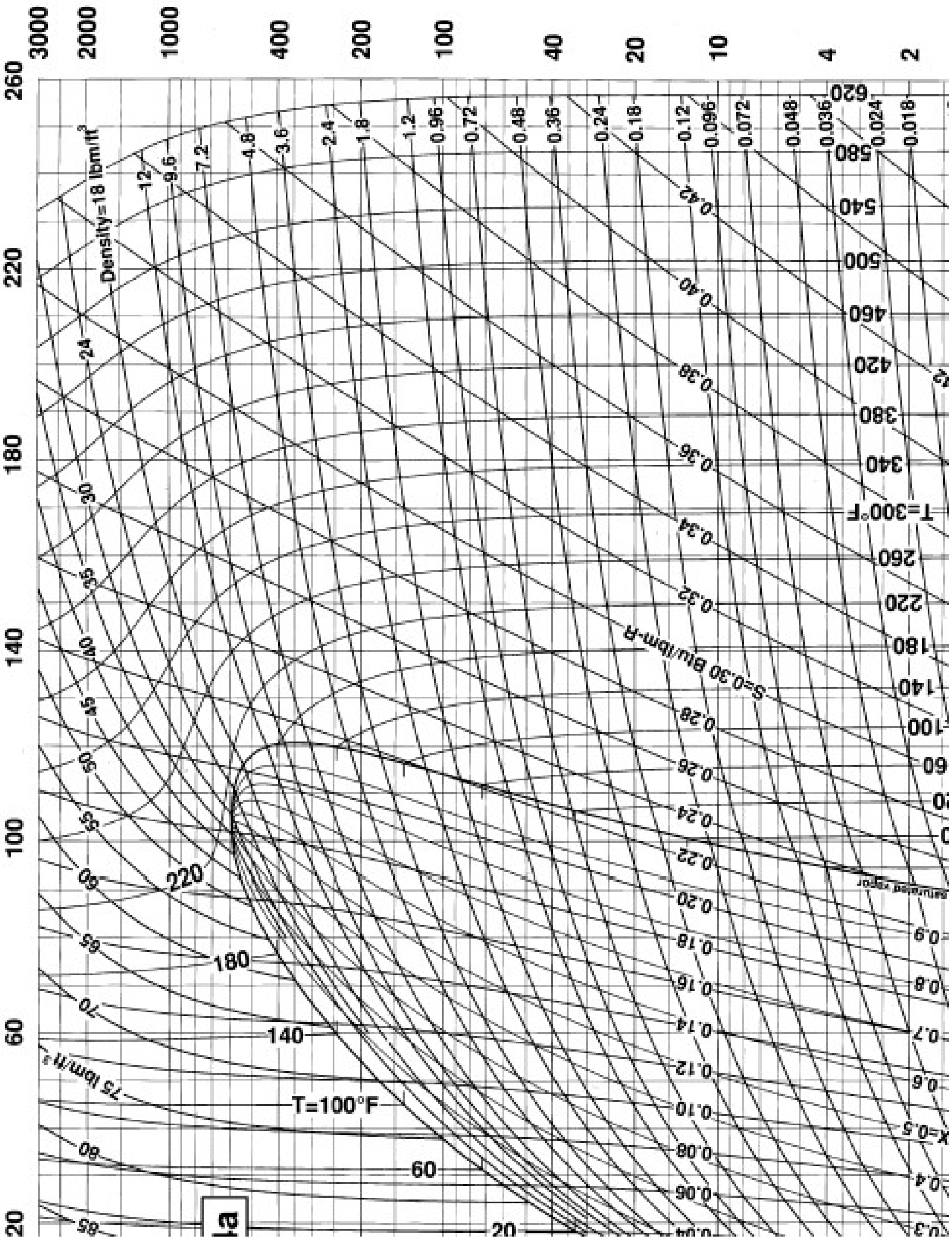
volume = 0.20 ft³/lb
saturated vapor
saturated liquid
quality = 0.3
temperature = 0 °F
entropy = 0.37 BTU/lb·°F


R-32
Density=12 lbm/ft³
S=0.40 Btu/lbm·R
T=190°F
T=90°F
X=0.5
S=0.04


R-125
Density=6.4 lbm/ft³
0.32 lbm/ft³
60 lbm/ft³
T=170°F
T=110°F
S=0.23 Btu/lbm-R
S=0.12
S=0.04
X=0.5
10°F
saturated vapor
2000
1000
400
200
100
40
20
10
160
140
120
100
80
60
40
20
0


3000
2000
1000
400
200
100
40
20
10
4
2
260
220
180
140
100
60
20
Density=18 lbm/ft³
24
30
35
40
45
50
55
60
65
70
75 lbm/ft³
80
85
T=300°F
T=100°F
220
180
140
60
20
S=0.30 Btu/lbm-R
Saturated vapor
X=0.5