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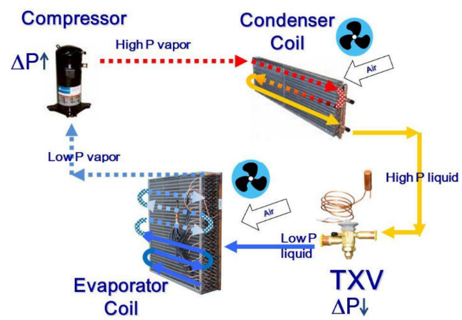
Refrigeration Fundamentals-Agenda

- Basic components/terminology
- Piping design
- How to troubleshoot existing systems
- Questions



Refrigeration Basics

- Refrigeration is the process of removing heat from one substance and transferring it to another substance.
- Heat energy cannot be destroyed – only transferred.
- Heat always flows from a higher temperature to a lower temperature substance.

1. Example – ice melting in the sun (heat flowing from hot to cold)

Refrigerant Types

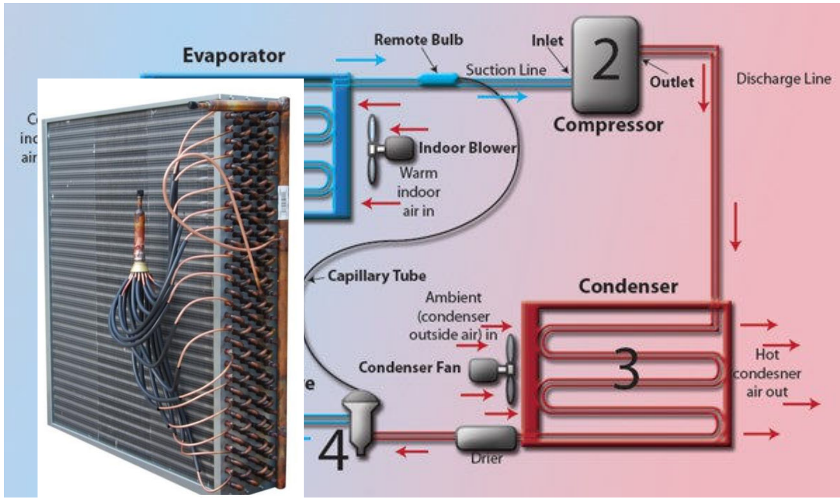
- Refrigerant is used to absorb and transport heat from the purpose of cooling.
- Think of it as a sponge that transfers heat from one location (inside) to another (outside).

- R-22 no longer produced in the USA as of 1/1/10 – can no longer import after 2020.
- Latest amendment to the Montreal Protocol called for phase down of HFC refrigerants (R-404a, R-410a, and R-134a). Likely starting in 2025 in the USA.
- R-32 has 1/3 of the global warming potential of R-410a and has been used in Japan for 4+ years.

After 2020, any or heat pump system using R-22 that requires servicing will have to depend on potentially expensive R-22 stockpiles or reclaimed refrigerant.

The latest amendment to the Montreal Protocol has proposed to phase-down the use of refrigerants such as R-410A. The phase down is expected to begin sometime in the 2020's. The leading replacement for R-410A refrigerant is a pure, single component refrigerant called R-32, which has one-third the global warming potential of R-410A.

Components

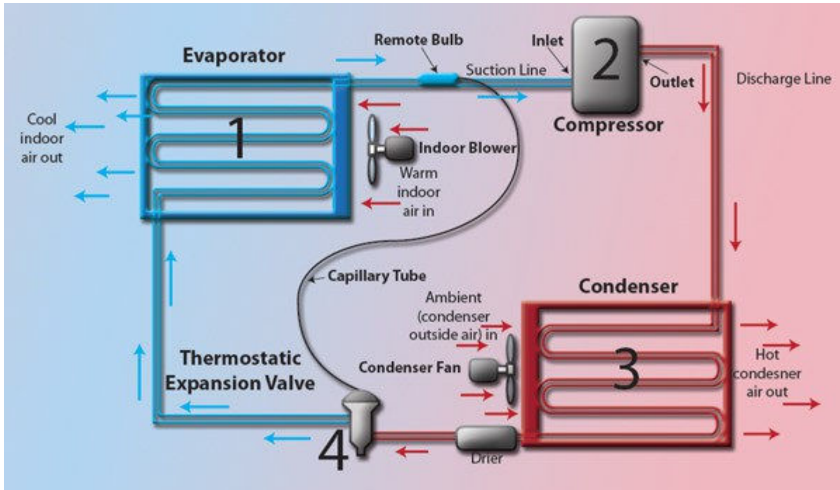


- (1) Evaporator – refrigerant enters the evaporator coil as a mixture of cold liquid and vapor → exits the coil as a warm vapor

An evaporator coil is located indoors. Inside the coil, the refrigerant evaporates as it absorbs heat from the indoor air that passes over it. Enters the coil 80/20 liquid gas mix.

The coil essentially serves as a “heat exchanger”. In an air conditioner, refrigerant absorbs heat from a room in the evaporator coil, causing it to change from a cold liquid to a low-pressure, warm refrigerant gas. As it comes out of the evaporator coil, is the **Superheat**. Low pressure, low temp vapor.

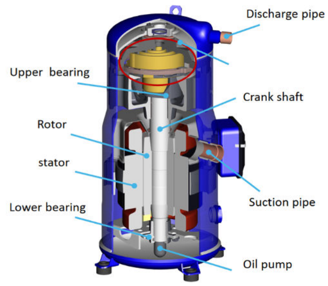
Components

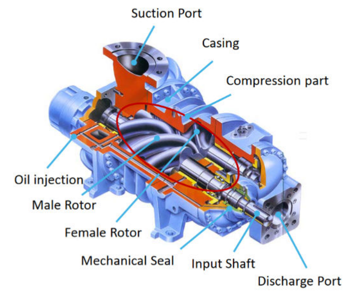


- (2) Compressor – The compressor squeezes the refrigerant gas, reducing its volume and turning it into a high-pressure, hot gas.

Its functions include drawing in the cool vaporized refrigerant that carries the heat energy from the evaporator coils, compressing it from a low pressure and temperature to a high pressure and temperature, and pushing it around the refrigeration loop for the purpose of heat rejection.

Types of Compressors





- There are basically 5 types of air conditioner compressor that are commonly used in the HVAC industry:
  - Reciprocating (Piston)
  - Scroll (Constant, 2-stage, Digital, Variable Speed)
  - Screw
  - Rotary
  - Centrifugal (Turbo, Radial)

A Reciprocating compressor adopts the back and forth piston motion in a cylinder synchronized with suction and discharge valves to compress the vaporized refrigerant from a low pressure and temperature to a high pressure and temperature. The motion of the piston is achieved via a crankshaft which converts motor rotations to piston reciprocations.

A scroll compressor has one fixed scroll which remains stationary and another moving or orbiting scroll that rotates through the use of swing link. When this happens, the pockets of refrigerant between the two scroll are slowly pushed to the center of the two scrolls causing the reduction of the volume of the gas. It is then discharged though the center port to the condenser.

The advantage of scroll compressor is that it has fewer moving parts and less torque variation compared to the reciprocating compressor. This advantage is translated to a smooth and quiet operation. However, some constant speed compressor designs adjust their cooling capacity by lifting or separating one of the scrolls intermittently from its normal operating position based on the amount of thermal load to adjust its cooling capacity. The less load, the more time the scrolls remain separated, preventing refrigerant compression. This method is not a variable speed compressor, but a variable capacity compressor. A common industry term used to describe this type of compressor is digital scroll compressor. Their best feature is low noise operation and reduced vibrations.

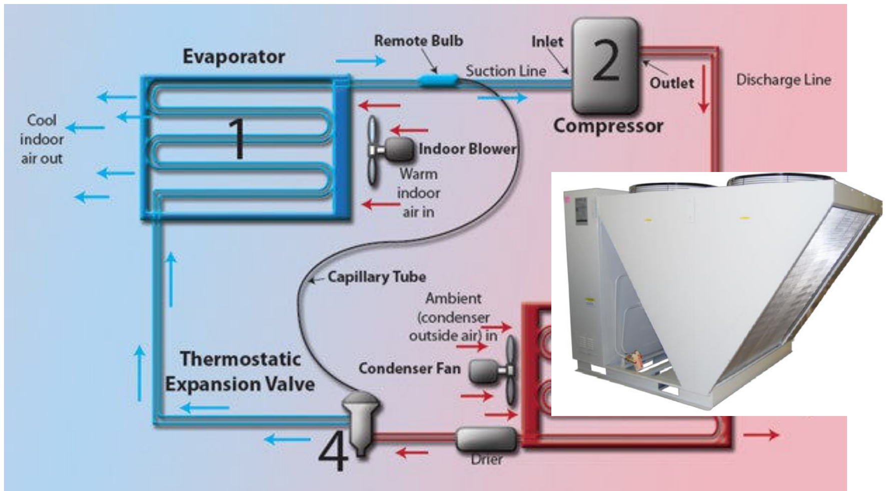
The screw compressor uses a pair of helical rotors where it traps and compresses the gas as the rotors revolve in the cylinder. In HVAC, they are usually used in systems with 20 ton capacity and above. The male rotor and the female rotor are built inside the cylinder. The low pressure refrigerant enters one end of the compressor and the resultant high pressure refrigerant is discharged into the opposite end to the condenser.

Centrifugal compressor is usually used in large capacity refrigerating system. In this compressor, the vapor is moved in a circular motion known as centrifugal force. An impeller which is a disk with radial blades spins rapidly inside this housing causing the gas to gain velocity.

A diffuser converts this energy into pressure energy and is then discharged into the condenser. The pumping efficiency increases with speed, hence this type of compressors are designed to operate at high speed.

The main advantage of centrifugal compressor is that there are no valves, pistons or cylinders. The wearing parts that need attention are the main bearings.

Components

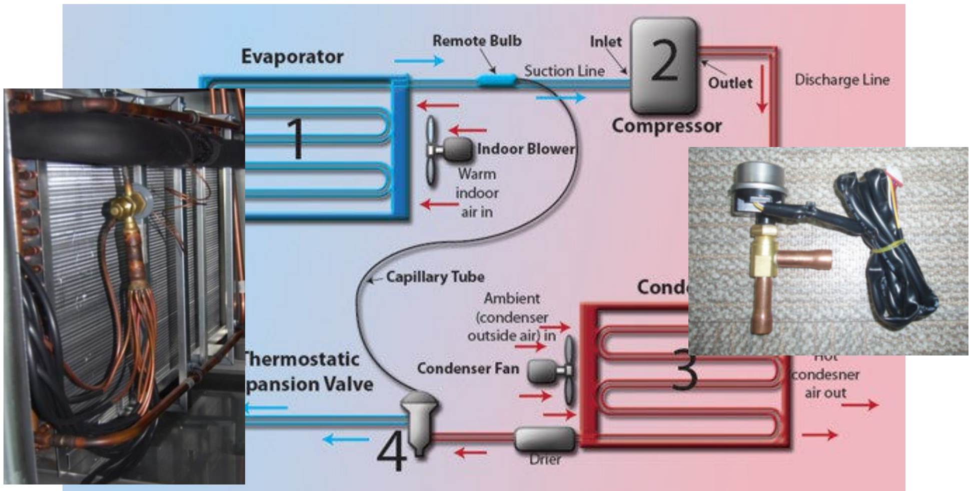


- (3) Condenser - A fan blows across the coils, dissipating the heat from the refrigerant inside them and allowing it to convert back into a liquid.

The condenser is a set of coils, also located inside the outdoor unit. Here, a fan blows across the coils, dissipating the heat from the refrigerant inside them and allowing it to convert back into a liquid, at which point it's sent back inside to start the process over again. The condenser outlet is called **subcool** (temp decrease in liquid form). The filter drier absorbs any moisture in the system.

Without the condenser, the refrigerant would retain its heat and the process would not work. Therefore, it's important to be able to tell if the condenser is malfunctioning or broken..

Components

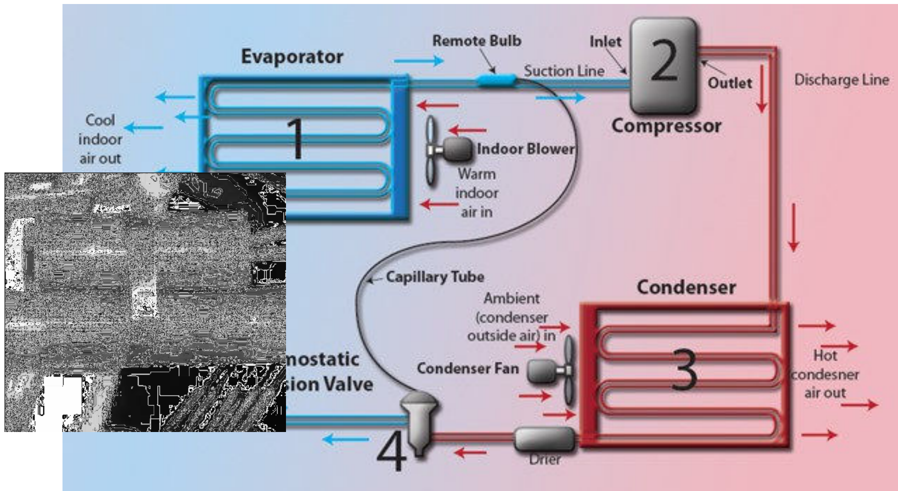


- (4) TEV - Used for refrigerant flow control to maintain constant superheat in the evaporator.

Often abbreviated as **TEV**, TXV, or TX valve. Decreased pressure automatically makes temperature decrease.

First image is Thermostatic Expansion Valve, second is Electronic Expansion Valve

Components

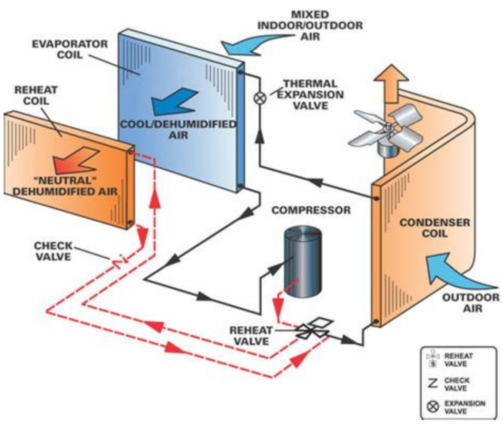


- Remote bulb is connected by capillary tube to the TXV. This remote bulb is at the outlet of the evaporator and is responsive to changes in refrigerant vapor temperature.

The bulb is fastened to the outside of the evaporator outlet so that temperature changes in the refrigerant leaving the evaporator are sensed by expansion or contraction of the fluid. Ideally the gas should leave with 6–7 degrees of superheat. This ensures that the refrigerant is being used efficiently and that no liquid reaches the compressor.

The high pressure liquid then enters the expansion valve where the TX valve allows a portion of the refrigerant to enter the evaporator. In order for the higher temperature fluid to cool, the flow must be limited into the evaporator to keep the pressure low and allow expansion back into the gas phase. The TXV has sensing bulbs connected to the suction line of the refrigerant piping. The gas pressure in the sensing bulbs provides the force to open the TXV, therefore adjusting the flow of refrigerant and the superheat.

Components



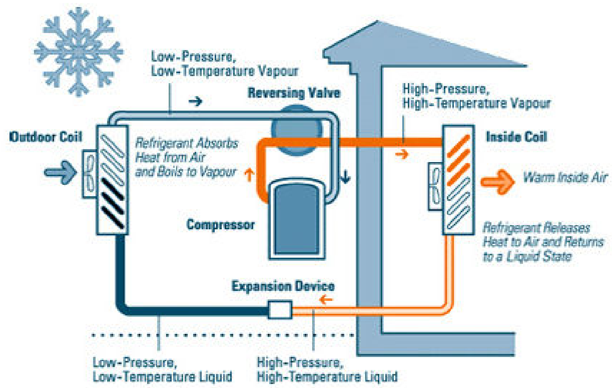
- Hot-Gas bypass valve bypasses the refrigerant from the supply of the evaporator back to the return of the compressor, bypassing the coil.
- Hot-Gas reheat is typically used for dehumidification. Wring the water out on the evaporator coil and then reheat the air on the second coil.

Hot-Gas bypass valve bypasses the refrigerant from the supply of the evaporator back to the return of the compressor, bypassing the coil. In effect, that 5 ton compressor would be doing 5 tons of work but netting, say, 3 tons of capacity. This would get the job done, although not in an efficient way.

HGRH - If you have a mild day and run the air conditioner, the only way to remove moisture is to cool the air, but if the air is not warm enough, you will create a cold clammy situation. By using a hot coil, you wring the water out on the evaporator coil and then reheat the air on that second coil, providing neutral dry air. A lot of people think the hot-gas reheat dehumidifies but it's really the cooling coil doing the work.

Compressor Exit – High Pressure, Hot Gas -> HGRH Coil

Air-Source Heat Pump



- Heat pumps are used to both cool and heat the home. The same device accomplishes this by reversing the flow of refrigerant.

A heat pump can switch from air condition mode to heat mode by reversing the refrigeration cycle, making the outside coil function as the evaporator and the indoor coil as the condenser.

The refrigerant flows through a closed system of refrigeration lines between the outdoor and the indoor unit.

Although outdoor temperatures are cold, enough heat energy is absorbed from the outside air by the condenser coil and release inside by the evaporator coil.

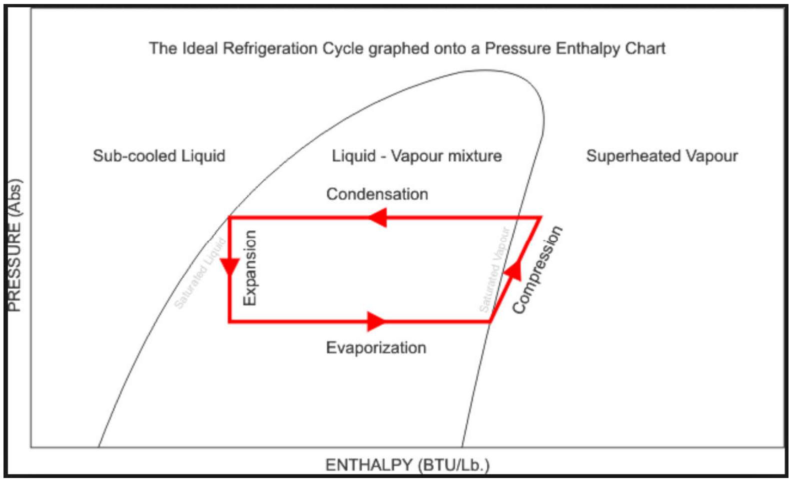
Air from the inside of your house is pulled into ductwork by a motorized fan.

The refrigerant is pumped from the interior coil to the exterior coil, where it absorbs the heat from the air.

This warmed air is then pushed through connecting ducts to air vents throughout the home, increasing the interior temperature.

The refrigeration cycle continues again, providing a consistent method to keep you warm.

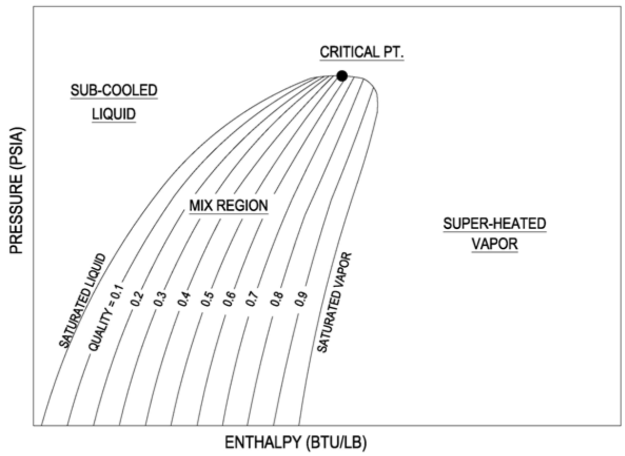
P-H Diagram



- Used in designing and analyzing performance of vapor-compression refrigeration systems.

Each refrigerant has it's own chart which is a graph of the Enthalpy of a refrigerant during various pressures and physical states. Mollier charts are also called Pressure-Enthalpy diagrams. Pressure is shown on the verticle axis, enthalpy is on the horizontal axis. You can compare Imperial versus SI Unit Mollier Charts by clicking on the buttons below the chart.

P-H Diagram

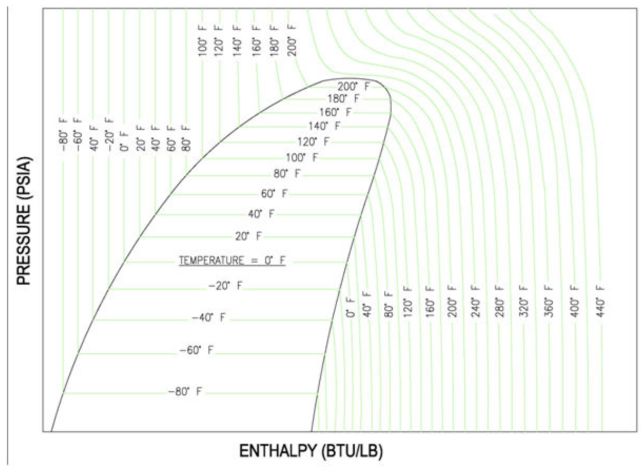


- The curves break up the diagram into three regions (1) Liquid, (2) Vapor and (3) Mix.

The upside down U figure shown on the diagram designates the points at which the refrigerant changes phase. The left vertical curve indicates the saturated liquid curve and the right vertical curve indicates the saturated vapor curve. The region in between the two curves describe refrigerant states that contain a mixture of both liquid and vapor. The locations to the left of the saturated liquid curve indicate that the refrigerant is in liquid form and locations to the right of the saturated vapor curve indicate that the refrigerant is in vapor form. The point at which the two curves meet is called the critical point. The importance of this point is that at any point above, no additional pressure will change the vapor into a liquid.

There are also upward sloping curves which indicate quality. Quality is a measure of the ratio of vapor mass to total mass. For example quality of 0.1 or 10%, which is located near the saturated liquid line, describes points that have 10% vapor by mass. The 0.9 or 90% line, which is located near the saturated vapor line, describes points that have 90% vapor by mass.

P-H Diagram



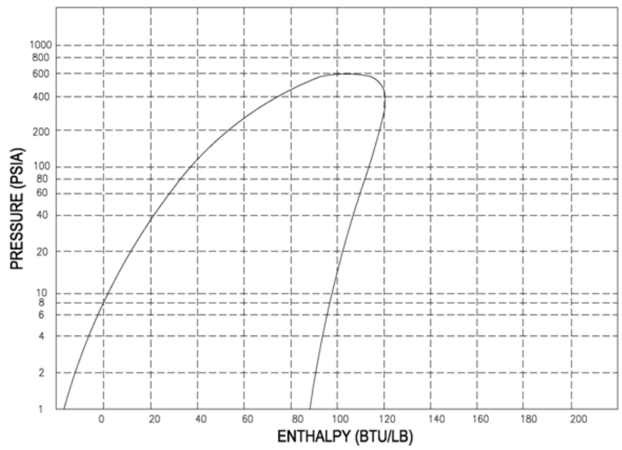
- Vertical constant temperature lines increase as enthalpy increases.
- Inside the upside-down "U" is the phase change region

(1) Liquid Region: The liquid region is also known as the sub-cooled region. In this region there are vertical constant temperature lines, which increase as enthalpy is increased.

(2) Vapor Region: The vapor region is also known as the super heated region. In this region there are vertical temperature lines, which increase as enthalpy is increased.

(3) Liquid-Vapor Mix Region (under u curve) : In this region, the P-H diagram shows horizontal temperature lines, which indicate constant temperature. The mix region is the phase change region, where any addition of enthalpy will cause additional liquid to vaporize instead of raising the temperature.

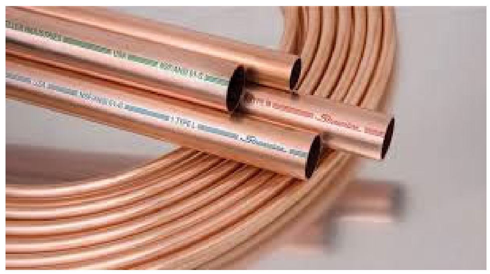
P-H Diagram



- The pressure lines running from left to right. The enthalpy lines are the vertical lines.
- Example

Piping

- Role of piping in the refrigeration cycle:
  - Return Oil from the evaporator coil to the compressor
  - Ensure that only liquid refrigerant enters the expansion device (TXV)
  - Minimize system capacity loss
  - Minimize refrigerant charge



Oil is used to lubricate the compressor and reduce wear and tear

Use sight glass on compressor to see oil level (should be ¼ to ½ way up on sight glass)

Suction pipe must slope toward compressor to allow oil to return

If possible, the refrigerant line should travel a direct and straight course between evaporator and compressor.

Piping

- Product Information
  - Model number of unit components (condensing section, evaporator, etc.)
  - Min & Max capacity per refrigeration circuit
  - Refrigerant type
  - Unit options (Hot Gas Bypass, etc.)

- Jobsite Information
  - Sketch of how piping will be run, including:
  - Distances
  - Elevation changes
  - Equipment layout
  - Fittings
  - Ambient conditions where piping will be run
  - Ambient operating range

Do NOT size the line set based on the connection sizes at the indoor or outdoor units

Piping

- Pipe Sizing
  - The actual equivalent length is estimated by calculating the path length in feet that the piping will follow and adding the pressure drops of the fittings and/or accessories along that length.
  - Pipe type, ΔT, Pressure Drop, etc. must be considered
- Installation
  - Suction & Liquid lines are generally insulated, discharge lines are usually not insulated.
  - Lines should be secured to minimize vibration (rubber grommets & brackets)
  - Lines that pass through walls must have sleeves to avoid rubbing
- Good refrigeration piping design requires that the refrigeration lines be pitched in the direction of flow at approximately 1/2 inch per 10 feet or 1 inch per 20 feet.
- Refrigerant velocities in vertical lines should be at least 1500 ft/m in to ensure good oil return; velocities in horizontal lines should be at least 750 ft/min.

Service

- **A Dirty or Blocked Condenser** - system is now running very inefficiently because of the higher condensing temperature and pressure
- **A Dirty Evaporator Coil** - makes it much harder for the refrigerant to absorb heat from the air, and this will result in a rise in temperatures
- **Filter Dryer Restriction** - A starved evaporator from the liquid line will cause high superheats. The low evaporator pressure will cause high discharge temperatures.
- **Restricted Components**
  - Restricted TXV screen or orifice;
  - Kinked liquid line;
  - Kinked U-bend in liquid line;
  - Restricted liquid line solder joint;

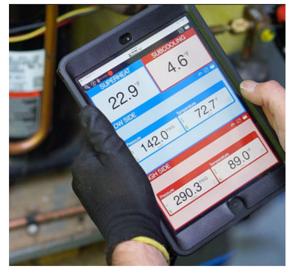
- **Symptoms of Restricted Line:**
  - Higher than normal discharge temperature
  - High superheats;
  - Low pressures;
  - Short cycling on the low-pressure control

If less heat can be rejected to the surrounding air with an air-cooled condenser, the heat will start to accumulate in the condenser. This accumulation of heat in the condenser will make the condensing temperature rise. Now that the condensing temperature is rising, there will come a point where the temperature difference between the condensing temperature and the surrounding ambient (Delta T) is great enough to reject heat from the condenser.

Remember, a temperature difference is the driving potential for heat transfer to take place between anything. The greater the temperature difference, the greater the heat transfer. The condenser is now rejecting enough heat at the elevated Delta T to keep the system running with a dirty condenser. However, the system is now running very inefficiently because of the higher condensing temperature and pressure causing high compression ratios.

Troubleshooting

- **Superheat** - By assuring that we have superheat at the evaporator outlet, we know:
  - The expansion valve is operating as designed
  - There will be no liquid refrigerant entering the compressor – this is important, since it would cause compressor damage due to oil dilution. HVAC superheat is between 8F and 15F.
- **TXV Operation** – adjustments at the valve can be made to increase or decrease superheat.
- **Subcooling** – By assuring a reasonable subcooled state at the outlet of the condenser, we know that we have a good seal at the inlet of the expansion device. No subcooling can be a result of:
  - An evaporator mounted higher than the condensing unit can cause liquid line pressure to drop as the refrigerant is "lifted".
  - The liquid line running through an ambient space warmer than the subcooled liquid (hot attic).
- **Charge** – Subcooling can be used to identify an over or under-charged system. Should be between 10F and 20F. Too much subcooling will back liquid up in the condenser and cause inefficiencies.



Diagnosing can be a challenge. One a tech grasps the principles of superheat and subcooling, these two parameters can be very useful in determining if the system is properly charged and working correctly.

When a refrigerant is at it's saturation point, the temperature of the liquid and vapor are the same. If additional heat is added to the vapor, the temperature of the vapor will increase. This temp increase above it's saturation temp is called Superheat.

PT Chart – evaporator pressure = 142 psig, saturation temp = 50F

If we measure temp of the suction line just after evap coil and it's 60F, we have 10F of superheat

When heat is removed from a saturated refrigerant, the temperature of the liquid is reduced. The difference between the saturated liquid temperature and the actual liquid temperature is the subcooled temp.

PT Chart – condensing pressure = 295 psig, condensing temp = 95F

If we measure temp of the refrigerant leaving the condenser coil and it's 85F, the refrigerant is subcooled 10 degrees

Compressor Failure

What can cause a Compressor Failure?

- Short cycling the compressor causing oil loss
- Excessive liquid refrigerant entering the compressor
- Insufficient oil returning to the compressor (not applicable in TurboCor compressors which are oil-free)
- Compressor operating outside of the operating envelope (temps, pressures, electrical limits). The more critical issue is temperatures above the limits rather than below limits.
- Excessive temperatures can cause the oil to break down.
- Eventual wear from too many on/off cycles

Final Thoughts

DX Systems Have Benefits

- Less expensive to install, and use less space in mechanical and electrical rooms than centralized cooling systems
- Can be expanded in an incremental fashion to match changing building requirements
- Packaged Systems have standardized operating performances per unit, allowing more precise system sizing.
- Split Systems have lower noise levels because the compressor unit is located further away from the cooling load area
- Many options allow for unique applicaitons

But they must be sized and installed correctly

- Proper pipe sizing for split systems
- Troubleshooting and Diagnostics can be tricky
- Many options can make them complicated

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