June 7, 2021

Mechanical Refrigeration Cycle

Before we can advocate for our customers on HVAC compressorized equipment we must know the basics of the mechanical refrigeration cycle. Mechanical refrigeration is the process of using a volatile fluid (refrigerant) to absorb heat from a lower temperature place, raising the fluid's pressure and temperature so it can be rejected to a higher temperature place.

Mechanical refrigeration is used for two major types of markets; Comfort, where we cool and dehumidify to keep people comfortable, and Process, where we control the temperature and humidity for products or processes.

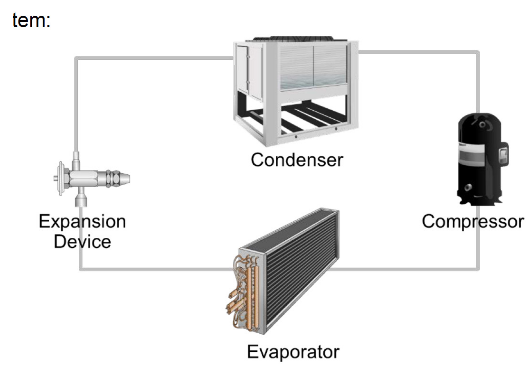
Key Concepts

- A fluid's boiling point where it evaporates from a gas to a liquid or condenses from a liquid to a gas is a function of its pressure. Higher pressures have higher boiling points. For example, at sea level (0 psig) water boils at 212°F but in the mile-high city of Denver, CO, water boils at 202°F. If we take that same pound of water and pressurize it to 50 psig, we can get the water to boil at 298°F.
- We use evaporation and condensation because of the much higher energy required to change the state of matter. For example, it takes 1 Btu to raise a pound of water 1°F, but 970 Btu to change that pound of water from liquid to steam or from steam to liquid.
- Refrigerants are fluids that change state at temperatures and pressures suitable for the comfort or process application.
- Heat flows from high temperature to low temperature. The refrigeration cycle provides a means for heat to flow from the building (load) to the ambient air, even when the building temperature is lower than the ambient temperature.

Components:

There are four main components in any refrigeration system:

Evaporator: This is where low pressure liquid refrigerant evaporates into a gas. The heat required to boil the refrigerant typically comes from the building load side; air or water which in turn cools down.



Condenser: This is where high pressure refrigerant gas condenses back into a highpressure liquid. The heat required to condense the refrigerant typically comes from air or water which in turn is exhausted into the ambient air.

Expansion Device: This is usually a thermal expansion valve or other metering device that controls the flow of liquid refrigerant from the discharge side of the condenser to the inlet of the evaporator.

Compressor: This is the heart of the refrigeration system. It takes low pressure gas from the outlet side of the evaporator and compresses it, raising the pressure and boiling point to a level where it can be condensed in the condenser.

There are other minor components of the refrigeration system; Evaporator fans, condenser fans, pumps, refrigerant piping and pipe specialties, operating and safety controls, etc.

The refrigerant lines that connect the four major components are commonly refered to as:

Suction Line: This line carries low pressure refrigerant vapor from the discharge side of the evaporator to the inlet of the compressor. This line is typically insulated to prevent condensation.

Hot Gas Line: This line carries high pressure vapor from the discharge side of the compressor to the inlet of the condenser

Liquid Line: This line carries liquid refrigerant from the outlet of the condenser to the inlet of the expansion device.

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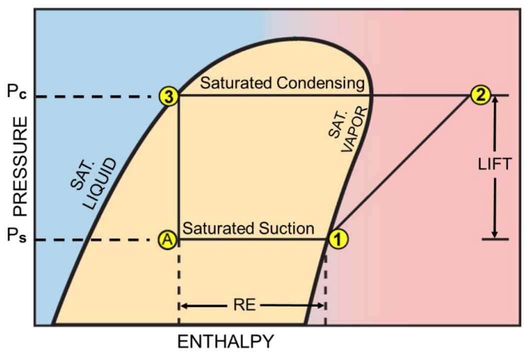
Pressure-Enthalpy Diagram



The image to the right is a typical pressure-enthalpy (P-H) diagram for refrigerant. Everything to the left in blue is 100% liquid and everything to the right in red is 100% vapor. The yellow region is a mixture of liquid and vapor.

It is common to divide the refrigeration cycle into two pressures ranges: High side, marked with Pc for condensing pressure and low side, marked with Ps for suction pressure.

For a common comfort application, the lowpressure side would have a boiling point of 40 to 45°F where we could cool air or water returning from the building. The high pressure side would have a boiling point of 95 to 100+°F where we could condense the refrigeration with relatively "cool" ambient air or water from a cooling tower.

The evaporation effect occurs on the low pressure side from A to 1. This is marked "RE" for refrigeration effect and is the useful work done in the system.

Refrigerant gas enters the compressor at point 1 and the compressor increases the refrigerant pressure to point 2 where it enters the condenser. This is the work required to create the refrigeration effect. If we can reduce the lift, we can reduce the energy input and increase the efficiency of the system.

The refrigerant condenses back to a high pressure liquid in the condenser from points 2 to 3. The expansion device drops the pressure from point 3 to point A. Some of the liquid flashes to a gas, cooling the remaining liquid refrigerant.There are two additional processes that are not shown on this chart:

- **Superheat:** Because liquid does not compress, we want to avoid sucking liquid refrigerant droplets into the compressor. So we move point 1 to the right to assure all the refrigerant is in a gaseous state when it enters the compressor.
- **Subcooling:** To increase the refrigeration effect and improve the overall efficiency, we subcool the refrigerant by moving point 3 to the left. We'd also like to have 100% liquid to the inlet side of the expansion device for better control.

Any questions on this, please contact the Engineering Department.

Thanks,

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