B.tech Ag .Engg. Second Sem. Thermodynamics, Refrigeration and Air Conditioning Lectura 8- By- Yogesh Kumar

Topic- Vapour Compression Refrigeration cycle-

The **Vapor Compression Refrigeration Cycle involves four components:** compressor, condenser, expansion valve/throttle valve and evaporator.

It is a compression process, whose aim is to raise the refrigerant pressure, as it flows from an evaporator. The high-pressure refrigerant flows through a condenser/heat exchanger before attaining the initial low pressure and going back to the evaporator. A more detailed explanation of the steps is as explained below.

STEP 1: **COMPRESSION** -**The refrigerant (for example R-717) enters the compressor at low temperature and low pressure. It is in a gaseous state. Here,** compression takes place to raise the temperature and refrigerant pressure**. The refrigerant leaves the compressor and enters to the condenser. Since this process requires work, an electric motor may be used. Compressors themselves can be scroll, screw, centrifugal or reciprocating types.**

STEP 2: **CONDENSATION-** The condenser is essentially a heat exchanger. **Heat is transferred from the refrigerant to a flow of water.** This water goes to a cooling tower for cooling in the case of water-cooled condensation. Note that seawater and air-cooling methods may also play this role. As the refrigerant flows through the condenser, it is in a constant pressure.

STEP 3: **THROTTLING AND EXPANSION- When the refrigerant enters the throttling valve, it expands and releases pressure.** Consequently, the temperature drops at this stage. **Because of these changes, the refrigerant leaves the throttle valve as a liquid vapor mixture, typically in proportions of around 75 % and 25 % respectively.**

Throttling valves play two crucial roles in the vapor compression cycle. First, they maintain a pressure differential between low- and high-pressure sides. Second, they control the amount of liquid refrigerant entering the evaporator.

STEP 4: **EVAPORATION-** At this stage of the Vapor Compression Refrigeration Cycle, the refrigerant is at a lower temperature than its surroundings. Therefore, **it evaporates and absorbs latent heat of vaporization**. Heat extraction from the refrigerant happens at low pressure and temperature. Compressor suction effect helps maintain the low pressure.

There are different evaporator versions in the market, but the major classifications are liquid cooling and air cooling, depending whether they cool liquid or air respectively.

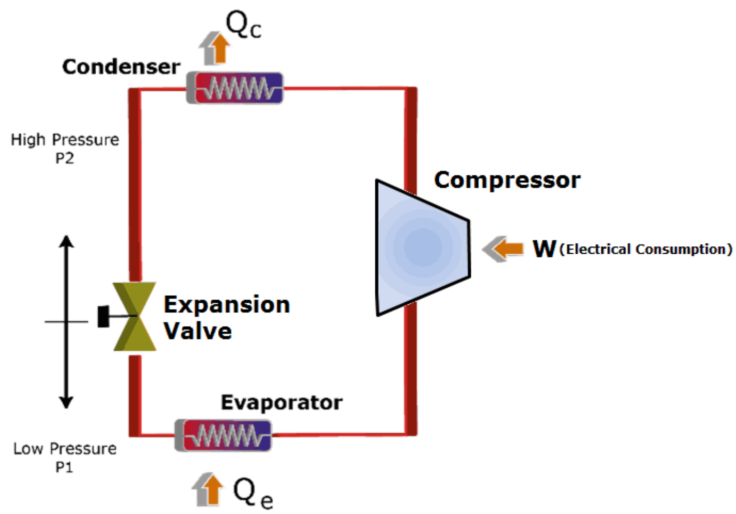


Fig 1: Schematic Representation of the Steps

Vapor-compression refrigeration, Vapour-compression refrigeration or vapor-compression refrigeration system (VCRS), in which the refrigerant undergoes phase changes, is one of the many refrigeration cycles and is the most widely used method for air-conditioning of buildings and automobiles. It is also used in domestic and commercial refrigerators, large-scale warehouses for chilled or frozen storage of foods and meats, refrigerated trucks and railroad cars, and a host of other commercial and industrial services. Oil refineries, petrochemical and chemical processing plants, and natural gas processing plants are among the many types of industrial plants that often utilize large vapor-compression refrigeration systems. Cascade refrigeration systems may also be implemented using 2 compressors.

☑ **Description of the vapor-compression refrigeration system--**

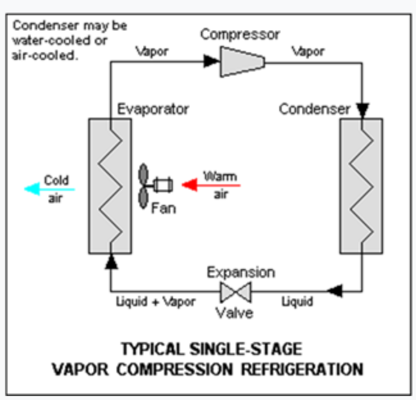
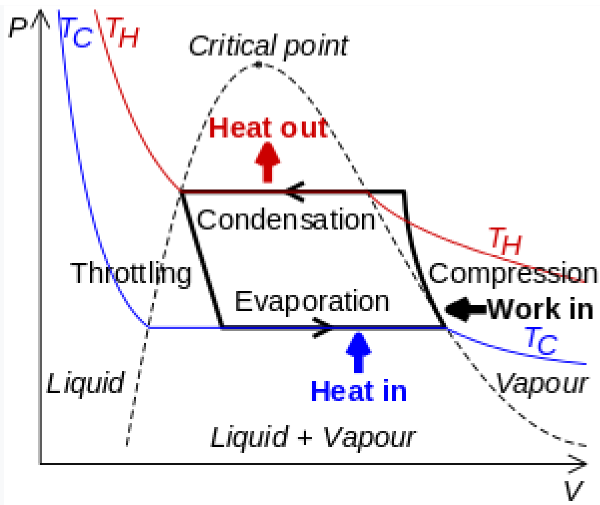


Figure 1: Vapor compression refrigeration

Vapor-compression uses a circulating liquid refrigerant as the medium which absorbs and removes heat from the space to be cooled and subsequently rejects that heat elsewhere. Figure 1 depicts a typical, single-stage vapor-compression system. All such systems have four components: a compressor, a condenser, a thermal expansion valve (also called a throttle valve or metering device), and an evaporator. Circulating refrigerant enters the compressor in the thermodynamic state known as a saturated vapor[2] and is compressed to a higher pressure, resulting in a higher temperature as well. The hot, compressed vapor is then in the thermodynamic state known as a superheated vapor and it is at a temperature and pressure at which it can be condensed with either cooling water or cooling air flowing across the coil or tubes. This is where the circulating refrigerant rejects heat from the system and the rejected heat is carried away by either the water or the air (whichever may be the case).



A fictitious pressure-volume diagram for a typical refrigeration cycle

The condensed liquid refrigerant, in the thermodynamic state known as a saturated liquid, is next routed through an expansion valve where it undergoes an abrupt reduction in pressure. That pressure reduction results in the adiabatic flash evaporation of a part of the liquid refrigerant. The auto-refrigeration effect of the adiabatic flash evaporation lowers the temperature of the liquid and vapor refrigerant mixture to where it is colder than the temperature of the enclosed space to be refrigerated. The cold mixture is then routed through the coil or tubes in the evaporator. A fan circulates the warm air in the enclosed space across the coil or tubes carrying the cold refrigerant liquid and vapor mixture. That warm air evaporates the liquid part of the cold refrigerant mixture. At the same time, the circulating air is cooled and thus lowers the temperature of the enclosed space to the desired temperature. The evaporator is where the circulating refrigerant absorbs and removes heat which is subsequently rejected in the condenser and transferred elsewhere by the water or air used in the condenser. To complete the refrigeration cycle, the refrigerant vapor from the evaporator is again a saturated vapor and is routed back into the compressor. Over time, the evaporator may collect ice or water from ambient humidity. The ice is melted through defrosting. The water from the melted ice or the evaporator then drips into a drip pan, and the water is carried away by gravity or by a pump.

Thermodynamic analysis of the system

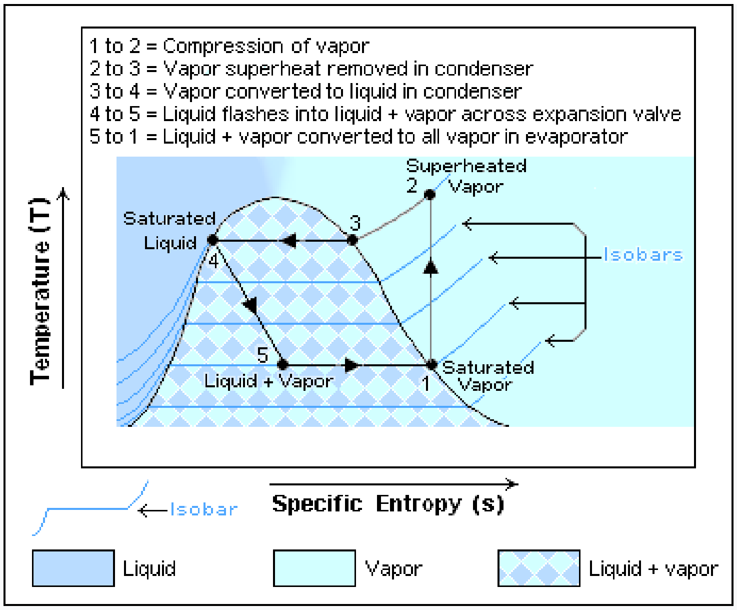


Figure 2: Temperature–Entropy diagram

The thermodynamics of the vapor compression cycle can be analyzed on a temperature versus entropy diagram as depicted in Figure 2. At point 1 in the diagram, the circulating refrigerant enters the compressor as a saturated vapor. From point 1 to point 2, the vapor is isentropically compressed (compressed at constant entropy) and exits the compressor as a superheated vapor. Superheat is the amount of heat added above the boiling point. From point 2 to point 3, the vapor travels through part of the condenser which removes the superheat by cooling the vapor. Between point 3 and point 4, the vapor travels through the remainder of the condenser and is condensed into a saturated liquid. The condensation process occurs at essentially constant pressure. Between points 4 and 5, the saturated liquid refrigerant passes through the expansion valve and undergoes an abrupt decrease of pressure. That process results in the adiabatic flash evaporation and auto-refrigeration of a portion of the liquid (typically, less than half of the liquid flashes). The adiabatic flash evaporation process is isenthalpic (occurs at constant enthalpy). Between points 5 and 1, the cold and partially vaporized refrigerant travels through the coil or tubes in the evaporator where it is totally vaporized by the warm air (from the space being refrigerated) that a fan circulates across the coil or tubes in the evaporator. The evaporator operates at essentially constant pressure and boils off all available liquid there after adding 4–8 kelvins of superheat to the refrigerant in order to make sure the liquid has evaporated completely. This is a safeguard for the compressor, as it cannot pump liquid. The resulting refrigerant vapor returns to the compressor inlet at point 1 to complete the thermodynamic cycle.

The above discussion is based on the ideal vapor-compression refrigeration cycle which does not take into account real world items like frictional pressure drop in the system, slight internal irreversibility during the compression of the refrigerant vapor, or non-ideal gas behavior (if any).