Fundamentals of Refrigeration and Air Conditioning

المرحلة الثانية

محاضرة رقم (7)

التبريد

Refrigeration

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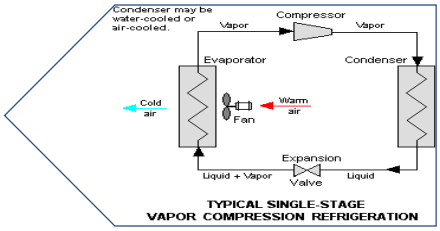
Lecture 7
Refrigeration



TYPICAL SINGLE-STAGE VAPOR COMPRESSION REFRIGERATION

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1. Refrigeration Concept

- **Refrigeration** is a process in which work is done to move heat from one location to another.
- The work of heat transport is traditionally driven by mechanical work, but can also be driven by heat, magnetism, electricity, laser, or other means.
- Refrigeration has many applications, including, but not limited to: household refrigerators, industrial freezers, cryogenics, and air conditioning.
- Heat pumps may use the heat output of the refrigeration process, and also may be designed to be reversible, but are otherwise similar to refrigeration units.

- Refrigeration has had a large impact on industry, lifestyle, agriculture and settlement patterns. The idea of preserving food dates back to the ancient Roman and Chinese empires. However, refrigeration technology has rapidly evolved in the last century, from ice harvesting to temperature-controlled rail cars.

2. Methods of refrigeration

Non-cyclic refrigeration

- In non-cyclic refrigeration, cooling is accomplished by melting ice or by subliming dry ice (frozen carbon dioxide). These methods are used for small-scale refrigeration such as in laboratories and workshops, or in portable coolers
- Ice owes its effectiveness as a cooling agent to its melting point of 0 °C (32 °F) at sea level. To melt, ice must absorb 333.55 kJ/kg (about 144 Btu/lb) of heat. Foodstuffs maintained near this temperature have an increased storage life.
- Solid carbon dioxide has no liquid phase at normal atmospheric pressure, and sublimes directly from the solid to vapor phase at a temperature of -78.5 °C (-109.3 °F), and is effective for maintaining products at low temperatures during sublimation. Systems such as this where the refrigerant evaporates and is vented to the atmosphere are known as "*total loss refrigeration*".

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Cyclic refrigeration

- This consists of a refrigeration cycle, where heat is removed from a low-temperature space or source and rejected to a high-temperature sink with the help of external work.
- *A refrigeration cycle* describes the changes that take place in the refrigerant as it alternately absorbs and rejects heat as it circulates through a refrigerator. It is also applied to HVACR work, when describing the "process" of refrigerant flow through an HVACR unit, whether it is a packaged or split system.
- Heat naturally flows from hot to cold. Work is applied to cool a living space or storage volume by pumping heat from a lower temperature heat source into a higher temperature heat sink. Insulation is used to reduce the work and energy needed to achieve and maintain a lower temperature in the cooled space. The operating principle of the refrigeration cycle was described mathematically by Sadi Carnot in 1824 as a heat engine.

- The most common types of refrigeration systems use the reverse-Rankine vapor-compression refrigeration cycle, although absorption heat pumps are used in a minority of applications.
- Cyclic refrigeration can be classified as:

1. Vapor cycle, and
2. Gas cycle

- Vapor cycle refrigeration can further be classified as:

1. Vapor-compression refrigeration
2. Vapor-absorption refrigeration

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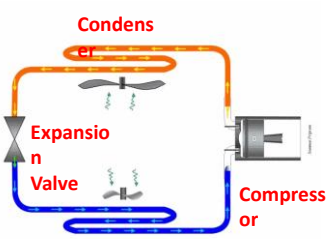
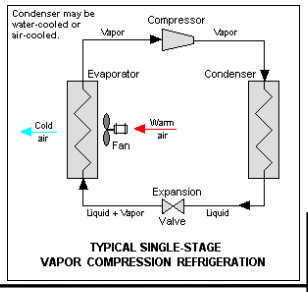
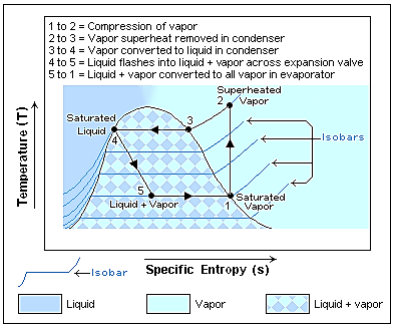
3. Vapor-compression cycle

- The vapor-compression cycle is used in most household refrigerators as well as in many large commercial and industrial refrigeration systems. Figure provides a schematic diagram of the components of a typical vapor-compression refrigeration system.





- The thermodynamics of the cycle can be analyzed on a diagram as shown in Figure .
- In this cycle, a circulating refrigerant such as Freon enters the compressor as a vapor. From point 1 to point 2, the vapor is compressed at constant entropy and exits the compressor as a vapor at a higher temperature, but still below the vapor pressure at that temperature.
- From point 2 to point 3 and on to point 4, the vapor travels through the condenser which cools the vapor until it starts condensing, and then condenses the vapor into a liquid by removing additional heat at constant pressure and temperature.
- Between points 4 and 5, the liquid refrigerant goes through the expansion valve (also called a throttle valve) where its pressure abruptly decreases, causing flash evaporation and auto-refrigeration of, typically, less than half of the liquid.
- That results in a mixture of liquid and vapor at a lower temperature and pressure as shown at point 5. The cold liquid-vapor mixture then travels through the evaporator coil or tubes and is completely vaporized by cooling the warm air (from the space being refrigerated) being blown by a fan across the evaporator coil or tubes. The resulting refrigerant vapor returns to the compressor inlet at point 1 to complete the thermodynamic cycle.



4. Vapor absorption cycle

- In the early years of the twentieth century, the vapor absorption cycle using water-ammonia systems was popular and widely used.

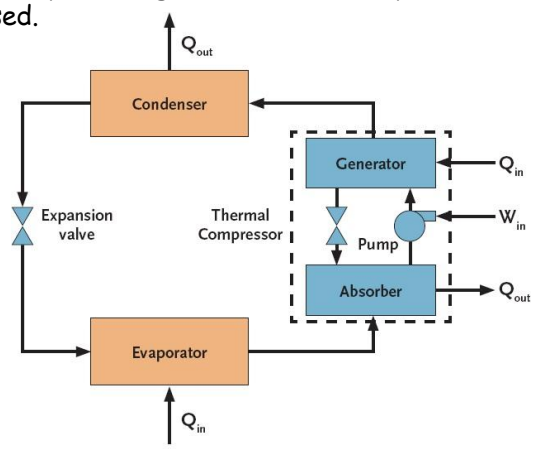


Figure 1 Basic absorption cycle

- After the development of the vapor compression cycle, the vapor absorption cycle lost much of its importance because of its low coefficient of performance (about one fifth of that of the vapor compression cycle).
- Today, the vapor absorption cycle is used mainly where fuel for heating is available but electricity is not, such as in recreational vehicles that carry LP gas (**liquid petroleum gas)** . It is also used in industrial environments where plentiful waste heat overcomes its inefficiency.

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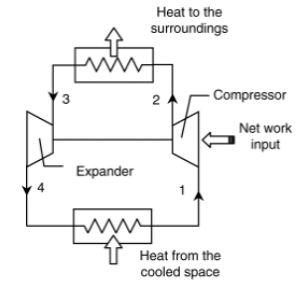
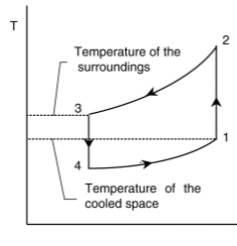
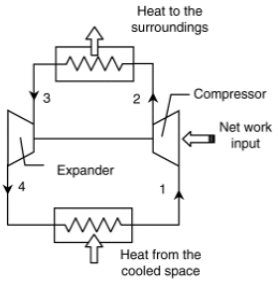
5. Gas cycle

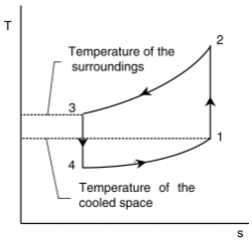
- When the working fluid is a gas that is compressed and expanded but doesn't change phase, the refrigeration cycle is called a *gas cycle*.
- Air is most often this working fluid. As there is no condensation and evaporation intended in a gas cycle, components corresponding to the condenser and evaporator in a vapor compression cycle are the hot and cold gas-to-gas heat exchangers in gas cycles.





- The gas cycle is less efficient than the vapor compression cycle because the gas cycle works on the reverse **Brayton cycle** instead of the reverse **Rankine cycle**.
- As such the working fluid does not receive and reject heat at constant temperature. In the gas cycle, the refrigeration effect is equal to the product of the specific heat of the gas and the rise in temperature of the gas in the low temperature side. Therefore, for the same cooling load, a gas refrigeration cycle needs a large mass flow rate and is bulky.





- Because of their lower efficiency and larger bulk, *air cycle* coolers are not often used nowadays in terrestrial cooling devices.
- However, the air cycle machine is very common on gas turbine-powered jet aircraft as cooling and ventilation units, because compressed air is readily available from the engines' compressor sections. Such units also serve the purpose of pressurizing the aircraft.

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