Salahaddin University - Erbil

College of Agricultural Sciences Engineering

Food Technology Department

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**Lecture 5 \ Refrigeration**

Cooling is a fundamental operation in food processing and preservation. Removal of heat could involve either the transfer of eat from one fluid to another or from a solid to a fluid, or it could be accomplished by adiabatic vaporization from liquid water. Knowledge of the principles of heat transfer is an essential prerequisite to the understanding of the design and operation of refrigeration systems.

When heat has to be removed from a system continuously, at temperatures below ambient and for prolonged periods, a mechanical refrigeration system acts as a pump that extracts heat at low temperatures and transfers this heat to another part of the system where it is eventually dissipated to the surroundings at a higher temperature. The operation requires energy, and a well-designed system will allow the maximum removal of heat at minimum energy cost.

**Refrigerants:**

 Refrigerant is a fluid that is continuously recirculated through the refrigeration system to maintain the high and low temperature.

**The Refrigeration Cycle**

The following figure shows a schematic diagram of a mechanical refrigeration system. The heart of the system is the compressor. When the compressor is operating, refrigerant gas is drawn into the compressor continuously. Low pressure is maintained at the suction side, and because of the low pressure, the refrigerant can vaporize at a low temperature. In the compressor, the refrigerant gas is compressed increasing in both pressure and temperature during the process. The hot refrigerant gas then flows into a heat exchange coil called the condenser where heat is released in the process of condensation at constant pressure and temperature. From the condenser, the liquid refrigerant flows into a liquid refrigerant holding tank. In small systems, there may be no holding tank, and the refrigerant just continuously cycles through the system.



**The Refrigeration Cycle as a Series of Thermodynamic Processes:**

Starting from the compressor in the figure above, low-pressure gas is compressed adiabatically to high pressure, which should allow condensation at ambient temperature. Work is required to carry out this process, and this energy is supplied in the form of electrical energy to drive the compressor motor. The gas also gains in enthalpy during this compression process. At the condenser, the gas condenses and transfers the latent heat of condensation to the surroundings. There is a loss of enthalpy in a constant pressure process. At the expansion valve, the liquid expands to low pressure at constant enthalpy, while at the evaporator, the liquid evaporates at constant pressure and gains in enthalpy. The two processes crucial to the efficiency of the refrigeration system are the adiabatic compression process where energy is applied and the isobaric expansion process where energy is extracted by the refrigerant from the system. Here, the ratio of enthalpy change to work in adiabatic compression of an ideal gas is equal to the specific heat ratio.

$$\frac{∆H}{W}= -γ ;W= -\frac{∆H}{γ}$$

The negative sign indicates that energy is being used on the system.

**The Refrigeration Cycle on the Pressure/Enthalpy Diagram for a Given Refrigerant:**

The thermodynamic properties of refrigerants when plotted on a pressure-enthalpy diagram result in a plot that is useful in determining capacities and power requirement for a refrigeration system.



The figure above is a schematic diagram of a refrigeration cycle on a pressure-enthalpy diagram. The diagram consists of lines representing the vapor and liquid pressure-enthalpy relationship, lines representing change in enthalpy with pressure during adiabatic compression (constant entropy), and in some charts, lines representing specific volumes at various pressures and enthalpies.

Point A in the figure represents the liquid refrigerant at high pressure entering the expansion valve. The refrigerant expands at constant enthalpy (HL) as it goes through the expansion valve and leaves the valve as a mixture of liquid and vapor at a lower pressure, represented by point B. As the refrigerant absorbs heat in the evaporator, it gains in enthalpy represented by the line BC. The refrigerant leaves the evaporator as saturated vapor (represented by point C) having the enthalpy Hcv. The compressor raises the pressure, and the change is represented by the line CD that parallels the lines of constant entropy. As

the compressed refrigerant gas leaves the compressor at point D, it will have an enthalpy represented by Hhv. At the condenser, heat is dissipated resulting in a drop in enthalpy represented by line AD. The liquid refrigerant leaves the condenser with the pressure and enthalpy represented by point A. The cooling capacity of the refrigeration system is represented by the length of line BC:

 Cooling capacity = Hcv – HL

The condenser heat exchange requirement or condenser duty is represented by the length of line AD:

 Condenser duty = Hhv – HL­

The change in enthalpy due to compression ΔHc is:

 ∆Hc = Hhv – Hcv

**The Condenser and Evaporator:**

Most refrigeration systems transfer heat between the refrigerant and air. Because heat transfer coefficients to air are usually very low, the air film resistance controls the rate of heat transfer. Very large heat transfer areas would be required to achieve the necessary heat transfer rate. To accomplish the necessary heat transfer rate and still have equipment that is reasonably sized, the heat transfer surface area of the tubes that comprise the evaporator or condenser coil is increased by the use of fins.