COLLEGE OF ENGINEERING & TECHNOLOGY

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AI3001 REFRIGERATION AND COLD STORAGE

UNIT I

Refrigeration is the science of producing and maintaining temperatures below that of the surrounding atmosphere. This means the removing of heat from a substance to be cooled. Heat always passes downhill, from a warm body to a cooler one, until both bodies are at the same temperature. Maintaining perishables at their required temperatures is done by refrigeration.

Important refrigeration applications:

• 1. Ice making

• 2. Transportation of foods above and below freezing

• 3. Industrial air-conditioning

• 4. Comfort air-conditioning

• 5. Chemical and related industries

• 6. Medical and surgical aids

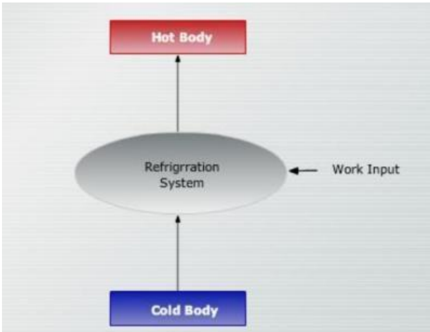
• Processing food products and beverages

• 8. Oil refining and synthetic rubber manufacturing

• 9. Manufacturing and treatment of metals

• 10. Freezing food products

The principle of refrigeration is based on second law of thermodynamics. It states that heat does not flow from a low temperature body to a high temperature body without the help of an external work.



Net Refrigeration effect

NRE is defined as the product of the mass flow rate of the cooling medium (water or brine) and the difference in enthalpy between the entering and leaving fluid. This metric is typically expressed in heat units per unit of time, allowing HVAC professionals to gauge the effectiveness of their cooling systems accurately. Net Refrigerating Effect (NRE) is crucial for optimizing the efficiency of cooling systems. The NRE represents the rate at which heat is removed from a cooling medium—often a secondary coolant such as water or brine—by the primary refrigerant in a refrigeration cycle.

The formula can be expressed as:

NRE = ṁ × (h_in - h_out)

Where:

ṁ = mass flow rate of the coolant (kg/s)
h_in = enthalpy of the incoming coolant (kJ/kg)
h_out = enthalpy of the outgoing coolant (kJ/kg)

In refrigeration, **COP (Coefficient of Performance)** measures efficiency, defined as the ratio of desired cooling (heat removed from cold space) to the work input (energy used by compressor). A higher COP means better efficiency, requiring less electricity for the same cooling, calculated as

$$COP = \frac{Q_{cold}}{W_{in}},$$

One tonne of refrigeration

It's defined as the amount of heat required to freeze one ton of water at 0°C (32°F) into ice at the same temperature over a 24-hour period.

COMPRESSOR

A compressor is the most important and often the costliest component (typically 30 to 40 percent of total cost) of any vapour compression refrigeration system (VCRS). The function of a compressor in a VCRS is to continuously draw the refrigerant vapour from the evaporator, so that a low pressure and low temperature can be maintained in the evaporator at which the refrigerant can boil extracting heat from the refrigerated space. The compressor then has to raise the pressure of the refrigerant to a level at which it can condense by rejecting heat to the cooling medium in the condenser.

CLASSIFICATION OF COMPRESSORS

Compressors used in refrigeration systems can be classified in several ways: a) Based on the working principle:

i. Positive displacement type ii. Roto-dynamic type

In positive displacement type compressors, compression is achieved by trapping a refrigerant vapour into an enclosed space and then reducing its volume. Since a fixed amount of refrigerant is trapped each time, its pressure rises as its volume is reduced. When the pressure rises to a level that is slightly higher than the condensing pressure, then it is expelled from the enclosed spaceand a fresh charge of low-pressure refrigerant is drawn in and the cycle continues. Since the flow of refrigerant to the compressor is not steady, the positive displacement type compressor is a pulsating flow device. However, since the operating speeds are normally very high the flow appears to be almost steady on macroscopic time scale. Since the flow is pulsating on a microscopic time scale, positive displacement type compressors are prone to high wear, vibration and noise level.

Depending upon the construction, positive displacement type compressors used in refrigeration and air conditioning can It is classified into: i. Reciprocating type ii. Rotary type with sliding vanes (rolling piston type or multiple vane type) iii. Rotary screw type (single screw or twin-screw type) iv. Orbital compressors, and v. Acoustic compressors.

b) Based on arrangement of compressor motor or external drive: i. Open type ii. Hermetic (or sealed) type iii. Semi-hermetic (or semi-sealed) type

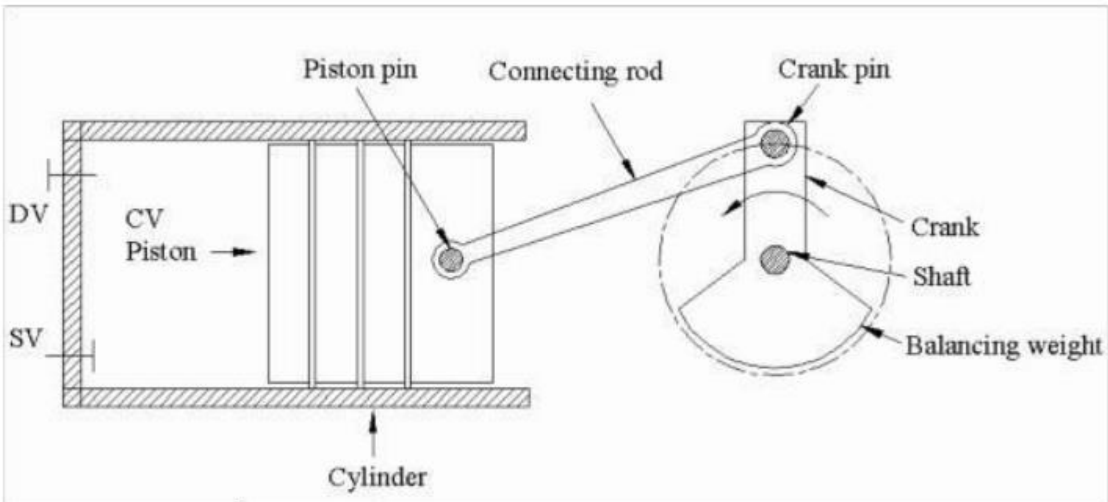
In open type compressors the rotating shaft of the compressor extends through a seal in the crankcase for an external drive. The external drive may be an electrical motor or an engine (e.g. diesel engine). The compressor may be belt driven or gear driven. Open type compressors are normally used in medium to large capacity refrigeration system for all refrigerants and for ammonia (due to its incompatibility with hermetic motor materials).

Open type compressors are characterized by high efficiency, flexibility, better compressor cooling and service ability. However, since the shaft has to extend through the seal, refrigerant leakage from the system cannot be eliminated completely. Hence refrigeration systems using open type compressors require a refrigerant reservoir to take care of the refrigerant leakage for some time, and then regular maintenance for charging the system with refrigerant, changing of seals, gaskets etc. In hermetic compressors, the motor and the compressor are enclosed in the same housing to prevent refrigerant leakage. The housing has welded connections for refrigerant inlet and outlet and for power input socket. As a result of this, there is virtually no possibility of refrigerant leakage from the compressor. All motors reject a part of the power supplied to it due to eddy currents and friction, that is, inefficiencies. Similarly the compressor also gets heated-up due to friction and also due to temperature rise of the vapor during compression.

In Open type, both the compressor and the motor normally reject heat to the Surrounding air for efficient operation. In hermetic compressors heat cannot be rejected to the surrounding air since both are enclosed in a shell. Hence, the cold suction gas is made to flow over the motor and the compressor before entering the compressor. This keeps the motor cool. The motor winding is in direct contact with the refrigerant hence only those refrigerants, which have high dielectric strength, can be used in hermetic compressors. The cooling rate depends upon the flow rate of the refrigerant, its temperature and the thermal properties of the refrigerant. If flow rate is not sufficient and/or if the temperature is not low enough the insulation on the winding of the motor can burn out and short-circuiting may occur. Hence, hermetically sealed compressors give satisfactory and safe performance over a very narrow range of design temperature and should not be used for off-design

Reciprocating compressors:

Reciprocating compressor is the workhorse of the refrigeration and air conditioning industry. It is the most widely used compressor with cooling capacities ranging from a few Watts to hundreds of kilowatts. Modern day reciprocating compressors are high speed (≈ 3000 to 3600 rpm), single acting,single or multi-cylinder (upto 16 cylinders) type. Reciprocating compressors consist of a piston moving back and forth in a cylinder, with suction and discharge valves to achieve suction and compression of the refrigerant vapor.



construction and working are somewhat similar to a two-stroke engine, as suction and compression of the refrigerant vapor are completed in one revolution of the crank. The suction side of the compressor is connected to the exit of the evaporator, while the discharge side of the compressor is connected to the condenser inlet. The suction (inlet) and the discharge (outlet) valves open and close due to pressure differences between the cylinder and inlet or outlet manifolds respectively. The pressure in the inlet manifold is equal to or slightly less than the evaporator pressure. Similarly the pressure in the outlet manifold is equal to or slightly greater than the condenser pressure. The purpose of the manifolds is to provide stable inlet and outlet pressures for the smooth operation of the valves and also provide a space for mounting the valves. The valves used are of reed or plate type, which are either floating or clamped. Usually, backstops are provided to limit the valve displacement and springs may be provided for smooth return after opening or closing. The piston speed is decided by valve type. Too high a speed will give excessive vapour velocities that will decrease the volumetric efficiency and the throttling loss will decrease the compression efficiency.

Rolling piston (fixed vane) type compressors:

Rolling piston or fixed vane type compressors are used in small refrigeration systems (upto 2kW capacity) such as domestic refrigerators or air conditioners. These compressors belong to the class of positive displacement type as compression is achieved by reducing the volume of the refrigerant. In this type of compressors, the rotating shaft of the roller has its axis of rotation that matches with the center line of the cylinder, however, it is eccentric with respect to the roller. This eccentricity of the shaft with respect to the roller creates suction and compression of the refrigerant as shown in Fig.20.1.

A single vane or blade is positioned in the non-rotating cylindrical block. The rotating motion of the roller causes a reciprocating motion of the single vane.

Agricultural Refrigeration

Agricultural refrigeration is the process of removing heat from agricultural products to slow down biological, chemical, and physical changes that lead to spoilage. It plays a vital role in maintaining the quality, safety, and shelf life of perishable commodities such as fruits, vegetables, dairy products, meat, fish, and flowers.

• Purpose and Importance

• Preservation of Quality: Reduces metabolic activity, respiration rate, and moisture loss in fresh produce.

• Extension of Shelf Life: Slows down microbial growth and enzymatic reactions.

• Reduction in Post-Harvest Losses: Minimizes spoilage during storage, transport, and distribution.

• Market Flexibility: Allows storage for longer periods, enabling supply when demand or prices are favorable.

• Food Safety: Inhibits the growth of harmful bacteria and pathogens.

• Applications in Agriculture

• Cold Storage of Produce:

• Fruits (apples, grapes, mangoes)

• Vegetables (potatoes, onions, tomatoes)

• Dairy and Meat Processing:

• Milk chilling, cheese maturation, meat freezing

• Seed Preservation:

• Storing seeds under controlled temperature and humidity

• Floriculture:

• Refrigerated storage of flowers to extend freshness

• Transport:

• Refrigerated trucks and containers for long-distance movement