In the stacking process the robot places flat parts on top of each other, where the vertical location of the drop-off position is continuously changing with cycle time. In the insertion process robot inserts parts into the compartments of a divided carton.

Module – V

Refrigeration

Lecture 26:

Objective: Introduction to refrigeration and discussing its principle.

Introduction

Refrigeration is the art and science of maintaining a space at a temperature lower than the surrounding temperature. The device, which is used for this purpose, is the refrigerator. Food stuff, medical supplies and other important products have to be kept cool to stay fresh and usable. The bacteria and enzymatic activity are responsible for degradation of food stuffs and other products. So, by cooling or reducing the temperature of these products, the growth of bacteria and enzymatic activity can be reduced. This helps to preserve the products for longer time.

Definition:

It can be defined as the process of transferring heat from a low temperature region to a high temperature region. In other words, it is the process of cooling a substance. This can be achieved only if the heat is removed from the substance.

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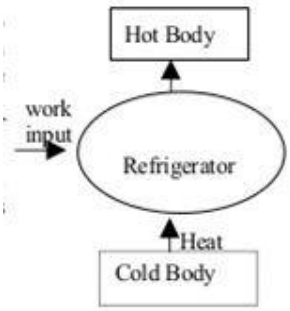
Principle of refrigeration

Refrigeration chamber has to be maintained at a temperature lower than the surrounding temperature. Due to temperature difference there is a tendency for the heat to flow from the surrounding to the refrigerated chamber, which result in an increase in the temperature of the chamber. In order to maintain low temperature in the chamber, heat has to be removed from the chamber to the surroundings at a rate equal to the rate at which heat is leaking into it. But heat cannot flow from a cold body to a hot body spontaneously.



Principle of Refrigeration

We need to have a third body which acts as a medium for heat transfer between the chamber and the surrounding. When the medium comes in contact with the chamber its temperature should be less than the temperature of the chamber so that it can absorb heat from chamber. Similarly when the medium comes in contact with the surrounding, its temperature should be greater than the atmospheric temperature, so that it can reject heat to the atmosphere. The medium is usually a fluid, which is referred to as refrigerant. Heat transfer usually changes the phase of the refrigerator, i.e., when it absorbs heat it changes its phase from liquid to vapour and when it rejects heat, it changes its phase from vapour to liquid. In other words the refrigerant absorbs or rejects heat in the latent heat region.

The temperature of the refrigerant, which comes out of the refrigerated chamber, is well below the atmospheric temperature. In order to reject heat to the atmosphere, the

temperature of the refrigerant should be raised above that of the surrounding. We can achieve this by either compressing the refrigerant to a high pressure (vapour compression cycle), or by dissolving the vapour in a liquid, increasing the pressure of the liquid and then heating the liquid to give off vapour at high pressure and temperature (vapour absorption refrigeration cycle).

Lecture 27:

Objective: Discussion about refrigerant and its properties.

In a refrigerator, a medium which continuously extracts the heat from the space within the refrigerator which is to be kept cool at temperatures less than the atmosphere and finally rejects that heat to the atmosphere itself is called a **refrigerant**.

List of commonly used refrigerants

- AMMONIA (NH3) – Is one of the widely used of all the refrigerants. It is highly toxic and not suitable for domestic refrigerators. It is widely used in large commercial applications like ice manufacturing plants, packaging plants, cold storage, etc.
- CARBONDIOXIDE(CO_2) – It is non-toxic, non-flammable, inexpensive and odourless gas. It is mainly used in large ships, theater air conditioning systems and similar such applications where space consideration is more important.
- SULPHUR DIOXIDE(SO_2): - It is non-flammable, non-corrosive, absorbs a lot of heat in evaporation and dissolves oil well. It was used in domestic applications in plden days, but now obsolete.
- FREON: These refrigerants are highly efficient and overcomes the disadvantages of all the above types of refrigerants.
- FREON-12(R 12) –It is used in domestic vapour compression refrigerators, water coolers, air conditioners, automobiles, etc.
- FREON-22(R 22) – It is used in large capacity plants like packaged air conditioning units where size of equipment and economy are important. It is also used for low and medium temperature refrigeration.

Properties of refrigerants

Thermodynamic properties:

- Low Boiling point- a good refrigerant should have a boiling point below the target temperature. Since boiling point is affected by pressure, refrigerants should be selected based on the operating pressures.
- Low Freezing point- so that the liquid refrigerant must not solidify under a specified pressure.
- High Latent heat of evaporation- so that heat transfer can occur with least possible circulating refrigerant.
- High critical temperature- for easy condensation of refrigerant vapour.

Physical properties:

- Low Specific volume – so that the refrigerant occupies minimum space thereby keeping the compressor capacity to a minimum and pipe diameters relatively small.
- Low liquid Specific heat and high vapour specific heat so as to increase the refrigerating effect per kg of refrigerant circulated.
- Low Viscosity- for easy circulation of the refrigerant.
- High thermal conductivity, so that heat transfer takes place easily.
- High electric insulation.

Safety working (chemical) properties:

- Nontoxic- for health and safety reasons
- Nonflammable and non-explosive to avoid risks of fire and explosion.
- Non corrosive, so that the refrigerant does not corrode the components.
- Chemical stability - non reactive, so that it does not disassociate or break down. The refrigerant has to be stable for the life time of the refrigerator.
- Miscible with lubricating oil, i.e., the refrigerant should have good mixing properties with the lubricant oil that is used to lubricate the moving parts of the compressor.

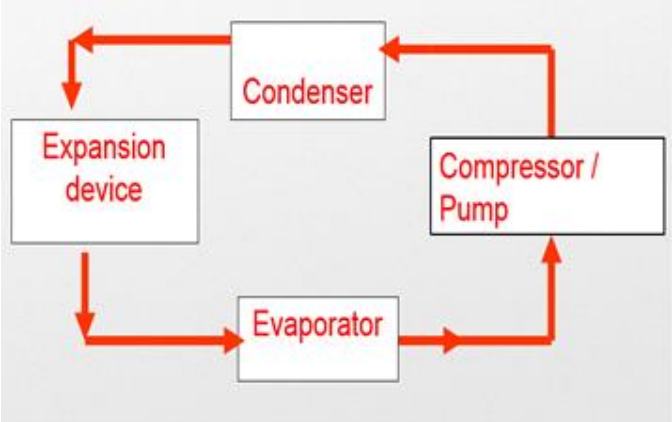
Other properties:

- Availability
- Low cost
- Ease of handling
- No impact on the ozone layer

Lecture 28:

Objective: Discussion about refrigerator parts and definitions.

Parts of a refrigerator



parts of a refrigerator

Evaporator

An evaporator is a component located inside the cabinet in which the substance has to be cooled. It consists of a serpentine or coiled set of pipes through which the refrigerant flows. The refrigerant during its flow through the coil absorbs heat from the inside of the cabinet by evaporating at low temperatures, i.e., the refrigerant after absorbing heat changes its state from liquid to vapour phase. Thus the temperature of the substance inside the cabinet is kept cold. The evaporator coils are usually made from copper aluminium due to its excellent thermal conductivity (conducts heat efficiency), and low cost.

Compressor (or) pump

A compressor is an equipment usually with a piston-cylinder arrangement, placed at the bottom portion of the refrigerator. It performs two functions:

- It compresses the vapour refrigerant to high pressures and temperatures
- It circulates the refrigerant around the circuit so that the refrigerant can perform its heat absorbing function over and over again.

  The compressor can be rotary, reciprocating or centrifugal type. Reciprocating compressors are mostly preferred compared to other types, and widely used for domestic (household) purposes and industrial applications.

Condenser

The condenser is similar in appearance to the evaporator, and is placed at the back of the refrigerator. The condenser acts like a heat exchanger, wherein the vapour refrigerant while flowing through it, gives away its heat to the cooling medium (air or water) circulating around the coils.

For large capacity refrigerators, water is used as the cooling medium and for small capacity refrigerators like the domestic refrigerator, air cooling is adopted.

Expansion/ Throttle valve

The expansion valve is a small orifice (tiny openings), which perform two functions:

- It reduces the pressure of the refrigerant as it flows through it.
- It regulates the flow of refrigerant to the evaporator.

Definitions

Coefficient of performance of refrigerator (COP)

Coefficient of performance of refrigerator is the ratio of heat absorbed in the refrigerated chamber to the work input to the compressor.

COP = Heat absorbed (**Q**)/ work input (**W)**.

COP as the name indicates is a measure of the performance of the refrigeration cycle. It is similar to the efficiency term associated with any work-developing device. Efficiency or COP cab be loosely defined as the ratio of output to input. In a refrigerator, the *output* is the desired effect, which is the heat absorbed in the refrigerated chamber, and *input* is the work input to the compressor.

Refrigerating effect

It is the amount of heat absorbed in the refrigerated chamber per unit mass of the refrigerant. More refrigerating effect means less mass of refrigerant required.

Refrigeration capacity

Refrigeration capacity is the rate at which heat is absorbed from the refrigerated chamber. Refrigeration capacity is expressed in tons of refrigeration.

One ton of refrigeration is the rate at which heat is absorbed to convert one ton (1000 kg) of water at 0^oC into ice at 0^oC, in one day.

1 ton of refrigeration = latent heat of ice x 1000 kJ/day.
= latent heat of ice x 1000/24 kJ/hr.
= latent heat of ice x 1000/ (24x60) = 210 kJ/min.
= latent heat of ice x 1000/ (24x60x60) = 3.5 kJ/s

Ton of refrigeration (TOR)

A ton of refrigeration is defined as the quantity of heat absorbed in order to form one ton of ice in 24 hours whose initial temperature of the water is 0°c.

1 ton of refrigeration= 210 KJ/min = 3.5 kJ/sec=3.5 KW

Ice making capacity: An Ice making machine is normally specified by its Ice making capacity. Ice Making Capacity is defined as the capacity of the refrigerating system to make ice beginning from water (at room temperature) to solid ice. It is usually specified by Kg/hr.

Relative coefficient of performance (RELATIVE COP)

Relative COP is defined as the ratio of actual COP to theoretical COP of a refrigerator.

Relative COP= Actual COP/ Theoretical COP

Actual COP = Q/W, where Q and W are measured during a test.

Theoretical COP= Q_{th}/W_{th} where Q_{th} and W_{th} are obtained by applying theoretical equations (laws of thermodynamics) to the refrigeration cycle.

Unit of refrigeration

Ton is the unit of refrigeration. kW is also used as the unit of refrigeration system in SI units. “Ton” is normally the unit of mass. But in refrigeration system, it is the amount of ice formed or melted in 24 hours from and at zero degrees centigrade water.

Lecture 29:

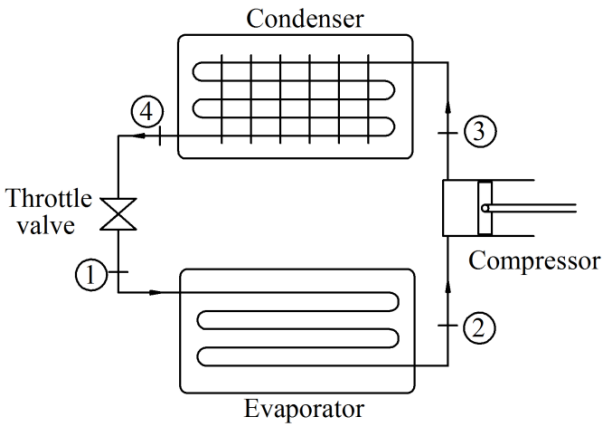
Objective: Discussion about types of refrigerators and their explanations.

Types of refrigeration systems:

There are two types of refrigerators. They are

1. Vapour compression refrigerator
2. Vapour absorption refrigerator

Vapour Compression Refrigerator:



1- Low temperature, low pressure liquid
2- Low temperature, low pressure vapour
3- High temperature, high pressure vapour
4- High temperature, high pressure liquid

Vapour compression refrigerator.

Vapour compression refrigerator consists of mainly four components – (i) Evaporator or refrigerated chamber, (ii) compressor, (iii) condenser or cooler, and (iv)Throttle valve or pressure reducing valve.

A low pressure, low temperature liquid enters the refrigerated chamber. It absorbs heat in the chamber and changes its phase from liquid to vapour. At the exit of the refrigerated chamber we have a low pressure, low temperature vapour. This vapour is taken by the compressor, which compresses it to a high pressure. Due to high compression, the temperature of the vapour rises above that of the atmosphere.

The high temperature, high-pressure vapour passes through the condenser. It loses heat to the atmosphere and changes its phase from vapour to liquid. At the exit of the condenser we have high-pressure liquid at moderate temperature. The liquid passes through a throttle valve where it suddenly expands to a low pressure. There is a sudden decrease in temperature due to decrease in pressure, and at the inlet to the refrigerated chamber we have a low pressure, low temperature liquid. Thus the cycle is completed.

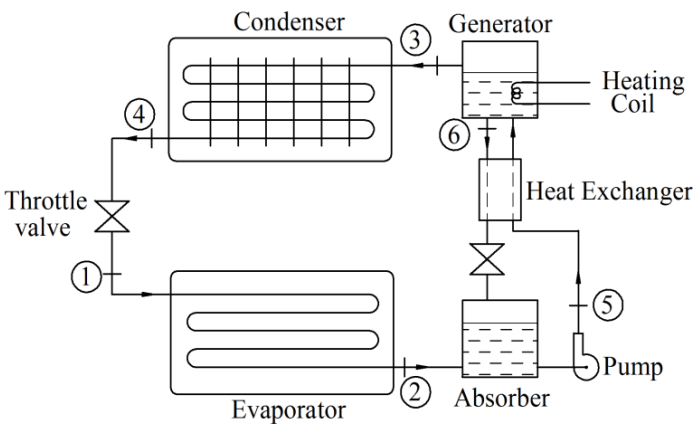
Lecture 30:

Objective: Discussion about Vapour Absorption refrigerator.

Vapour Absorption refrigerator:

In vapour absorption refrigeration system, we choose a combination of a refrigerant and solvent in such a way that the solvent absorbs large quantities of vapour refrigerant at low temperatures and gives off vapour when heated to higher temperature. Ammonia and water are such a combination.

Low pressure, low temperature ammonia liquid enters the evaporator chamber. It absorbs latent heat in the evaporator and becomes vapour. The ammonia vapour, which is at low temperature, is absorbed in water in the absorber. A pump pressurizes the ammonia solution and supplies it to the generator. The solution is heated in the generator and water gives off ammonia vapour at high temperature and pressure. This vapour is condensed in the condenser by rejection of heat to the atmosphere. The high-pressure high temperature liquid is suddenly expanded in the throttle valve to a low pressure. Sudden drop in pressure results in drop in temperature of the liquid. Then the low pressure, low temperature liquid ammonia enters the evaporator chamber, and the cycle is repeated.



1- Low temperature, low pressure liquid
2- Low temperature, low pressure vapour
3- High temperature, high pressure vapour
4- High temperature, high pressure liquid
5- Strong ammonia solution

Vapour absorption refrigerator.

In the heat exchanger, the pressurized strong ammonia solution passing from the pump to the generator recovers some amount of heat from the weak ammonia solution, which is passing from the generator to the absorber. A pressure-reducing valve is provided between the heat exchanger and the absorber to reduce the pressure of the weak ammonia solution to that of the evaporator pressure.

Comparison between Vapour Compression and Absorption refrigerators:

Sl. No.	Vapour Absorption System	Vapour Compression System
1.	Maintenance cost is less due to absence of moving parts.	Maintenance cost is more due to compressor's mopving parts.
2.	Does not depend on electric power.	Needs electric power to run compressor
3.	No chance of refrigerant leakage.	Chances of refrigerant leakage are more due to failure (wear) of reciprocating parts in the compressor.
4.	At reduced loads, the system is almost as efficient as at full load.	COP of the system decreases with increase in load.
5.	Works on heat energy	Works on mechanical energy(compressor)
6.	Since the pump is required only to circulate the refrigerant, energy required to run the pump is less.	Mechanical energy required is more, because refrigerant vapours are compressed to high pressures.
7.	The vapour refrigerant is absorbed and heated.	Vapour refrigerant is compressed.
8.	Specific refrigerants which are soluble in another solution are used as refrigerant.	There is no such restrictions for the type of refrigerant to be used.
9.	Absorption systems can be built in capacities well above 1000 Tons.	Maximum capacity is 1000 Tons.
10.	Used for food storage in recreational vehicles. Can also be used in industrial environments where plentiful waste heat is available.	Used for domestic, commercial and industrial applications.
11.	Absence of moving parts makes the system run quiet.	Noisy due to the moving parts of the compressor.