Refrigerants

Refrigerants

- The refrigerant is a **heat carrying medium** which during their cycle (i. e. compression, condensation, expansion and evaporation) in the refrigeration system absorbs heat from a low temperature system and discards the heat so absorbed to a higher temperature system.

- The natural ice and a mixture of ice and salt were the first refrigerants.
- In 1834, ether, ammonia, sulphur dioxide, methyl chloride and carbon dioxide came into use as refrigerants in compression cycle refrigeration machines.
- Most of the early refrigerant materials have been discarded for safety reasons or for lack of chemical or thermal stability.
- In the present days, many new refrigerants including halo-carbon compounds, hydro-carbon compounds are used for air conditioning and refrigeration applications.

- The suitability of a refrigerant for a certain application is determined by its physical, thermodynamic, chemical properties and by various practical factors.
- There is no one refrigerant which can be used for all types of applications i.e. there is no ideal refrigerant.
- If one refrigerant has certain good advantages, it will have some disadvantages also.
- Hence, a refrigerant is chosen which has greater advantages and less disadvantages.

Desirable properties of ideal refrigerant

- Low boiling point
- High critical temperature
- High latent heat of vapourisation
- Low specific heat of liquid
- low specific volume of vapour
- Non-corrosive to metal
- Non-flammable and non-explosive
- Non-toxic
- Low cost
- Easy to liquify at moderate pressure and temperature
- Easy of locating leaks by odour or suitable indicators

Classification of refrigerants

- **Primary refrigerants**: The refrigerants which directly take part in the refrigeration system are called as primary refrigerants
  - Halo-carbon refrigerants
  - Azeotrope refrigerants
  - Inorganic refrigerants, and
  - Hydro-carbon refrigerants

- **Secondary refrigerants**: The refrigerants which are first cooled by primary refrigerants and then used for cooling purposes are called as secondary refrigerants
  - Calcium chloride
  - Sodium chloride and
  - Glycols such as ethylene glycol, propylene glycol etc.

Halo-carbon refrigerants

- The American Society of Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) identifies 42 halo-carbon compounds as refrigerants, but only a few of them are commonly used.
- The first of the halo carbon refrigerant i.e. R-12 was developed in 1930 by Thomas Midgley.

Refrigerant No.	Refrigerant name	Chemical formula
R-11	Trichloromonofluoromethane	
R-12	Dichlorodifluoromethane	
R-13	Monochlorotrifluoromethane	
R-14	Carbontetrachloride	
R-21	Dichloromonofluoromethane	
R-22	Monochlorodifluoromethane	
R-30	Methylenechloride	
R-40	Methyl chloride	
R-100	Ethyl choride	
R-113	Trichlorotrifluoromethane	
R-114	Dichlorotetrafluoromethane	
R-115	**Monochloropentafluoroethane**	

Azeotrope refrigerants

- The term azeotrope refers to a stable mixture of refrigerants whose vapour and liquid phases retain identical compositions over a wide range of temperatures.
- However, these mixtures usually, have properties that differ from either of their components.

Refrigerant No.	Azeotrope mixing refrigerants	Chemical formula
R-500	73.8% R-12 and 26.2% R-152	
R-502	48.8% R-22 and 51.2% R-115	
R-503	40.1% R-23 and 59.9% R-13	
R-504	**48.2% R-32 and 51.8% R-115**	

Inorganic refrigerants

- The inorganic refrigerants were exclusively used before the introduction refrigerants.
- These refrigerants are still in use due to their inherent thermodynamic and physical properties.

Refrigerant No.	Chemical name	Chemical formula
R-717	Ammonia	
R-729	Air	
R-744	Carbon dioxide	
R-764	Sulphur dioxide	
R-118	Water	

Inorganic refrigerants

a) R-717 (Ammonia) - The R-717 (Ammonia) is one of the oldest and most widely used of all the refrigerants. The use of this refrigerant is extensively found in cold storage, warehouse plants, icecream manufacture, ice manufacture, beer manufacture, food freezing plants etc.

b) R-729 (Air) - The dry air is used as a gaseous refrigerant in some compression systems, particularly in air craft air conditioning.

c) R-744 (Carbon dioxide) - The principal refrigeration use of carbon dioxide is same as that of dry ice. However because of its low efficiency as compared to other common refrigerants, it is seldom used in household units, but is used in some industrial applications and abroad ships.

d) R-764 (Sulphur dioxide) - This refrigerant is produced by combustion of sulphur in air. In the former years, it is widely used in household and small commercial units. This refrigerants is not injurious to food and is used commercially as a ripener and preservative of foods. It is however injurious to flowers, plants and shrubbery.

e) R-118 (Water) - The principal refrigeration use of water is as ice. The high freezing temperature of water limits its use in vapour compression systems. It is used as the refrigerant vapour in some absoption systems and in systems with steam jet compressors.

Hydro-carbon refrigerants

- Most of the hydrocarbon refrigerants are successfully used in industrial and commercial installations.
- They possess satisfactory thermodynamic properties but are highly flammable and explosive.

Refrigerant No.	Chemical name	Chemical formula
R-170	Ethane	
R-290	Propane	
R-600	Butane	
R-1120	Trichloroethylene	
R-1130	Dichloroethylene	

Secondary refrigerants - Brines

- Brines are secondary refrigerants and are generally used where temperatures are required to be maintained below the freeing point of water i.e. 0° C.
- In case the temperature involved is above the freeing point of water i.e. 0° C, then water is commonly used as secondary refrigerant.
- Brine is a solution of a salt in water.it may be noted when a salt is mixed in water, then the freezing temperature of the solution becomes lower than that of water.
- This is due to the fact the salt while dissolving in water takes off its latent heat from the solution an cools it below the freezing point of water.

Secondary refrigerants - Brines

- The mass of the salt in the solution expressed as the percentage of the mass of the solution is known as concentration of the solution.
- As the concentration of the solution increases, its freezing point decreases.
- But if the concentration of the salt is increased beyond a certain point, the freezing point increases instead of decreasing.
- The point, at which the freezing temperature is minimum, is known as eutectic temperature and the concentration at this point is known as eutectic concentration.
- The brine used in a particular application should have a concentration for which the freezing point of the brine is at least 5°C to 8°C lower than the brine temperature required.
- The brines commonly used are calcium chloride, sodium chloride and glycols such as ethylene glycol, propylene glycol etc.

Secondary refrigerants - Brines

- The calcium chloride brine has the eutectic temperature of -55°C at salt concentration of 30% by mass. This brine is primarily used where temperatures below -18 °C are required. It is generally used in industrial process cooling and product freezing. The chief disadvantages of calcium chloride brine are its dehydrating effect and its tendency to impart a bitter taste to food products.
- The sodium chloride brine has the eutectic temperature of -21.1 °C at salt concentration of 23% by mass. This brine is used in chilling and freezing of meat and fish. Both of the above two brines are corrosive in nature for metallic containers which put limitation on their use.

Designation systems for refrigerants

- The refrigerants are internationally designated as ‘R’ followed by certain numbers such as R-11, R-12, R-114 etc.
- A refrigerant followed by a two digit number indicates that a refrigerant is derived from the methane base while three digit number represents ethane base.
- The numbers assigned to hydro-carbon and halo-carbon refrigerants have a special meaning.
- The first digit on the right is the number of fluorine(F) atoms in the refrigerant.
- The second digit from the right is one more than the number of hydrogen atoms (H) present.
- The third digit form the right is one less than the number of carbon (C) atoms, but when this digit is zero, it is omitted.
- The general chemical formula for the refrigerant, either for methane or ethane base, is given as
- $$C_m H_n Cl_p F_q$$
- in which $n + p + q = 2m + 2$

Where,

m = Number of carbon atoms

n = Number of hydrogen atoms

p = Number of chlorine atoms

q = Number of fluorine atoms

Therefore, the number of the refrigerant is given by R (m-1)(n+1)(q).

Examples

- Dichlorotetrafluoroethane
- Dichlorodifluoromethane

Examples

1. Dichlorotetrafluoro-ethane

In this refrigerant,

Number of chlorine atoms, p = 2

Number of fluorine atoms, q = 4

Number of hydrogen atoms, n = 0

WKT, $n + p + q = 2m + 2$

$0 + 2 + 4 = 2m + 2$

$m = 2$

Therefore, No of carbon atoms = 2

Thus the chemical formula for dichlorotetra fluoro ethane becomes $C_2Cl_2F_4$ and the number of refrigerant becomes R (2-1)(0+1)(4) or R-114.

Examples

1. Dichlorodifluoro-methane

In this refrigerant,

Number of chlorine atoms, $p = 2$

Number of fluorine atoms, $q = 2$

Number of hydrogen atoms, $n = 0$

WKT, $n + p + q = 2m + 2$

$0 + 2 + 2 = 2m + 2$

$m = 1$

therefore, No of carbon atoms = 1

Thus the chemical formula for dichlorodifluoro methene becomes CCl_2F_2 and the number of refrigerant becomes R(1-1)(0+1)(2) or R-12.

The inorganic refrigerants are designated by adding 700 to the molecular mass of the compound For example, the molecular mass of ammonia is 17, therefore it is designated by R-(700 + 17) or R-717.

Thermodynamic properties of refrigerants

- Boiling temperature
- Freezing temperature
- Evaporator and condenser pressure
- Critical temperature and pressure
- Coefficient of performance and power requirements.
- Latent heat of vaporization
- Specific volume

Chemical properties of refrigerants

- Flammability
- Toxicity
- Solubility of water
- Miscibility
- Effect on perishable materials

Physical properties of refrigerants

- Stability and inertness
- Corrosive property
- Viscosity
- Thermal conductivity
- Dielectric strength
- Leakage tendency
- Cost