

Refrigerants

Expected Learning Outcome

- Refrigerants and their properties
- Secondary refrigerants
- Insulating materials and their properties
- Defrosting and types of defrosting methods
- Non condensable gas in refrigeration system

4.1.Refrigerants

The refrigerant is a heat carrying medium which during their cycle in the refrigeration system absorb heat from a low temperature system and discard the heat so absorbed to a higher temperature system.

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 application i.e, there is no idea 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 an ideal refrigerant

A refrigerant is said to be ideal if it has the following properties:

- Low boiling point
- High latent heat of vaporization
- Low specific volume of vapour
- Low specific heat of liquid
- Non corrosive to metal
- Non flammable and non explosive
- Non toxic
- Low cost
- Easy to liquefy at moderate pressure and temperature
- Mixes well with oil

4.2.Classification of Refrigerants

The refrigerants may broadly, be classified into the following two groups.

* Primary refrigerants

* Secondary refrigerant

4.2.1.Primary refrigerants

The primary refrigerant which directly take part in the refrigeration system. Where as the refrigerant which are first cooled by primary refrigerants and then used for cooling purpose is called secondary refrigerants.The primary refrigerants are further classified into the following groups,

- Halo carbon refrigerant
- Azeotrope refrigerant
- Inorganic refrigerant
- Hydrocarbon refrigerants

4.2.1.1.Halo carbon refrigerant

The American society of Heating, Refrigeration and Air-conditioning Engineers (ASHRAE) identified 42 halo carbon compounds as refrigerants but few of them are commonly used. The halo carbon compounds are all synthetically produced and were developed as a Freon family refrigerants eg, R11, R12, R 22, etc.

Azetrope refrigerant

The term 'azetrope' refers to a stable mixture of refrigerants whose vapour and liquid phases retain identical compositions over a wide range of temperature

Refrigerant number	Azeotropic mixing refrigerants	Chemical formula
R-500	73.8% R-12 and 26.2% R-152	$C_{12}F_2 / CH_3CHF_2$
R-502	42.8% R-22 and 51.2% R-115	$CHClF_2 / CCl_1F_2CF_3$
R-503	40% / R-23 and 59.9% R-13	$CHF_3/CClF_3$
R-504	48.2%. R-32 and 51.8%.R-115	$CH_2F_2/CClF_3$

4.2.1.2.In-organic Refrigerants

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

The various inorganic refrigerants are as follows

Refrigerant number	Chemical	Chemical name
R-717	Ammonia	NH_3
R-744	Carbon dioxide	CO_2
R-764	Sulphur dioxide	SO_2
R-729	Air	-
R-118	Water	H_2O

- R-717, (NH_3) Ammonia
 - Most widely used refrigerant
 - Used in commercial reciprocating compression system and in absorption system.
 - Boiling point is $-33.30C$
 - Latent heat of vapourisation is $1315KJ/Kg (-150c)$
 - Poisonous, irritating to eyes nose and throat
- R-744 (Co_2) carbon dioxide
 - Boiling point is $-73.60C$
 - used in dry-ice
 - Non toxic, non irritating and non flammable
 - Low efficiency as compared to ammonia
- R-764 (SO_2) sulphur dioxide
 - Boiling points- $100C$
 - Latent heat of vaporization $396 KJ/Kg (-150C)$

- Non flammable non explosive, unpleasant and irritating odour, Not injurious to food.
- R-729 (Air)
 - The dry air used as a gaseous refrigerant in compression system particularly in air- craft air conditioning
- R-118 (Water)
 - Use of water is as ice
 - Used as a refrigerant vapour in some absorption systems and in systems with steam jet compressor
 - Hydro carbon refrigerants

Hydro- carbon refrigerant

Most of the hydro- carbon refrigerant are successfully used in industrial and commercial installations. They possess satisfactory thermodynamic properties but are highly flammable and explosive. The various hydro carbon refrigerants are as follows,

Refrigerant number	Chemical name	Chemical formula
R-170	Ethane	C_2H_6
R-290	Propane	C_3H_8
R-600	Butane	C_4H_{10}
R-6009	Isobutene	C_4H_{10}
R-1120	Trichloroethylene	C_2HCl_3
R-1130	Dichloroethylene	$C_2H_2Cl_2$
R-1150	Ethylene	C_2H_4
R-1270	Propylene	C_3H_6

4.2.2. Thermodynamic properties

Boiling temperature

The boiling temperature of the refrigerant at atmospheric pressure should be low, if the boiling temperature of the refrigerant is high, the compressor should be operated at high vacuum and the operating cost will be on the higher side.

Freezing temperature

The freezing temperature of a refrigerant should be well below the operating evaporator temperature

Evaporator and condenser pressure

Both evaporator and condenser pressure should be positive (i.e above atmosphere)

Latent heat of vaporization

A refrigerant should have a high latent of evaporation at the evaporator temperature. The high latent heat results in high refrigerating effect per kg of refrigerant circulated which reduces the mass of refrigerant to be circulated per tonne of refrigerant

Critical temperature and pressure

The critical temperature of refrigerant is the highest temperature at which it can be condensed

to a liquid, regardless of a higher pressure the critical temperature should be higher than condensing temperature that might be encountered

	Critical temperature	Critical pressure (bar)
R717	133	113.86
R12	112	41.2
R.22	96	49.38

Coefficient of performance and power requirements

For al ideal refrigerant operating between -15°C evaporator temperature and 3°C condenser temperature the theoretical cycle is 5.74,

Refrigerant	C.O.P	KW/TR
R-717	4.76	0.738
R-12	4.70	0.746
R-22	4.66	0.753
R-744	2.56	1.372

Refrigerant	Mass of refrigerant circulated pre standard tonne in KG	Latent heat of vaporization at 15°C
R-717	0.19	1316.5
R-12	1-81	159.0
R-22	1.31	218.1

Specific volume

The specific volume of the refrigerant vapour at evaporator temperature (volume of suction vapour to the compressor) indicates the theoretical displacement of the compressor

Refrigerant	Specific volume of the refrigerant	Volume displacement for standard tonne of refrigerant
R-717	0.51	0.096
R-12	0.091	0.163
R-22	0.078	0.101

4.2.3.Chemical properties of refrigerants

Flammability

Hydro carbon refrigerant are highly flammable. Ammonia is also somewhat flammable ad becomes explosive when mixed with air. Halocarbon refrigerants are neither flammable nor explosive

Toxicity

All fluorocarbon refrigerants mix with certain percentage of air become toxic

Miscibility

The ability of a refrigerant to mix with oil is called miscibility. The degree of miscibility depends on the temperature of the oil and pressure of the refrigerant vapour.

Effect on perishable materials

The refrigerant used in cold storage plant and in domestic refrigerators should be such that in case of leakage, it should have no effect on the perishable materials. The Freon group of refrigerant have no effect upon dairy products, meats vegetables, flowers. There will be no change in color exposed to freon. Ammonia may react with fruits and vegetables which are acidic in nature.

4.2.4. Physical properties of refrigerants

Stability

An ideal refrigerant should not decompose at any temperature normally encountered in the refrigeration system.

Corrosive

The corrosive property should be taken in to account while selecting the refrigerant. The freon group of refrigerants are non corrosive with all metals practically. Where as Ammonia is used with iron or steel.

Viscosity

The refrigerant in the liquid and vapor states should have low viscosity. The heat transfer through condenser and evaporator is improved at low viscosity.

Thermal conductivity

The refrigerant in the liquid and vapor states should have high thermal conductivity.

Cost and leakage tendency

The cost of refrigerant is also important for industrial and commercial refrigerating system.

4.2.5. Secondary refrigerant

Brine is a secondary refrigerant and is generally used where temperature is required to be maintained below the freezing point of water (0°C). In case the temperature involved is above the freezing point of water, then water is commonly used as a secondary refrigerant.

Brine is a solution of salt and water. It may be noted that when a salt is mixed with water, then the freezing temperature of the solution becomes lower, because when the salt is dissolving in water it takes off its latent heat from the solution and cools it below the freezing point of water.

The brine commonly used are calcium chloride (CaCl_2) and sodium chloride (NaCl) the CaCl_2 has the eutectic temperature of -55°C at salt concentration of 30% by mass. This type of brine is primarily used where temperature below -18°C is required. It is generally used in industrial process cooling and product freezing.

The sodium chloride brine has the eutectic temperature of -21.1°C at salt concentration of 23% by mass.