

## REFRIGERANTS

### 3.1 Designation of refrigerants

International designation as *Refrigerant* of R

#### 3.1.1 Inorganic refrigerants

Air, Ammonia, carbon dioxide, sulphur dioxide

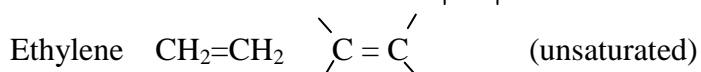
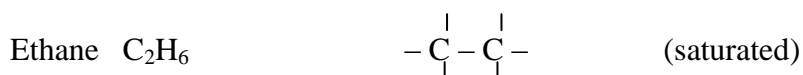
Molecular mass added to 700. eg:

Ammonia	$\text{NH}_3$ , M = 17	—————>	R717
	$\text{CO}_2$ , M = 44	—————>	R744
	$\text{H}_2\text{O}$ , M = 18	—————>	R718

#### 3.1.2 Organic refrigerants

halocarbons or halogenated hydrocarbons, are hydrocarbons for which one or more of the hydrogen atoms are substituted by one or more of the halogens Cl, Br, I.

(i) saturated hydrocarbon



\* saturated if only has single bonds between carbon atoms.

Consider a compound with the general formulae,

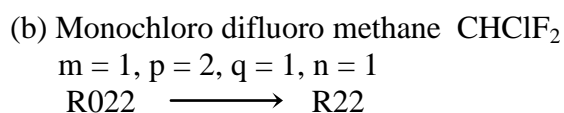
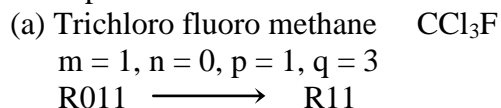


saturated if,

$$n + p + q = 2m + 2 \quad \dots\dots\dots (1b)$$

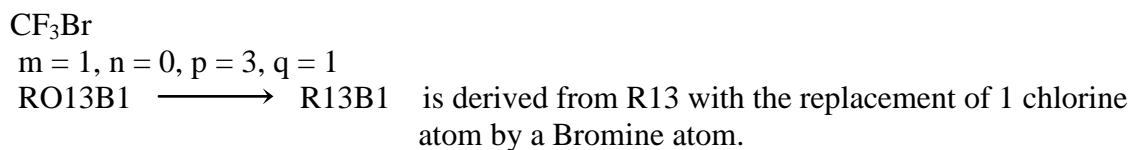
designation for saturated hydrocarbon,     **R(m – 1)(n + 1)(p)**

Examples:



(ii) Brominated refrigerants

add the letter B and a number to denote the number of chlorine atoms replaced by bromine atoms, eg:



(iii) Unsaturated hydrocarbons

Double bond between carbon atoms, consider a compound

$$\text{C}_m \text{H}_n \text{F}_p \text{Cl}_q \quad \dots\dots\dots (2a)$$

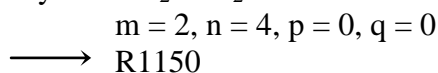
Unsaturated if,

$$n + p + q = 2m \quad \dots\dots\dots (2b)$$

designated as

$$\mathbf{R1(m - 1)(n + 1)p} \quad \dots\dots\dots (2c)$$

Eg, ethylene  $\text{CH}_2=\text{CH}_2$



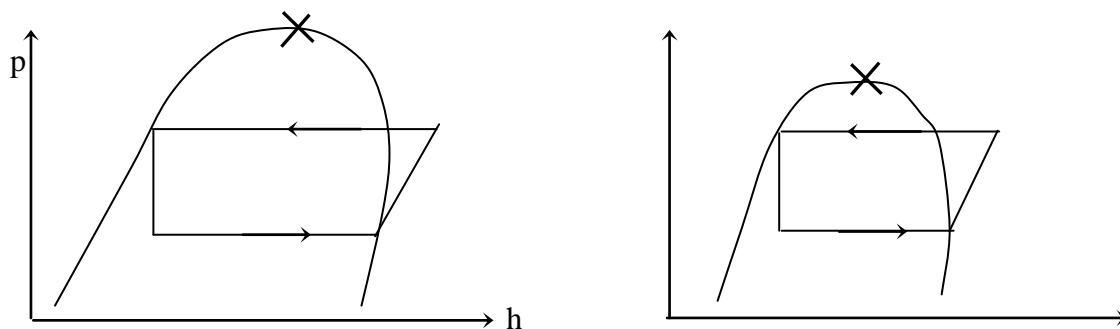
(iv) Azeotropes

Azeotropic mixture of 2 substances is one in which the components cannot be separated by distillation. Designation is arbitrary,

R502 is a mixture of R22 (44.8 % by mass) and R115 (51.2 % by mass).

### 3.2 Thermodynamic requirements

- (a) Moderately low condensing pressures, allowing use of lightweight equipment and piping.
- (b) Positive evaporating pressure, to prevent entry of air and water vapour into the system.
- (c) Relatively high critical temperature, so that the condenser temperature line on the p-h diagram is far removed from the critical point (CP). This ensures reasonable refrigerating effect which becomes very small if state of liquid entering the expansion valve is near the CP.



- (d) Low freezing point – will not freeze at normal evaporating temperature.

## (e) Volume of suction vapour

The volume of suction vapour required per unit of refrigeration (say per ton) is an indication of the size of the compressor.

- Low volume – reciprocating compressors
- High volume – centrifugal compressors

(f) High latent heat of evaporation ( $h_{fg}$ ), thus requiring low mass flow rate for a given refrigeration load.

$$m = \frac{Q_{ref}}{\Delta h}$$

### 3.3 Chemical requirements

(a) Flammability – hydrocarbons such methane, propane and butane are highly explosive and flammable. None of the fluorocarbons is explosive or flammable. R134a is not flammable.

(b) Toxicity. Sulphur dioxide is very toxic. Ammonia being flammable and toxic is not used in domestic refrigeration and air-conditioning.

Refrigerants	Kills or serious injuries (duration in hours)	Breathed, % by volume
R717	0.5	0.5
CO <sub>2</sub>	0.5 – 1	5.7 (suffocation)
R11	2	10
R12	2	about 30
R13	2	> 30
R22	-	-
R502	-	-

(c) Action of refrigerant with water – good solubility is preferred.

Example: R12 and R114 ; poor solubility  
R11 and R113 ; good solubility

Insolubility leads to ice formation and choking of expansion valve, since the refrigerant can't absorb water that is present in the system. Poor solubility requires proper dehydration and use of silica gel drier in the liquid line.

Moisture should not be allowed to enter refrigeration systems.

(d) Action of refrigerant with oil.

Refrigerants that are not miscible with oil can be problematic – oil build-up in the evaporator results in reduced heat transfer coefficient, *oil choking* (blockage of refrigerant flow) and oil starvation in the compressor. This can be overcome by installing an oil separator a little away from the compressor in the discharge line, and the separated oil is continuously returned to the compressor crank-case.

- Fully miscible – R11, R12, R21, R113
- Immiscible – R13, R14, ammonia (thus need oil separator in the system)
- Intermediate (fully miscible above some temperature, only partly miscible at low temperature) – R22, R114.

(e) Action with materials of construction.

Certain refrigerants react with a particular type of material. For example Ammonia attacks copper and its alloys, but does not attack iron and steel. Recommended piping material with halocarbons is copper. Aluminium (cheap and available) is replacing copper, but thermal conductivity of *Al* is half that of *Cu*, making *Cu* the preferred material in Freon systems.

### 3.4 Physical requirements

(a) High dielectric strength means a good insulator – R11, R113, R12, R22. Important in hermetically sealed units where the electrical motor winding is cooled by suction vapour.

(b) High thermal conductivity is desirable for a high heat transfer coefficient. R 22 has better heat transfer characteristics than R 12.

(c) Low viscosity is desirable for a high heat transfer coefficient.

(d) Low leak tendency is desirable. The detection of a leak should be easy. Unfortunately fluorocarbons are odourless, as opposed to Ammonia which is pungent-smelling. Most common method of leak detection is *soap-bubble method*. Most sensitive is an *electronic leak detector*.

(e) Low cost. Ammonia is cheapest, while R12 is slightly cheaper than R 22.

### 3.5 Refrigerant applications

Application	Refrigerant
Domestic refrigerator	R12, R22
Domestic food freezer	R12, R22, R502
Car air-conditioner	R12
Ice plants	Ammonia
Cryogenic application	R13, R503
Home air-conditioner	R22, R500
Public building air-conditioner	R11, R12, R22
Food freezers	CO <sub>2</sub> , N <sub>2</sub>