Refrigerants

Dr. M. Zahurul Haq

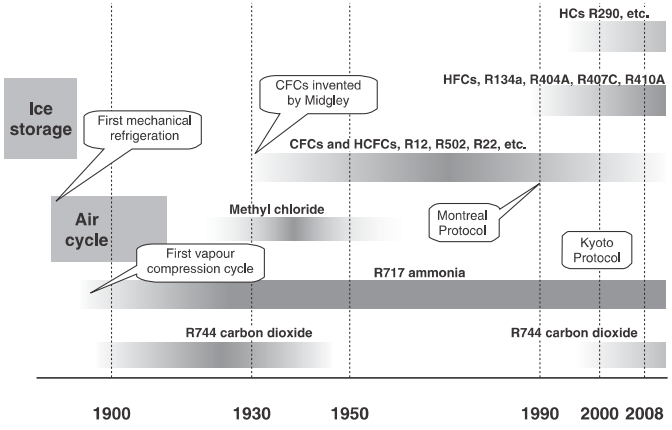
Professor
Department of Mechanical Engineering
Bangladesh University of Engineering & Technology (BUET)
Dhaka-1000, Bangladesh

zahurul@me.buet.ac.bd
http://teacher.buet.ac.bd/zahurul/

ME 415: Refrigeration & Building Mechanical Systems

Refrigerants & its Time Line

Refrigerants are well known as the fluids providing a cooling effect during the phase change from liquid to vapour. These are used in refrigeration, air conditioning, and heat pump systems, as well as process systems.



Some Desirable Properties of Refrigerants

- High latent heat of vaporisation ⇒ less refrigerant flow required
- High suction gas density ⇒ small and compact equipment
- Low compression ratio ⇒ low power consumption and higher volumetric efficiency of compressors.
- Positive but not excessive pressures at evaporating and condensing conditions.
- Low condensing pressure ⇒ lighter compressors, piping etc.
- High thermal conductivity ⇒ good heat transfer, reduced size of heat transfer equipment.
- Chemically stable, compatible with construction materials and miscible with lubricants.
- Non-corrosive, non-toxic, non-flammable and environmentally friendly.

Classifications of Refrigerants

A refrigerant may be a single chemical compound or a mixture (blend) of multiple compounds.

- **Azeotropic Mixtures**: these are blends of multiple refrigerants that evaporate & condense as a single substance & do not change their volumetric composition or saturation temperature when they evaporate or condense at a constant pressure.
- **Zeotropic Mixtures**: these are blends of multiple refrigerants that evaporate & condense as a single substance & do change their volumetric composition or saturation temperature when they evaporate or condense at a constant pressure.
- **Blends**: mixtures of two or more chemical compounds are blends.

Prefixes & Atoms in Refrigerants

Name	Prefix	Atoms Contained
Chlorofluorocarbon	CFC	Cl, F, C
Hydrochlorofluorocarbon	HCFC	H, Cl, F, C
Hydrobromofluorocarbon	HBFC	H, Br, F, C
Hydrofluorocarbon	HFC	H, F, C
Hydrocarbon	HC	H, C
Perfluorocarbon	PFC	F, C
Halon	Halon	Br, Cl (in some), F, H (in some), C

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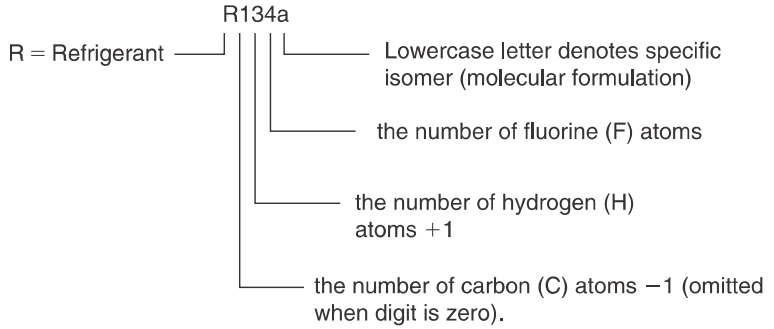
Numbering of Refrigerants: Halocarbon/Hydrocarbon



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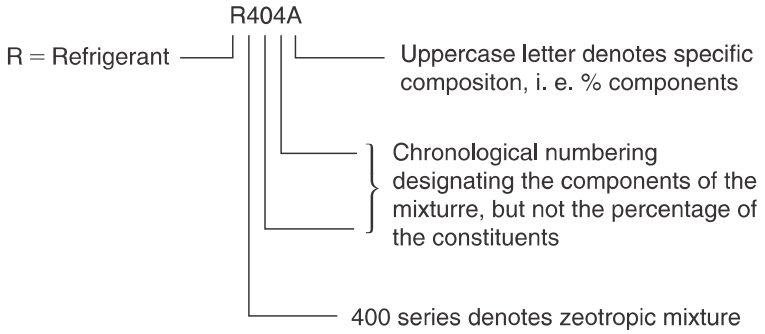
- $CHCl_2CF_3 \rightarrow 3F + 1H + 2C \rightarrow R123$
- $CCl_3F \rightarrow 1F + 0H + 1C \rightarrow R11$
- $CHClF_2 \rightarrow 2F + 1H + 1C \rightarrow R22$
- $CH_4 \rightarrow 0F + 4H + 1C \rightarrow R50$
- $C_3H_8 \rightarrow 0F + 8H + 3C \rightarrow R290$

Numbering of Refrigerants: Zeotropic Mixtures



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Zeorropic mixtures are assigned an identifying number in the 400 series. This number designates which components are in the mixture, and the following upper case letter denotes the proportions. The numbers are in chronological order of the refrigerant's approval by ASHRAE. For example: R407A (R32/Rl25/R134a (20/40/40)), R407B (R32/R125/R134a (10/70/20)), R407C (R32/R125/R134a (23/25/52)), etc.

Numbering of Other Refrigerants

- **Azeotropic Mixtures**: are in 500 series. Example: R507 (R125/R134a (50/50)).
- **Organic Compounds**: are in 600 series; numbers are given in numerical order, for example R600a, isobutane.
- **Inorganic Compounds** are in 700 series; identifications are formed by adding the relative molecular mass of components to 700.

Chemical Name	Formula	Number
Ammonia	NH_3	717
Water	H_2O	718
Air	-	729
Carbon-di-oxide	CO_2	744
Sulphur-di-oxide	SO_2	764

Refrigerant	Composition	Application	ODP (R11 = 1)	GWP (CO_2 = 1)	Boiling point (°C)	Vapour pressure at 50°C (bar abs)
HCFCs low chlorine						
R22	$CHClF_2$	HT, MT, LT	0.05	1500	−41	19.4
R22 Blends	R22 + HFCs	MT	0.03 to 0.05	970 to 1770	−33 to −35	13 to 14
R22 Blends	R22 + HFCs	LT	0.02 to 0.03	1960 to 3570	−44 to −51	20 to 25
HFCs chlorine free						
R134a	CF_3CH_2F	HT, MT	0	1300	−26	13.2
R404A	R143a/125/134a	LT	0	3260	−47	23.0
R407C	R32/125/134a	HT	0	1525	−44	19.8
R410A	R32/125	HT	0	1725	−51	30.5
Other R32 blends	R32 + HFCs	LT	0	1770–2280	−46 to −48	21 to 23
Other R125 blends	R125 + HFCs	HT, MT, LT	0	1830–3300	−43 to −48	18 to 25
HCs halogen free						
R290	C_3H_8 propane	HT, MT	0	3	−42	17.1
R1270	C_3H_6 propylene	LT	0	3	−48	20.6
R600a	C_4H_{10} isobutane	MT	0	3	−12	6.8
R290 blends	R290 + HCs	HT, LT, MT	0	3	−30 to −48	10 to 18
Other halogen free						
R717	NH_3 ammonia	LT (MT, HT)	0	0	−33	20.3
R744	CO_2 carbon dioxide	HT, MT, LT	0	1	−57*	74**

*Triple point (5.2 bar abs).
**At critical temperature 31°C.
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- **Ozone Depletion Potential (ODP)**: of a refrigerant represents its effect on atmospheric ozone, and the reference point usually adopted is ODP = 1.0 fro CFC R11.
- **Global Warming Potential (GWP)**: of a gas may be defined as the index comparing the climate impact on its emission to that of emitting the same amount of carbon dioxide. R134a has a GWP equivalent to 1300 kg CO_2.

Safety Requirements of Refrigerants

Refrigerants may leak and therefore must be acceptably safe for humans and manufacturing processes, with little or no toxicity or flammability. According to ANSI/ASHRAE 34-1997, safety groups are classified as follows:

A1 : lower toxicity & no flame propagation
A2 : lower toxicity & lower flammability
A3 : lower toxicity & higher flammability
B1 : higher toxicity & no flame propagation
B2 : higher toxicity & lower flammability
B3 : higher toxicity & higher flammability

Leak Detection Methods

- **Halide Torch**: when air flows over a copper element heated by a CH_3OH flame, the vapour of halogenated refrigerant decomposes and changes the color of the flame. GREEN → small leak, Bluish with red tip → large leak.
- **Electronic:** reveals a variation of electric current due to ionization of decomposed refrigerant between two oppositely charged electrodes.
- **Bubble Method:** a solution of soap is brushed over the seal and joints where leakage is suspected, producing bubbles that can be easily detected.