Rameez Anwar 09-ME-100

Definition of Refrigerants

R & AC 2K9 MECH

- ***Refrigerant** is the primary working fluid used for absorbing and transmitting heat in a refrigeration system. Refrigerants absorb heat at a low temperature and pressure and release heat at a higher temperature and pressure. Most refrigerants undergo phase changes during heat absorption — evaporation, and heat releasing — condensation.* *OR*
- ***Refrigerant** is a heat carrying medium which during their cycle (i.e., compression, condensation, expansion and evaporation) in the refrigeration system absorb heat from low temperature system and discard the absorbed heat to higher temperature system*

***Cooling Medium** is the working fluid cooled by the refrigerant to transport the cooling effect between a central plant and remote cooling units and terminals.*

- In a large centralized system, it is often more economical to use a coolant medium that can be pumped to remote locations where cooling is required.
- Chilled water, brine, and glycol are used as cooling media in many refrigeration systems.
- The cooling medium is often called a secondary refrigerant, because it prevents extensive circulation of the primary refrigerant. The thermodynamic efficiency of a refrigeration system depends mainly on its operating temperatures.

- However, important practical issues such as the system design, size, initial and operating costs, safety, reliability, and serviceability etc. depend very much on the type of refrigerant selected for a given application.
- Due to several environmental issues such as ozone layer depletion and global warming and their relation to the various refrigerants used, the selection of suitable refrigerant has become one of the most important issues in recent times.
- Replacement of an existing refrigerant by a completely new refrigerant for whatever reason, is an expensive proposition as it may call for several changes in the design and manufacturing of refrigeration systems.
- In principle, any fluid can be used as a refrigerant. Air used in an air cycle refrigeration system can also be considered as a refrigerant.

With regard to the vapor compression cycle, *the refrigerant is the working fluid of the cycle that alternately vaporizes and condenses as it absorbs and gives off heat, respectively.*

- To be suitable for use as a refrigerant in the vapor compression cycle, a fluid should possess certain chemical, physical. and thermodynamic properties that make it both safe and economical to use.
- It should be recognized at the onset that there is no "ideal" refrigerant and that. because of the wide differences in the conditions and requirements of the various applications, there is no one refrigerant that is universally suitable for all applications.
- Hence, a refrigerant approaches the "**ideal**" only to the extent that its properties meet the conditions and requirements of the application for which it is to he used

Properties for an Ideal refrigerant

a) A high latent heat of vaporization
b) A high density of suction gas
c) Non-corrosive, non-toxic and non-flammable
d) Compatibility with component materials and lubricating oil
e) Reasonable working pressures (not too high, or below atmospheric pressure)
f) High dielectric strength (for compressors with integral motors)
g) Low cost
h) Ease of leak detection
i) Environmentally friendly

Classification of Refrigerants

Fluids suitable for refrigeration purposes can be classified into primary and secondary refrigerants.

Primary refrigerants are those fluids which are used directly as working fluids, for example in vapour compression and vapour absorption refrigeration systems.

When used in compression or absorption systems, these fluids provide refrigeration by undergoing a phase change process in the evaporator.

Secondary refrigerants are those liquids which are used for transporting thermal energy from one location to another. Secondary refrigerants are also known under the name brines or antifreezes.

- If the operating temperatures are above **0°C,** then **pure water** can also be used as **secondary refrigerant**, for example in large air conditioning systems.

Antifreezes *or* **brines** are used when refrigeration is required at sub-zero temperatures. Unlike primary refrigerants, the secondary refrigerants do not undergo phase change as they transport energy from one location to another.

- An important property of a secondary refrigerant is its freezing point. Generally, the freezing point of a brine will be lower than the freezing point of its constituents. The temperature at which freezing of a brine takes place its depends on its concentration.

- The concentration at which a lowest temperature can be reached without solidification is called as **eutectic point**.
- The commonly used secondary refrigerants are the solutions of water and *ethylene glycol, propylene glycol or calcium chloride*. These solutions are known under the general name of brines.
- This lecture is mainly focused on primary refrigerants that are used in vapour compression refrigeration systems. As discussed earlier in an absorption refrigeration system, a refrigerant and absorbent combination is used as the working fluid.

The primary refrigerants are further classified into the following four groups:

- Halo-carbon Refrigerants
- Azeotrope Refrigerants
- Inorganic Refrigerants and
- Hydro-carbon Refrigerants

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 for eg. R-12,R-22R-114 etc.

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. The example of Azeotrope Refrigerants are R-500 (73.8 % R-12 & 26.2% R-152),R-502, R-152 etc.

Inorganic Refrigerants: The inorganic refrigerants were exclusively used before the introduction of halocarbon refrigerants. These refrigerants are still in use due to their inherent thermodynamic and physical properties; for example Ammonia R-717, Air R-729, CO_2 R-744 etc.

Hydro-carbon refrigerants: Most of the hydro-carbon refrigerants are successfully used in industrial and commercial installations. They possess satisfactory thermodynamic properties but are highly flammable and explosive e.g. Ethane R-170,Propane R-290,Propylene R-1270 etc.

Refrigerant Selection Criteria

In order to select the a correct refrigerant, it is necessary that it should satisfy those properties which make it ideal to be used for a particular application. The considered properties are:

- ➢ Thermodynamic properties,
- ➢ Chemical properties,
- ➢ Physical properties
- ➢ Environmental and safety properties/concerns & Cost

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 at atmospheric pressure, the compressor should be operated at high vacuum. The high boiling temperature reduces the capacity and operating cost of the system.

Freezing *temperature* :The freezing temperature of a refrigerant should be well below the operating evaporator temperature. Since the freezing temp. of most of refrigerant are below -35°C. Therefore this property is taken into consideration only in low temperature operation.

Evaporator and Condensor pressure: Both the evaporating (low side) and condensing (high side) pressures should be positive (i.e., above atmospheric)and it should as near to the atmospheric pressure as possible. The positive pressure are necessary in order to prevent the leakage of air and moisture into the refrigerating system. It also permits easier detection of leaks.

Too high evaporating and condensing pressure (above atmospheric) would require stronger refrigerating equipment resulting in higher initial cost.

The reciprocating compressor are used with refrigerants having low specific volumes, high operating pressure and high pressure ratios. The centrifugal compressor are used with refrigerants having high specific volumes, low pressures and low pressure ratios.

Critical temperature and pressure: *The* critical temperature of a refrigerant is the highest temperature at which it can be condensed to a liquid, regardless of a higher pressure. It should be above the highest condensing temperature that might be encountered. If the critical temp. of a refrigerant is too near the desired condensing temperature, the excessive power consumption results.

The critical temperature for most of the common refrigerants is well above the normal condensing temp. with the exception of carbon dioxide (R-744) whose *critical* temperature *is 31°C.*

Latent *heat of vaporisation.* A refrigerant should have a high latent heat of vaporisation 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 refrigeration.

Specific volume: The specific volume of the *refrigerant* vapour *at* evaporator temperature *(i.e* volume of suction vapour to the compressor) indicates the theoretical displacement of the compressor.

The reciprocating compressors are used with refrigerants having high pressures and low volumes of the suction vapour.

The centrifugal or turbo compressors are used with refrigerants having low pressures and high volumes of the suction vapour.

The rotary compressors are used with refrigerants having intermediate pressures and volume of the suction vapour.

Coefficient of performance and power requirements:

For an ideal refrigerant operating between - 15°C evaporator temperature and 30°C condenser temperature, the theoretical coefficient of performance for the reversed Carnot cycle is 5.74.

The refrigerant R- 11 has the coefficient of performance equal to 5.09 which is closest to the Carnot value of 5.74. The other refrigerants have also quite high values of coefficient of performance except R-744 (carbon dioxide) which has the value of coefficient of performance as 2.56 with a power requirement of 1.372 kW per tonne of refrigeration.

This is due to its low critical point (31°C) and the condensing temperature is very close to it which is 30°C. Practically, all common refrigerants have approximately the same coefficient of performance and power requirement.

Chemical properties of refrigerants

Flammability: Hydro-carbon refrigerants such as, ethane, propane etc., are highly flammable. Ammonia is also somewhat flammable and becomes explosive when mixed with air in the ratio of 16 to 25 percent of gas by volume. The halo-carbon refrigerants are neither flammable nor explosive

Toxicity: The toxicity of refrigerant may be of prime or secondary importance, depending upon the application. Some non- toxic refrigerants (i.e. all fluorocarbon refrigerants) hence mixed with certain percentage of air become toxic.

The R-717 (ammonia) and R-764 (sulphur dioxide) are highly toxic and strong irritants. Therefore these refrigerants are not used in domestic refrigeration and comfort air conditioning. The use of toxic refrigerants is only limited to cold storages

Solubility of water: Water is only slightly soluble in R-12. The solution formed is very slightly corrosive to any of the common metals. The solubility of water with R-22 is more than R-12 by a ratio of 3 to 1.

It more water is present than can be dissolved by the refrigerant, the ice will be formed which chokes the expansion valve or capillary tube used for throttling *in the system.*

This *may* be avoided by the proper dehydration of the refrigerating unit before charging and by the use of silica gel drier of the liquid line.

Ammonia is highly soluble in water. Due to this reason, a wetted cloth is put at the point of leak to avoid harm to the persons working in ammonia refrigerating plants.

Effect on Perishable Materials. The refrigerants 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 refrigerants have no effect upon dairy products, meats, vegetables. flowers and furs. There will be no change in colour. taste or texture of the material when exposed to freon.

Methyl chloride vapours have no effect upon furs, flowers, eating foods or drinking beverages. Sulphur dioxide destroys flowers, plants and furs, but it does not effect foods *. Ammonia dissolves easily in water and becomes alkaline in nature.

Since most fruits and vegetables are acidic in nature, therefore ammonia reacts with these products and spoils the taste.

Miscibility: The ability of a refrigerant to mix with oil is called miscibility. This property of refrigerant is considered to be a secondary factor in the selection of a refrigerant.

The degree of miscibility depends upon the temperature of the oil and pressure of the refrigerating vapour. The freon group of refrigerants are highly miscible refrigerants while ammonia, carbon dioxide, sulphur dioxide and methyl chloride are relatively non-miscible.

The non-miscible refrigerants require larger heat transfer surfaces due to poor heat condition properties of oil. The miscible refrigerants are advantageous from the heat transfer point of view.

They give better lubrication as the refrigerant acts as a carrier of oil to the moving parts. The miscible refrigerants also eliminate oil-separation problems and aid in the return of nil from the evaporator.

Physical properties of refrigerants

Stability and inertness: *An* ideal refrigerant should not decompose at any temperature normally encountered in the refrigerating system. It should not form higher boiling point liquids or solid substances through polymerization.

Some refrigerants disintegrate forming non-condensable gases which causes high condensing pressure and vapour lock. The disintegration of refrigerant may be due to reaction with metals. In order to avoid this, a refrigerant should he inert with respect to all materials used in refrigerating system

The freon group of refrigerants are stable upto a temperature of 535°C. Above this temperature, it decomposes and forms corrosive and poisonous products.

The freon refrigerants are not used with rubber gaskets as it acts as a solvent with rubber. Since sulphur dioxide do not decompose below 1645°C, therefore it is one of the most stable refrigerants

Physical properties of refrigerants

Corrosive property: The corrosive property of a refrigerant must be taken into consideration while selecting the refrigerant. The freon group of refrigerants are non-corrosive with practically all metals. Ammonia is used only with iron or steel. Sulphur dioxide is non-corrosive to all metals *in* the absence of water because sulphur dioxide reacts with water and forms sulphuric acid.

Viscosity: The refrigerant in the liquid and vapour states should have low viscosity. The low viscosity of the refrigerant is desirable because the pressure drops in passing through liquid and suction lines are small. The heat transfer through condenser and evaporator is improved at low viscosities.

The following table shows the viscosities (in centipoises) at atmospheric pressure for the common refrigerants..

Thermal conductivity: The refrigerant in the liquid and v states should have high thermal conductivity. This property is required in finding the heat transfer coefficients in evaporators and condensers.

Dielectric strength: The dielectric strength of a refrigerant is important in hermetically sealed units in which the electric motor is exposed to the refrigerant.

The relative dielectric strength of the refrigerant is the ratio of the dielectric strength of nitrogen and the refrigerant vapour mixture to the dielectric strength of nitrogen at atmospheric pressure and room temperature. The following table shows the relative dielectric strengths of common refrigerants.

Leakage tendency: The leakage tendency of a refrigerant should below. If there is a leakage of refrigerant, it should be easily detectable. The leakage occurs due to opening in the joints or flaws in material used for construction.

Since the fluorocarbon refrigerants are colourless, therefore, their leakage will increase the operating cost. The ammonia leakage is easily detected due to its pungent odour.

The leakage of fluorocabon refrigerants may be detected by *soap* solution, a halide torch or an electronic leak detector. The latter is generally used in big refrigerating plants.

The ammonia leakage is detected by using burning sulphur candle which *in the presence of ammonia forms white* fumes of ammonium sulphite.

Environmental and Safety Properties/Concerns

Presently, the environment friendliness of the refrigerant is a major factor in deciding the usefulness of a particular refrigerant. The important environmental and safety properties are:

a) **Ozone Depletion Potential (ODP):** According to the Montreal protocol, the ODP of refrigerants should be zero, i.e., they should be non-ozone depleting substances. Refrigerants having non-zero ODP have either already been phased-out (e.g. R 11, R 12) or will be phased-out in near-future (e.g. R22).

Since ODP depends mainly on the presence of chlorine or bromine in the molecules, refrigerants having either chlorine (i.e., CFCs and HCFCs) or bromine cannot be used under the new regulations

b) **Global Warming Potential (GWP):** Refrigerants should have as low a GWP value as possible to minimize the problem of global warming.

Refrigerants with zero ODP but a high value of GWP (e.g. R134a) are likely to be regulated in future.

c) **Total Equivalent Warming Index (TEWI):** The factor TEWI considers both direct (due to release into atmosphere) and indirect (through energy consumption) contributions of refrigerants to global warming.

Naturally, refrigerants with as a low a value of TEWI are preferable from global warming point of view.

d) **Toxicity:** Ideally, refrigerants used in a refrigeration system should be non-toxic. However, all fluids other than air can be called as toxic as they will cause suffocation when their concentration is large enough.

Thus toxicity is a relative term, which becomes meaningful only when the degree of concentration and time of exposure required to produce harmful effects are specified. Some fluids are toxic even in small concentrations.

Some fluids are mildly toxic, i.e., they are dangerous only when the concentration is large and duration of exposure is long.

Some refrigerants such as CFCs and HCFCs are non-toxic when mixed with air in normal condition.

In general the degree of hazard depends on:

- Amount of refrigerant used vs. total space
- Type of occupancy
- Presence of open flames
- Odor of refrigerant, and
- Maintenance condition

Thus from toxicity point-of view, the usefulness of a particular refrigerant depends on the specific application

e) **Flammability:** The refrigerants should preferably be non-flammable and non-explosive. For flammable refrigerants special precautions should be taken to avoid accidents.

Based on the above criteria, ASHRAE has divided refrigerants into six safety groups (A1 to A3 and B1 to B3). Refrigerants belonging to Group A1 (e.g. R11, R12, R22, R134a, R744, R718) are least hazardous, while refrigerants belonging to Group B3 (e.g. R1140) are most hazardous.

f) **Chemical stability:** The refrigerants should be chemically stable as long as they are inside the refrigeration system.

g) **Compatibility:** With common materials of construction (both metals and non-metals)

h) **Miscibility with lubricating oils:** Oil separators have to be used if the refrigerant is not miscible with lubricating oil (e.g. ammonia). Refrigerants that are completely miscible with oils are easier to handle (e.g. R12). However, for refrigerants with limited solubility (e.g. R 22) special precautions should be taken while designing the system to ensure oil return to the compressor

(i) **Dielectric strength:** (See Physical properties)

(j) **Ease of leak detection:** (See Physical properties)

COST

The refrigerant used should preferably be inexpensive and easily available. The cost of refrigerant is not so important in small refrigerating units but it is very important in high capacity refrigerating systems like industrial and commercial.

The ammonia, being the cheapest is widely used in large industrial plants such as cold storages and ice plants. The refrigerant R-22 is costlier than refrigerant R-12. The cost of losses due to leakage is also important.

Designation of refrigerants

Before the invention of chlorofluorocarbons (CFCs), refrigerants were called by their chemical names. Because of the complexity of these names, especially the CFCs the fully halogenated CFCs, and hydrochlorofluorocarbons (HCFCs), the not fully halogenated HCFCs, a numbering system was developed for hydrocarbons and halocarbons, and is used widely in the refrigeration industry.

From the number one can get some useful information about the type of refrigerant, its chemical composition, molecular weight etc.

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 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 (H) atoms present.

The third digit from 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 $C_mH_nCl_pF_q$, in which $n+p+q = 2m+2$ where

m = Number of carbon atoms,

n = Number of hydrogen atoms,

p = Number of chlorine atoms, and

q = Number of fluorine atoms.

As discussed above. the number of the refrigerant is given by $R\ (m-1)(n+1)\ (q)$

Examples: (See Class notes)

- **R12** = CCl2F2
- **R134a** = C2H2F4 (derivative of ethane)

•(letter a stands for isomer, e.g. molecules having same chemical composition but different atomic arrangement, e.g. R134 and R134a)

ii) Inorganic refrigerants: These are designated by number 7 followed by the molecular weight of the refrigerant (rounded-off).

Examples:

Ammonia: Molecular weight is 17,the designation is R 717

Carbon dioxide:Molecular weight is 44, the designation is R744

Water: Molecular weight is 18,the designation is R 718

iii) <u>Mixtures</u>: Azeotropic mixtures are designated by 500 series, where as zeotropic refrigerants (e.g. non-azeotropic mixtures) are designated by 400 series.

Azeotropic mixtures:

- R 500: Mixture of R 12 (73.8 %) and R 152a (26.2%)
- R 502: Mixture of R 22 (48.8 %) and R 115 (51.2%)⇨
- R503: Mixture of R 23 (40.1 %) and R 13 (59.9%)
- R507A: Mixture of R 125 (50%) and R 143a (50%)

<u>Zeotropic mixtures:</u>

R404A : Mixture of R 125 (44%), R 143a (52%) and R 134a (4%)

R407A : Mixture of R 32 (20%), R125 (40%)and R 134a (40%)

R407B : Mixture of R 32 (10%),R 125 (70%) and R134a (20%)

R410A : Mixture of R 32 (50%) and R 125 (50%)

iv) Hydrocarbons:

Propane (C3H8) : R 290

n-butane (C4H10) : R 600

iso-butane (C4H10) : R 600a

Unsaturated Hydrocarbons: R1150 (C2H4)

R1270 (C3H6)

Synthetic refrigerants that were commonly used for refrigeration, cold storage and air conditioning applications are: R 11 (CFC 11), R 12 (CFC 12), R 22 (HCFC 22), R 502 (CFC 12+HCFC 22) etc.

However, these refrigerants have to be phased out due to their Ozone Depletion Potential (ODP).

The synthetic replacements for the older refrigerants are: R-134a (HFC-134a) and blends of HFCs.

Generally, synthetic refrigerants are non-toxic and non-flammable. However, compared to the natural refrigerants the synthetic refrigerants offer lower performance and they also have higher Global Warming Potential (GWP).

Prior to the environmental issues of ozone layer depletion and global warming, the most widely used refrigerants were: R 11, R 12, R 22, R 502 and ammonia. Of these, R 11 was primarily used with centrifugal compressors in air conditioning applications. R 12 was used primarily in small capacity refrigeration and cold storage applications, while the other refrigerants were used in large systems such as large air conditioning plants or cold storages.

Among the refrigerants used, except ammonia, all the other refrigerants are synthetic refrigerants and are non-toxic and non-flammable.

Though ammonia is toxic, it has been very widely used due to its excellent thermodynamic and thermo-physical properties. The scenario changed completely after the discovery of ozone layer depletion in 1974.

Comparison between different refrigerants:

As a result, the synthetic refrigerants face an uncertain future. The most commonly used natural refrigerant is ammonia. This is also one of the oldest known refrigerants. Ammonia has good thermodynamic, thermo-physical and environmental properties.

However, it is toxic and is not compatible with some of the common materials of construction such as copper, which somewhat restricts its application. Other natural refrigerants that are being suggested are hydrocarbons (HCs) and carbon dioxide (R-744).

Though these refrigerants have some specific problems owing to their eco-friendliness, they are being studied widely and are likely to play a prominent role in future.

The depletion of stratospheric ozone layer was attributed to chlorine and bromine containing chemicals such as Halons, CFCs, HCFCs etc. Since ozone layer depletion could lead to catastrophe on a global level, it has been agreed by the global community to phase out the ozone depleting substances (ODS).

As a result except ammonia, all the other refrigerants used in cold storages had to be phased-out and a search for suitable replacements began in earnest. At the same time, it was also observed that in addition to ozone layer depletion, most of the conventional synthetic refrigerants also cause significant global warming.

In view of the environmental problems caused by the synthetic refrigerants, opinions differed on replacements for conventional refrigerants. The alternate refrigerants can be classified into two broad groups:

i) ***Non-ODS****, synthetic refrigerants based on Hydro-Fluoro-Carbons (HFCs) and their blends*

ii) ***Natural refrigerants*** *including ammonia, carbon dioxide, hydrocarbons and their blends.*

It should be noted that the use of natural refrigerants such as carbon dioxide, hydrocarbons is not a new phenomena, but is a revival of the once-used-and-discarded technologies in a much better form.

Since the natural refrigerants are essentially making a comeback, one advantage of using them is that they are familiar in terms of their strengths and weaknesses.

Another important advantage is that they are completely environment friendly, unlike the HFC based refrigerants, which do have considerable global warming potential.

The alternate synthetic refrigerants are normally non-toxic and non-flammable. It is also possible to use blends of various HFCs to obtain new refrigerant mixtures with required properties to suit specific applications.

However, most of these blends are non-azeotropic in nature, as a result there could be significant temperature glides during evaporation and condensation, and it is also important take precautions to prevent leakage, as this will change the composition of the mixture.

Phase-out of CFCs, HCFCs, and Their Blends

- On September 16, 1987, the European Economic Community and 24 nations, including the United States, signed a document called the Montreal Protocol.
- It is an agreement to restrict the production and consumption of CFCs and BFCs in the 1990s because of ozone depletion.
- The Clean Air Act amendments, signed into law in the United States on November 15, 1990, concern two important issues: the phase-out of CFCs and the prohibition of deliberate venting of CFCs and HCFCs.
- In February 1992, President Bush called for an accelerated ban of CFCs in the United States. In late November 1992, representatives of 93 nations meeting in Copenhagen agreed to phase out CFCs beginning January 1, 1996. Restriction on the use of HCFCs will start in 2004, with a complete phaseout by 2030.
- In the earlier 1990s, R-11 was widely used for centrifugal chillers, R-12 for small and medium-size vapor compression systems, R-22 for all vapor compression systems, and CFC/HCFC blend R-502 for low-temperature vapor compression systems.

- Because of the phase-out of CFCs before 1996 and HCFCs in the early years of the next century, alternative refrigerants have been developed to replace them:
- **R-123** *(an HCFC of ODP = 0.02) to replace R-11 is a short-term replacement that causes a slight reduction in capacity and efficiency. R-245 a (ODP = 0) may be the long-term alternative to R-11.*
- **R-134a** *(an HFC with ODP = 0) to replace R-12 in broad applications. R-134a is not miscible with mineral oil; therefore, a synthetic lubricant of polyolester is used.*
- **R-404A** *(R-125/R-134a/143a) and R-407C (R-32/R-125/R-134a) are both HFCs near azeotropic of ODP = 0. They are long-term alternatives to R-22.*

- For R-407C, the composition of R-32 in the mixture is usually less than 30% so that the blend will not be flammable. R-407C has a drop of only 1 to 2% in capacity compared with R-22.
- R-507 (R-125/R-143a), an HFC's azeotropic with ODP = 0, is a long-term alternative to R-502.
- Synthetic polylester lubricant oil will be used for R-507. There is no major performance difference between R-507 and R-502.
- R-402A (R-22/R-125/R-290), an HCFC's near azeotropic, is a short-term immediate replacement, and drop-in of R-502 requires minimum change of existing equipment except for reset of a higher condensing pressure.