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Practical Considerations when Switching over to HFC-134a & HC from CFC-12

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The awareness to protect the en vironment from the harmful ef fects of CFCs has motivated the industry globally to switch over from CFCs to Zero-Ozone Depleting Potential (ODP) refrigerants like HFC- 134a and Hydrocarbon (HC). This article presents the thermodynamic properties and analysis, which led to the selection of these refrigerants as alternatives to CFC-12 for different applications. Some practical aspects have also been highlighted, which are being faced during the change over either to HFC-134a or HC refrigerants by the industry.

With India, a party to the Montreal Protocol, having issued the 'Ozone Rules 2000', all original equipment manufacturers (OEMs) in India using CFCs as refrigerants have had to change over to non-CFC refrigerants with effect from 1st Jan 2003. CFCs along with their compatible mineral lubricating oils have in fact proved to be excellent working fluids as they are non-toxic, nonflammable, chemically and thermally stable, reliable and user friendly. CFC-12 was widely used in domestic refrigerators, stand alone plug in commercial refrigeration appliances and mobile air conditioning (cars and buses). A life of 15 to 20 years could be expected in sealed systems like domestic refrigerators and this led to compressor manufacturers and OEMs providing 7 year-warranties for the sealed system. Users would therefore continue to expect such assurances for the CFC substitutes like HFC-134a and HC blends now adopted as CFC substitutes. It would be interesting to compare the thermo-physical and thermodynamic performance of these refrigerants with CFC-12 and also look at the issues of reliability and life associated with these substitutes, particularly HFC-134a and its synthetic lubricant and the care that needs to be taken to ensure the same type of reliability and life offered by CFC- 12. This article is presented in two parts with Part 1 dealing with the properties, analysis and performance of the CFC substitutes and Part 2 with the practical issues associated with the application of these substitute refrigerants and their lubricating oils.

Part 1 : Alternatives to CFCs, comparison of properties and performance

Alternative refrigerants to CFC-12

Worldwide, developments were initiated as early as in 1988 to identify suitable replacements for CFC-12. Numerous candidates were assessed using application criteria including:

- Environmental acceptability (ODP and GWP)
- Safety (toxicity and flammability)
- Thermal stability over anticipated temperature range
- Chemical compatibility with contacting materials
- Low chemical reactivity with contacting materials
- Thermodynamic efficiency

- Availability and cost
- Compatibility with high volume production technology

It is worth mentioning that the refrigerants are predominantly from a group of compounds called fluorocarbons – halocarbons containing fluorine. While scanning through the methane and the ethane derivatives it was very clear that there are very few non-chlorinated chemicals that can be adopted as refrigerants. The intensive research and development resulted in a limited selection of alternatives. These alternatives are listed in **Table 1** with some selected properties. A number of other single components and blends are the subject of ongoing research but are not considered to be within the scope of this article.

HFC-134a and HC-600a being single component refrigerants, became the most technically acceptable choice globally as alternative refrigerants to replace CFC-12 in domestic as well as in stand alone plug-in commercial refrigeration appliances. Other alternative refrigerants have regional application, primarily driven by availability of suitable compressor or refrigerants. For example – a mixture of HC-600a and HC-290 has been adopted by one of the manufacturers in India in domestic refrigerators and in a number of countries for commercial refrigeration. **Figure 1** shows the variation of vapour pressures with temperature for the refrigerants in this sector. It can be observed that HFC -134a and blend of HC- 600a/HC- 290 have similar vapour pressure as that of CFC-12, while HC-600a has much lower vapour pressures as compared to CFC-12. The use of HC-600a/HC-290 hydrocarbon blend allows retention of volumetric capacity to avoid capital expense for retooling compressors. Currently, about 25% of the total global production of domestic refrigerators is with HC-600a and there is increasing trend to convert even from even HFC -134a to HC- 600 isobutene especially in developed countries like Japan.

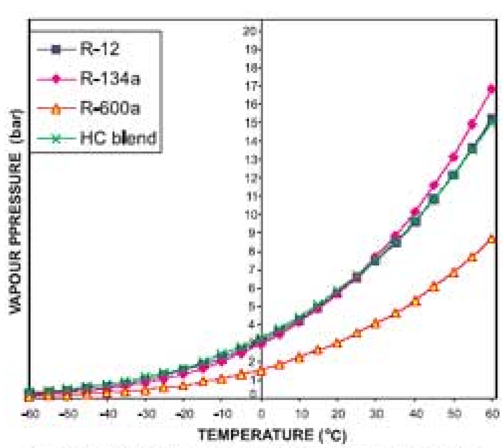

Figure 1 : Variation of vapour pressure with temperature.

HFC-134a

Refrigerant HFC-134a is nonflammable and has zero-ozone depletion potential. This refrigerant has been extensively studied and developed and has been selected as the alternative to CFC-12 globally.

Most of the HFCs including HFC-134a have relatively high GWP (see **Table 1**) and therefore HFCs have been included in the basket of Green House Gases along with other gases such as CO_2, CH_4, NO_2, PFCs and SF_6 and their emissions have to be controlled under the Kyoto Protocol (which is yet to be ratified).

Table 1: Alternative refrigerants to CFC-12 for domestic refrigeration and commercial refrigeration appliances.

Refrigerant	CFC-12	HFC-152a	HFC-134a	MP66/39	HC-290 / 600a	HC-600a Isobutene	HC-290 Propane
Formula	CF2Cl2	CH3CHF2	CH2FCF3	HCFC/	C3H8-	C4H10	C3H8
				HFC blend	C4H10		
Molecular Weight	120.93	66.05	102.03	(dependent)	51.12	58.13	44.1
Critical temperature	112.0	113.5	101.1	96.0	96.0	135.0	96.8
Boil point	–29.8°C	–25.0°C	–26.16°C	–30°C	–30°C	–11.73°C	–42.1°C
(100 kPa)							
Density (kg/m³;–25°C) sat vapour sat liquid	7.57 1472.0	3.25 1013.0	5.50 1371.0	– –	3.14 584.4	1.66 608.3	2.42 580.7
Flammable limits (%in air), 20°C, 100 kPa	None	3.7-18.0	None	None	1.8-9.0	1.4-8.4	2.2-9.5
TLV	1000	1000	1000	1000	Simple Asphyxiant	Simple Asphyxiant	Simple Asphyxiant
ODP	1.0	0	0	0.036	0	0	0
GWP	10600	120	1300	1100	3	3	3

The volumetric capacity of HFC-134a is about 12% lower than CFC-12 at the standard rating conditions –23.3°C evaporator, 55°C condenser) used by compressor manufacturers for performance measurements on calorimeters for LBP applications. Increasing the displacement of the compressor offsets the capacity loss. Efficiencies of compressors with the displacement change have been measured to be equivalent to CFC- 12 compressors. All major compressor manufacturers are offering models optimised for use with HFC-134a. Recent energy consumption tests in refrigerator-freezers have shown that HFC-134a is approximately equal in performance to CFC-12 in optimised units. HFC-134a is benign and shown to be compatible in sealed tube tests in the presence of metals, oils, plastics, and elastomers common in refrigeration systems.

HIDECOR (Human and Institutional Development in Ecology Refrigeration), a bilateral project of the Swiss Agency for Development and Cooperation (SDC) and Ministry of Environment and Forest (MoEF, Gol) started in 2000 to contribute its efforts to phase out the use of CFCs in the servicing sector. Managed by a consortium, Swiss-Contract and IT Power India Pvt. Ltd. from their office in Pondicherry, HIDECOR will have trained 10,000 technicians from the Micro and Small Enterprise (MSE) RAC servicing sector to adapt to new environmentfriendly refrigeration technology by end 2004. At very low cost, HIDECOR trains technicians in 2-day practical training programmes, faclitated through a network of training cells in 11 states in India. The larger RAC industry (Godrej, Whirlpool, Electrolux and Kirloskar Copeland) contribute their expertise by providing training at their own facilities. The hands-on training covers servicing new HFC and HC-based refrigerators and small commercial appliances and includes retrofitting CFC appliances. HIDECOR provides information on new products/equipment and *supports the development of indigenous equipment : Evacuating & charging units* and micron-level vacuum gauges, now available at affordable prices on the Indian market. Other activities include R&D, and the redesign and upgrading of the syllabus for CTS and ATS courses for refirgeration mechanics to include handling new eco-friendly refrigerants.

The project disseminates information to servicing sector technicians through a quarterly newsletter, ECO-COOL, in English, Hindi and Tamil, providing a medium of exchange for those technicians who have little access to publications such as the ISHRAE Journal.

Professor R. S. Agarwal and R. S. Iyer, members of the editorial board of Eco-Cool, contribute their expertise and experience to the aims of the project, along with other partners from industry, universities, government and private institutions, As of end 2004, an initiative supported by the Multilateral Fund of the Montreal Protocol – The National CFC Consumption Phase-out Plan (NCCOPP) Service Sector – will take up the challenge. NCCOPP envisages the complete phase out of CFC consumption by January 2010.

HFC refrigerants are immiscible with the napthenic mineral oils and alkyl benzene oils historically used with CFC-12. Several types of synthetic polyol-ester oils have been developed for use with HFC-134a. These oils are hygroscopic and require enhanced process control to ensure maintenance of low system moisture requirements. HFC-134a is a more powerful solvent than CFC- 12 and may require conversion to more solvent-resistant grades of electrical insulation in the compressor motor. Molecular sieve filter/dryer grades different from those used with CFC-12 are required. HFC-134a cannot be considered, a drop-in replacement for CFC-12, and substantive modifications are required. Typical changes for HFC- 134a refrigeration systems include changed compressor, restrictive capillary tubes, new filter dryers (XH-9)*and less refrigerant charge.

Several manufacturers have encountered problems of capillary tube plugging due to sludge generation during developmental endurance testing of refrigerators containing HFC-134a. Paraffinic motor winding, lubricant and incompatible fabrication process fluids were identified as root causes for these problems. Observed problems have been resolved, but the application of HFC- 134a is highly sensitive to contamination compared to CFC-12. Disciplined manufacturing cleanliness and process controls are essential for successful application of HFC-134a. The caveats mentioned above about the use of HFC-134a and synthetic oils have been treated in greater detail in Part 2 of this article i.e. "Practical issues in the applications of HFC-134a and HCs".

Hydrocarbon refrigerants

Hydrocarbons are environment friendly refrigerants due to their zero- Ozone Depletion and negligible Global Warming Potential (GWP). Their efficiency is slightly better especially in case of HC-600a than other leading alternative refrigerants and these are fully compatible with the lubricating oils conventionally used with CFC-12 i.e. mineral oils. The latent heat of vapourisation of hydrocarbon refrigerants is very high in comparison to CFC-12 and HFC -134a and its density is approximately one third that of CFC-12 making these refrigerants attractive because of its low charge requirements and circulation rates. However, hydrocarbons are flammable. Hydrocarbons have been used as refrigerants for decades in refrigeration systems. Their use has increased in the last 10 years and they are now being used in place of CFC-12 in domestic and commercial refrigeration appliances. The initial active application efforts of HC refrigerants in Europe have rapidly expanded to other regions of the world.

There are two HC refrigerants, which are commonly used in new refrigeration appliances and to convert old CFC-12 appliances:

Isobutane (R-600a)

R-600a is widely accepted for domestic refrigeration and some stand alone plug-in commercial refrigeration appliances. The suction specific volume of R-600a is much larger than CFC-12. Thus, compressors used with R-600a have a higher displacement, but have the same size motor as of CFC-12 for a similar cooling capacity. R-600a is generally used for domestic refrigerators but sometimes also for commercial refrigeration appliances. R-600a possesses some of following thermo-physical properties:

- Single substance
- Boiling Point : –12°C
- Much lower vapour pressures
- Miscible with mineral oil
- HC-600a/mineral oil is compatible with compressor materials
- HC-600a is flammable

Propane / Isobutane blend (HC blend)

HC blend has almost similar vapour pressure as that of CFC-12 and thus its thermodynamic characteristics are also similar to CFC-12. It gives the same capacity while operating at similar conditions. HC blend is being used by an Indian manufacturer of domestic refrigerators. It is also being used in manufacturing stand alone plug-in refrigeration appliances in some countries (e.g. ice cream freezers, water coolers), and is the refrigerant to use when converting (retrofitting) existing CFC-12 systems. The blend possesses following characteristics:

- HC290 (propane) / HC600a (isobutane)
- About 50/50% by weight (most common)
- Zeotropic blend
- Fully miscible with mineral oil
- Compatible with compressor materials
- HC blend is flammable

Flammability and safety issues with Hydrocarbons

Hydrocarbon refrigerants are flammable when mixed with air and ignited. Necessary safety precautions need to be taken, like use of nonsparking electrical components. (OLP, relay, bulb-holder, thermostat and door switch).

Typical operating conditions of CFC-12 and its alternatives

Typical operating conditions for some common applications with HFC-134a are given in **Table 2**.

Table 2: Operating conditions.

Appliance (Cabinet Temperature)	Temperature °C		Pressure					
			CFC-12		HFC-134a		HC Blend	
	Evap.	Cond.	Evap.	Cond.	Evap.	Cond.	Evap.	Cond.
Bottle Cooler (2 to 4°C)	–10	55	2.2 bar (abs) (17 psig)	13.6 bar (abs) (183 psig)	2 bar (abs) (14 psig)	15 bar (abs) (200 psig)	2.3 bar (abs) (19 psig)	12.1 bar (abs) (161 psig)
Ice Cream Freezer (–20°C)	–30	55	1 bar (abs) (–0.1 psig)	13.6 bar (abs) (183 psig)	0.84 bar (abs) (–2 psig)	15 bar (abs) (200 psig)	1.1 bar (abs) (1.3 psig)	12.1 bar (abs) (161 psig)
Visi-cooler (2 to 4°C)	–10	55	2.2 bar (abs) (17 psig)	13.6 bar (abs) (183 psig)	2 bar (abs) (14 psig)	15 bar (abs) (200 psig)	2.3 bar (abs) (19 psig)	12.1 bar (abs) (161 psig)
Display cabinets (2 to 4°C)	–10	55	2.2 bar (abs) (17 psig)	13.6 bar (abs) (183 psig)	3 bar (abs) (14 psig)	15 bar (abs) (200 psig)	2.3 bar (abs) (19 psig)	12.1 bar (abs) (161 psig)
Refrigerators (7 to +5°C)	–23.3	55	1.35 bar (abs) (17 psig)	13.6 bar (abs) (183 psig)	1.15 bar (abs) (14 psig)	15 bar (abs) (200 psig)	1.45 bar (abs) (6 psig)	12.1 bar (abs) (161 psig)

Comparative performance indices of leading refrigerants for Domestic Refrigerators

Table 3 presents the calculated relative performance parameters for a mixture of Propane-Isobutane, pure Isobutane and HFC-134a as leading alternative refrigerants to CFC-12 for a theoretical cycle having a –23.3°C evaporator and a +55°C condenser.

Table 3 : Comparative performance indices of leading refrigerants for domestic refrigerators.

Refrigerant	CFC-12	HFC-134a	HC-290 / 600a	HC-600a Isobutane
Formula	CF_2Cl_2	CH_2FCF_3	C_3H_8-C_4H_{10}	C_4H_{10}

Volum.cap. (kJ/m3), –23.3°C	1237	1185	1254	626
Press.ratio(–23.3°C /+55°C) subc. to 32°C	11.03	14.07	11.42	13.39
COP, theoretical (–23.3°C/ +55°C) subcooling to 32°C	equal HFC-134a	–	to equal HFC-134a	>HFC-134a
Disch.temp. Theoretical (–23.3°C /+55°C) + suct.gas cooled motor (practical)	120-125 170-175	115-120 150-155	105-110 140-145	100-105 135-140

The thermodynamic analysis carried out using HFC-134a and HCs above gives a theoretical comparison of how HFC-134a and HCs perform under LBP conditions. It may be noted that the discharge gas temperature is lower for all the substitutes as compared to CFC-12, particularly for HCs. However both these refrigerants have actually performed far better in refrigeration appliances/equipments than what the thermodynamic analysis indicates due to the following reasons:

- Better system designs
- Better heat exchange properties
- Capillary optimization
- Better compressor designs

(improvement of volumetric efficiency, better gas management etc.)

We can now take up each of these refrigerants and look at the other practical problems that one has to encounter when using these refrigerants and the measures to be adopted to ensure reliable and safe running of the appliances when working with these refrigerants.

Part 2 : Practical issues in HFC-134a and HC applications

HFC-134a

Some of the key issues that need to be addressed when using HFC- 134a are the following:

Refrigerant-oil miscibility

HFC-134a is immiscible with mineral lubricating oil used with CFC-12 and HCFC-22 and poses problems for oil return and reliable system working. Therefore special synthetic lubricating oils have been developed (which ensure good miscibility at all operating conditions) for use with HFC-134a and have been in use for over a decade. The synthetic oil used for MACs (mobile air conditioning) is PAG (poly alkylene glycol) oil and for refrigeration (stationary) POE (polyol ester oils) have been used. These oils have their own problems which need to be understood and addressed when using HFC-134a.

Hygroscopic nature of HFC-134a and synthetic oils

Both HFC-134a and the synthetic oils are much more hygroscopic as compared to CFC-12 and mineral oils. **Figure 2** compares the solubility of moisture in CFC-12 and HFC-134a at different temperatures in the liquid phase of the refrigerant. It is evident from this that HFC-134a is much more hygroscopic than CFC-12.

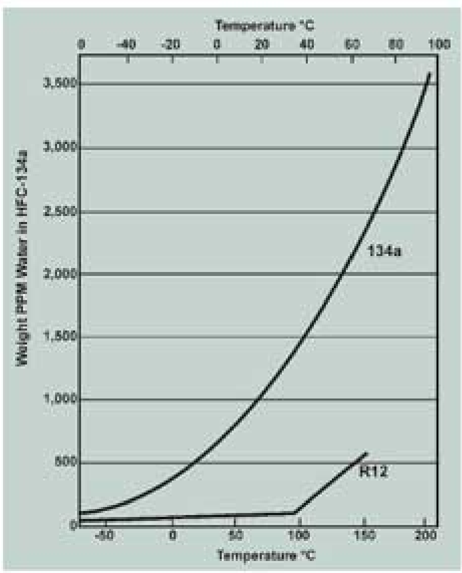

Figure 2 : Solubility of water in HFC-134a.

Figure 3 gives a hygroscopicity comparison between mineral oils used with CFC-12 and HCFC-22 systems and polyol-ester oils used with HFC-134a in refrigeration. It can be seen that when both the oils are kept exposed to the atmosphere, the moisture absorbed by the POE oil rises sharply as the exposure in hours increases whereas the moisture absorbed by the mineral oil is almost the same irrespective of the exposure time.

Now it is well known that the moisture present in refrigerants and oils contributes to ice formation in capillaries/expansion valves and evaporators, corrosion of metal parts, copper plating, damage to motor insulation in hermetic systems and hydrolysis of refrigerants/lubricants and damage to other materials. So it is clear that the risks of all this occurring with HFC-134a and synthetic oils is much more than in CFC-12 and mineral oils. POE oil has been used for comparison as PAG oils are used only in MACs and are incompatible for use in hermetic systems. Further PAGs are even more hygroscopic than POE oils.

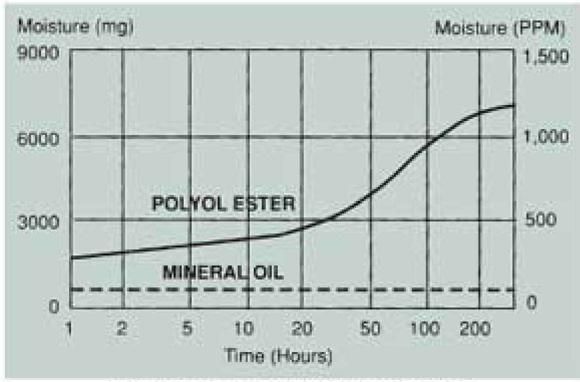

Figure 3 : Hygroscopicity comparision.

Effects of moisture in HFC-134a systems

Apart from the consequences of moisture in refrigeration systems in general, mentioned above, there are other reactions between moisture and polyol ester oils which leads to acid formation and also to the formation of sludge that gets deposited in the capillaries and eventually reduces cooling and results in compressor failures. This is because polyol-ester oils are produced by the reaction between an alcohol and an organic acid. This results in the formation of an organic ester and water. The water is separated and the organic ester is used as a lubricant. This reaction is however reversible whenever excessive moisture is present and results in the formation of acid and alcohol. This is described as under:

- RCOOR + HOH «» RCOOH + R'OH
- ESTER + WATER «» ACID + ALCOHOL

Free carboxylic acid can react with metal surfaces to cause corrosion. The metal carboxylate soaps thus produced can cause capillary tube blockage. If the moisture content of the POE oil in a refrigeration system rises above 100 ppm, corrosion of metallic parts and copper plating may occur.

The lesson from the above is that evacuation of HFC-134a systems has to be done with greater care and deliberation so as to reduce the moisture content as low as possible and that the POE oils should never be exposed to the atmosphere for long periods, preferably not more than a few minutes during servicing of these systems.

Material compatibility

- **With materials of construction of compressors and heat exchangers:** HFC-134a – POE oil combination is compatible with most of the commonly used metals like copper, iron/steel, brass, aluminium etc.

Plastics like PVC, polyethylene, nylon, polycarbonate also offer good resistance to HFC-134a.

Elastomers like natural rubber and neoprene are compatible whilst silicone, buna S, butyl rubber are incompatible. Motor wire insulation like polyamide imide is compatible with HFC-134a/POE oil combinations. However the right equivalent grade of electric wire coating (paraffin/ beewax) has to be used, as otherwise there is extraction of this material by the HFC-134a/POE combination leading to capillary blockage. Whilst compressor manufacturers take care of this, the problem will arise during servicing if the motor is to be rewound and this work should be entrusted preferably to the compressor manufacturer. Likewise some of the materials used on CFC- 12 compressors for motor slot insulation also need to be changed.

- **With in-process materials:** During the manufacture of compressors, copper tubes etc. a large variety of oils (cutting oils, presswork oils, drawing oils), rust inhibitors and cleaning agents (chlorine based) are used. Many of these, which were used with CFC-12 are paraffin based and also chlorine based. All these oils, greases, cleaning agents etc. are left behind in the components as residues and assembled into the refrigeration system. Whilst this causes no severe problems in CFC-12 systems, as most of these residues are soluble in CFC- 12 – mineral oil combinations, it would cause serious problems in HFC- 134a – POE systems as these are insoluble or react with the POE oils and result in capillary blockage. Manufacturers of compressors and OEMs have to take great pains to have a washing system, which would clear the components of all these residues or use substitute in-process materials, which are compatible with HFC-134a/POE combination. The problem would arise again during servicing/repair, which is done under uncontrolled conditions and here also the right type of cleaning materials have to be used. Commonly used cleaning agents like Carbon Tetrachloride or R11 cannot be used as these are under phase-out and would also react with the POE oil. In lieu of these, Trichloroethylene can be used with necessary safety precautions but it has to be ensured that all the liquid Trichlorethylene is completely vapourized and cleared out of the system so that there is no residual chlorine left behind. Alternately, Hexane-based cleaning agents can be used.
- **With other components of the refrigeration system:** One of the most important elements of the refrigeration system is the filter-drier that is used to adsorb excess moisture in the system. It is important that the desiccants used in the

drier are compatible with the HFC-134a/ POE combination. The desiccants used in CFC-12 systems are molecular sieves 4AXH5* and these are not compatible with HFC-134a/POE combination. Molecular sieves of the XH7* and XH9* have been specially developed for HFC-134a applications and it is important to ensure the use of these desiccants. This is to be particularly emphasized during servicing and repairs.

** Trade names of desiccants manufactured by UCAL, USA*

System Hygiene

System cleanliness is to be maintained as per DIN Standard 8964 for CFC/HCFC appliances. It is recommended that the levels of dust, dirt, debris, moisture etc. should be maintained at $1/3^{rd}$ of the levels mentioned in the above standard. The point to be noted here is that the HFC-134a/POE combination is a much better scouring agent than CFC-12/MO and will therefore extract any of the dirt/debris remaining in the system components and piping. Further the extracted debris is not soluble in HFC-134a/POE as it is in CFC-12/MO combinations. Therefore, it is safe to start with as clean a system as possible. One safe procedure is to have pure dry nitrogen swept through the system at low pressure whilst carrying out brazing. This prevents the formation of black copper oxides inside the tubes, which later block capillaries.

Thus, it can be seen that for reliable and trouble-free working of HFC-134a hermetic systems a great deal of care, discipline and quality control is necessary during both manufacture as well as during servicing/ repairs. Whilst the bigger OEMs may be able to handle this with relatively less difficulty, it is not going to be easy for the middle level and smaller manufacturers and service technicians unless they are well trained in these disciplines. Years of mishandling CFC-12 and mineral oils without too much of consequential failures due to the more tolerant behaviour of CFC-12 and mineral oil has made many manufacturers/service personnel indifferent to good practices and this mental conditioning could pose severe problems for these manufacturers and service technicians in terms of reliable appliance performance when handling HFC-134a systems. The developed countries have by and large, mastered the problems of HFC-134a/POE oils but the developing countries have to go through the learning curve.

HCs as substitutes for CFC-12

HCs or hydrocarbons like Propane (R-290) and Isobutane (R- 600a) have been used as refrigerants in lieu of HCFC-22/CFC-12 in the past in applications like refineries and petrochemical plants which have a flammable/explosive environment. Their use as refrigerants in households or in commercial/industrial applications has however been rare due to the highly flammable nature of these refrigerants. However, with the Montreal Protocol's CFC/HCFC phase out and the relatively high GWP of HFCs, HCs have gained a lot of acceptance in Europe, particularly in the highly environment conscious nations of Germany, the Scandinavian countries and Britain. It began in Germany with the use of binary mixtures of Propane and Isobutane in about 50% proportion of each by weight, as it was possible to use this blend as a drop - in refrigerant to CFC-12. Later this was replaced by Isobutane where the compressor had to be completely redesigned and the system design also altered suitably. The advantage with Isobutane was the higher COP and lower noise levels of the refrigerators, which found good acceptance in Germany as explained in Part 1 of this article.

The greatest advantage of HCs (apart from their zero ODP and near zero GWP) is that they are compatible with mineral oil and most of the practices followed with CFC-12 can be continued. Further, the refrigerant charge when HCs are used is just about 40% of what is needed with CFC-12 and so the charge in domestic refrigerators and some commercial appliances is so small as to render it innocuous from the flammability point of view.

However on account of their inherent flammable nature, sparking components in the appliance like thermostats, compressor relays, OLPs and door switches etc. will have to be replaced with non-sparking or sealed types. In India, Godrej is one of the companies that has opted for HC blends for their refrigerators. In Japan, Matsushita has come out with a complete range of Isobutane basedcompressors. HCs like Propane are being considered as replacements for HCFC-22 also and British Standard 4434 clearly lays down the code for the use of HCs as refrigerants in larger installations also.

Another singular advantage of HCs is the ease with which the HC blends of Propane/Isobutane can be used as drop-in refrigerants for CFC- 12 to give a performance close to that of CFC-12. The only additional work is to replace the sparking components with non-sparking ones.

This could make the job of servicing of millions of refrigerators with CFCs in the field much easier when CFCs will soon disappear from the market. As compared to this, the job of retrofitting CFC-12 appliances with HFC-134a is costly, tough, tedious and fraught with unreliability problems. HCs are therefore a worthwhile alternative substitute for CFC-12 particularly for appliances with small charges i.e. less than 350 grams of CFC-12.

Acknowledgements

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