1- INTRODUCTION

The destruction of the ozone layer by the chlorofluorcarbons (CFC's), among which are CFC 11, CFC 12, and CFC 13 and its vital effect on the earth's eco-system, were the principal reasons for the signing of the Montreal Protocol in 1987, which regulates the world production and consumption of these substances. The question which must be answered is based on the alternative to be chosen concerning the future availability of CFC's, mainly CFC 12.

One of these alternatives, especially in domestic refrigeration, is the R 134a alternative refrigerant which was chosen due to its ozone layer non damaging characteristics, and it also has physical-chemical properties very similar to CFC 12.

This document has been prepared as part of the services we are providing our customers with during this period of change, in order to offer guidance and avoid pitfalls that may be encountered during the introduction of R 134a in new refrigeration systems.

It must be noted that recommendations contained in this guide are intended to complement any measures devised by the manufacturer and do not carry any responsibility on our part as to their efficiency and applicability to each individual situation.

2- THE ALTERNATIVE REFRIGERANT R 134a

Due to its environmentally compatible characteristics, i.e., the absence of chlorine (an ozone depleting agent) and the fact that it presents physical and thermodynamical properties which are relatively similar to those of the R 12 refrigerant, the R 134a is one of the present choices for replacing the R 12.

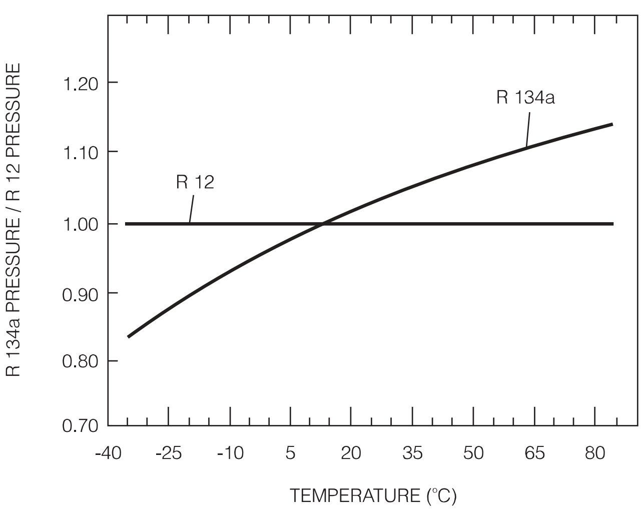

Fig. 1 - Pressure versus temperature behavior of R 134a, as compared to R 12.

As demonstrated in figure 1, R 134a presents higher pressures at high temperatures and lower pressures at low temperatures when compared to R 12. Both refrigerants present the same pressure at around 20°C .

The following table shows the major impacts of the use of R 134a compared to the use of R 12.

The tests were performed with the current EM 55NP 220-240/50Hz R 12 compressor and its R 134a replacement, the EM 60HNP 220-240V/50Hz.

COMPRESSOR		EM 55 NP	EM 55 NP	EM 60 HNP
Displacement	cm^3	4.99	4.99	5.54
REFRIGERANT		R 12	R 134a	R 134a
A - Evaporating Pressure (-25 °C)	bar	1.237	1.068	1.068
Condensing Pressure (55 °C)	bar	13.66	14.92	14.92
Enthalpy (-25 °C/32 °C)	kJ/kg	375	431	431
Enthalpy (55 °C)	kJ/kg	254	279	279
Enthalpy Difference	kJ/kg	121	152	152
B - Refrigerating Capacity (C1)	W	102	88	101
Mass Flow Rate	kg/h	3.07	2.08	2.39
Cylinder Outlet Gas Temperature	°C	133	123	
C - Expansion Device Inlet Temperature	°C	55	55	55
Specific Volume	dm^3/kg	0.841	0.927	0.927
Volume Flow	dm^3/h	2.58	1.93	2.22
D - Liquid Enthalpy (32 °C)	kJ/kg	231	244	
Enthalpy Difference	kJ/kg	144	187	
Refrigerating Capacity (C2)	W	121	108	
Capacity Ratio (C2/C1)		1.19	1.23	

As demonstrated in the above table the enthalpy difference of R 134a is significantly larger than that of R 12.

Consequently, a smaller mass flow is required for the same refrigerating capacity.

Section B, of the same table, shows lower discharge temperatures with R 134a, obtained in experimental measurements.

It also demonstrates the significant drop in capacity, which reached 14.5% in the EM 55NP model using R 134a.

The refrigerant conditions at the entrance of the expansion device are presented in section C - table 1. The volume flow with R 134a is about 25% lower than with R 12, when using the same compressor model. Should a compressor with the same refrigerating capacity be used, there would be a decrease of around 14%, indicating the need to increase the refrigerant flow resistance in the capillary tube.

The influence of subcooling in the refrigerating capacity is shown in section D - table 1. Note that R 134a presents an increase in the refrigerating capacity of about 23% against 19% of that of R 12 when the liquid temperature at the entrance of the expansion device is decreased from 55°C to 32°C.

As observed in section B, the refrigerating capacity is, depending on the evaporating temperature, strongly affected by the replacement of R 12 with R 134a. This influence may be verified using the volumic refrigerating effect (ratio between the specific enthalpy difference in the evaporator and the specific volume of the refrigerant under suction condition). The greater the volumic refrigerating effect, the greater the refrigerating capacity produced by a compressor with a fixed displacement.

Figure 2 shows the behavior of this effect on R 134a and R 12, under different evaporating temperatures.

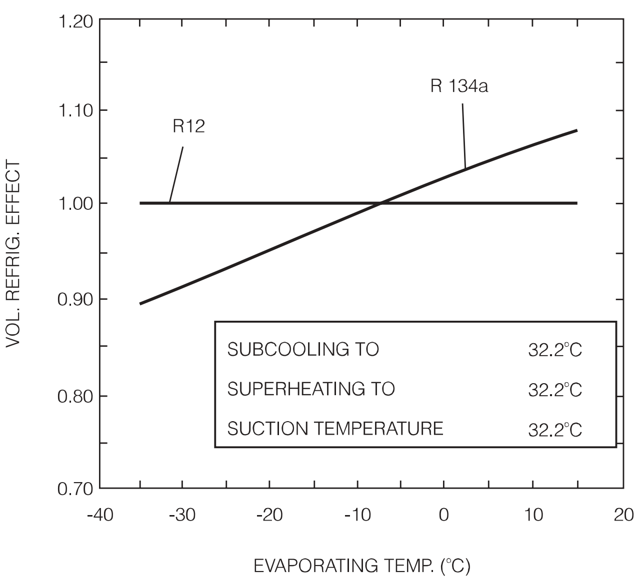

Fig. 2 - Volumic refrigerating effect versus evaporating temperature.

As observed in fig. 2, R 134a presents larger refrigerating capacities (high volumic refrigerating effect) at high evaporating temperatures (HBP conditions) and smaller refrigerating capacities at low temperatures (LBP conditions).

3 - R 134a COMPRESSOR SELECTION

Embraco's R 134a compressors have the same displacements as the R 12 compressors.

As previously mentioned, there is a 10-15% decrease in the refrigerating capacity under LBP conditions, depending on the compressor displacement. Small displacement compressors are more sensitive to the refrigerant substitution process.

Depending on the refrigeration system design it is possible to use an R 134a compressor with the same displacement as used for R 12. However, to obtain the same refrigerating capacity under LBP conditions, it is necessary to select an R 134a compressor with the next higher displacement to the one used for R 12.

4 - LUBRICANT OIL

Apart from its lubricating characteristics, one of the most important properties of a refrigeration compressor lubricant oil is its capability to mix with the refrigerant being used.

A lubricant with this property ensures a perfect mixing with the refrigerant, enabling a passage throughout the system and back to the compressor without causing oil pockets inside the evaporator and the condenser.

The mineral and synthetic oils, presently used as refrigeration compressor lubricants, are fully miscible with R 12 in all ranges of concentration and temperature.

However, R 134a, due to its high polarity, is immiscible with these oils. Therefore, it is necessary to use another type of lubricant oil for this system to function properly.

To solve this immiscibility of the R 134a, high polarity ester oils have been developed.

Although ester oil is miscible with R 134a, it is not as miscible with R 12 as the mineral oil is.

This aspect together with R 134a pressure behavior related to temperature, elevates the system's characteristic curve, as shown in figure 3.

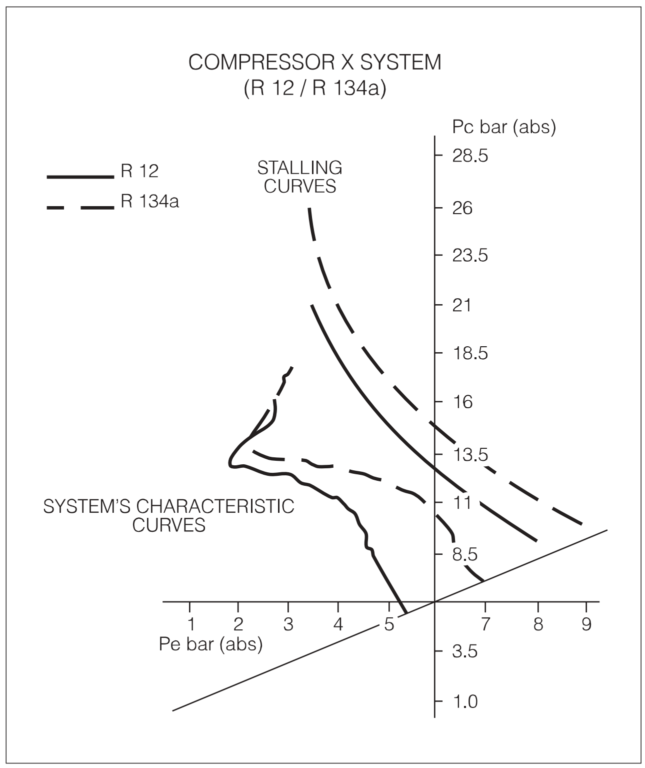

Fig. 3 - System's characteristic curve versus compressor's stalling curves, considering the same systems with R 12 and R 134a.

As shown in figure 3, the R 134a systems running pressures are higher than for R 12 systems, therefore requiring stronger electrical motors to elevate the stalling curve (maximum compressor loading) to a higher level.

It is expected that R 12 systems which have regular equalized pressures do not show starting problems.

Another distinct and very important characteristic of ester oils, when compared to mineral oils is the ability to absorb moisture (hygroscopicity), as shown in figure 4.

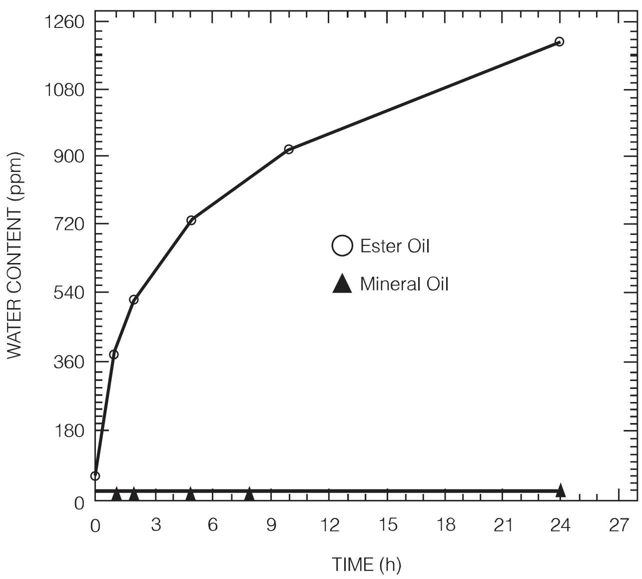

Fig. 4 - Moisture absorption by ester and mineral oils versus time (open beaker).

As seen in figure 4, ester oils are more hygroscopic than mineral oils. Despite the moisture absorption by the oil takes longer when the oil is inside the compressor housing, this characteristic is extremely important because a high moisture concentration causes hydrolisis, i.e., the transformation of ester oil into acid and alcohol.

The presence of such chemicals has a serious impact on compressor components such as the electric wire insulation, stator slot and winding insulating materials, causing them to become fragile and ultimately rendering the compressor inoperable.

Despite the higher hygroscopicity of the ester oils, the rules applied for compressors with open connectors at the assembly line may not have great impact on the assembly process, since the following parameters are observed:

1. No component, including compressor, must remain open for more than 15 minutes;

2. The R 134a must be as moisture free as possible.

5 - REFRIGERATION SYSTEMS FOR R 134a

The substitution of R 12 by R 134a is not solely restricted to the change of refrigerant in the hermetic refrigeration systems.

The components must be suitable for use with R 134a, as described below.

It must be emphasized that cleanliness in the system is extremely important for the use of R 134a. Further details in item 7 of this document.

5.1 - TUBING

The R 134a is compatible with all metals, i.e., steel, copper, brass and aluminum, presently used in refrigeration.

Elastomers such as CAF, Nylon and Neopren are also R 134a compatible. However, natural rubber, Butyl and Vitons are not recommended due to swelling and bubble formation properties.

5.2 - HEAT EXCHANGERS

Condensers and evaporators not showing adverse operational effects in R 12 refrigeration systems can also be used in R 134a systems.

Should the R 134a compressor capacity be larger than the capacity which the R 12 system was originally designed for, it may be necessary to use a larger condenser.

5.3 - CAPILLARY TUBE

Theoretical and experimental results have shown that the capillary tube in LBP refrigeration systems must be adjusted to increase the refrigerant flow resistance in accordance to its different operating conditions, as can be observed in table 1.

When a compressor with the same refrigerating capacity is selected, a 10-15% reduction in the N_2 flow is generally required for a 10 bar pressure at the inlet of the capillary tube.

5.4 - FILTER DRIER

The desiccants presently used in filter driers of the R 12 refrigeration systems are not compatible with R 134a. Desiccants similar to XH7 or XH9 (3Å) type are recommended.

The quantity of desiccant used in R 134a filter driers should be about 20% higher. This is due to the lower water absorption by XH7/XH9 combined with the fact that the moisture level of R 134a refrigeration systems may be higher due to the extreme hygroscopic properties of ester oils, as previously mentioned.

5.5 - REFRIGERANT CHARGE

The R 134a charge should be determined in accordance to the same procedures used for R 12.

In unchanged R 12 refrigeration systems, the R 134a charge may be about 5-10% lower.

6 - IMPACT OF REPLACEMENT OF R 12 BY R 134a IN DOMESTIC REFRIGERATION SYSTEM

Certain behavior trends become evident in the pressure and operation temperatures of the system when R 12 is replaced by R 134a in a domestic refrigerator, as shown in figures 5, 6, 7 and 8.

It is interesting to observe in this example that some original R 12 refrigerator components were adapted for use with R 134a.

An R 134a compressor of the same capacity as the one used in the original R 12 system was chosen. It used the XH7 desiccant in the filter drier and a 5% lower refrigerant charge. There were no changes to the condenser, evaporator and capillary tube.

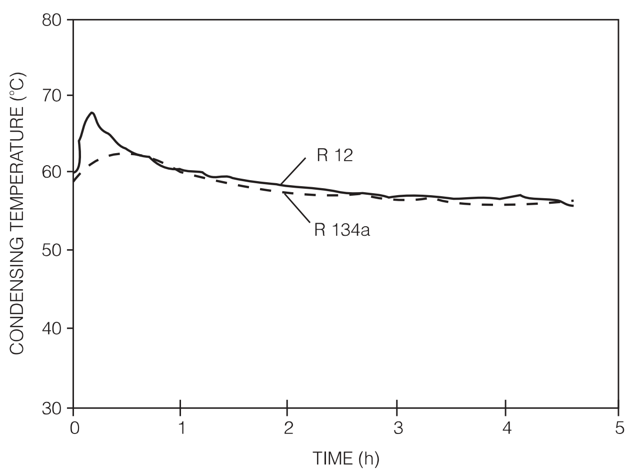

Fig. 5 - Condensing temperature behavior of the system with R 12 and R 134a.

As observed in figure 5, the condensing temperature was not affected with the use of R 134a. This is due to the fact that in many domestic refrigerators, such as the one used in this experiment, the condenser heat transfer is dominated by the air-side, which is not influenced by a different refrigerant.

However, as shown in figure 6, the condensing pressure of the system with R 134a is higher than with R 12. This was expected because both refrigerants presented the same condensing temperatures (see fig. 1).

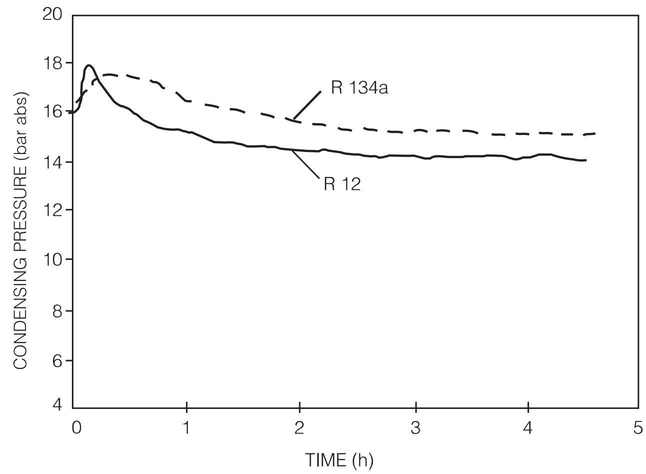

Fig. 6 - Condensing pressure behavior of the system with R 12 and R 134a.

Figures 7 and 8 show that the refrigeration system operating with R 134a presents an increase in the evaporating temperature while having the same evaporating pressures. Therefore, in order to reach the same evaporating temperature the capillary tube must be adjusted to increase the refrigerant flow resistance.

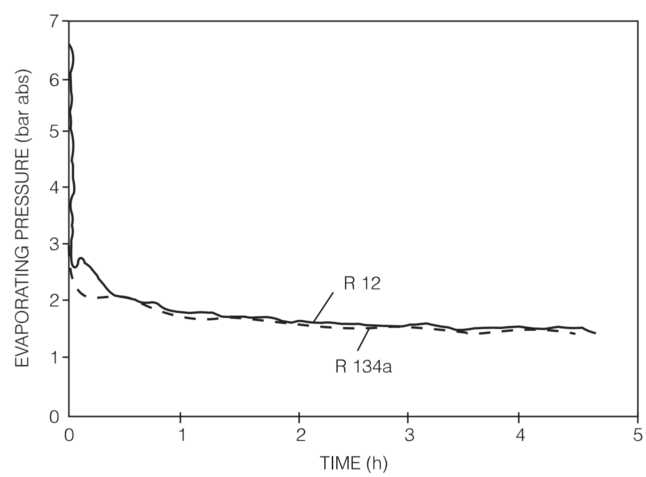

Fig. 7 - Evaporating pressure behavior of the system with R 12 and R 134a.

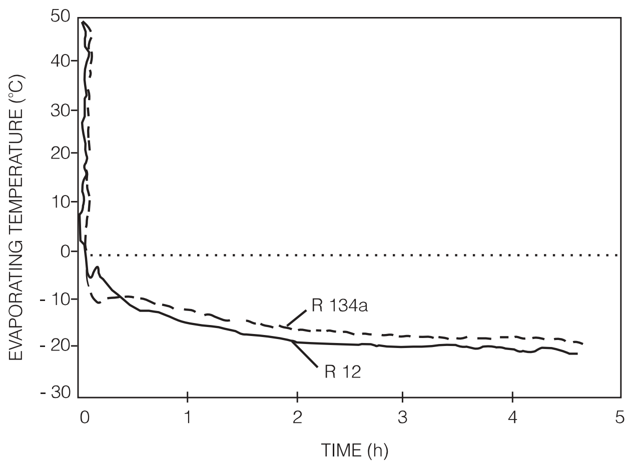

Fig. 8 - Evaporating temperature behavior of the system with R 12 and R 134a.

7 - R 134a REFRIGERATION SYSTEM CLEANLINESS

Since the beginning of the utilization of CFCs in hermetic refrigeration systems, special care has been taken regarding the cleanliness of the inner surfaces of the system before filling. The reason for this is to avoid greasy and oily residues coming from the manufacturing process of components.

The solubility with the refrigerant or the lubricant oil allows these residues to move around the system possibly causing a blockage of the refrigerant flow, specially in the capillary tube.

One of the main reasons is the low solubility of R 134a and ester oils with waxes, such as the paraffin found in the electrical motor wires of compressors, with the protective oils used in compressor components and greases used in the manufacture of tubings, evaporators and condensers.

Strongly alkaline substances, such as the protective agents used in the manufacture of compressor components can also be responsible for capillary tube blockage. These substances react with ester oil producing salts which may deposit in the capillary tube.

Other impurities, such as chlorinated residues from the component cleaning process must be avoided.
The reaction of this type of residue with ester oil can result in harmful acids (HF, HCl), causing metal corrosion and deterioration of the desiccant and lubricant. Mineral-oil residues must also be avoided as they result in the decrease of R 134a and ester oil miscibility causing oil return problems.

It is essential that all other components of the refrigerating system be completely free of these types of residues.

The knowledge acquired in the last years, supporting and following the experience of the leaders of the refrigeration industries around the world indicates that a successful conversion operation as well as a relatively simple manufacturing process can be achieved.

The presence of foreign substances such as chlorinated or greasy residues and mineral oil or impurities in the R 134a Embraco compressor would render warranty null and void.

Therefore, it must be emphasized that before filling with refrigerant, refrigeration system cleanliness is much more critical in the case of R 134a systems than R 12 systems.

Through its intensive research, Embraco is aware of this problem and the R 134a compressor production has been designed to eliminate such residues.

8 - ASSEMBLY OF NEW R 134a REFRIGERATION SYSTEMS

Due to the sensitivity of the R 134a ester oil systems we should like to make the following recommendations, which would also apply to any existing refrigerant:

8.1 - One system only to be connected to each vacuum pump.

8.2 - Form vacuum on both sides of appliance, with vacuum level below 0.6 mbar.

8.3 - Vacuum pumps must be installed on the same level as the compressor or lower.

8.4 - Use short hoses wherever possible.

8.5 - Vacuum level to be measured on the appliance and not on the pump.

8.6 - Perform final vacuum through charging board.

8.7 - Perform rough leak detection through charging board. In case of leak, there should be no filling.

8.8 - Limit content of non-condensable gases to 1%.

8.9 - Use R 134a as flushing agent to clean systems.

8.10 - Gas charging and evacuating equipment must be reserved exclusively for R 134a to avoid chlorinated residue contamination.

8.11 - The halogen leak detectors presently used in R 12 systems are not efficient with R 134a. This type of leak detector reacts with chlorine, a halogen, which is absent in R 134a. Therefore, equipment that uses helium as a tracer gas in combination with helium detectors, is recommended for the assembly lines of R 134a systems.

There are compact electronic leak detectors on the market which are compatible with the R 134a refrigerant.

8.12 - To prevent excessive moisture from entering the compressor the connector should be kept sealed at all times. Plugs should be removed immediately before brazing connectors to system tubes (maximum time allowed is 15 minutes).

Based on Embraco's experience to date, we intend to provide our customers with some recommended pratices to handle systems utilizing HFC 134a and ester lubricants. The scope of this document was neither to approve nor reject any of current procedures, nor to give final solutions to nonconformities. Rather, Embraco's intention is to provide assistance and guidance in order to achieve maximum performance and customer satisfaction.

Should you require any further assistance in the development of your refrigeration system to R 134a, please contact our sales staff at the following telephone and fax numbers indicated below.

Embraco

Rua (Street) Rui Barbosa, 1020 - Cx. Postal (P.O. Box) 91
89219-901 Joinville - SC - Brazil
Phone: +55 47 441-2430
Fax: +55 47 441-2870

Embraco North America, Inc.
2232 Northmont Parkway
Duluth, Georgia - USA 30096
Phone: +1 770 814-8004
+1 800 549-9498
Fax: +1 770 622-4620
+1 800 462-1038

Embraco Europe S.r.l.
Via Buttigliera 6
10020 - Riva Presso Chieri (Torino) - Italy
P.O. BOX 151 - 10023 - Chieri (TO)
Phone: +390 11 943-7111
Fax: +390 11 946-8377 / +390 11 946-9950