NEW RANGE OF HCFC-22 ALTERNATIVES

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ABSTRACT

The phase-out of the production of HCFC-22, currently scheduled for the year 2030 will require from manufacturers to find suitable alternatives for this widely used refrigerant. Presently it appears that only blends performance at least equivalent to R-22 will be acceptable.

For the low temperature refrigeration, replacement of R-22 is largely possible now by various blends and especially by the refrigerant R-404A.

The remaining major problem to solve out today is the substitution of R-22 in the Air-Conditioning Industry and particularly for unit systems.
Elf Atochem is currently developing a complete range including :

- substitutes dedicated to new or existing installations (typical R-22 technology) which will present thermodynamic performance close to those of R-22.
- substitutes dedicated to new installations which will enhance the performance of the system, but leading to a significant change in technology.

The objectives of this article is to present current work being done and results obtained by Elf Atochem regarding the replacement of R-22 for the Air Conditioning application.

INTRODUCTION

HCFC-22 is widely used as a refrigerant in residential air-conditioning and heat pumping. This fluid has favorable thermodynamic and transport properties and well-known material compatibility characteristics.

However, questions rose about the long term viability of HCFC-22. In 1992, the Copenhagen revision of the Montreal protocol trigerred the regulation of consumption of HCFCs [1]. In the European Community, a proposal intends to schedule the phase-out of HCFC-22 for the year 2015.

It appears very difficult to identify a substitute that exhibits in the same time thermodyn properties close to those of HCFC-22 and with better performance better than those of HCF(Consequently, Elf Atochem develops two types of alternatives :

- A "look-alike" of HCFC-22 in order to ensure aftermarket of existing installations but als start of new installations with very slight modifications of material.
- "Higher performance alternatives" which leads OEMs to optimize their material.

"LOOK-ALIKE" ALTERNATIVE

Elf Atochem has already identified a ternary mixture, the FORANE® FX 220, as HCFC-22 "l alike" alternative. Its thermodynamic properties match closely to those of HCFC-22 (Table 1)

- Similar boiling point and critical point, and especially a high critical temperature contrib therefore to good coefficient of performance (COP).
- Higher latent heat of vaporisation combined with a lower saturated vapor density w contributes to similar volumetric cooling capacity.

Table 1 :Thermodynamical properties of FORANE® FX 220

	HCFC-22	FORANE® FX 220
Bubble point at 1.013 bar (°C)	- 40.8	- 42.7
Critical temperature (°C)	96	93
Critical pressure (bar)	50	48
Latent heat of vaporisation at 1.013 bar (kJ/kg)	233.5	268.5
Bubble pressure at 25°C (bar)	10.4	11
Liquid density at 25°C (kg/dm3)	1.19	1.15
Saturated vapor density at 1.013 bar (kg/m3)	4.7	4.3
Glide at 1.013 bar (K)	0	10

An important criterion to select a good "look-alike" alternative is the vapor pressure substitute compared to that of HCFC-22. When reporting bubble and dew pressure of FORAN FX 220 versus the vapor pressure of HCFC-22, we can observe :

- A maximum of 10 % increase in low bubble pressure with FORANE® FX 220
- Similar compression ratio and similar difference between condensing and evaporating pressu

Besides its similar thermodynamic properties, other FORANE® FX 220 properties has be evaluated such as transport properties, or flammability.

IMPACT OF TRANSPORT PROPERTIES

In Table 2, we have reported transport properties which are considered to be most influential [2].

These properties are very similar for both refrigerants.

Higher liquid thermal conductivity at evaporator and lower liquid viscosity (- 5 to - 26 %) enhance performance of FORANE® FX 220 especially with an air to air system.

Higher liquid heat capacity of FORANE® FX 220 leads to optimize the installation by increasing liquid subcooling

Table 2 : Transport properties of FORANE® FX 220 compared to HCFC-22

	HCFC-22	FORANE® FX 220
Liquid heat capacity (kJ/kg.K)		
at 5°C	1.19	1.44
at 55°C	1.43	2.09
Liquid thermal conductivity (W/m.K)		
at 5°C	0.095	0.099
at 55°C	0.073	0.071
Liquid viscosity (cp)		
at 5°C	0.231	0.220
at 55°C	0.163	0.129

FLAMMABILITY EVALUATION

In contrast to pure compounds or azeotropes, zeotropes have a slightly different composition in the liquid and vapor phase ; in the event of a leak (especially from the vapor phase), this composition may vary due to the preferential distillation of the most volatile compounds. The FORANE® FX 220 contains a flammable compound. Therefore fractionation studies at the most severe conditions have been conducted (according to UL Standards [3]). Worst case of fractionation has been identified at low temperature (- 33°C)with slow leak (3 % weight/hour) conditions.

The remaining vapor and liquid composition have been measured and plotted in the ternary flammability diagram established at 100°C (according to ASTM E681-85 [4]).

Figure 2 illustrates the leakage path. The vapor composition, identified as worst composition, remains in the non flammable area.

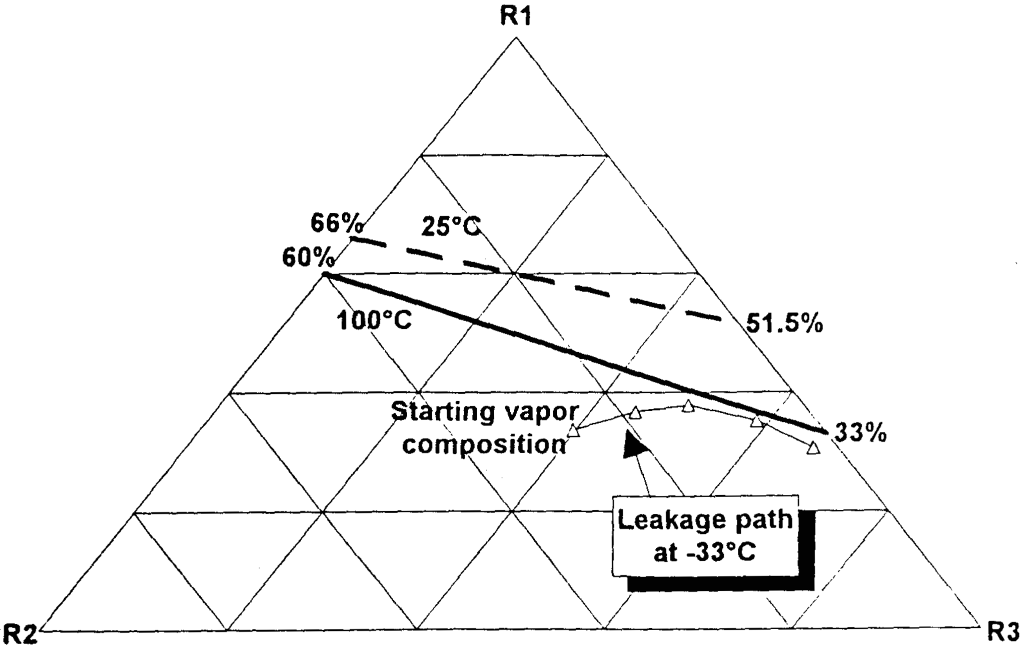

Figure 2 : Worst case of fractionation and flammability diagram.

All these data show that FORANE® FX 220 is a good choice as "look-alike" alternative of HCFC-22.

HEAT PUMPS TEST RESULTS

In order to test the performance of the FORANE® FX 220 blend described above on actual equipment and to compare its behavior to that of HCFC-22, a field test was set up and carried out by Elf Atochem's Applications Lab.

The test equipment consisted of 4 split system residential heat pumps, in pairs of two identical units, manufactured by two different OEMs. The systems were placed in volunteer residences in the Philadelphia, PA, suburbs replacing already existing indoor and outdoor units as well as refrigerant tubing. Except for the air handler's blower in the indoor unit, no modifications to the houses air delivery system was performed. Houses for each pair of heat pumps were chosen to be similar in size type and insulation values. Their relative close geographical proximity ensures similar outdoor weather conditions.

Out of each pair, one heat pump was kept with HCFC-22 and the original mineral oil and the other was retrofitted to FORANE® FX 220 with an ester oil (PLANETELF ACD 32W). In addition to the pressure transducers and thermocouples installed at different locations around the system, no other modifications was done ; therefore, the equipment remains essentially original.

The data acquisition system, based on a 286 type computer, took and stored in approximately 5 minute intervals on 16 different parameters. The parameters measured were as follows :

1. Thermal expansion valve (TVE) inlet pressure and temperature for indoor and outdoor units.
2. TVE outlet temperatures at indoor units
3. TVE outlet temperature and pressure at outdoor unit
4. Compressor suction and discharge pressures and temperatures
5. Inlet air temperature and relative humidity at the indoor units
6. Outdoor air temperature
7. Compressor motor current draw and voltage.

Where the terms inlet and outlet depend on whether the units is in the heating or cooling mode at the time.

While the data obtained from this test does not represent a strict comparison of FORANE® FX 220 and HCFC-22 on the same units, it certainly indicates what kind of trends in the data can be expected when using either refrigerant in split system heat pumps (SSHP).

<u>Some of the results from the study based on the data seen so far are as follows</u> :

For the theat pumps operating on <u>Heating Mode</u> (outdoor air temperatures in the range 30 to 55 F) :

- Compressor suction pressures are 5 to 10 psig lower and temperature 6 to 10 F lower with FORANE® FX 220 THAN FOR HCFC-22
- Compressor discharge pressures are slightly higher with FORANE® FX 220 (8 to 25 psig) and temperature are 0 to 20 F cooler with HCFC-22.
- Compressor amperage draw is about the same (± 0.1 amps)
- Temperature differential is 50 to 70 F for HCFC-22 and 70 to 85 for FORANE® FX 220 from the inlet to the outlet of the indoor heat exchanger (including subcooling).

For the heat pumps on <u>Cooling Mode</u> (outdoor air temperatures in the range of 84 to 100 F).

- Compressor suction pressures are 5 to 23 psig lower with HCFC-22 and temperature are to 7 F higher with FORANE® FX 220.

- Compressor discharge pressures are 25 to 45 psig lower with HCFC-22 than FORAN FX 220 and temperatures are 5 to 15 F lower with FORANE® FX 220

- Compressor amperage draw is 0 to 1 amp higher with FORANE® FX 220 than with HCFC-2

- Temperature differential is 0 to 26 with HCFC-22 and 0 to 15 with FORANE® FX 220 at indoor unit's heat exchanger (including superheating).

- Temperature differential is 69 to 79 F with HCFC-22 and 60 to 80 with FORANE® FX across the outdoor unit's heat exchanger (including subcooling).

From a subjective point of view, based on house. occupant comments, the house can maintained at comfortable temperature levels, during both the cooling and heating seasons, and comparable electric bills with either refrigerant.

LONG TERM ALTERNATIVE

The purpose of this part is to explain how Elf Atochem is conducting its search of a long t alternative which will enhance the performances of HCFC-22 based on cycle efficiency, volume capacity, operating pressures, low temperature glide and flammability.
The first step consists in the selection and the evaluation of pure components. More than products were chosen based primarily on their normal boiling point, although the selection crit also included whether data are available for their critical temperatures and pressures.

A simple cycle, has described below was chosen in order to represent air conditioner condition

- 43°C condensing temperature
- 7°C evaporating temperature
- 11K liquid subcooling
- 18°C return gas temperature

Results of capacity and efficiency was reported on a graph (see Figure 3).

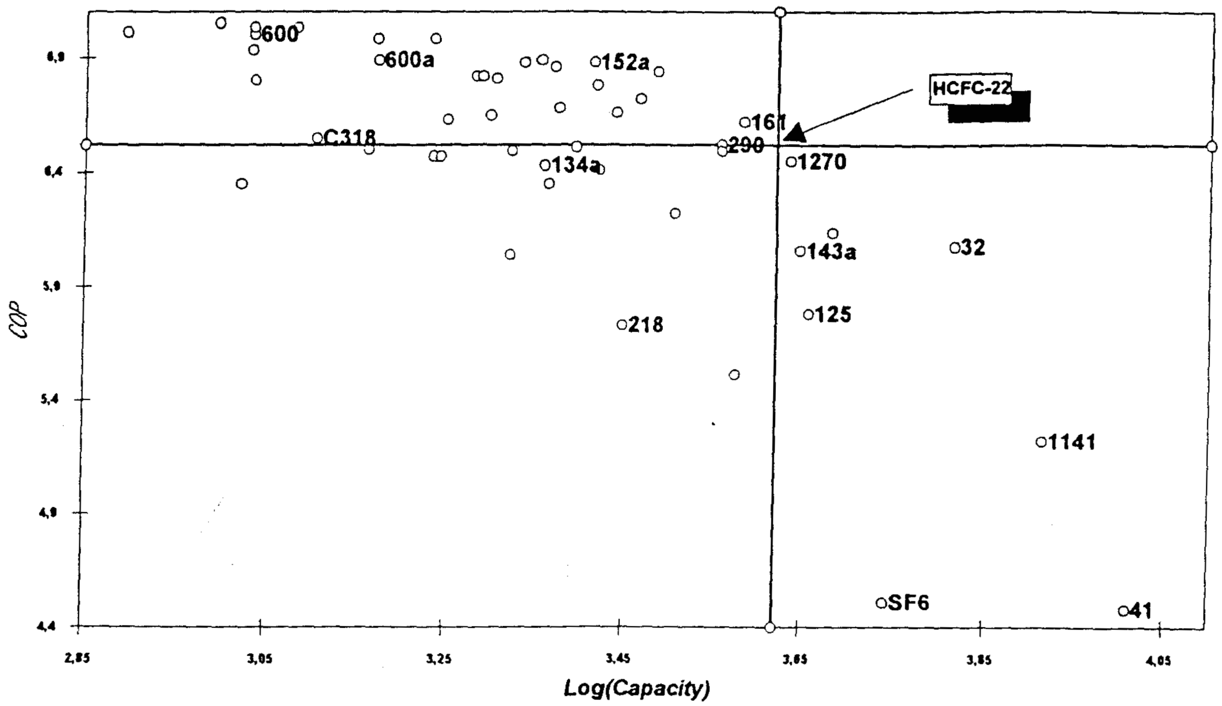

Figure 3 : Pure refrigerant evaluation

Ideal alternative must be in the top right area of the graphic. None (high efficiency and capacity) is currently present.

Nevertheless potential alternative can also be chosen in the bottom right area of the graphic (high capacity). Indeed a reduction of compressor volume leads to limit losses and consequently increase efficiency. But today no pure component are suitable replacement of HCFC-22, due to of flammability (R-32, R-143a), high pressure (R-125), toxicity (R-41), no stability (R-1141) concerns.

Therefore the second step consists in the evaluation of blends. In this case an important parameter is necessary to have reasonably accurate calculations of the blend properties : it is the interaction factor (kij).

In order to obtain this factor, vapor liquid equilibrium measurements have to be performed.

Among the 50 pure refrigerants studied in the first step, we have selected 24 of them such as hydrofluorocarbons, fluorinated ethers, cyclic refrigerants....

A data base of more than 50 interaction factors has already be obtained. But to evaluate all binary blends we need still 220 interaction factors.

From the available data, we have chosen to use a group contribution method in order to estim other interaction parameters. This method was developed by Abdoul [6] and applicated CFC/HCFC by E. Franson [7].

The results based on the kij data base are presented in Figure 4. Estimation of the interact factor is obtained with an average error of 0.008 and a maximum error of 0.03.

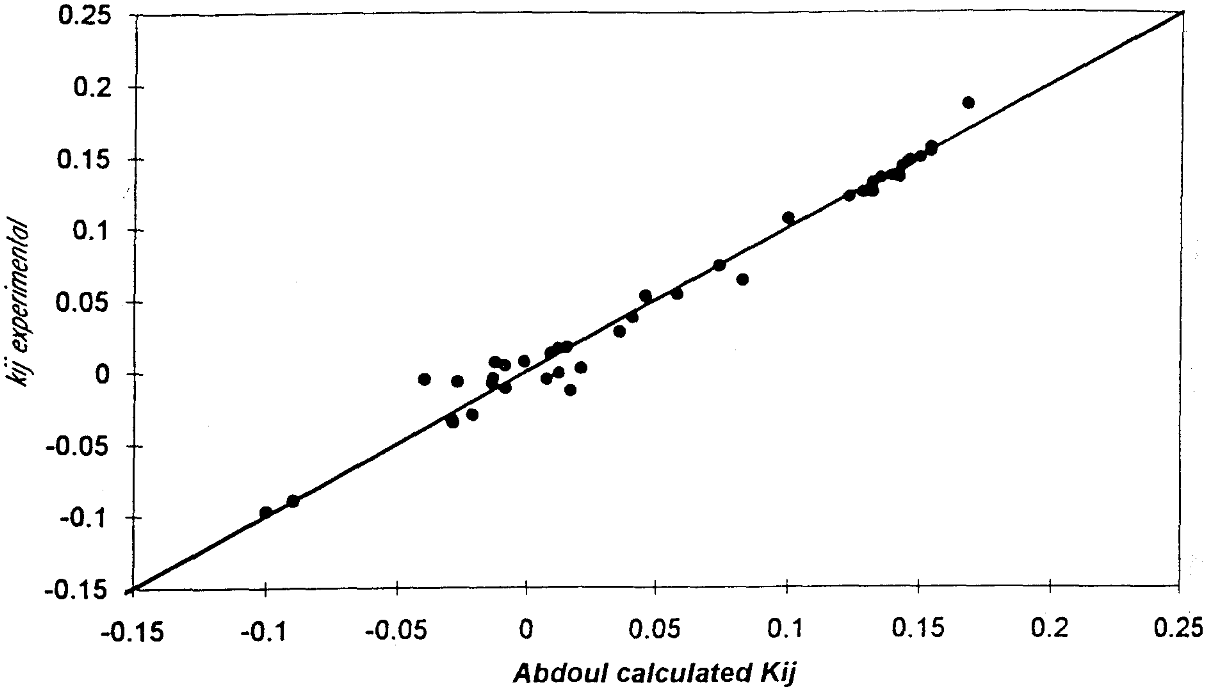

Figure 4 : Comparison of experimental and calculated kij.

The last step consists now to estimate unknown interaction factors with the Abdoul parame previously obtained and evaluate binary and ternary blends on the already cited cycle. A blend high capacity, low glide and low pressure will be a good alternative of HCFC-22.

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