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TWIN-SCREW COMPRESSOR PERFORMANCE AND SUITABLE LUBRICANTS WITH HFC-134a

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ABSTRACT

The performance of oil flooded twin-screw compressors is influenced both by the refrigerant and the type of lubricant used. HFC-134a has been suggested as a possible alternative refrigerant for replacement of CFC-12. Compressor performance based on calorimeter tests has been carried out on both CFC-12 and HFC-134a. The test results with the two refrigerants are compared.

The current status of evaluating lubricants through laboratory tests is discussed. Particular attention has been given to studying the miscibility of various types of lubricants. The use of synthetic lubricants is shown to have performance advantages over mineral oils which may make them a requirement for HFC-134a. These performance advantages have also led to efficiency improvements in twin-screw compressors with HFC-134a favorable to that of CFC-12.

INTRODUCTION

The twin-screw compressor consists of two mating, helically grooved rotors "male and female" in a stationary housing with inlet and outlet ports. The flow of the gas in the rotor grooves is mainly axial. Common lobe combinations are 4-6, 5-6, 5-7 and 6-7. The capacity is normally controlled with a slide valve (reference 1). There are three different types of screw compressors: oil flooded, oil reduced, and oil free (reference 2). This paper deals with the oil flooded twin-screw compressor. The performance of a screw compressor is mainly dependent on the interlobe clearance of the rotors. For better understanding of rotor quality, quality classes have been discussed for screw compressor rotors (reference 3).

OIL SELECTION

HFC-134a (CH_2FCF_3) is highly insoluble and non-miscible with conventional mineral oils and synthetic hydrocarbons. Lower molecular weight polyalkylene glycols and certain types of esters have been found to have good miscibility with HFC-134a. Most high viscosity grades (above 100 ISO) have poor miscibility. Higher viscosity grades are desirable to provide an efficient operating viscosity in the presence of the refrigerant for sealing during compression and for bearing lubrication.

An extensive miscibility study was undertaken at various concentrations of refrigerant with various types of synthetic fluids. It was found that one type of experimental, oil soluble, synthetic lubricant EXP-0139 exhibited miscibility characteristics (figure 1) which are similar to that of a paraffinic oil with R-22 (reference 4). Small amounts of this type of lubricant, but with lower viscosity, has been used during the determination of the heat transfer coefficient for two phase boiling of HFC-134a (reference 5). Original compressor tests were with a 150 ISO viscosity grade polyalkylene glycol (figure 2). Modifications were made to increase viscosity, improve miscibility at low temperatures, and reduce the tendency to solubilize water. The result was EXP-0272, with a viscosity of 180 cSt at 40°C (104°F). This was selected for rotary screw compressor applications, (reference 6).

The inverse miscibility of EXP-0272 at higher temperatures at oil concentrations found in the compressor is thought to be ideal for effective sealing of the compressor and to provide a good lubricant film for bearing lubrication, see figure 3. The characteristics observed with the liquid refrigerant and lubricant indicated a "non-ideal" solution characteristic. This term for solutions indicated insolubility of the two liquids. Further compressor test observations confirmed the indication that the HFC-134a gas also exhibits insolubility with the EXP-0272 at higher temperatures.

The EXP-0272 offers unique properties as a lubricant for HFC-134a in rotary screw compressors. This lubricant has been tested for solubility in a variety of viscosity grades above 100 ISO and found to behave in a similar manner to that described. The high viscosity behavior in the presence of HFC-134a at higher oil concentrations and temperatures, offers the possibility of improved efficiency in the compressor while effective oil return is maintained.

COMPARISON BETWEEN HFC-134a AND CFC-12 COMPRESSOR PERFORMANCE TEST DATA

Based on test results with a screw compressor tested on HFC-134a with an experimental oil ISO 236 and on CFC-12 with a PAO (polyalphaolefin) ISO 400, at 50°C(122°F) condensing temperature and comparison based on pressure ratio, the following favorable HFC-134a results were obtained (figure 4):

- the volumetric efficiency is 2 percent higher,
- the refrigeration capacity is 21 percent higher,
- the coefficient of performance is 12 percent higher.

The comparison of performance vs. pressure ratio is only applicable to the compressor. For the refrigeration system the comparison must be made vs. evaporation temperature. The picture of HFC-134a now becomes somewhat deteriorated since HFC-134a normally corresponds to higher pressure ratio for the same evaporation temperature compared with CFC-12. Figure 5 shows the test results based on evaporation temperature comparison. The refrigeration capacity for HFC-134a compared with CFC-12 is larger at evaporation temperatures above -7°C(19°F). The coefficient of performance (in cooling mode) is also larger for HFC-134a compared with CFC-12 at evaporation temperatures above -10°C(14°F). These tests are done without an economizer, which is a simplified two stage system but with only one compressor (reference 7). Economizer operation will put HFC-134a in a better position since it is more favorable to sub-cooling than CFC-12. An economizer calculation based on the test results without an economizer indicated that the refrigeration capacity and the coefficient of performance always is higher for HFC-134a compared with CFC-12 above about -20°C(-4°F) in evaporation temperature (figure 6). Let us now look for some explanation of these results.

THE BEHAVIOR OF THE SCREW COMPRESSOR

To get a better understanding of this discussion we include HCFC-22 besides HFC-134a and CFC-12. To make the presentation more popular we have added faces to the rotor bores (figure 7). Happy rotor bores and a position high up in each column represents good conditions. Neutral rotor bores and a position in the middle of each column represents neutral conditions of a quantity, with given gas, that will not affect the screw compressor to any significant degree. Unhappy rotor bores represent undesirable conditions.

The Refrigeration Capacity - CAP (figure 7)

HCFC-22 is a small compressor compared with HFC-134a and CFC-12 but the difference is not of any large significance, since the screw compressor can easily handle large volume flows (the displacement is proportional to the rotor diameter to the power of three).

The Pressure Difference - DP (figure 7)

The lowest pressure difference has CFC-12 and HFC-134a which means the lowest possibility for leakage. The screw compressor is more sensitive to the pressure differential than the reciprocating compressor since it has no sealing elements corresponding to piston rings.

The Pressure Ratio - P.R. (figure 7)

In principle, the screw compressor is independent of the pressure ratio (compression ratio) since all its volume takes part in the compression process (no "dead volume"). The reciprocating compressor has "dead volume" at the discharge valves and this is the main reason why it is sensitive to high compression ratios.

The Discharge Temperature - T_D (figure 7)

The discharge temperature puts HFC-134a and CFC-12 on the top position since the compressor can be run at very high compression ratios un-cooled.

The Discharge Pressure - P_D (figure 7)

The discharge pressure puts CFC-12 and HFC-134a on the top position because they give the lowest discharge pressure. This allows for cost effective screw compressors with long and slim rotors and inexpensive bearing arrangements as well as thin wall thickness, especially for the sump and the oil separator.

The Oil In The Compressor and The Refrigeration System (Figure 7)

The solubility characteristic of HFC-134a with the oil described puts HFC-134a in the top position of figure 7. The refrigerant gas has low solubility in the oil separator. The liquid refrigerant and the oil have good miscibility in the refrigeration system (mainly evaporator). In contrast, CFC-12 has high solubility with most lubricants. This explains why CFC-12 never been the most suitable screw compressor refrigerant.

Improvement With Economizer - ECO (figure 7)

HFC-134a indicates the best improvement, regarding both refrigeration capacity and coefficient of performance, with economizer operation.

Besides the above viewpoints it should be mentioned that HFC-134a is operated most economically at low superheat. To keep low superheat or even wet suction is no problem with the screw compressor since it does not have any suction valves.

All things considered, HFC-134a looks very good as a screw compressor refrigerant. The cost for the larger displacement requirement for HFC-134a is balanced out by the less expensive rotors and bearings, when the comparison is made with HCFC-22.

CONCLUSIONS

The performance of the screw compressor is, for most applications, the same or better for HFC-134a compared with CFC-12.

The HFC-134a - lubricant characteristics give the potential to optimize the screw compressor and refrigeration system performance.

HFC-134a is very suitable for economizer operation.

The HFC-134a screw compressor has chances to take market shares from the HCFC-22 screw compressor as well as reciprocating compressors in general.

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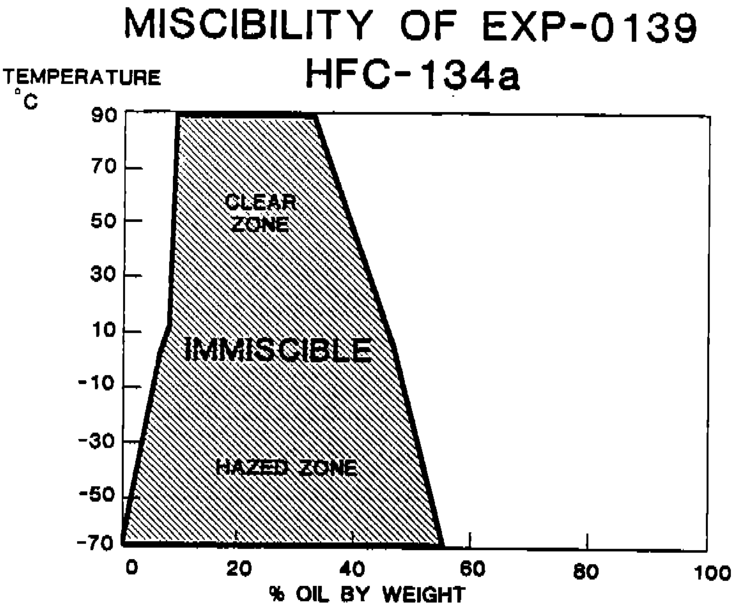

FIGURE 1

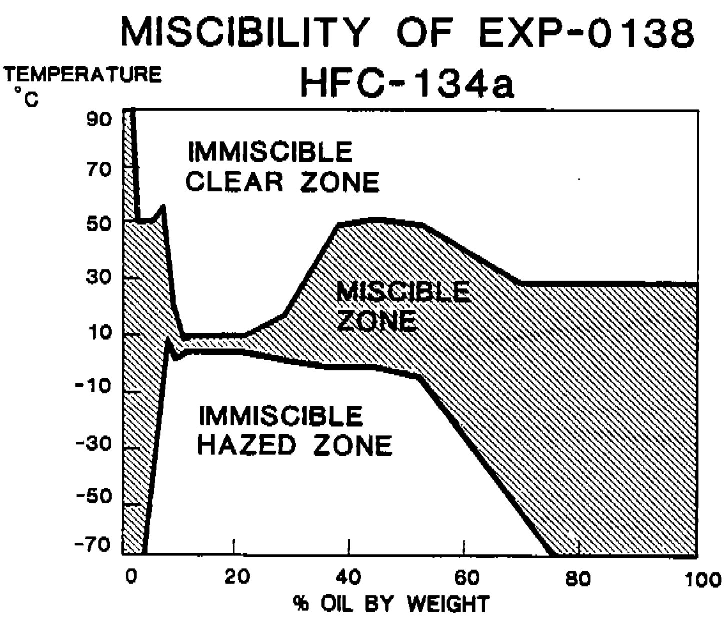

FIGURE 2

MISCIBILITY LIMITS W/HFC-134a

EXP-0272

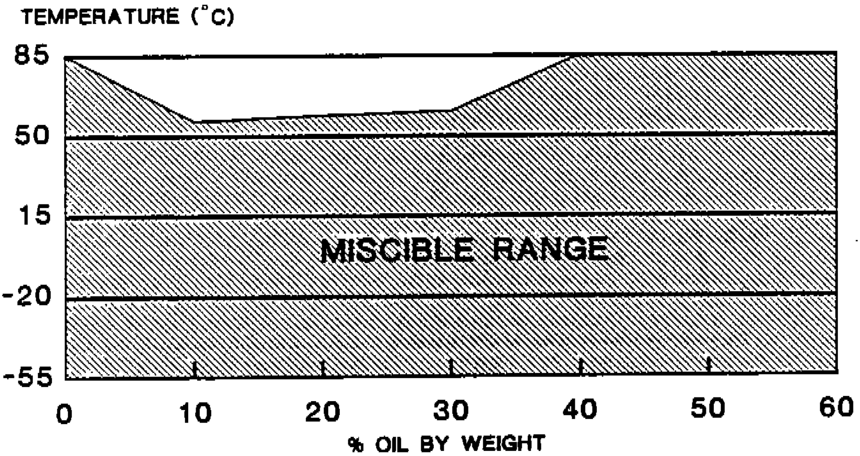

FIGURE 3

COMPRESSOR PERFORMANCE

HFC-134a/CFC-12

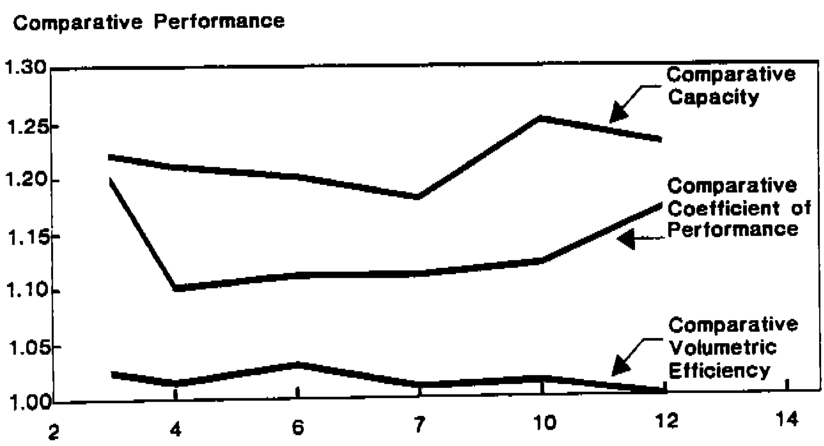

FIGURE 4

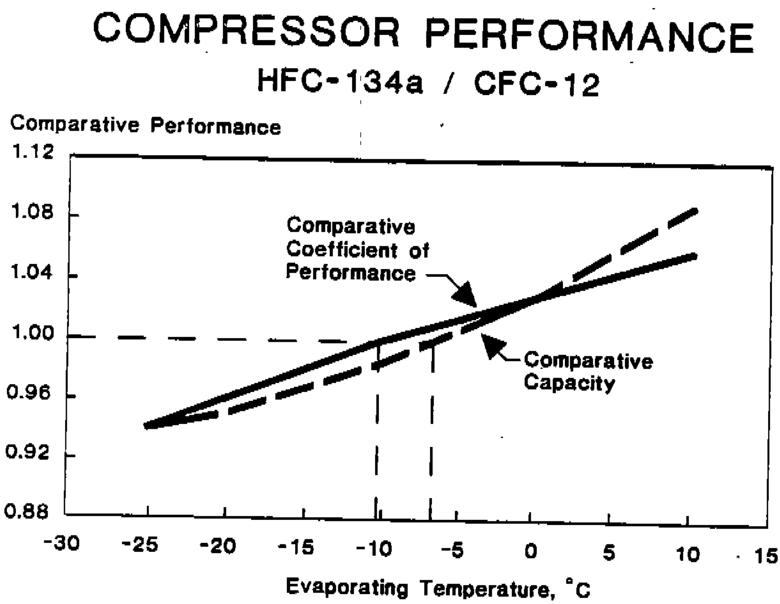

FIGURE 5

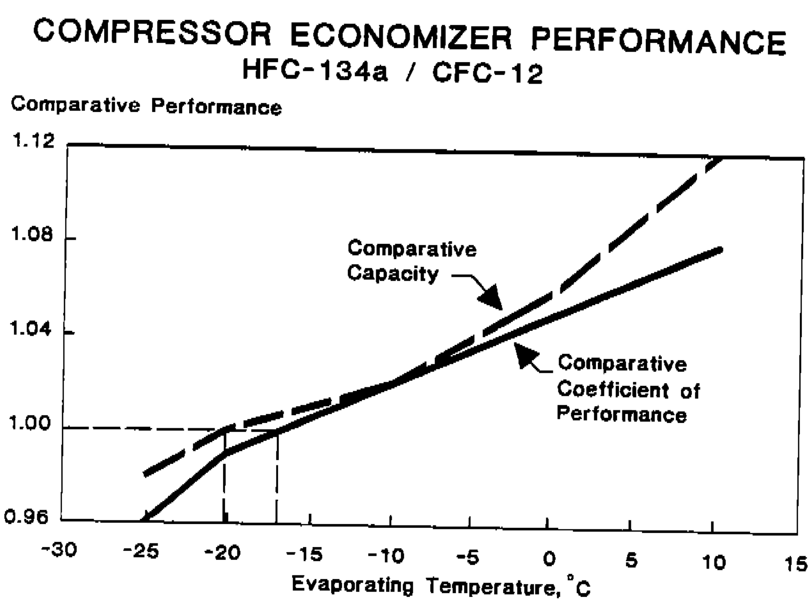

FIGURE 6

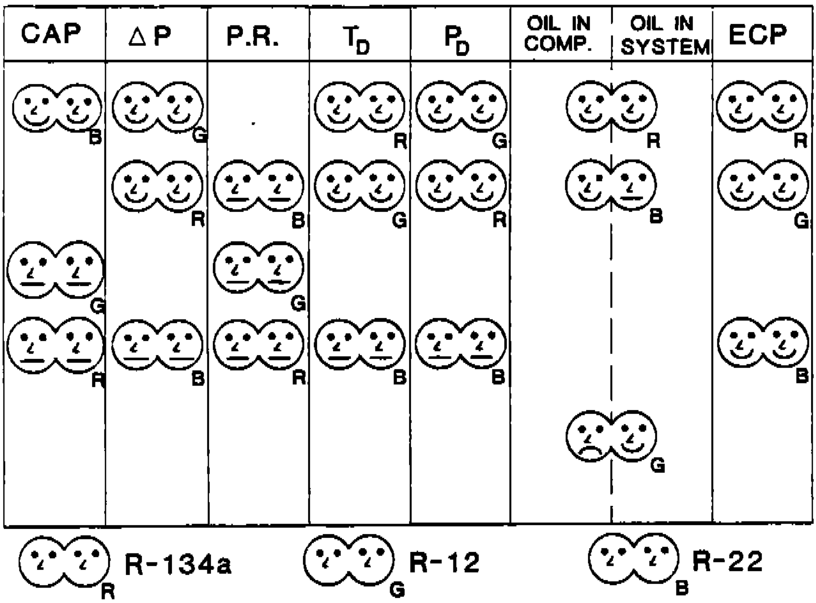
CAP
Δ P
P.R.
T_D
P_D
OIL IN COMP.
OIL IN SYSTEM
ECP
B
G
R
R
G
B
G
R
G
R
G
B
G
R
B
R
B
B
B
B
G
R-134a
R
R-12
G
R-22
B

FIGURE 7