Analysis of R134a Cabinets from the First Series Production in 1990

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ABSTRACT

Series production of R134a compressors started in 1990. 200 compressors, from the very first series, were built into cabinets placed in an apartment house in Denmark. Cabinets with R12 compressors were placed in the same apartment house as well. The cabinets have two separate cooling systems; one for a cold cabinet and one for a freezer. 10 running cabinets were called back for analysis; 7 cabinets with R134a compressors and 3 cabinets with R12 compressors.

Analysis of the cabinets comprises both the refrigeration systems and the compressor from each system. From the refrigeration system the refrigerant, the filter dryer and the capillary tube are analysed; the refrigerant is verified on composition, the filter dryer on water-uptake and the capillary tube is examined for flow rate changes. Further the amount and composition of deposited material are determined . The performance of the compressor is verified. After disassembling the compressor, the refrigeration oil is analysed and the mechanical parts are evaluated.

The overall conclusion is that the reliability of R134a and R12 cabinets is equal.

INTRODUCTION

In the years 1988-1989 the European compressor manufacturers were facing a major challenge from the market: a redesign of the compressors for R12 to R134a as fast as possible. Many problems, which are today considered trivial, had to be solved by the pioneers in this development, e.g. finding a substitute for mineral oils, establishing new guidelines for compressor cleanness etc. For the involved companies and persons it was a very exciting period of time, during which most of the well-known hermetic chemistry for R12 systems had to be scrapped. After a hectic period of development it was possible to produce the first series of compressors for R134a in 1990. In this paper some of these are analysed after 5 years of life time.

DESCRIPTION OF CABINETS

Each cabinet comprises two separate refrigeration systems, one for the cold cabinet and one for the freezer. The volumes of the cold cabinet and the freezer are 197 l and 89 l, respectively. The cold cabinet is equipped with automatic defrosting. The displacement of the compressors used in the R134a cabinets for the cold cabinet and the freezer, respectively, was 4 cm^3 (TL4F) for both. For the R12 cabinets a 2.5 cm^3 (TL2.5A) compressor was used for the cold cabinet and a 3 cm^3 (TL3A) compressor was used for the freezer.

ANALYSIS OF THE REFRIGERATION SYSTEM

Filter dryer

Each refrigeration system is equipped with a pencil dryer filled with approximately 7.5g of XH7 molecular sieve beads. After dismounting of the filter dryers they were placed in an oven at 190°C for 50h to determine the total water-uptake, which was found as the difference in weight before and after the reactivation. The refrigerant was removed with dry nitrogen before the first weighing. Using this method a level of water-uptake is achieved. It should be noted that the condition for the pencil dryers from the beginning is not known. The average water-uptake for the R134a and R12 systems is shown below:

	Average water-uptake, system
R134a system, n = 14	0.194g
R12 system, n = 6	0.117g

Table 1. Average water-uptake in filter dryers from cabinets.

The water-uptake for both types of systems is seen to be very small. A slightly higher water-uptake is seen for R134a systems than for R12 systems. This could be due to the fact that the starting water level in both R134a and polyolester oils are higher than for R12 and mineral oil, giving a higher amount of water in the filter dryer after equilibrium has been reached.

Furthermore, the water absorption capacity and the crushing strength were measured. The crushing strength was determined for dried beads from both R134a and R12 systems. No difference in crushing strength was seen between R134a and R12 systems. Also no correlation between water-uptake and crushing strength was seen. The mechanical properties of the beads are concluded to be "as new" with a crushing strength of 90% > 45N and 100% > 25N.

The water absorption capacity was found at 80°C and a relative humidity of 2%. The average water-uptake and the water absorption capacity for the filter dryers from the R134a and the R12 systems are shown below:

	Average water uptake, 80°C, 2%RH	**Water absorption capacity, 80°C, 2%RH**
R134a system, n = 14	1.046g	13.9%
R12 system, n = 6	1.068g	14.2%

Table 2. Water absorption capacity of filter dryers from cabinets.

No difference in water absorption capacity between filter dryers from R134a and R12 systems is seen. New filter dryers of this type have a water absorption capacity of 14-16%.
The conclusion is that no deterioration of the molecular sieves is found after 5½ years of life time.

Refrigerant

After a run time of at least 12h a gas sample was taken out for analysis from each system The gas analysis was performed on a HP 5890 gas chromatograph equipped with a Hayesept Q column. The initial temperature is -30°C in order to detect N_2, O_2, CO and CO_2, ref. no. 1. Figure 1 shows the results from the R134a cabinets and from the R12 cabinets, respectively:

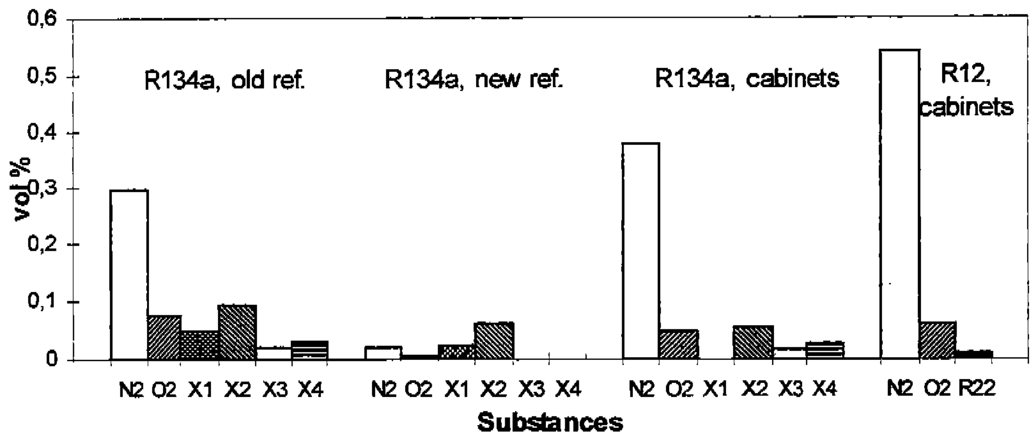

Fig. 1. Gas analysis, old and new R134a reference together with average results from R134a and R12 cabinets.

The gas analysis from both the R134a cabinets and the R12 cabinets shows no detectable amounts of CO and CO_2. The distribution of the impurities, X1 to X4, in the R134a from the cabinets is close to the old reference R134a gas. The impurities X1 and partly X2 are seen to have reacted. However, there are no indications, that this has had any influence on the stability of the R134a. In the gas from the R12 cabinets only very small amounts of R22 have formed. When compared to gas analyses achieved from accelerated life time testing with R12, the amount of R22 formed is less than seen for a 2000h test, ref. no. 2. No degradation of the refrigerants is detected in these cabinets.

Capillary tube

The capillary tube is separated from the evaporator and the flow rate through it is measured. The capillary tubes are then flushed with chloroform, $CHCl_3$, which is known to remove all precipitated material. Afterwards the flow through the capillary tube is measured again to calculate the flow reduction. Figure 2 shows the calculated flow reduction from all 10 cabinets comprising both the cold cabinet and the freezer:

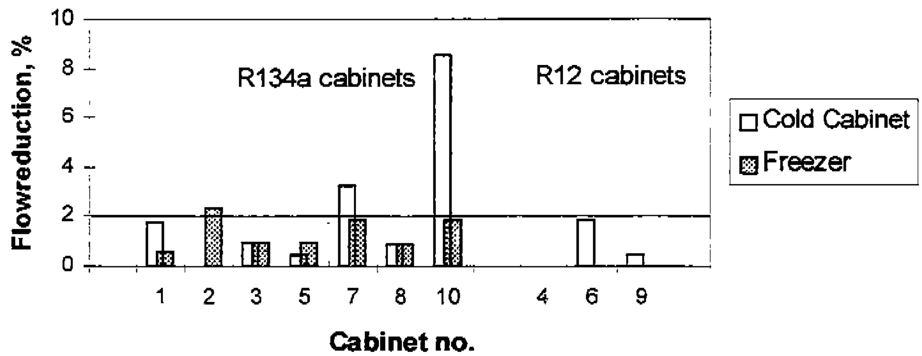

Figure 2. Measured flow reduction in capillary tubes from R134a and R12 cabinets.

For the R134a refrigeration systems, 11 out of 14 capillary tubes show a flow reduction smaller than 2%. As expected for the R12 systems all the capillary tubes show a flow reduction below 2 %.

In the capillary tubes from the R134a systems no solid material was found. The precipitated material from the R134a capillary tubes was analysed using G.C., FT-IR and GPC. In the three R134a capillary tubes with flow reduction large than 2%, a specific material was found. This material is known to be an internal lubricant in a plastic part in the compressor. At that time it was not possible to have this lubricant removed from the plastic material. Extensive testing had shown that it would not cause any major problems in the capillary tubes. This conclusion is confirmed here. A few months later all plastic parts inside the compressor were produced without internal lubricant.

ANALYSIS OF THE COMPRESSOR

Performance

The compressors were removed from the cabinets and calorimeter measured at the rating conditions: -25 °C / +55°C / +32°C. Table 3 outlines the average results from the measurement compared to reference calorimeter measurements. The change in performance is within normal accuracy of measurement and production deviations.

Refrigerant	R134a	R134a	R12	R12	R12	R12
Compressor	TL4F	TL4F	TL3A	TL3A	TL2.5A	TL2.5A
Type	Cabinet	Ref. 1990/91	Cabinet	Ref. 1990/91	Cabinet	Ref. 1990/91
Capacity, W	57	59	52	56	40	42
COP, W/W	0.74	0.73	0.73	0.75	0.70	0.72

Table 3. Calorimeter measurements of compressors from cabinets versus reference compressors.

Noise Measurement

All the compressors were noise measured according to test specification ISO 3743 and CECOMAF / CECED GT4-008 at the conditions -25°C / +55°C. Table 4 shows the average noise level of the compressors from the cabinets compared to reference noise measurements. No significant change is seen. This first series of R134a compressors was not fully noise optimised. It has to be noted that the TL4F was later fine-tuned to give the same level of noise as the R12 compressors.

Refrigerant	R134a	R134a	R12	R12	R12	R12
Compressor	TL4F	TL4F	TL3A	TL3A	TL2,5A	TL2,5A
Type	Cabinet	Ref. 1990/91	Cabinet	Ref. 1990/91	Cabinet	Ref. 1990/91
Lw(A), dBA	38.6	38	34.8	33	33.6	33

Table 4. Noise measurements of compressors from cabinets versus reference compressors.

Refrigeration oil

The R134a compressors had been charged with a linear ISO17 polyolester oil of the following composition: PE with ~10% diPE reacted with pure C5 acid. The R12 compressors had been charged with a 100% naphthenic based mineral oil of ISO grade 15. From each compressor an oil sample was taken out for analysis. Figure 3 shows the average viscosity, TAN and water content for each cabinet:

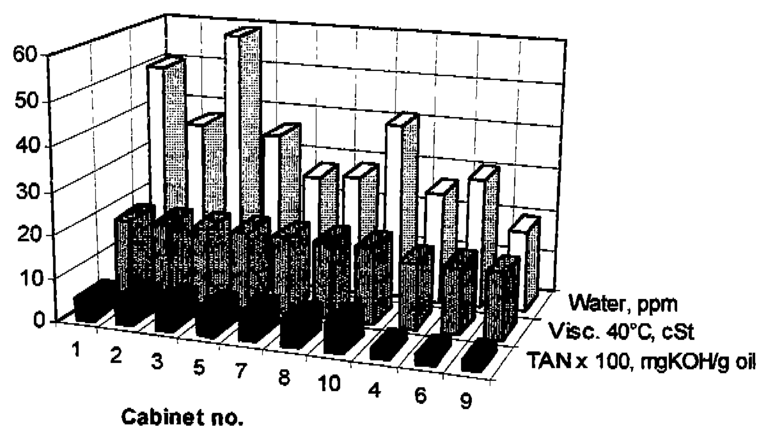

Figure 3. Average viscosity, TAN and water content for each cabinet. No. 4, 6 and 9 are R12 cabinets. The rest are R134a cabinets.

The TAN values of the polyolester oil samples vary between 0.051 mgKOH/g oil and 0.066 mgKOH/ g oil. The polyolester oil manufactured at that time had an average TAN of 0.041 mgKOH/g oil. The rise in TAN for the linear polyolester oil in these cabinets is therefore in the range of 0.01 mgKOH/g oil to 0.025 mgKOH/g oil. This means that in the cabinets no significant hydrolysis of the polyolester oil has taken place. The average TAN values for the mineral oil samples are 0.021 mgKOH/g oil, meaning that no change has occurred.

The water content of the polyolester oils is only for one cabinet, no. 3, higher than the initial maximum level of 50ppm. Another cabinet, no. 1, holds 50ppm of water, all others have a water content below 40ppm. It can be concluded that the influence from the system on the water content in the polyolester oil is negligible. The water contents of the mineral oils are all below the initial level of 35ppm.

The viscosity of both the polyolester oils and the mineral oils is within the ISO limit for their specific grade.

Evaluation of wear, Cu-plating and deposits

After finishing the performance measurements, all compressors were cut open, disassembled and evaluated for wear, Cu-plating and valve deposits. Table 5 shows the average evaluation of compressors from the cabinets along with a reference from an 8000h accelerated life test. The results of the analysis of Fe and Cu in the oil samples are also listed.

Type	TL4F, Cabinet	TL5F, * 8000h life test	TL2.5A, Cabinet	TL3A, Cabinet	Fe, ppm R134a Cabinet	Cu, ppm R134a Cabinet	Fe, ppm R12 Cabinet	Cu, ppm R12 Cabinet
Wear	0-1	1	0-1, (2)**	0-1, (2)**	4	-	8	-
Cu-plating	0-1	1	0	0	-	5	-	4
Valve deposits	0	0	0	0	-	-	-	-

Table 5. Evaluation of wear, Cu-plating and valve deposits of disassembled compressors from cabinets. 0=as new, 1 and 2 = acceptable, 3 and 4 = not acceptable.

* The TL5F is from an accelerated life test of 8000h with a 14cSt polyolester oil, ref. 3.

** The general wear level of the compressors is 0-1. The designation "2" indicates polishing of the piston.

The results in table 5 show no sign of abnormal wear. For the R12 compressors the highest wear level is 2 because of slight polishing of the pistons. The low values of both Fe and Cu found in the oils from the compressors indicate that no severe wear or Cu-plating has taken place.

Conclusions

The analysis of the refrigeration system comprising the filter dryer, the refrigerant and the capillary tube, and the analysis of the compressor covering performance, noise, the refrigeration oil and the compressor parts show an excellent condition for both the R134a cabinets and for the R12 cabinets. In general, no difference was seen between these types of R134a and R12 cabinets. The life time of the R134a cabinets is therefore expected to be equal to the life time of the R12 cabinets.

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