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R134a in Small Commercial Refrigeration System: Some Practical Aspects

K. D. Gerdsmeyer
Danfoss GmbH; Germany

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K. D. Gerdsmeyer
Danfoss GmbH, Carl-Legien-Str. 8, D-6050 Offenbach/Main

Numerous investigations about the refrigerant R134a have already been published. Apart from automotive air conditioning, experiences with R134a are in the main still limited to laboratory plants and field tests. Practical aspects concerning the application of R134a in small commercial refrigeration systems with hermetic compressors will be presented here. Especially series products like beverage coolers, cooling units for electronic circuit cabinets, warm water heat pumps, etc, will be considered. Capacity characteristics, energy efficiency, oil behavior, moisture, and other contaminations within the refrigerant cycle will be discussed as well as retrofitting. Compared to the content of the printed version of this paper it is expected, that supplementary experiences with R134a will be available until the presentation of the paper.

1. INTRODUCTION

In this context, commercial refrigeration should be understood mainly as a distinction to domestic refrigerators. Systems with small hermetic compressors (displacement volumes up to about 20 cm³), frequently used at evaporating temperatures between -15 °C and +15 °C, are considered here. Particular interest lies in mass produced refrigeration devices like beverage coolers, cooling units for electronic circuit cabinets (ECC), commercial refrigerators, or warm water heat pumps. Hitherto, experience with R134a in this area of commercial refrigeration has been restricted to some experimental systems, where the chief concern has been the examination of performance and material compatibility. So far there is not enough knowledge with long term tests, dealing e.g. with the effects of contaminations in the refrigeration cycle. Neither are there statistically meaningful experiences with large numbers of R134a systems.

2. SYSTEM PERFORMANCE

Compared to R12, the refrigerant R134a is often reputed to gain lower volumetric capacity as well as higher energy consumption. Various measurements (e.g. /1/, /2/), however, have shown that this is not generally the case. With the application of hermetic compressors, the energy characteristcs seem to be very similar for R12 and R134a, provided, the evaporating temperature is not too low.

Fig. 1 shows a comparison of cooling capacities for a compressor with a displacement volume of 7.95 cm³ at calorimetric tests with R12 and R134a. Tests with R134a were carried out in this case without any alterations having been made to the compressor apart from using a suitable ester oil. The known capacity decrease with R134a at low evaporating temperatures is confirmed by this test as well as the capacity increase at higher evaporating temperatures, such as occur e.g. with warm water heat pumps, EDP cooling, ECC cooling, and other applications of commercial refrigeration. At decreasing condensing temperatures the intersection of both curves shifts to lower evaporating temperatures. This is due to a smaller gradient of the boiling line of R134a in the lg p, h diagram, which means that measures to reduce the condensing temperature have a more positive effect with R134a than with R12.

The appertaining COP figures are compared in Fig. 2, whereby the values of R134a are somewhat higher than those of R12, excepting evaporation temperatures below -25 °C. Taking due account of measuring accuracy, R134a does *not* gain any energetic disadvantages in *this* comparison. Fig. 3 is another comparison of COP measurements for a hermetic compressor with a displacement volume of 12.9 cm^3. R134a measurements did not involve any alterations being made to the standard R12 compressor in this case either. (This means that for the tests, which are presented here, the original series compressors for R134a were not available.) Again, there is no evidence of R134a having any energy disadvantages. On the contrary, in this case R134a even shows clear energy advantages at low condensing temperatures compared to R12, taking account of measuring uncertainty.

The different results in Figs. 2 and 3 can not be due to refrigerant properties but solely to influences by the compressors that were used. This reveals the limitations of making comparative statements about the energy properties of the two refrigerants. One can also see significant potential for further energy improvements when R134a is introduced, and these will involve the complete refrigeration systems and the compressors, respectively. The latter, especially when hermetic compressors are used, will depend to a large degree on a proper adaption of the compressor and motor to the operating conditions of the total system. However, the great variety of applications, which must be taken into account for the design of commercial refrigeration compressors, are the reason that such improvements are only possible to a limited extend. On the other hand, general system optimizations should be brought about by the introduction of R134a. An optimization like this might be for example the substitution of a capillary tube or orifice by a thermostatic expansion valve in a system running at variing operating conditions.

The favourable results with R134a at calorimetric tests illustrated here, have been confirmed by the operation of a warm water heat pump at realistic conditions. Fig. 4 shows the results of a heating-up test according to DIN 8947 /3/. Standard R12 heat pumps were tested, whereby the heat pump operated with R134a was unmodified, apart from the required R134a components (compressor with same displacement volume, filter drier, expansion valve).

While the same quantity of water was heated up from 15 °C to 55 °C, the heat-up time was reduced in the case of R134a by 13% on account of its greater heating capacity (see also Fig. 1 - cooling capacities) at moderate and high evaporating temperatures. At the same time a roughly 6% lower expenditure of electrical energy was measured. Because of the same overall net energy in both cases this corresponds to an improvement in the integrated COP by 6.4%. It should be further pointed out that the R12 measurement was carried out with a special, energy-optimised heat pump compressor (SC15HH), whilst in the case of R134a a usual heat pump compressor (SC15H) was used. Consequently, if the basis of comparison were identical, one could expect additional advantages with R134a in this application.

Supplementary experiences with R134a at further applications will be included in the presentation of this paper.

3. OIL BEHAVIOR

The refrigeration oil required special attention in the development of hermetic compressors for R134a. Highly satisfactory results have been attained with the ester oil now being used. Long-term tests carried out under extreme operating conditions showed not higher, but in some cases even fewer signs of wear compared to conventional R12/oil systems. Moreover, the newly developed ester oil has the important advantage of being biologically degradable when the compressor or refrigeration system has to be disposed of and scrapped.

But concerning the oil behavior there are also items, which need particular attention, when R134a and ester oils are considered. For one thing, miscibility is not as complete; although the miscibility gaps occur beyond the application limits with respect to temperature and mixture composition. Nevertheless, oil pockets in the piping system should be avoided to ensure reliable oil return to the compressor. Secondly, the water solubility of the ester oil is a little bit greater than that of earlier refrigeration oils. Behavior, however, is not nearly as problematic as with PAG oils.

4. Moisture and Other Contaminations

When ester oils are used, the presence of water in the refrigerant cycle is an additional problem in that the chemical reaction between water and ester produces alcohol and acid. Moreover, the ester oils are more difficult to dry compared to earlier refrigeration oils. For this reason it is recommended firstly that the other components of the cycle at least meet the requirements for dryness stipulated under DIN 8964 with maximum 50 mg/m² interior surface. Secondly, it is necessary to use a filter drier that is suitable for R134a and adequately dimensioned. The filter drier is of particular significance in commercial refrigeration technology wherever the dryness, customary in mass produced systems, cannot be assured during manufacture. It is important to use a filter drier with a 3Å-molecular sieve.

Standards of maximum impurity levels for the cycle components are laid down in DIN 8964, which makes a distinction between soluble and non-soluble substances. For R134a systems the components should at least meet the requirements specified here, namely a maximum 60 mg insoluble substances and a maximum 40 mg soluble substances for every m² of interior surface. Particular attention has to be paid to the soluble substances especially for systems with capillary throttling because of limited solubility for R134a.

With respect to soluble contaminations mineral oil is another special issue of concern because of miscibility gaps within the ternary system R134a/ester-oil/mineral-oil. Fractions of high oil concentration may impair e.g. the operation of the expansion device or the evaporator.

The issue of contaminations raises the question regarding retrofitting:

5. Retrofitting

Tests have shown that chlorine in refrigeration systems with R134a and ester oil leads to increased wear. When existing R12 systems are converted, chlorine contaminations can only be avoided, if at all, at very great expense and effort. In systems with hermetic compressors it would almost be impossible to guarantee residue-free removal of the oil used with R12. For these reasons, conversion from R12 to R134a should, in principle, be avoided in the case of smaller refrigeration systems with hermetic compressors. This particular applies to maintenance work carried out on mass-produced devices.

6. PROSPECTS

The introduction of R134a and ester oil presupposes that much new know-how will be acquired. Careful preparation of serial up-scaling is essential, particularly in the case of small refrigeration systems. It has been shown that special attention has to be paid to the dryness and cleanliness of the systems. Several questions need answering before R134a is introduced in practice. These concern, for example, rigorous separation between R12 and R134a systems in both manufacture and maintenance, as well as an optimal method of identifying R134a systems.

The search for leaks with halogen detectors needs special equipment adapted to the bonding energy between fluorine and carbon. But such equipment requires an atmosphere which is free of other halocarbons. For this reason, leak tests with helium as a trace gas and the use of helium detectors may be a better alternative for series production.

When these items are taken into account, there is no doubt that R134a can successfully be used for commercial refrigeration applications. Complete programs of expansion valves and filter driers, which must be special products for R134a as well as the compressors, are availabe. Also hermetic compressors for small capacities can already be supplied to a large extend and a complete program will be available at the end of 1992.

References:

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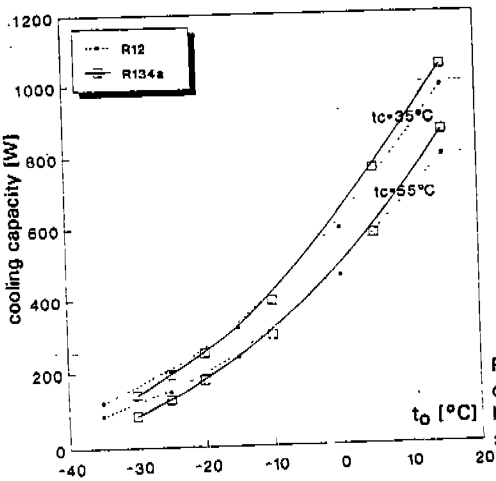

Fig.1: Comparison of compressor cooling capacities with a 7.95 cm³ hermetic compressor (no subcooling sction gas: 32 °C)

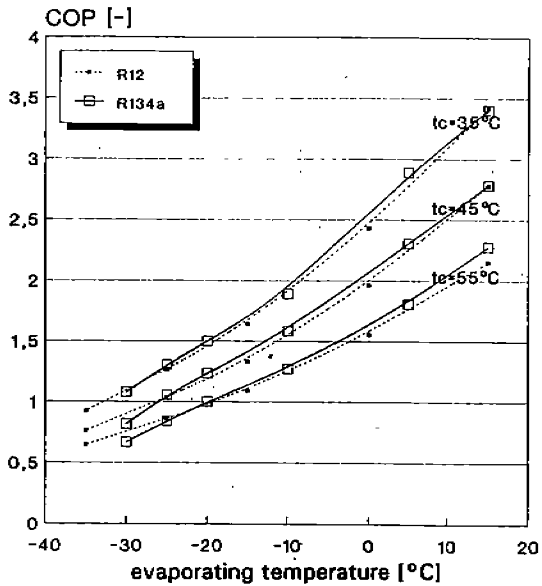

Fig.2: Comparison of COP data with a 7.95 cm³ hermetic compressor (no subcooling, suction gas: 32 °C)

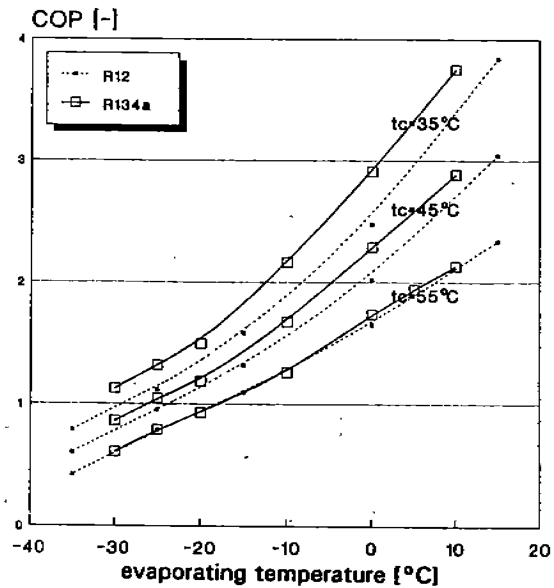

Fig.3: Comparison of COP data with a 12.9 cm³ hermetic compressor (no subcooling, suction gas: 32 °C)

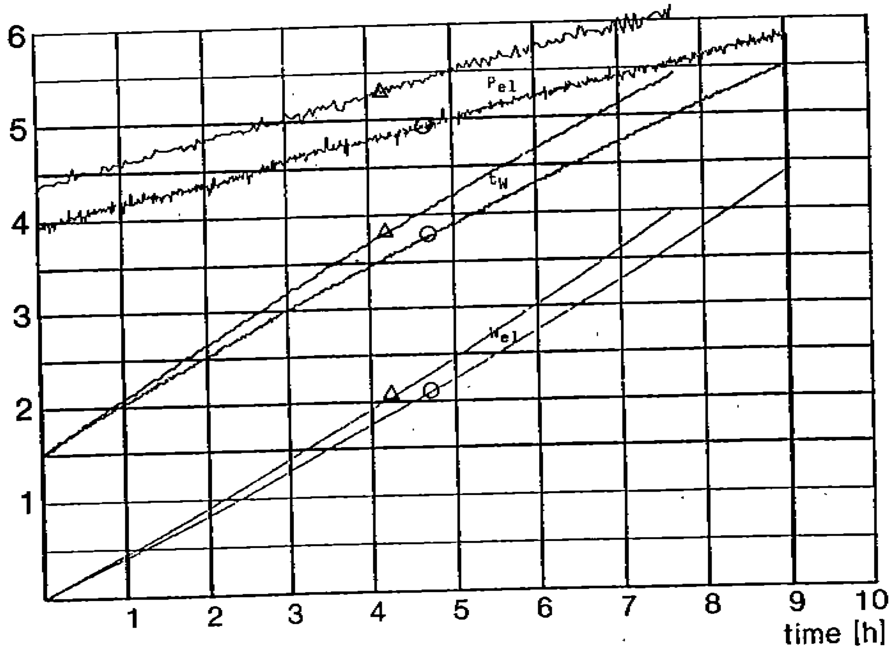

Fig. 4: Heat-up test with a warm water heat pump; comparison of R12 (O) and R134a (Δ); P_{el} = power consumption/100 W; W_{el} = energy consumption/kWh; t_W = water temperatur/10 °C