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R507 in Comparison to R404A and Practical Experiences

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Refrigerants for Commercial Refrigeration:

R-507 in Comparison to R-404A and Practical Experiences

Dipl.-Ing. Christoph Meurer

SOLVAY FLUOR UND DERIVATE GmbH

Summary

This paper discusses the low temperature refrigerants R404A and R507. A performance comparison of R404A and R507 in a cold store refrigeration installation is presented. Further, the conversion (retrofit) of a CFC-502 refrigeration plant to R507 is described.

The situation regarding the phase-out of CFC-502 and possible replacements are introduced as well as the properties of two CFC-502 replacements, R507 and R404A. A short discussion of the azeotropic property of R507 is included. A comparison of the compressor power consumption figures achieved by various manufacturers for the refrigerants CFC-502, R-04A and R507 will finalise the general part.

The results of a performance comparison of R404A and R507 in a cold store refrigeration installation are presented. In this case study, both refrigerants are used in two identical refrigeration installations. The results show, that both refrigerants are suitable for this application with the advantage for R507, resulting in a slightly higher coefficient of performance.

1. The refrigerants R404A and R507 as options for low temperature refrigeration

The refrigerant R502, a blend of HCFC-22 and CFC-115, is currently phased out on a world-wide basis. In fact, the production of CFC-115 has ceased. Therefore, the availability of R502 is already limited.

The industry is offering several replacements, drop-in blends on basis of HCFC-22 and long-term replacements on basis of HFC without an ozone depletion potential. By using a R502 drop-in blend, existing R502 installations can be converted without major changes of the components or the lubricant. However, this presentation focuses on long-term replacements on basis of HFC's, namely R404A and R507. Table 1 summarises some of the properties of R507 and R404A in comparison to R502.

Table 1: Properties of R502, R507, R404A

	R502	R507	R404A
blend components	HCFC-22/CFC-115 (48.8 %-wt. / 51.2 %-wt.)	HFC-125/HFC-143a (50 %-wt. / 50 %-wt.)	HFC-125/HFC-143a/HFC-134a (44 %-wt. / 52 %-wt. / 4 %-wt.)
azeotrope	yes	yes	no
boiling point at 1,013 bar [°C]	-45.3	-46.5	approx. -46.4 (start of boiling)
density (liquid) at 25°C [kg/dm ³]	1.216	1.057	1.045
vapour pressure at 50°C [bar]	20.83	23.55	23.04
enthalpy of evaporation at -30°C [kJ/kg]	163.29	186.07	196.57
critical temperature [°C]	82	70.8	72.1
critical pressure [bar]	40.8	37.2	37.3
ODP [-]	0.23	0	0
H-GWP (rel. to R11=1.0)	18.1	0.84	0.83
flammable	no	no	no

With the exception of the azeotropic refrigerant R507, all of the blends, which are considered as long-term replacements, show a temperature glide during evaporation and condensation. R404A shows a temperature glide of approximately 0.6 K through the liquid/vapour phase change. Section 2 of this paper will discuss the azeotropic property of R507 in comparison to the zeotropic blend R404A in detail.

Both, R404A and R507 are non flammable refrigerant blends. In comparison to R502, the global warming potentials of both blends are significantly lower (Table 1). Both R507 and R404A usually require polyol ester oil as the compressor lubricant. An AEL (Acceptable Exposure Limit) of 1000 ppm has been laid down for R404A and R507. In terms of material compatibility (i.e. corrosiveness) with seals / elastomeres and metals, including copper and aluminium, R507 and R404A are comparable to R134a.

The refrigerants R502 and R22 have been used for low temperature applications (supermarkets, industrial and commercial refrigeration). The azeotropic R507 and the blend R404A are appropriate replacements for these applications. Compressors are available in the evaporating temperature range of -45°C up to +10°C. German refrigeration contractors are using R507 and R404A in the low temperature range as well as in the medium temperature range. The higher volumetric refrigerating capacity of R507 and R404A in comparison to R134a is advantageous since smaller compressors can be used. Furthermore both, low and medium temperature range applications can by that means be serviced with a single refrigerant blend. In the medium temperature range both, R404A and R507 are energetically less efficient than R134a.

2. Azeotropic properties of refrigerants

Azeotropes are mixtures of two or more liquids in which the liquid and vapour have the same composition at equilibrium and display mono-substance behaviour at

various temperatures and concentrations [1, 2, 3]. In non-azeotropic mixtures the vapour is rich in the lower-boiling or more volatile component. The precise composition required for an azeotropic blend depends on the pressure and temperature. If the blend composition is different to the azeotropic concentration, or if the blend itself is a non-azeotropic one, then the relative concentration of the blend components changes continuously throughout the liquid-vapour phase transition region.

The refrigerant R507 consists of an equal blend by weight of the refrigerants R-125 and R143a. At atmospheric pressure, a blend by weight of 53% R125 and 47% R143a results in an azeotropic blend. At -40°C , Δt or Δp is very small, therefore the azeotropic characteristic of the blend is very broad (from 40 to 60% R143a by weight).

Non-azeotropic refrigerant blends show at constant temperature a pressure difference between the vapour pressure of the liquid and gas phase. At constant pressure, non-azeotropic blends show a temperature glide. The pressure difference is zero at the azeotropic point. Figure 1 shows the temperature differences for the refrigerants R502, R507 and R404A.

A further advantage is the absence of separation or fractionation effects and stability of the vapour pressure curve under leak conditions. The boiling points of the R507 blend components R125 and R143a are very close to each other and the vapour pressure curves are similar. Therefore, no significant composition shifts are observed for R507 during use and handling. The effect of composition shift after a leak of the blend R404A (52% R143a, 44% R125, 4% R134a) followed by balancing the leak with original R404A will be small. For this near-azeotropic blend the temperature glide is small (0.6 K). The impact of such a composition shift on the performance of the installation will be negligible.

Tests, in which up to 80 % by weight of the refrigerant R507 have been released from the vapour phase of a vessel, resulted in a ± 2 % change in the composition. In practice this change will not have a significant impact on the performance [4]. The refrigerant R507 can be filled into refrigeration installations either from the liquid or from the vapour phase. Filling from the vapour phase is not recommended for R404A.

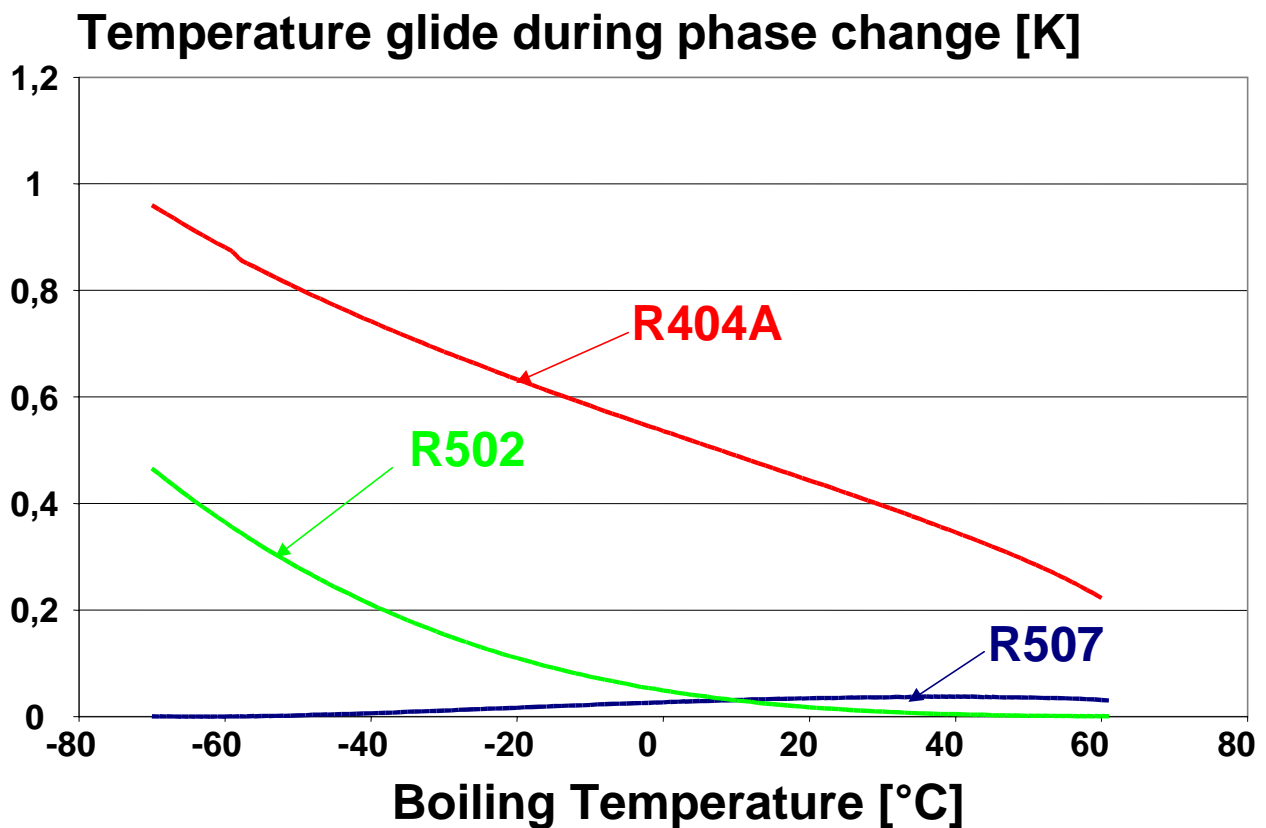


Figure 1: Temperature Glide during phase change for R502, R507 and R404A
(Source: REFPROP 6.01)

Beside the easy handling of azeotropes (mono-substance behaviour), a better heat transfer compared to near-azeotropic or zeotropic blends can be observed. The surface coefficient of heat transfer α of a blend is usually lower than the one of a single working fluid [5]. If the blend forms an azeotrope an increase of α at the azeotropic point is observed [3]. This effect is only significant for nucleate boiling, for example in flooded evaporators. In dry expansion evaporators this effect is less pronounced. However, in a research project the differences in the heat transfer of the refrigerants R404A and R507 have been studied. An approx. 10 % higher surface coefficient of heat transfer α for R507 was measured (nucleate boiling) in comparison to R404A [6].

3. Compressor power consumption data

Various authors have measured the power consumption of compressors in plants operating with R507 and R404A as refrigerants. Figure 2 shows a summary of the calculated COP for R404A and R507, normalised to the COP of R502 [7].

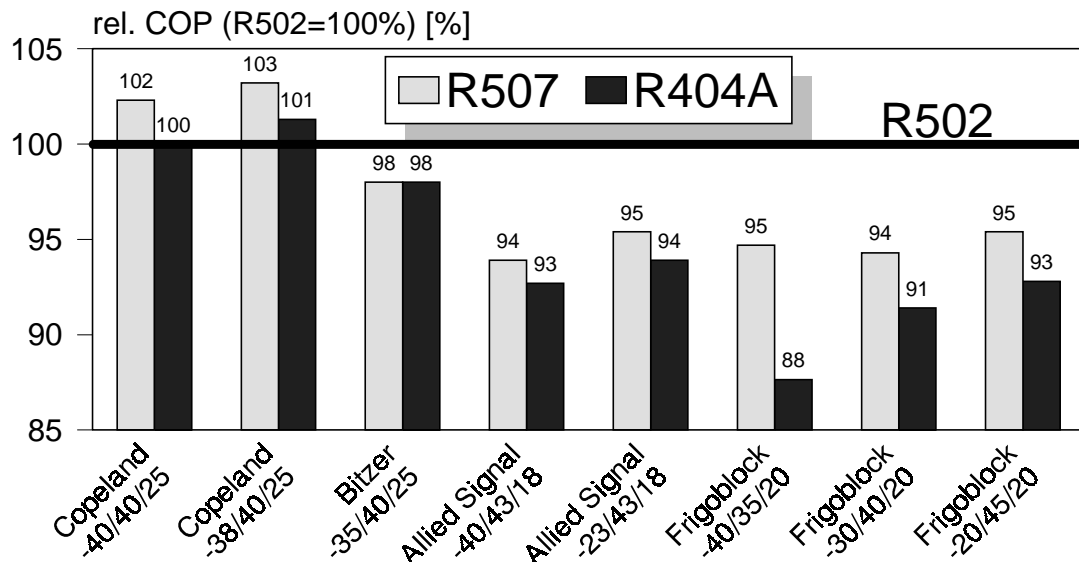


Figure 2: COP for R404A and R507 compare to R502 for different compressor measurements [7]

The data shown here are derived primarily from measurements of compressor performance. In each case, the author's name is noted, followed by the value of the evaporating temperature t_0 the condensing temperature t_c , and the superheat ΔT_{sh} at the compressor suction side. The degree of refrigerant sub-cooling in each case was $\Delta T_{sc} = 0$ K. One clear result is that the refrigerant R507 has a higher COP than R404A. In only one case were the figures for the two refrigerants largely identical.

4. Practical experience and applications

Linde AG in Germany has delivered a refrigeration plant, which has been investigated in a detailed study, to a production site of Solvay Pharma. The Linde refrigeration plant, using R507 and R404A in two identical systems, is employed for the purpose of cooling a storage room. In Figure 3 the sketch of the two systems are shown.

Both systems have been filled first for four weeks with R404A. During this time temperature, pressure and mass flow were measured continuously. The systems were refilled after this first measuring series with R507. The inconstant of the ambient conditions and furthermore the different internal load of the storage room are main problems for a real comparison of the performance data of the two refrigerants. Further building complexes were connected to an air conditioning system, which is also connected to the same cooling tower during measuring. To eliminate these influences a special calculation method has been developed.

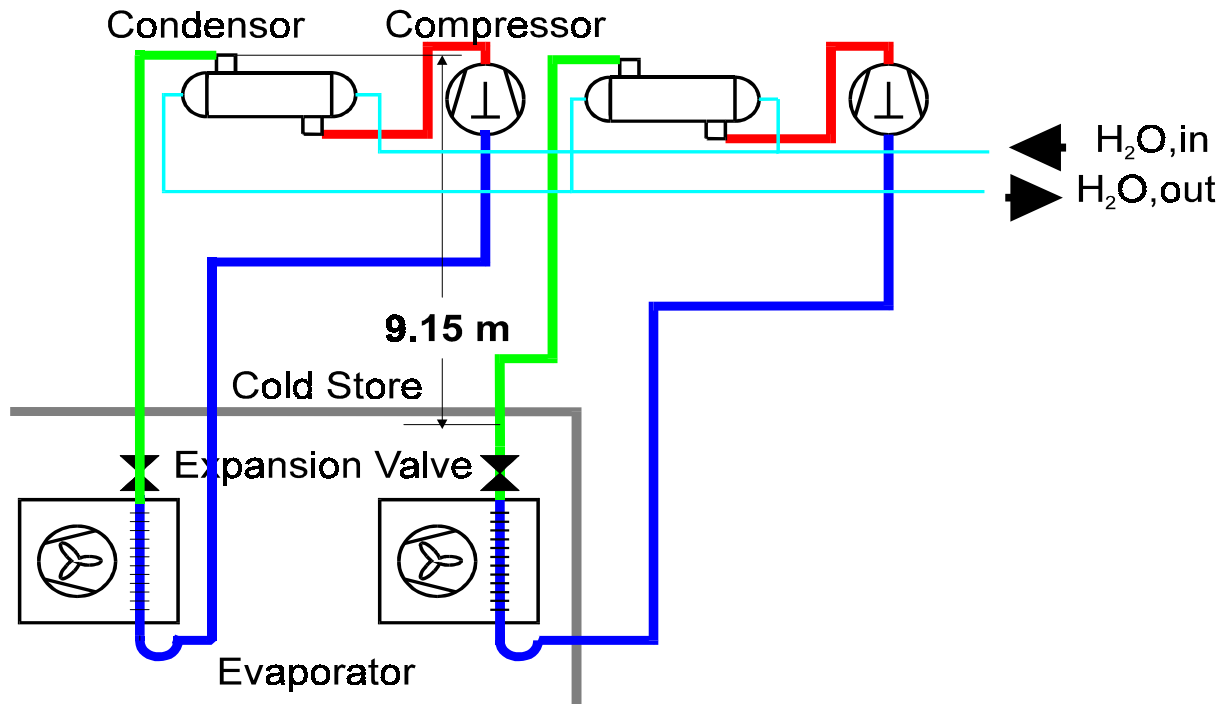


Figure 3: Identical Refrigeration System with R404A and R507

The calculated COPs, using the measured data as basis, for both systems are shown in Figure 4 as an example for the results. The data for both are theoretically transformed to the ambient temperature as mentioned. Also transformed are the other cycle points to the different evaporating temperature. Under practical operation conditions similar COPs are reached for both refrigerants. However, the tests with R507 resulted in a higher COP. This result is in good agreement with calculations of a theoretical refrigeration cycle.

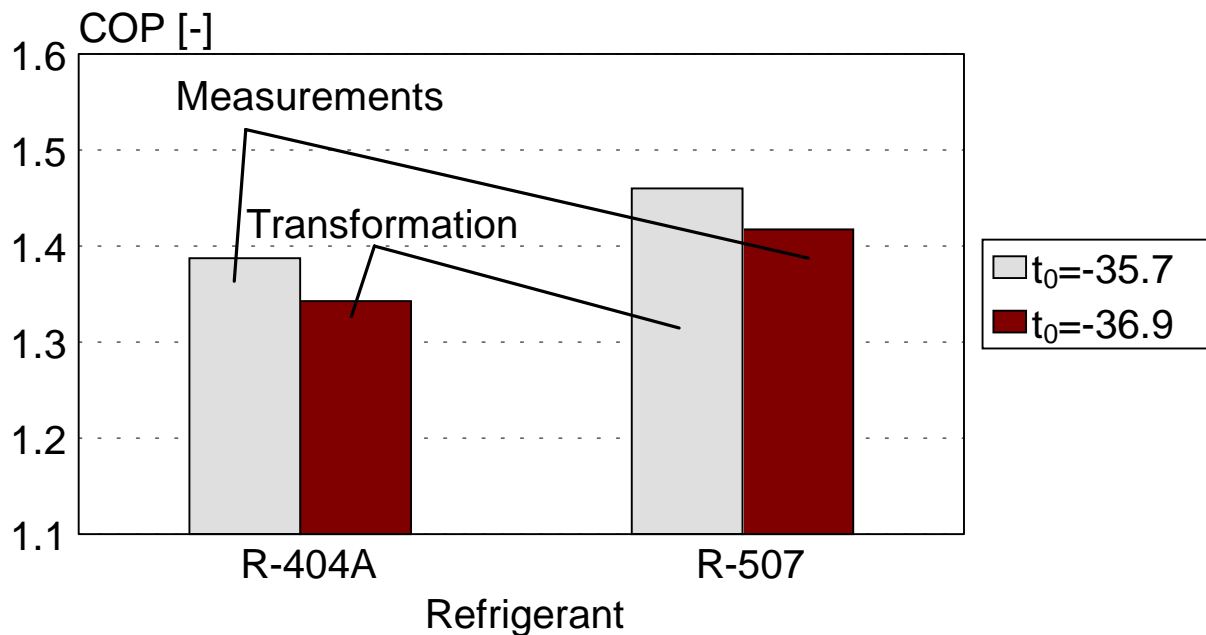


Figure 4: COPs for R507 and R404A for two different evaporating temperatures

5. Summary

Two refrigerant candidates for low temperature refrigeration have been presented and compared to each other. Both blends have zero ozone depletion potential and are regarded as long term replacements for commercial refrigeration applications. The power consumption data for compressors operating with the two refrigerants R404A and R507 are comparable to R502. In comparison to R404A, tests at a new installation resulted in a higher coefficient of performance for R507. The volumetric capacity is slightly higher for R507. This gap grows with lower evaporating temperatures. Advantages in heat transfer coefficients are also evident. Easy handling is an additional benefit of R507.

Both refrigerants are suitable solutions for commercial refrigeration applications. Several slight advantages for R507 however sum up to make R507 appear to be the smarter solution.

6. Literature

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