Comparison of Performances Between R404A and AZ50 Used in Commercial Refrigeration

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COMPARISON OF PERFORMANCES BETWEEN R404A AND AZ50 USED IN COMMERCIAL REFRIGERATION

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Abstract
A test bench has been developed consisting in an open display-case and a refrigerating system composed mainly of four hermetic compressors, an air cross-current condenser and an evaporator.

The evaporating temperature of -40°C allows to keep the temperature of the products at -18°C for a room temperature of 25°C and a relative humidity of 50%.

The test bench is designed in order to acquire the following data:
- temperature in the core of products
- temperature of blowing air
- temperature of returned air
- temperature and humidity of air in the room
- different temperatures at the surface of the evaporator
- high and low pressure of refrigerating system
- 10 different temperatures at the surface of the condenser
- temperature of air at the two ends of the condenser
- flow of the cooling air at the condenser
- electric power consumed by the compressors
- temperatures of the compressors (suction, discharge, oil)
- composition of the vapor at the suction and the discharge of compressors
- composition of the liquid in the receiver.

A testing method was defined to allow comparison performances between R404A and AZ50 with respect to refrigerating capacity, energy efficiency as well as preservation of inner temperature of products laying into the display case.

1. Introduction

R 502 production phase out is scheduled in the European Community for the end of 1994. R22-based blends could be convenient to manage the transition for existing intallations. A previous paper /3/ has presented the comparison between HP 80, R 69L, FX 10 and R502.

For new installations, R22 that has been often used in the last years to replace R502 is only a mid-term solution as it still contains chlorine. Chemists have consequently developped HFC blends with thermodynamic characteristics that are close to R502's.

We present here the comparison of the performances of AZ50, R404A and R502 when used in low temperature commercial refrigeration. As one can see the major componants of those two blends are the same:

	R125	R143a	R134a
AZ50	45%	55%	--
R404A	44%	52%	4%

However the performances are different as we will analyse.

The test bench in which the refrigerants are tested has been designed to compare the different refrigerants in conditions close to those on the field.

2. General design

Figure 1 shows the test bench as it has been realized. It consists in the following elements :

• An open vertical display case with triple air screen, loaded with 700 kg of "ballast" products - tylose and anti-freeze liquid. The evaporator is composed of four parallel raws and its internal volume is 18 liters. Using R502 at -40 °C, the refrigerating capacity is about 5 kW.

• A liquid-vapor heat exchanger which allows a slight sub-cooling of the liquid.

• A thermostatic expansion valve with an external pressure equalization.

• A rack of four hermetic compressors, two by Maneurop and two by L'Unité Hermétique.

• A condenser made of six successive rows and a four-liter capacity liquid tank.

• A display case that stands inside a climatic room, so that temperature and humidity can be controlled.

3. Measured and controlled parameters

• **Temperatures in the display case**

In the display case, temperatures in the core of products or at their surface, and temperatures in the blowing or the intake air show different values:

- for the products because of their localization (near or far from the blowing air)
- for the air because the speed of the air is far from constant and by consequence its temperature is also variable.

Before the tests a special study was carried out to define the position of the necessary temperature probes to obtain representative values of the average temperature in the display case.

For the product also a representative product has been chosen. Its temperature shows an "average" temperature between the coldest and the warmest products.

• **Control parameters**

For the sake of comparison between the blends and R502, the conditions of the condensation are controlled by the intake temperature of air at the condenser. This intake temperature implies a level of pressure specific to each refrigerant.

In order to measure the refrigerating performances in a thermal steady state, only one defrosting is operated per 24 hours.

• **Temperatures of other components of the refrigerating system**

- Condenser: five air temperatures and five wall temperatures allow monitoring of the blend's temperature glide when condensation occurs.
- Compressors: temperature is taken at the suction collector, the discharge collector and at the discharge of each compressor.

• **Other data**

- Four pressures are measured at the intake and at the outlet of the evaporator and the condenser.
- The refrigerant mass flow is measured in liquid phase and the condenser air flow is also registered.
- The electrical power of the four compressors is continually registered.

4. Conditions of the test

• **Control of the climatic room and defrosting**

The running of low temperature display cases under real operation conditions in supermarket is characterized by four defrostings per 24 hours. Each defrosting phase lasts between 30 and 45 minutes, during which the temperature of the products rises.

Once the operation conditions were created in the climatic room - a steady room temperature of 20°C with a 50% moisture rate - tests have been carried out with R502. Such temperature changes at the core of the products were shown that they did not allow to compare easily the different refrigerants. It was consequently decided to reduce the number of defrostings in order to reach steady state temperatures inside the products.

The blowing of outdoor air in the climatic room was stopped and consequently the display case turned this room into a small cold room, which enables to perform defrosting operations only about every 24 hours.

• **Condensing temperatures**

For each blend, the system is run until a steady temperature inside the products is reached. This low temperature steady state is performed three times with the following air intake temperatures at the condenser : 32°C, 38°C and 43°C. Each time, parameters are registered and processed in order to define:

- the refrigerating capacity,
- the electric consumption,
- the energy efficiency ratio,
- the liquid and vapor compositions,
- the temperature glide at the condenser.

• **Charge of lubricant and refrigerant**

For each blend the lubricant and the dehydrater filter are changed. The lubricant is a polyol ester oil (ISO 32). Two series of tests have been carried out for R502 - one with POE oil and another one with mineral oil - to check if the electrical consumption of the compressors is different or not according to the lubricant No significant difference was observed. The system is evacuated before each test to a 3 millibar absolute level.

The different blends are charged in the refrigerating system under liquid phase. The refrigerant charge is specific for each thermal range. For the sake of comparison we have determined the optimum charge at one range only: 32°C. The criteria that has been chosen to charge the installation is a 5 to 7°C superheat at the evaporator outlet in steady thermal range for a 32°C outside temperature. When the air temperature at the condenser is 43°C, the superheat is consequently higher.

5. Results

The results are presented in two series of three tables. Each serie corresponds to one of the three thermal range defined by the air intake temperature at the condenser: 32°C (90°F), 38(100°F) et 43°C(110°F). Hereafter are the comments on the two series of tables.

• **Core temperatures of the products and evaporating temperatures**

Core temperatures of the products are in the same order of magnitude in the three tests. Only, some small differences can be noticed: at 32°C, the core temperature of the product is lower with R502 compared to the temperatures obtained with HFC blends but it is the other way round at 38°C. At 43°C, the temperatures are the same for all blends.

AZ50 and R502 are azeotropic blends at the evaporating pressure of 1 bar. The small glide of temperature (about 0.6K) of R404A is very difficult to assess because of the control of the thermostatic valve. The tests show no difference in the control of the evaporation between those three blends. Whatever the blend tested, no change in the evaporation control was necessary. The evaporating temperature of AZ50 is generally 1K below the one of R502, the one of R404A is 0.5K below.

• **Condensing pressures and pressure ratios**

For the same temperature of air entering the condenser, the pressures of R404A and of AZ50 are higher than the pressure of R502. Moreover the pressure ratios of R404A and AZ50 are higher than the one of R502:

2% at 32°C and 6% at 43°C for R404A, and 6% at 32°C and 8% for AZ50.

• **Discharge temperature**

The discharge temperatures of Maneurop and L'Unité Hermétique compressors are slightly different (2 to 4K). For comparison between the three blends, one temperature is monitored on the common collector which is isolated and located at about one meter of each compressor outlet.

The data show that:

- the discharge temperature of R502 and R404A are very close (depending on the external conditions, discharge temperature of R404A can be slightly higher, equivalent or lower than the one of R502);
- the discharge temperature of AZ50 is always higher of 8 to 14K than the discharge temperature of R502.

• **Mass flow rate**

The mass flow rate is in the same order of magnitude for AZ50 and R502. We can notice that the mass flow rate of R404A is about 12% smaller than the one of R502.

• **Electrical consumption and energy efficiency**

To compare the energy performances of the HFC blends and of R502, we compare the power consumption through the ratio Rw :

$$R_W = \frac{W_{elec}\ blend}{W_{elec}\ R502}$$

where W_{elec} is the power consumption of the compressors when running with a HFC blend or R502.

So we can verify that the R_W ratio is in the same order of magnitude for R502 and AZ50 and the electrical consumption of R404A is more than10% lower than the one of R502. Complementary calculations show that the refrigerating capacity of R404A is lower than the one of R502 or AZ50. Those differences: lower capacity and lower electrical consumption of R404A lead to the conclusion that the C.O.P of the three blends are rather the same. In the conditions of the test, this difference in capacity does not lead to any difference of the core temperature of the products because the refrigerating capacity of the compressor's rack is oversized about 30% even at a temperature of 43°C. This is not unusual on the field.

6. Conclusion

The main conclusion: the two HFC blends are able to maintain the products at the same temperature as the one reached with R502. We can also notice that the discharge temperature with AZ50 is about 10°C above the temperature of R404A and R502, but the level is quite acceptable. The energy efficiency of the three blends are in the same order of magnitude but capacity and electrical consumption are lower with R502 and R404A.

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GENERAL RESULTS

	Cond. air intake T. (°C)	Cond. T. (°C)	Cond. pres.(bar)	Pressure ratio	Evap. pres. (bar)	Evap. T. (°C)	W blend /WR502	Disch. T. (°C)	Mass flow rate (g/s)
R 502	32.8	37.7	15.82	15.4	1.03	-45	1	102	29
AZ50	32.7	37.3	17.42	16.4	1.06	-46.1	1.02	117	29
R404A	32.7	38.9	16.89	16.9	1	-46.4	0.89	105	25

	Cond. air intake T. (°C)	Cond. T. (°C)	Cond. pres.(bar)	Pressure ratio	Evap. pres. (bar)	Evap. T. (°C)	W blend /WR502	Disch. T. (°C)	Mass flow rate (g/s)
R 502	38.6	43.3	18.02	16.2	1.1	-43.6	1	117.4	28
AZ50	38.6	42.5	19.69	17.9	1.1	-45.4	1.02	126.4	28
R404A	38.6	42	19.06	18.1	1.05	-45.2	0.88	114	25

	Cond. air intake T. (°C)	Cond. T. (°C)	Cond. pres.(bar)	Pressure ratio	Evap. pres. (bar)	Evap. T. (°C)	W blend /WR502	Disch. T. (°C)	Mass flow rate (g/s)
R 502	43.6	46.9	19.54	17.6	1.13	-43.4	1	122	28
AZ50	43.6	46.6	21.61	19.1	1.13	-44.8	1.01	131	28
R404A	43.5	46.4	21.10	19.4	1.09	-44.8	0.87	120	25

SIGNIFICANT TEMPERATURES IN THE DISPLAY CASE

Air intake temperature at the condenser : 32°C

	Room T.(°C)	Blowing T.(°C)	Suction T.(°C)	Prod. core T. (°C)	Evap. T. (°C)
R 502	-6.6	-39	-25.4	-32.7	-45
AZ50	-2.1	-37.4	-19.6	-31.1	-46.1
R404A	-4.9	-37.5	-24.2	-30.2	-46.4

Air intake temperature at the condenser : 38°C

	Room T.(°C)	Blowing T.(°C)	Suction T.(°C)	Prod. core T. (°C)	Evap. T. (°C)
R 502	-1.7	-35.6	-19.9	-30.5	-43.6
AZ50	-2.8	-37.6	-20.7	-32.9	-45.4
R404A	-5.2	-35.5	-23.3	-31.9	-45.2

Air intake temperature at the condenser : 43°C

	Room T.(°C)	Blowing T.(°C)	Suction T.(°C)	Prod. core T. (°C)	Evap. T. (°C)
R 502	-5.6	-33.1	-21.4	-31.9	-43.4
AZ50	-4.2	-35.7	-24	-31.3	-44.8
R404A	-5.6	-34.4	-22	-33.3	-44.8

DETAILS OF THE TEST BENCH