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## **A DROP-IN ANALYSIS OF THE PERFORMANCE OF R-22 WITH R-134A FOR A DOMESTIC VAPOR COMPRESSION REFRIGERATION SYSTEM**

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**Abstract.** *The Montreal and Kyoto protocol's, and more recently Kigali amendment in 2016 determined the phase-down of the production and consumption of the CFCs, HCFCs, and including the HFCs. The refrigeration industry goes through a period in which refrigerants tend to be replaced by natural or environmentally friendly fluids. Thus, this paper is presented an experimental drop-in analysis of the performance of the R22 with R134a for a domestic vapour compression refrigeration system. Experimental tests were carried out at the same conditions parameters to compare the performance between the two fluids. Pressures and temperatures were measured and recorded by a Labview program. The software Engineering Equation Solver (EES) was used to calculate the others thermodynamics properties. For all results obtained, the R22 presented to have a coefficient of performance slight better than the R134a. The highest COP obtained for R134a was  $3.37 \pm 0.15$ , while for a same operation conditions the R22 was  $4.23 \pm 0.15$ .*

**Keywords:** *Experimental analysis, R-134a, R-22, Refrigeration system, Coefficient of performance.*

### **1. INTRODUCTION**

Currently, there is a growing demand for cooling systems, which are essential in our daily lives. However, researches for a good environmental friendly refrigeration fluid to be employed in these cooling systems have become a major challenge for the industry refrigeration and society in general. R-22 was one of the oldest and most widely used refrigerant fluids in the past decades. Nevertheless, this fluid has a chlorine in its molecular structure, which it is extremely harmful to the ozone layer. Also it has GWP values (Global Warming Potential) of 1700 and OPD (Ozone Depletion Potential) equal to 0055, which values are currently prohibited by the Montreal and Kyoto Protocol's and most recently the Kigali amendments (ANTUNES, 2015; SHRIVASTAVA e CHOUDHARI, 2016).

Nowadays, several researches such as Tashtoush and Younes (2019) and Petrenko and Mazur (2018) reported the trend of the new refrigeration fluids and their possible substitutes. Table 1 shows some alternative refrigerants fluids to R-22 and their respectively proprieties (KASERA and BHADURI, 2017). Calm (2004), presented the status of the transition environmentally safer refrigerants in phased out of R-22. The results showed that the R-134a takes over as the most widely used refrigerant fluid for a medium refrigeration system since for most of them there no need to change and redesigned the system. Shrivastava e Choudhari, (2016) investigated the theoretical aspects of HC-290 (propane) as potential substitute for HCFC-22. The theoretical analysis shows that the thermos-physical properties and environmental properties of HC-290 is much better than HCFC-22. Deshmukh and Mali (2015) study a vapor compression refrigeration system with various hydrocarbon refrigerants such as R-290, R-600a, R-1270 as well as their blend mixtures in various ratios are considered as a drop in candidate for R22. The results shows that the alternative refrigerants investigated have a slightly lower COP as compared to R22 but much higher refrigerating effect. Reis and Seidel (2015) developed a numerical simulation to analyze the performance of several refrigerants such as R-11, R-12, R-22, R-134A, R-410A and R-717 of conventional vapor compression cycle. R-134a demonstrated to be one of the best refrigerant fluid to replacement the R-22.

Then, the aim of this paper is to present an experimental drop-in analysis of R-22 with R-134a for a domestic vapor compression refrigeration system. The performance of each fluid is compared. Besides that, mass flow rate and the capacity cooling are investigated.

Table 1. Properties of some alternatives refrigerant fluids to R-22.

Refrigerant fluid	Molecular weight (kg/mol)	NBP (°C)	T <sub>cri</sub> (° C)	P <sub>cri</sub> (MPa)	ODP	GWP (100 years)
R-22	86.47	-40.8	96.20	4.99	0055	1700
R-134a	102.03	-26.1	101.1	4.06	0	1300
R-290	44.10	-42.1	96.8	4.25	0	11
R-407c	86.2	-43.6	86.1	4.62	0	1530
R-470A	72.56	-50.5	72.5	4.96	0	1730

Source: Adapted from Kasera and Bhaduri, 2017.

## 2. METHODOLOGY

The present work was developed in the laboratory of Thermodynamics and Heat Transfer of the University of Itaúna. The vapor domestic refrigeration system, as described by Perez-Garcia *et al.* (2013) is the basic refrigerant cycle composed of a compressor, condenser, evaporator and expansion device, according to Fig. 1

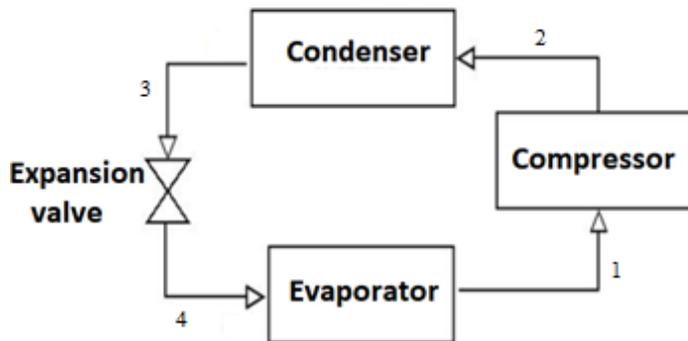


Figure 1. Basic refrigeration cycle

Figure 2 shows the experimental facility that it is composed by a hermetic compressor with voltage of 127 V, a compact finned copper condenser, a capillary tube and a compact finned copper evaporator. In each one of the four device's outlet, manometers and type K thermocouples were installed. Two others thermocouples were installed on the cooled air outlet duct and one to measure the ambient air. All the system piping were isolated with proper material.

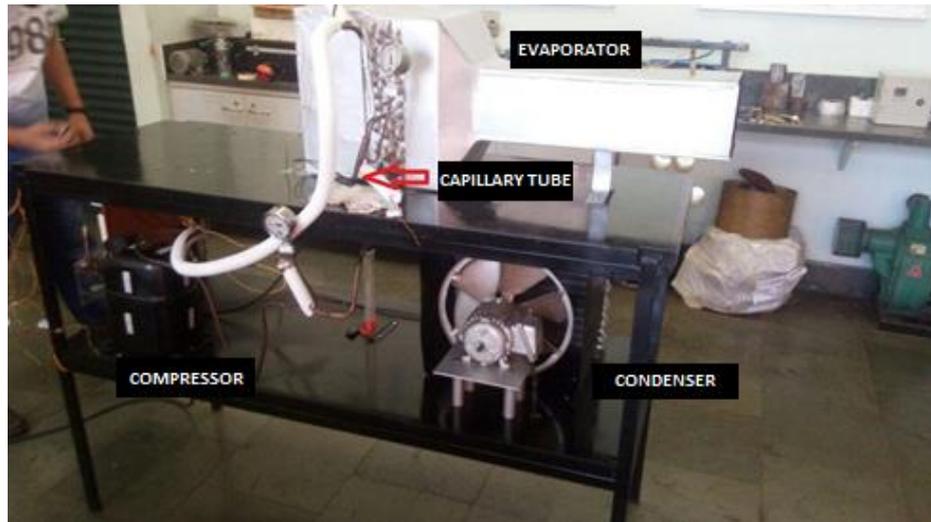


Figure 2. Experimental facility

The system also has a force convection through the condenser. A Schneider variable-frequency drive has been installed in order to control the rotation of an electric motor's shaft, which is coupled to a propeller that is responsible to force convection at this heat transfer. For the tests the frequency analyzed with both refrigerants, R-22 and R-134a, were 36, 48 and 60 Hz.

All data were collected after the system reached the steady-state condition, which it takes about 20 minutes. The software *LabVIEW* was implemented to collect the experimental data. In an addition, the software Engineering Equation Solver (EES) was used to calculate the thermodynamics properties and to determine the COP expanded uncertainty.

The amount of charge of both fluids, R22 and R134a were the same, 610 grams. After all tests were done with R-22, the fluid was completely removed and vacuum was performed before it charged with R-134a.

### 3. RESULTS AND DISCUSSION

For each point was carried out ten measurements, and the mean of these values was used to minimize the errors. All tests were performed with ambient temperature with average of 23°C with a maximum deviation of 1.2°C. The measured values for temperatures and pressure for R-22 and R-134a is given by Tab.1 and Tab.2. For both refrigerants tests were conducted for frequencies of 36, 48, and 60 Hz with a propeller rotating coupled to the motor responsible for forced convection in the condenser.

Table 2. Measurements for R-22.

Frequency (Hz)	T1 (°C)	P1 (MPa)	T2 (°C)	P2 (MPa)	T3 (°C)	P3 (MPa)	T4 (°C)	P4 (MPa)	Air outlet temp. (°C)
60	7.0 ± 1	0.40±0.12	78.3 ± 1	1.62 ± 0.15	31.0 ± 1	1.53± 0.15	-3.7 ± 1	0.44±0.12	0.0 ± 1
48	3.5 ± 1	0.43±0.12	86 ± 1	1.81 ± 0.15	35.3 ± 1	1.72±0.15	-2.0 ± 1	0.46±0.116	2.0 ± 1
36	0.0 ± 1	0.47±0.12	88.3 ± 1	2.11 ± 0.15	46.0 ± 1	2.06±0.15	0.0 ± 1	0.52±0.12	4.0 ± 1

Table 3. Measurements for R-134a.

Frequency (Hz)	T1 (°C)	P1 (MPa)	T2 (°C)	P2 (MPa)	T3 (°C)	P3 (MPa)	T4 (°C)	P4 (MPa)	Air outlet temp. (°C)
<b>60</b>	18.6 ± 1	0.27±0.12	87.4 ± 1	1.38±0.15	35.4 ± 1	1.38±0.15	1.9 ± 1	0.28±0.12	8.8 ± 1
<b>48</b>	18 ± 1	0.28±0.12	95.1 ± 1	1.47±0.15	38.2 ± 1	1.47±0.15	-1 ± 1	0.28±0.12	8.0 ± 1
<b>36</b>	18 ± 1	0.30±0.12	99.1 ± 1	1.72±0.15	47.0 ± 1	1.72±0.15	0.1 ± 1	0.30±0.12	8.9 ± 1

The enthalpies of the refrigeration cycle were calculated by the EES program developed considering the 1st law of thermodynamics. The compressor and the capillary tube were considered as adiabatic components. Table 4 shows the results of the coefficient of performance (COP) obtained for both fluids and calculated by Eq.(1).

$$COP = \frac{q_{41}}{w_{12}} \quad (1)$$

Where  $q_{41}$  (kJ/kg) is the specific receive heat by the evaporator, and  $w_{12}$ (kJ / kg) is the specific compressor work.

Table 4. Values of COP R-22 and R-134a fluids.

Fluid	R-22	R-134a
Frequency (Hz)	COP	COP
<b>60</b>	4.63 ± 0.15	3:37 ± 0.15
<b>48</b>	3.69 ± 0.11	2.82 ± 0.11
<b>36</b>	3.15 ± 0.09	2:54 ± 0.09

For a comparison of the drop-in between the refrigerating fluids, the diagram pressure versus specific enthalpy were plotted for the frequency that presented the best results, that means frequency of 60Hz. The R-22 and R-134a pressure versus specifi enthalpy diagrams are shown in Fig. 3 and Fig.4, respectively.

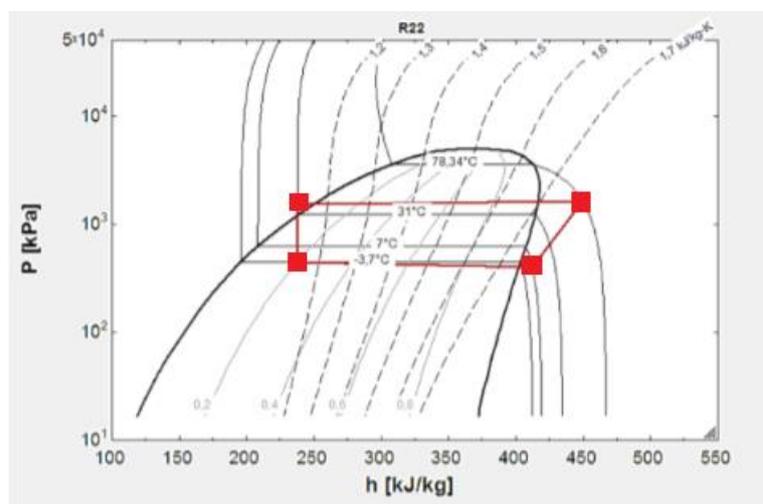


Figure 3. Pressure versus specific enthalpy for R22

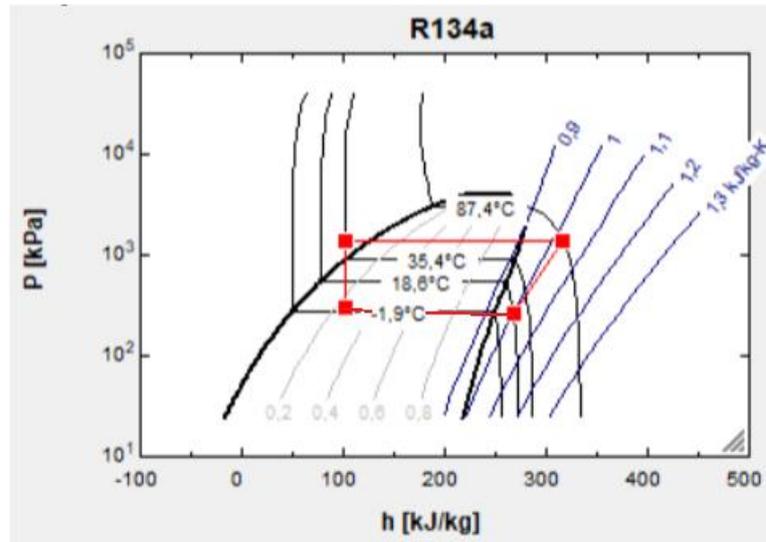


Figure 4. Pressure versus specific enthalpy for R-134a

The mass flow rates of the two fluids were calculate by the energy balance in the evaporator as demonstrated by Eq.(2), Eq. (3) and Eq. (4):

$$|Q_{evaporator}| = |Q_{air}| \quad (2)$$

$$Q_{evaporator} = \dot{m}_{fluid} (h_1 - h_4) \quad (3)$$

$$Q_{air} = \dot{m}_{air} c_p (T_o - T_i) \quad (4)$$

Where the heat transfer receives in the evaporator is equal to heat transfer lost by the air. The  $\dot{m}_{fluid}$  (kg/s) is the fluid refrigerant mass flow rate,  $h_1$  (kJ/kg) is the outlet enthalpy on the evaporator and  $h_4$  (kJ/kg) is the inlet enthalpy on the evaporator,  $c_p$  is the specific heat of the air (kJ/kg.K),  $\dot{m}_{air}$  is the air mass flow rate (kg/s),  $T_o$  is the air outlet temperature and  $T_i$  is the air inlet temperature.

The air mass flow rate was calculated by measuring the cold air exit velocity and the area of the outlet duct, as is observed in Eq. (5).

$$\dot{m}_{air} = A * v * \rho \quad (5)$$

Where  $v$  (m/s) is the outlet air velocity,  $A$  (m<sup>2</sup>) is the area of the cold air outlet duct, and  $\rho$  is the air specific mass.

The mass flow rates were 0.0392 kg/s for R-134a, and 0.010 kg/s for a R-22. Since the cooling capacity of R-22 is greater than the R-134a and the charge are the same in both case analyzed, the results are considered relevant.

As seen in Tab.4, the performance of R-134a is lower than R-22 under the same conditions. This is because of the different fluid properties, such as the calorific capacity, which it represents the ability of the fluid to reject or absorb heat.

Even though the COP of R-134a reduces in about 27.21 % comparing to R-22 for a frequency of 60 Hz, the R-134a represents a viable fluid for immediate replacement of R-22 since no device in the system needs to be replaced. Reis and Seidel (2015) after comparing several fluids such as R-12, R-134a, R-410a, R-717 also came to the conclusion that the R-134a is the best immediate replacement of R-22.

#### 4. CONCLUSION

The results of the drop-in of R-22 by R-134a was satisfactory. For a frequency of 60 Hz, the R-134a presented a reduction of 27.2 % of efficiency compared to R-22. Although the efficiency of R-134a is slightly lower than R-22, it is one of the most compatible fluid to replace the R-22, since it is not necessary to change any equipment of the refrigeration cycle reducing costs of retrofit. As expected, the mass flow rate of the R-134a was higher than R-22 since the mass charge was the same and the cooling capacity of the R-22 is higher.

Immediately, the R-134a shows to be great substitute of the R-22. However, in the next years the cooling industry needs to undergo major changes in the search for environmentally friendly refrigerant fluids.

For future ideas, it aims to analyze the behavior of the R-134a fluid by adding new equipment to the bench. And compare how much each component can contribute to have a better performance of the machine.

## 5. ACKNOWLEDGEMENTS

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## 7. RESPONSIBILITY NOTICE

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