COMPARATIVE ANALYSIS OF ENERGY EFFICIENCY OF AN AUTOMOTIVE AIR CONDITIONER WITH R134a AND r437a, AND DIFFERENT FREQUENCIES OPERATION OF EVAPORATOR

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Abstract. *The reduction in energy consumption is the main requirement to be satisfied in refrigeration and air conditioning by mechanical vapor compression system. In automotive system isn´t different. Thermal analyses in these systems are crucial for a better performance in automotive air conditioner. This work aims to evaluate the conditions of use of R134A refrigerant (used in vehicles) and compare with R437A (alternative refrigerant), varying the speed of the electric fan in the evaporator. All tests were performed in automotive air conditioning unit ATR600, simulating the thermal conditions of the system. The equipment is instrumented for data acquisition temperature, condensation and evaporation pressures and electrical power consumed to determine the coefficient of performance of the cycle. The system was tested under rotations of 800, 1600 and 2400 rpm with constant load of R- 134a. It occurred with the same conditions with R437A. Both recommended by the manufacturer. The results show that the best system performance occurs in the rotation of 800 RPM, in the refrigerant R437A.*

Keywords*: performance coefficient, R134a, R437a, automotive refrigeration*

1. INTRODUCTION

The health, safety and environmental concerns are included in the environmental industry and thematic conservation of energy will continue to be a motivating factor for the relentless pursuit of quality materials and processes. The refrigerativos thermal systems has become increasingly important. Regardless if it is applied for comfort or industrially. In automotive systems, their functionality is crucial because it prioritizes the welfare of its driver.

However, comfort is not the only aspect to be evaluated in the vehicle coolant systems. With the advent of Environmental Management was passed to monitor the influence of these fluids when released into the atmosphere. This behavior is crucial in the development of automotive HVAC equipment. And with that, the type of refrigerant used in these systems is extremely important for assessing these energetic and environmental aspects.

Currently in automotive systems R134a (1,1,1,2-dichlorodifluoromethane) is extremely used and quoted alternative for applications such as air conditioning for domestic use. This hydrocarbon is not flammable and not explosive, is an HFC that has a null potential to destroy the ozone layer, but in return offers the significant greenhouse. Compared to R-12, an imperceptible toxicity. The R-134a also has a good feature as miscibility with lubricating the base polyol ester (POE's), which also contributes to eliminate explosive hazards oils.

In the present study an alternative fluid was used to R-134a, which also is commonly used in HVAC systems, R-437th. The coolant was developed for processes Retrofit R-12. Data from the manufacturer, this is compatible with the lubricants used in vehicle systems and is not generally necessary adjustments.
Table 1 below lists the technical specifications of the R-437A Manufacturer.

Components	Chemical name	Formula	Weight Percent
HFC-125	Pentafluoroethane	CF_3CHF	19,5
HFC-134a	1,1,1,2-tetrafluoroethane	CF_3CH_2F	78,5
Butane	n-butane	C_4H_{10}	1,4
Pentane	n-pentane	C_5H_{12}	0,6

Table 1. Composition of ISCEON MO49 PLUS (*Source: DuPont Brasil*)

In Table 2 below, it is possible to observe the physical properties of R-347. We notice that the potential for destruction of the ozone layer (ODP) and global warming (GWP) are lower when related to R-12.

Physical Property	Unit	ISCEON™ MO49*Plus*	R-12
Boiling point (1 atm)	°C °F	-29 -20	-30 -22
Vapor pressure at 25°C (77°F)	KPa Abs Psia	743 108	652 95
Liquid density at 25°C (77°F)	Kg/m^3 Lb/Ft^3	1176 73,4	1311 81,8
density of saturated steam at 25°C (77°F)	Kg/m^3 Lb/Ft^3	37,8 2,36	37 2,32
Ozone destruction potential (ODP)	CFC-11 = 1.0	0	1
Global Warming Potential (GWP)	CO_2 - 1	1684	8500

Table 2. Physical Properties ISCEON MO49 PLUS (*Source: DuPont Brasil*)

2. MATERIALS AND METHODS

The educational software ATR600 was used to simulate the thermal condition of an automotive cooling system. The original refrigerant was removed (R134a) is replaced by R437a. As recommended by the manufacturer according to the steps shown in Table 3:

Operation	Activity
1	Removing the R134a system and put it into a recovery cylinder. A vacuum pump was used to perform this step
2	Made as weighing was removed (it was verified with the manufacturer of the bench the amount of refrigerant that the system supported, because such information is not contained in the manual)
3	Checked the condition of the filter / drier (the original bench was kept)
4	Checked for leaks in order not to compromise the system performance
5	Insertion of R437a on bench

Table 3. Steps to Changing Coolant Fluid.

The data required for calculation of the COP (evaporating and condensing temperatures, pressures, high and low) were extracted by the machine's software. There are sensors distributed in several points that allow the data acquisition. Below we can see the HMI for reading data:

Figure 3. HMI for Data Acquisition (*Source: Student Manual – BIT9*)

To obtain data isn´t necessary a software installation in the computer. All it took was just make a copy of the application directly to the HD. Connection is made from a DB9 serial cable, which works with the communication protocol RS-232. The left and top of the screen monitoring program are located the options parameters of the cooling system that can be acquired.

The speed of 800 RPM corresponds to the simulation of the turning vehicle engine idling. On the other corresponds to 4000 rpm speed. The tests were performed with rotations: 800, 1600 and 2400 rpm, whose control was given by the potentiometer as shown below.

Figure 4. Speed Control Set (*Source: Student Manual – BIT9*)

The data collected were placed in an Excel spreadsheet. With the pressures of high and low, could be the saturation temperatures (through PT DuPont Calc software) and the data collected at the outlet of the evaporator and condenser, the subcooling and superheat one could be calculated as:

$$T_{OVERHEATING} = T_{EVAPORATOROUTPUT} - T_{SATURATION} \quad (1)$$
$$T_{SUBCOOLING} = T_{CONDENSEROUTPUT} - T_{SATURATION} \quad (2)$$

After acquisition of all data was resorted to Duprex 3.2 software of DuPont, and found the COP in all rotations.

3. RESULTS AND DISCUSSIONS

For this study, the compressor acted in rotation of 800, 1600 and 2400 rpm; now to the evaporator were analyzed V2, V3 and V4 speeds (as manufacturer).

The 800 RPM, speeds V3E (with applied voltage of 8,5 V), 10,8 V voltage across the electric fan of condenser in use of refrigerant R-437a, the highest values of COP were found.

The saturation temperature of the condenser and the evaporator and high and low pressures in the system were directly parameters for obtaining COP (as shown in Table 04, illustrating the conditions for the COP results in higher). In Figure 5 we observe the highest values of coefficient of performance for the rotation of 800 RPM. To check the speed V4 is greater consistency in the results, different from V2 and V4, with few sharp peaks. With increased speed, the system remained stable during the tests.

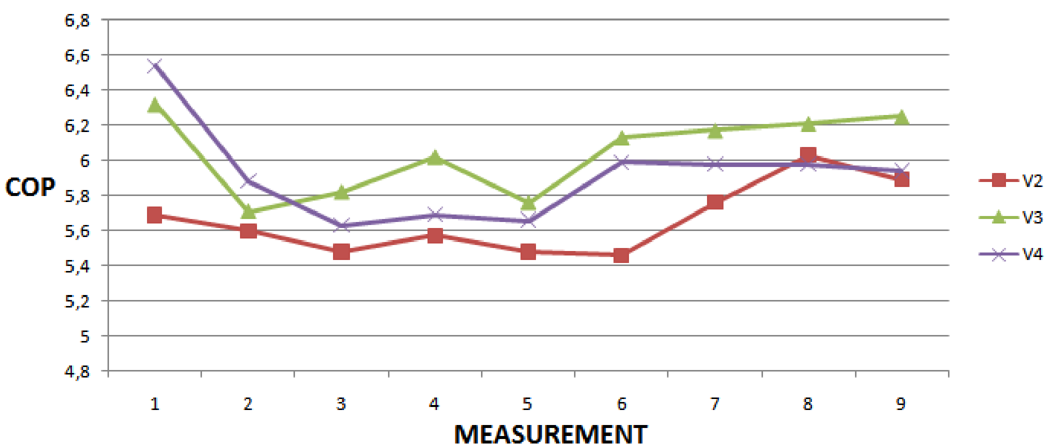

Figure 5. Variation of the COP with variation in voltage of the electric fan evaporator (800 RPM and R-437a)

Med	Palta (psi)	Tsat(alta)	Tsc(oC)	Subresf	Pbaixa (psi)	Tsat(baixa)	Tsr(oC)	Superaq	COP
1	192	47	33,1	13,9	74	18,6	20,3	1,7	6,32
2	194	47,4	35,8	11,6	70	17,1	20,3	3,2	5,71
3	195	47,6	36,3	11,3	72	17,8	20,3	2,5	5,82
4	195	47,6	36,3	11,3	74	18,6	20,3	1,7	6,02
5	194	47,4	36,3	11,1	71	17,4	20,3	2,9	5,76
6	192	47	36,3	10,7	74	18,6	20,3	1,7	6,13
7	191	46,8	36,3	10,5	74	18,6	20,3	1,7	6,17
8	192	47	36,3	10,7	75	18,9	20,3	1,4	6,21
9	191	46,8	36,3	10,5	74	18,6	20,3	1,7	6,25

Table 4. Acquired data in the evaporator on speed V3 (R-437a)

where:

Med = Measurement;
Palta = high pressure system;
Tsat (high) = saturation temperature for the pressure high;
Tsc = temperature at the condenser outlet;
Subresf = subcooling;
Pbaixa = low pressure system;
Tsat (low) = saturation temperature to low pressure;
Tsr = temperature at the evaporator outlet;
Superaq = Overheating;

4. CONCLUSIONS

For refrigerants analyzed, without any modification, as technical specifications provided by the manufacturer, the results were satisfactory. It was found that, with increasing compressor speed, reduced the coefficient of performance in R-134a. But in the R-437a, the intermediate speed (V3) was better in performance.

With the widest data stratification, it was noted that the best COP, with 800 RPM and value of 6,54; occurred when the voltages at electric fan of the evaporator and condenser were, respectively, with values of 10,4 and 10,.8 VDC (corresponding to the velocity V4 call by the manufacturer).

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