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PERFORMANCE OF A VAPOUR COMPRESSION SYSTEM FUNCTIONING WITH THE HYDROCARBONS 1, 4 PENTADIENE AND CYCLOBUTANE.

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ABSTRACT

During the last years, due to the confirmation of the depletion of the ozone layer by CFCs and the subsequent restriction, each time more severe, imposed by the Montreal protocol in relation to the use of these refrigerants, several alternative refrigerants have been evaluated. Hydrocarbons can be good substitutes for CFCs because their thermodynamics properties are similar to those of CFCs, they also present very low values of ODP and GWP. The aim of this study is to evaluate performance of the 1,4 Pentadiene and Cyclobutane in domestic refrigeration systems. The analysis of results shows that 1,4 Pentadiene and Cyclobutane can substitutes R11 in domestic refrigeration systems where flammability can be neglected.

Keywords: CFC, Refrigerating machine, R11, 1,4 Pentadiene, Cyclobutane.

NOMENCLATURE

h	: Enthalpy (kJ/kg).
P	: Pressure (bar).
Q	: Heat transfer rate (kJ).
qm	: Mass flow rate (kg/s).
T	: Temperature (°C).
V	: Volume (m^3).
W	: Work given to the compressor (kJ).
Wf	: power by ton of refrigerating effect (kW/TRE).
VRE	: Volumetric refrigerating effect (kJ/m3).
COPf	: Refrigerating coefficient of performance.
CFCs	: Chlorofluorocarbons.
GWP	: Global warming potential.
ODP	: Ozone depeletion potential.
Subscripts	
1,2...5	: Indicates different points of the cycle
co, ev, comp	: Denote the condenser, the evaporator and the compressor, respectively.

INTRODUCTION

The CFCs were once acknowledged to be perfect refrigerants, they are not toxic and not flammable and do not attack metals. However, it was proved in 1974 that CFCs are responsible for ozone destruction and participate in the greenhouse effect[1]. This implication led to the Montreal protocol of 1987, and the amendments of which resulted the elimination of the CFCs. On this basis, several research studies have been carried out to find some fluids of replacement. The use of hydrocarbons is promising in this field because they present thermodynamic properties similar to those of CFCs and present also very low values of ODP and GWP. In this study, we evaluate performances of 1,4 Pentadiene and Cyclobutane as substitutes for R11 in domestic refrigeration systems where flammability can be neglected because the charge of refrigerant is very weak.

SIMULATION METHOD

A vapor compression cycle is illustrated in Figure 1, it includes an evaporator, a compressor, a condenser, a heat exchanger and an expansion valve.

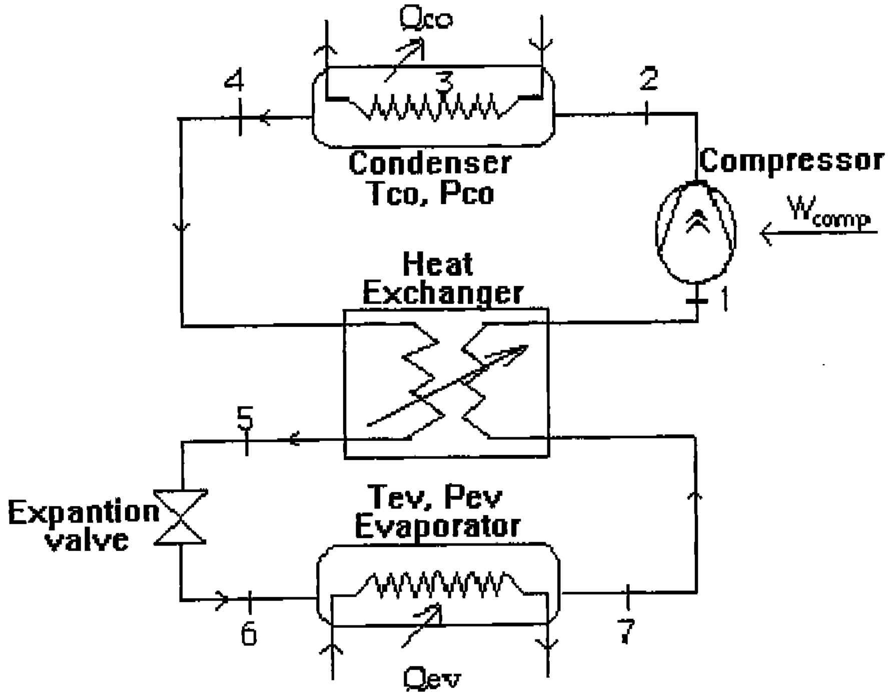

Figure 1 : Schematic diagram of vapor compression cycle with heat exchanger

The simulation is based on mass and heat balance equations for each component of the system:

- Condenser:

$$Qco = qm.(h2 - h4) \quad (1)$$

- Evaporator:

$$Qev = qm.(h1 - h5) \quad (2)$$

- Expansion valve:

$$h5 = h4 \quad (3)$$

- Heat exchanger :

$$h4 - h5 = h1 - h7 \quad (4)$$

- Compressor:

$$Wcomp = qm.(h2 - h1) \quad (5)$$

- Coefficient of performance:

$$COPf = \frac{Qev}{Wcomp} \quad (6)$$

Thermodynamic properties of fluid are evaluated from a method of estimation [2] which requires a limited number of data: the chemistry formula and boiling temperature. This method is based on a certain number of relations [3,4,5,6] allowing the calculation of critical parameters, acentric factor, saturated vapor pressure, specific volumes in liquid and vapor phases and calorific capacity in the vapor phase. The equation of state used is that of Patel-Teja.

SIMULATION RESULTS

We have studied the performance of 1,4 Pentadiene and Cyclobutane in comparison with R11. We have fixed a difference of temperature between the condenser and the evaporator at $\Delta T = 30°C$.
Figure 2, gives the variation of saturated vapor Pressure as a function of the temperature for the 1,4 Pentadiene, Cyclobutane and R11. We note a similarity of the curves of pressure between 1,4 Pentadiene and R11, this implies the ability of 1,4 Pentadiene to be used in a vapor compression system in replacement of R11. Cyclobutane presents values of pressure a little superior to those of R11, therefore Cyclobutane could replace R11 with some changes of the compressor.

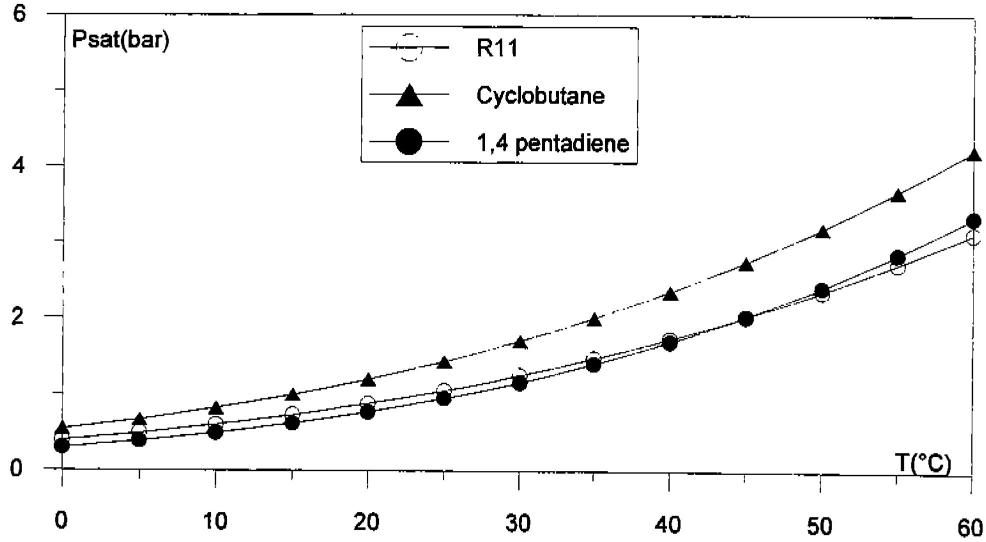

Figure 2: Variation of saturated vapor Pressure as a function of the temperature for 1, 4 Pentadiene, Cyclobutane and R11.

Figure 3, gives the evolution of the volumetric refrigerating effect as a function of the temperature of condensation for 1,4 Pentadiene, Cyclobutane and R11. Knowing that:

$$\mathbf{VRE} = \frac{\mathbf{Qev}}{\mathbf{Vec}} \quad (kJ/m^3) \tag{7}$$

VRE constitute the initial parameter of choice of compressor in a vapor compression cycle, with V_{ec} the volume entering the compressor. We note that 1,4 Pentadiene presents values of VRE close to those of R11. Therefore, for some capacities of cooling data, the utilization of 1,4 Pentadiene needs a volume on the entrance of the compressor approximately similar to that of R11. Cyclobutane presents values of VRE superior to those of R11, thus, the utilization of Cyclobutane in replacement of R11 needs some changes in the compressor.

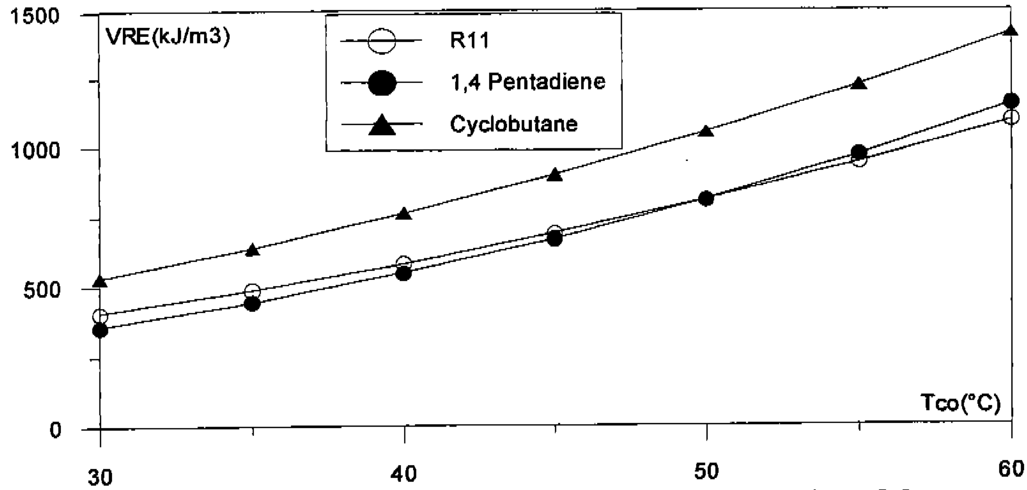

Figure 3: Variation of volumetric refrigerating effect (VRE) as a function of the temperature of condensation Tco for 1, 4 Pentadiene, Cyclobutane and R11.

Figure 4, compares the refrigerating coefficient of performance, COPf of the 1,4 Pentadiene, Cyclobutane and that of the refrigerant R11 as a function of the temperature of condensation T_{co}. We note that values of COPf of 1,4 Pentadiene are relatively similar to those of R11. Values of COPf of cyclobutane are little inferior to those of R11,so the energy consumption of 1,4 Pentadiene will be inferior to that of cyclobutane.

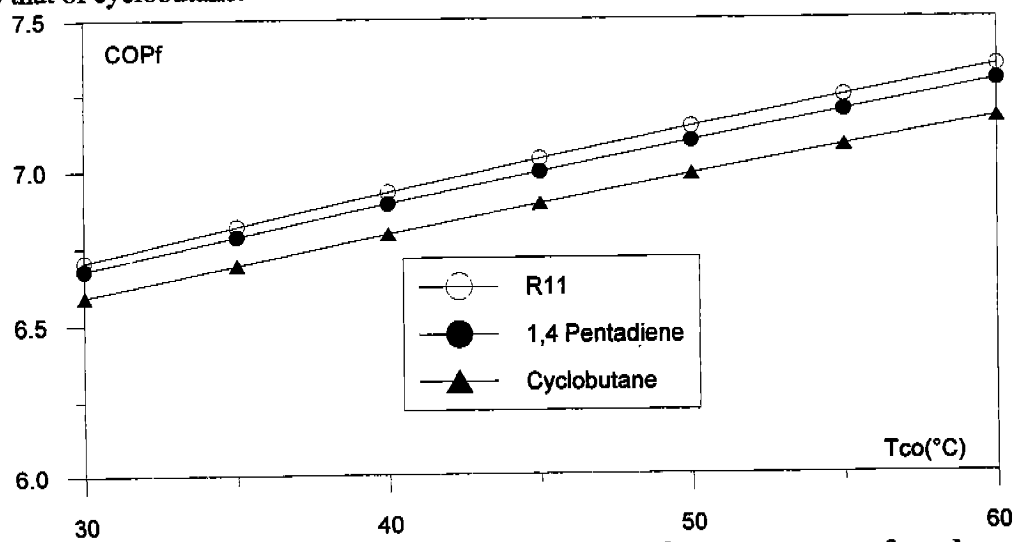

Figure 4: Variation of refrigerating COPf as a function of the temperature of condensation Tco for 1, 4 Pentadiene, Cyclobutane and R11.

Analyzing Figure 5, which illustrates the variation of power by ton of refrigerating effect Wf with the temperature of condensation, Wf allows to value the energy consumption of a refrigerating machine per one ton of refrigerating effect (1 TRE=3.517 kW):

$$\mathbf{Wf} = \frac{\mathbf{3.517Wcomp}}{\mathbf{Qev}} \quad \text{(kW/TRE)} \qquad (8)$$

We notes that the energy consumption of the machine functioning with the 1.4 Pentadiene is close to that of R11, whereas it is superior for the cyclobutane.

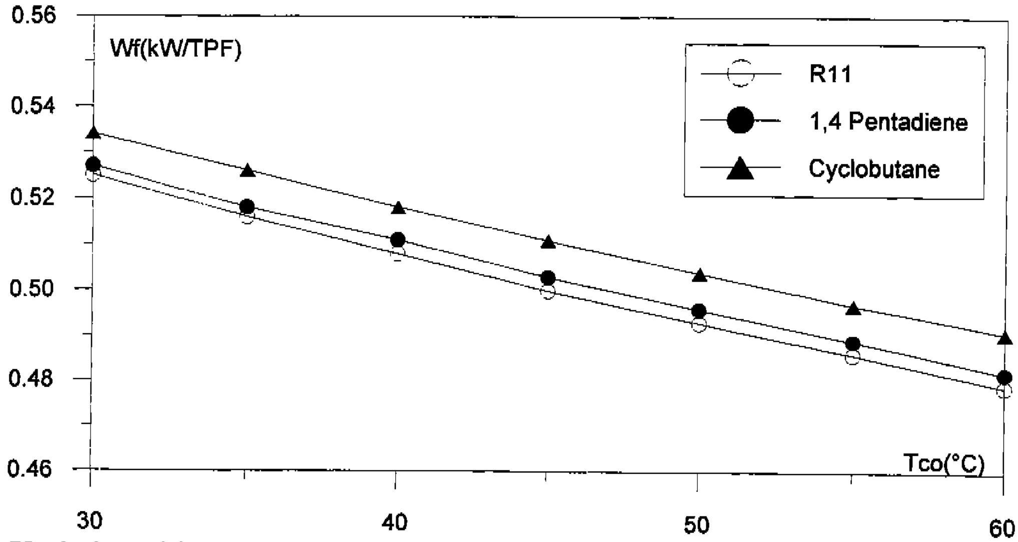

Figure 5: Variation of Pressure ratio, PR, as a function of the temperature of condensation Tco for 1, 4 Pentadiene, Cyclobutane and R11.

CONCLUSION

We have studied in this paper the possibility of replacing the R11 by new ecological fluids, which are 1,4 Pentadiene and Cyclobutane in a domestic refrigeration system. These fluids are not destructive of the ozone and do not participate in the greenhouse effect.
We have evaluated the performances of these fluids in the machine. Analysis of results showed that 1,4 Pentadiene could be a good substitute of R11. Indeed, it presents values of COPf, VRE and Wf relatively similar to those of R11. This similarity implies the possibility of substituting R11 by 1,4 Pentadiene without important changes of the compressor and system design. Cyclobutane presents values of COPf little inferior to those of R11, the values of VRE and Wf of this fluid are a little superior to those of R11, Therefore, the possibility of substituting R11 by Cyclobutane needs some changes in the compressor. The only inconvenience of 1,4 Pentadiene and Cyclobutane is the flammability. This problem doesn't present a risk for domestic machines for which the necessary quantity of refrigerant is very weak about 250g [7].

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