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INFLUENCE OF CONDITIONS OF THE RESTRICTION DEVICE EXPANSION IN THE PERFORMANCE OF A DOMESTIC REFRIGERATOR

Luiz Henrique Pinheiro de Lima, henriquengmec@yahoo.com.br
Universidade Federal do Rio Grande do Norte; Campus Lagoa Nova, Natal – RN – Brazil

Igor Marcel Gomes Almeida, igor.almeida@ifrn.edu.br
Cleiton Rubens Formiga Barbosa, cleiton@ufrnet.br
Francisco de Assis Oliveira Fontes, franciscofontes@uol.com.br
Cleiton Rubens Formiga Barbosa Júnior, cleitonformiga@gmail.com
Bruno Daniel Alves do Nascimento, bdaniel2012@bol.com.br
Universidade Federal do Rio Grande do Norte; Campus Lagoa Nova, Natal – RN – Brazil

Abstract. *The coolers are the equipments that have the highest energy consumption in Brazilian homes. It is estimated that the presence of refrigerators with more than 15 years of use in stock is approximately 12%. This indicates prolonged use of inefficient technologies and equipment with degraded efficiency. The operating point of a refrigerator is set by the interaction of the basic components. Changes in the type of refrigerant or charge influence in condensation and evaporation pressures due to excess or lack of fluid in the heat exchangers. The evaporating and condensing pressures affect the volumetric capacity of the compressor, the mass flow and power consumption. The expansion device plays an important role in the balance of operating pressures. Accordingly, the definition of the expansion device and calibration in relation to the compressor can improve or degrade the performance of the system. The objective of this study is to evaluate the influence of the restriction of a micrometer needle valve installed in place of, designed for R134a on the thermodynamic performance capillary tube of a commercial refrigerator. The combination valve calibration, tested in three different positions will expand or restrict the orifice of the device relative to the original capillary tube. Parameters of electricity, condensation and evaporation pressures, temperatures along the circuit tests lowering temperature were monitored. Results show that the correlation between inadequate constraint on expansion and refrigerant charge (maintained at 210 g) can provide high power consumption (about 15% higher) and lower cooling capacity in the inner compartment of the refrigerator.*

Keywords: *commercial refrigeration, micrometric expansion device, R134a, performance.*

1. INTRODUCTION

The expansion devices have the function of controlling the flow of refrigerant supplied to the evaporator and to maintain an appropriate pressure difference between the high and low sides of the system pressure. The expansion device more often used in home systems is the capillary tube, which consists of a long tube (4m), usually of copper, reduced diameter (0.7 mm) and constant cross section (Boeng, 2012).

This device, has fixed restriction, and does not respond adequately to the changing conditions of the system operation. When such changes occur the system always responds with performance degradation (Stoecker and Jo-nes, 1985).

The operating point of a cooling system for mechanical vapor compression depends not only on its components, but also of external conditions imposed on the system. It also appears that the components of a refrigeration system are completely interrelated. The condensation and evaporation pressures directly affect the compressor capacity and mass flow provided by the capillary tube and the opposite is true.

The temperature directly affects directly the condensing pressure and the evaporating pressure slightly due to the thermal insulation of the walls of the refrigerator. Since the refrigerant charge affects both the condensation pressure and the evaporation through the excess or lack of fluid in the heat exchangers (Boeng, 2012).

The operation and selection of an appropriate expansion device are the most important factors from the viewpoint of capacity and system control. Expansion devices that are commonly used in refrigeration systems such as capillary tubes, orifices into short tubes (pistons) and thermostatic expansion valves have been gradually replaced by the electronic expansion valve (EEV's) due to an increasing focus on comfort, energy conservation and environmentally safe to use in systems with variable speed compressors sodas.

Each expansion device has to regulate the flow of refrigerant differently in terms of appropriate or inappropriate loading. It is therefore necessary to develop methods of selection and design for EEV's, so obtain a satisfying and high performance control (Choi and Kim, 2002). Comprehensive studies of the effects of refrigerant charge in refrigeration with adjustable expansion valves (thermostatic or electronic) are needed aiming to seek improvements in system performance and obtain a modulation of adequate capacity.

The objective of this study is to evaluate the influence of constraint a micrometric needle valve installed to replace the capillary tube designed for R134a on the thermodynamic performance of a commercial refrigerator. The combination of the calibration of the valve, tested in three different positions will expand or restrict the orifice of the device relative to the original capillary tube. This configuration can be studied in the future (valve connection to a small stepper motor) and applied in order to modulate the operation of the system according to external environmental conditions commercial or residential systems, providing better performance of the equipment. The paper is structured as follows: 2 on topic equipment used in the assembly of the experimental apparatus and the acquisition and processing of data obtained are presented; 3 in the topic are presented and discussed the results indicating the performance scenarios for the experimental conditions and their impacts on the system; on topic 4 provides the conclusions of the discussions of the results, pointing out the necessary improvements to the experimental equipment.

2. MATERIALS AND METHODS

2.1. Experimental apparatus

For performing the experimental procedures a commercial refrigerator type "exhibitor drinks" with 414 liter capacity, Gelopar manufacturer, model GPTU-40 (nominal power of 380 W), which operates with R134a (210 g) was used. The refrigerator has only refrigerated roll-bond evaporator type and forced convection. The compressor is hermetic with 1/3 HP with forced convection and condenser with double helical tower.

The basic structural modification made on the device consisted of removing 75% capillary tube to install the micrometric valve. It is noteworthy that the original possessed capillary total length of 3,8 m and 1.07 mm inner diameter.

Then the micrometric valve (Autoclave Engineers, Model 10VRMM, 1/8 in.) was inserted between the filter drier and the final section of the capillary tube (see Figure 1) in order to simulate various conditions of restriction to coolant flow between the sides high and low pressure system. As an enhancement to the mounting suggested to obtain the refrigerator, by the manufacturer with the heat exchanger mounted externally to the housing of the cooler to facilitate complete replacement of the capillary valve.

2.2. Test procedure

Trials of lowering temperature were performed according to NBR 12868 (1993) standard that prescribes the method used to determine, without thermal load (package test), current and absorbed power, performance and operating conditions of the device, the lower the internal temperature when subjected to specific temperature conditions.

The apparatus has a 24 hour break before the first test and normal use without thermal load (test packets) and ambient temperature. The device was prepared with all their baskets, shelves and accessories. Complementary systems of the device (thermostat, timer automatic defrost and others), with the exception of the compressor thermal protector, were turned off to ensure continuity of operation of the unit.

The doors were closed and the unit operated simultaneously with the data acquisition system for counting the operating time. The unit continued to operate until the steady-state conditions were reached. This period of operation is normally done in 8 hours of operation, however, this study used a total operating time of 3 h. Results were recorded until the end of the trial. The time of temperature lowering is defined as the time required to reduce the temperature of the environment of the freezer compartment to the desired temperature until the final condition (6 ° C) according to ISO 8187 (1991) standard.

Reference tests with integral capillary tube for performance comparison purposes were carried out. The combinations of tests performed are show in Table 1.

The tests were made possible with thermal load by installing electrical resistances of 40 and 80 W at the bottom of the refrigerated compartment and testing of packaged water (10% of the volume of the refrigerator) distributed in the compartment. The NBR 12868 standard does not take into account the presence of heat load on the machine, however, was of interest to assess the behavior of micrometric valve load conditions.

Table 01. Test conditions

Expansion device	Internal Thermal Load
Capillary Tube	Without Load
	40 W
	80 W
Micrometric valve with 3 opening divisions (VM3)	Without Load
	40 W
	80 W

Micrometric valve with 6 opening divisions (VM6)	Without Load 40 W 80 W
Micrometric valve with 9 opening divisions (VM9)	Without Load 40 W 80 W

The definition of the position of the valve was made according to the same sensitivity adjustment, the micrometer scale divisions located on the valve stem, as shown in figure 1. Were tested three positions of the valve 3, 6 and 9 divisions. These points were obtained from the "fully closed" position of the valve by rotating the shank (opening the valve) to the desired marking divisions. Therefore, 9 divisions represent the condition of least restriction to coolant flow, now 3 divisions, representing the condition of greater restriction of the valve hole. The condition with 6 divisions indicates an intermediate condition. For all tests the charge of R-134a was used 210 g as determined by the manufacturer.

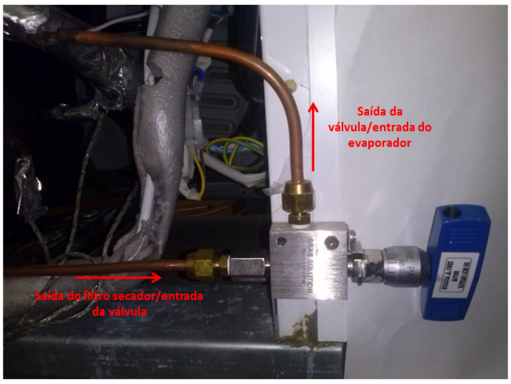


Figure 1. Micrometric valve allocated in the system

Table 02. Instruments

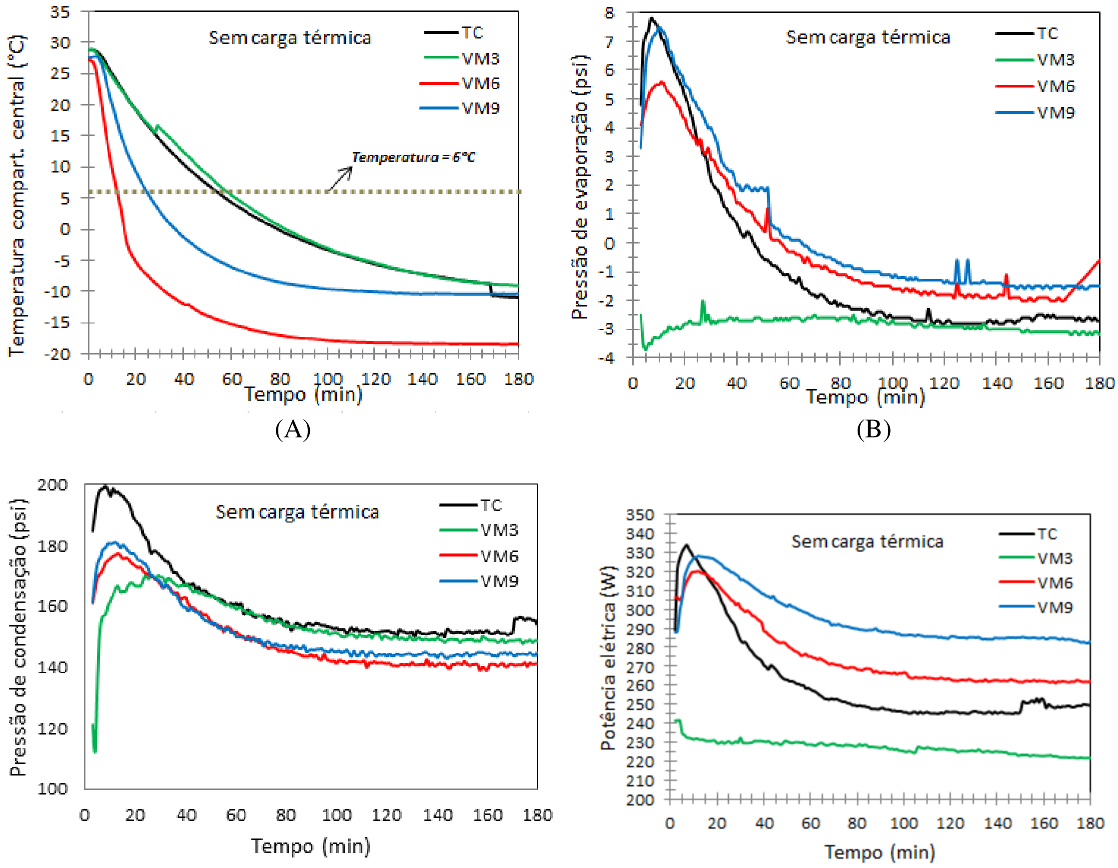
Instrument	Nomenclature	Uncertainty of measurement
Pressure transducer	Danfoss AKS33/060G211 5 (0-25 bar)	± 0,5 PSI
Electrical load measurement	Wattmeter pliers Minipa ET-4090	± 4%
Thermocouple	Tempar, Tipo J	± 0,3°C

After reaching steady state condition, data of pressure and temperature along the cooling system have been sent to REFPROP 6.0 software and the thermodynamic properties were obtained for the coefficient of performance (COP) of the refrigerator in the various test conditions.

3. RESULTS AND DISCUSSIONS

Figure 2 shows the test results of the refrigerator without thermal load. It can be seen that the test VM6 reaches the reference temperature (6c) in about 15 minutes after starting the test capillary tube (CT) reaches this same temperature for about 55 minutes. The VM9 test lies in an intermediate range between these two outcomes. Accordingly, the VM6 assay system reaches the condition permanent faster than the capillary tube. This fact can be attributed to minor transient losses after the departure of the system when operating with the valve.

The consumption calculations were based on the standard ISO 23953-2009 in item 5.3.65.3 item b in the stretch of continuous operation in an amount equivalent to 75% of range in steady state period. The method was linear adjustment that m uncertainty have an intrinsic uncertainty of <5%.a sentence.



(A) (B) (C) (D)

Figure 2. Results (a) the internal temperature of the platen, (b) evaporation pressure, (c) condensing pressure and (d) testing for electrical power without thermal load as a function of time.

4. CONCLUSIONS

The electrical power is strongly influenced by the pressures of evaporation and condensation. When the refrigerator is turned off, the refrigerant migrates through the capillary tube from the condenser to the evaporator to equalize the pressure of the system. This not only increases the migration pressure in the evaporator, but also its temperature.

The electrical power during system startup with CT was higher by around 10% to the system with VM6. In regi me permanent electrical power to the CT test is around 250 W while for test VM6, power stabilizes at around 260 W.

When you start the cycle (transient) does not work efficiently as almost static machine. This degradation is caused by many factors, including the redistribution of cooling that migrates during the off cycle as well as the thermal masses of the system components (compressor and heat exchangers). The COP is reduced during the initial minutes of operation cycle, as the system operates at reduced capacity; these minutes correspond to higher levels of performance degradation (Bullard and Coulter, 1995).

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