DETERMINATION OF REFRIGERANT CHARGE OF AN AIR CONDITIONER (WINDOW TYPE) AFTER MAINTENANCE

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Determinação da carga de fluido refrigerante para um condicionador de ar de janela após manutenção

Determinación de la carga de refrigerante para un acondicionador de aire tipo ventana después del mantenimiento

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ABSTRACT

Evaluating the amount of refrigerant charge of a refrigeration system is quite important to predict the lifetime of the compressor, to avoid undesired pressures and consequently leakage, to reduce costs related to the electricity consumed and to minimize environmental impacts. The maintenance of such equipment is often a complicated task that requires technical abilities and time, especially when the amount of refrigerant charge is not specified on the device. Due to this, many systems work in an overcharged or undercharged mode. In this study, a simple method was applied which uses the internal volume of the condenser and evaporator pipes to determine the ideal refrigerant charge for these specific systems. The procedures were adapted from refrigerators to air conditioners of the window type. The system working with the calculated charge presented a 0.9% reduction in the COP (Coefficient of Performance) of the system and a 3.5% reduction in electricity consumption. Furthermore, the application of this method saved 10.7% of the refrigerant. In conclusion, it is worth applying this method to reduce costs with the use of refrigerant and electricity and the reduction in COP is very small.

Keywords: air conditioning, refrigerant charge, energy efficiency.

RESUMO

A determinação da carga de fluido refrigerante de um sistema de refrigeração é muito importante para prever a vida útil do compressor, evitar pressões indesejadas e consequentemente vazamentos, reduzir custos relacionados à energia elétrica consumida e minimizar impactos ambientais. A manutenção de tais equipamentos é frequentemente uma tarefa complicada que requer habilidade técnica e tempo, especialmente quando a quantidade de carga de refrigerante não é especificada no dispositivo. Devido a isso, muitos sistemas funcionam em modo sobrecarregado ou com carga insuficiente. Neste estudo, foi aplicado um método simples que usa o volume interno dos tubos do condensador e do evaporador para determinar a carga de refrigerante ideal para esses sistemas específicos. Os procedimentos foram adaptados de geladeiras a condicionadores de ar do tipo janela. O sistema trabalhando com a carga calculada apresentou redução de 0,9% no COP (Coeficiente de Desempenho) do sistema e redução de 3,5% no consumo de energia elétrica. Além disso, a aplicação desse método economizou 10,7% do refrigerante. Concluindo, a aplicação deste método pode reduzir custos com o uso de refrigerante e eletricidade e a redução do COP é muito pequena.

Palavras-chave: *ar condicionado, carga de refrigerante, eficiência energética.*

RESUMEN
Evaluar la cantidad de carga de refrigerante de un sistema de refrigeración es muy importante para predecir la vida útil del compresor, evitar presiones no deseadas y, en consecuencia, fugas, reducir los costos relacionados con la electricidad consumida y minimizar los impactos ambientales. El mantenimiento de dicho equipo es a menudo una tarea complicada que requiere habilidades técnicas y tiempo, especialmente cuando la cantidad de carga de refrigerante no se especifica en el dispositivo. Debido a esto, muchos sistemas funcionan en modo sobrecargado o subcargado. En este estudio, se aplicó un método simple que utiliza el volumen interno de las tuberías del condensador y evaporador para determinar la carga de refrigerante ideal para estos sistemas específicos. Los procedimientos se adaptaron desde refrigeradores a acondicionadores de aire del tipo ventana. El sistema que trabaja con el cargo calculado presentó una reducción de 0.9% en el COP (Coeficiente de Desempeño) del sistema y una reducción de 3.5% en el consumo eléctrico. Además, la aplicación de este método ahorró un 10,7% de refrigerante. En conclusión, vale la pena aplicar este método para reducir costos con el uso de refrigerante y electricidad y la reducción de COP es muy pequeña.
Descriptores*: aire acondicionado, carga refrigerante, eficiencia energética.*

INTRODUCTION

Knowledge of the operational characteristics of a refrigeration system is vital for any energy conservation study, not only to predict the system performance, but also to optimize the combination of system components during the design process and to provide insights into control strategies that may improve the system performance (GONÇALVES and MELO, 2004).

In terms of energy consumption in commercial buildings, it is estimated that the use of air conditioning represents from 30% to 60% of the total energy consumption. Therefore, the industry has been working to produce increasingly efficient products, because the technological efforts of energy conservation are justified from the economic, social and environmental point of view (UDAYRAJ et al., 2018).

Due to this, much research has been carried out and is still being carried out into ways to maximize the coefficient of performance (COP) and minimize energy consumption through the implementation of an ideal charge of refrigerant in equipment. According to MEHRABI and YUIL (2017) and ZHANG et al. (2017), respectively, the quantity of refrigerant – referred to as charge – affects the performance of the system and the amount of refrigerant charge of the system is a primary parameter that influences the energy efficiency. Any undercharge or overcharge of refrigerant degrades performance and deteriorates the system reliability. For example, at 20% undercharge a system produces 80.7% of their nominal cooling capacity. There is a range to an ideal operation at around +/- 23% the nominal charge of refrigerant without reducing the COP of the refrigerators and heat pumps: system capacity and energy efficiency ratio – EER - were reduced at outrange of nominal charge conditions (HOUCEK and THEDFORD, 2002.

Among the several variables that can influence the performance, energy efficiency and stability of refrigeration equipment, the mass of refrigerant is one of the main ones. VJACHESLAV et al. (2001) show that there is a range of refrigerant charge values in which such equipment can operate without significant decreases in COP and considerable increases in energy consumption. This range is around 25% undercharge and 25% overcharge, with the undercharge being more damaging to the system. At charge levels below 25% undercharge the cooling capacity falls very rapidly and at 50% undercharge it drops down to 50% of its maximum value and at overcharge levels greater than 25% the cooling capacity also begins to fall slowly, dropping by 7% from its maximum value at 40% overcharge conditions. Insufficient refrigerant causes the evaporator to be incompletely filled so the boiling pressure is lowered, the vapor superheat at entry to the compressor is increased and the COP of the unit is lowered. On the other hand, overfilling the unit with refrigerant reduces the active surface of the condenser, thus increasing the temperature and pressure of condensation, lowering cold production and decreasing the COP1. Finally, through tests on automotive refrigeration systems, RATTS and BROWN (2000) found that a low refrigerant charge level led to a higher compressor frequency, a lower cooling capacity and a higher refrigeration temperature.

Equipment that operates with HFC fluids contribute to the greenhouse effect, though systems with the optimum charge of refrigerant can reduce environmental impacts as well as save energy costs. Excesses are avoided and the risk of leakage due to undesired high pressures in the system are mitigated.

This paper analyzes the influence of the refrigerant charge on the COP and the energy efficiency of a specific piece of equipment. The study compares results obtained for a system operating with a charge of refrigerant previously specified by the manufacturer and the same system operating with a calculated charge. The method used to calculate the refrigerant charge uses as reference the methods and parameters suggested, enhanced and applied by DIMITRIYEV and PISARENKO (1984) for domestic refrigerators. In this study, these are adapted for air conditioners.

The method used to determine the gas mass was applied in an air conditioner (window type) using a capillary tube expansion device. The choice of this kind of air conditioner is justified by the fixed length of its pipes and connections.

MATERIALS AND METHODS

Experimental setup

The entire case study was conducted inside a room of approximately 3m² using an window type air conditioner – 7,500 BTU/h cooling capacity, operating with 1,959 kPa at high pressure line and 593 kPa at low pressure line and 127 V voltage - as test equipment, initially with a refrigerant charge of 515 g, previously specified by manufacturer. Following the method adopted as reference, a known volume of air was expanded into the condenser and evaporator pipes and pressure was subsequently measured in order to determine the internal capacity of these devices in m³. Another way to estimate the internal volume of the condenser unit and the evaporator is to take measurements of the total length of the streamers and inner diameter of the pipes.

In order to adapt the air conditioner systems to the method suggested for refrigeration systems, the real cooling power of the equipment used in this case study was obtained according to the following parameters.

Considering the condition of the equipment new and the original fan running under normal operating conditions, the volumetric flow rate (Q) was obtained directly from the manufacturer’s label, specified at 420 m³/h. Converting to SI, 0.116 m³/s. The insufflation area (A_i) is 0.027 m², taking into account both air outlets.

Psychrometric data of the air, enthalpy (h - kJ/kg) and specific volume of insufflation (v - m³/kg), were extracted by psychometric chart. From the volumetric flow rate and specific volume of insufflation, the airflow ($\dot{m}$ — kg/s) is established in the Eq. (1).

$$\dot{m} = \frac{Q}{v} \tag{1}$$

The cooling power of the equipment (Pr), in kW, is established with the aid of the differential of enthalpy (Δh) between insufflation and return of air, in the Eq. (2).

$$\text{Pr} = \dot{m} * \Delta h \quad (2)$$

Finally, the COP of the air conditioner is calculated by the ratio between the cooling power (Pr – kW) and the electricity consumed (W – kW) by the equipment. The Eq. (3) and (4) show how these calculations proceed.

$$W = U * i \quad (3)$$

$$COP = \frac{Pr}{W} \quad (4)$$

U represents the source voltage in V (volts) and i represents the operation current of the air conditioner, considering the compressor working, at A (amperes).

The mass of refrigerant (Gr - g) is given in the Eq. (5).

$$Gr = 0.41 * Ve + 0.62 * Vc - 38 \quad (5)$$

V_e and V_c represent the internal volume of the evaporator and the condenser, respectively, in cm^3. According to DIMITRIYEV and PISARENKO (1984), this formula is applicable over a range of evaporator capacities of 100-140 cm^3 and condenser capacities of 90-150 cm^3, for a range of surrounding air temperature of 25-32 ºC. Nevertheless, in this paper, the data analysis will be done using the same method adapted for air conditioning systems.

The purpose of disregarding the mass portions of the regions with fluid in the vapor state is because the density of the fluid in the liquid state is much higher than that of the vapor state. In addition, it is a domestic air conditioner and the mass of liquid in the line between the evaporator and the expansion device is small, the latter being a small diameter tube and installed immediately after the condenser output. The portion of refrigerant dissolved in the compression oil is also not considered in this case study.

For this test procedure, the temperature of the surrounding air varies between 26ºC a 32ºC. These values were measured by a digital portable thermo-hygro-anemometer from the manufacturer Instrutherm; model THAL-300, which also checked the humidity of insufflation and return. A digital voltmeter plier and a digital ammeter plier, from the manufacturer FieldPiece, SC46, was used to measure the power of the compressor and the current operating values, which will determine the real energy consumption of the equipment respectively. A Starret 5m measure tape was used to ascertain the area of air insufflation, for both sides of the equipment, disregarding the area of the flaps.

Test procedures

Before the experiments, an important step is to ensure the correct calibration of all the data collection equipment. In this study, a window type air conditioner Consul, CCN07BB model, 7,500 BTU/h, was installed to acclimatize a room of $3m^2$.

Data collection was divided into two stages, both with measurements of the variables made between 6 p.m. and 7 p.m. on southern hemisphere winter days, in August, in the city of Salvador, Bahia, Brazil. The room was completely closed and the air conditioner was operating with a set of temperature of 18 °C and at maximum insufflation speed.

At the first stage of data collection, equipment operated with the 515g refrigerant charge. Seven days of data collection, each day with measurements taken at two moments, were sufficient to determine the profile of the air conditioner for these conditions, obtaining safe average values for each variable analyzed.

The average values of current and voltage measured in the first step were 5.15 A and 129.18 V, respectively.

Before the next step, it was necessary to uninstall and dismantle the device to gauge the necessary measurements to determine the internal capacity of the evaporator and the condenser. Using the simplest and most practical method, with a tape measure, the total length of the evaporator and condenser stream, 1,022 cm and 1,365 cm respectively, were measured. The internal diameter measured was 0.71 cm for both with the aid of a TMX pachymeter of 0.05 mm. From these data and from Eq. (5), the results of the evaporator and condenser capacity and the refrigerant charge for the equipment in this study are 404.43 cm^3, 540.42 cm^3 and 463g, respectively.

A prior step to add the calculated charge of 463g of R-22 to the device tested is first to remove all the 515g of refrigerant and obtain the vacuum of the system of 330 microns, ensuring that the cycle has an efficient operation with no presence of humidity inside their pipes. Accessories and equipment, such as the SURYHA manifold, the VULKAN LOKRING Vacuum Pump VP-340D, the digital WIGAM Vacuum Gauge - VG64, a collection cylinder of 40 pounds, an electronic refrigerant scale and the VULKAN LOKRING refrigerant recovery machine were used in this process. Due to the limitations of the accuracy of the refrigerant scale apparatus, setting the weight of the collection cylinder every 10g, the refrigerant charge inserted was 460g.

Finally, in the second stage of data collection, the equipment operated with 460g of refrigerant, the amount considered as the appropriated refrigerant charge for this specific equipment in this study. The number of days and measurements taken was the same as for the first stage.

The average values of current and voltage measured in the second step were 5.02 A and 127.81 V, respectively.

Fig. (1) and Fig. (2) show the behavior of the variables measured on each day of the analyses, compared in the same graphics, the values obtained for both conditions of the equipment operation, always considering the insufflation and the return of the air.

Figure 1 – Average values measured for relative humidity

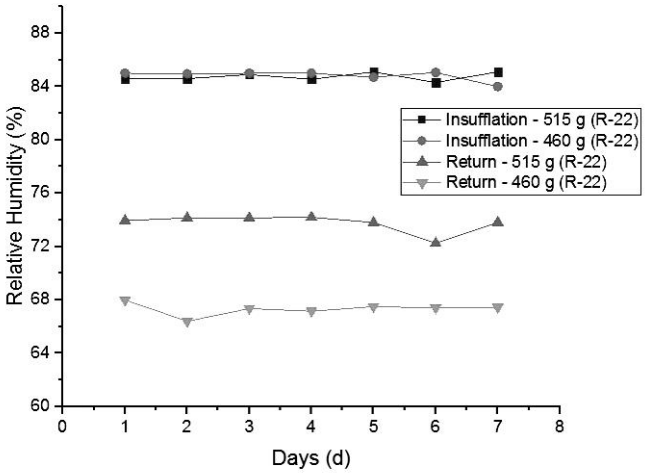
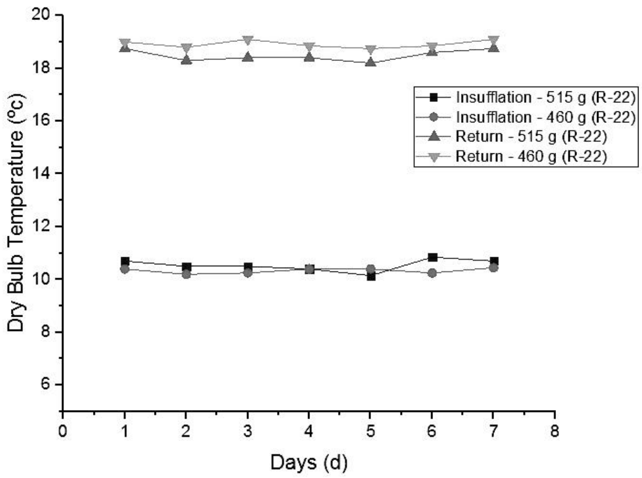


Figure 2 - Average values measured for dry bulb temperature



RESULTS AND DISCUSSION

From the data collected and with an aid of psychometric software, Table (1) shows the values calculated by Eq. (2), (3) and (4).

Table 1 - Results of equations mentioned

Variables	515g of R-22	460g of R-22
Cooling power (kW)	2.276	2.177
Electricity consumed (kW)	0.665	0.642
COP	3.422	3.392

For air insufflation, the average values of specific volume and enthalpy for the first stage, i.e. the air conditioner working with the refrigerant charge of 515g, are 0.811 m^3/kg and 27.490 kJ/kg, respectively. On the other hand, for the second stage, the air conditioner working with the refrigerant charge of 460g, these values are 0.811 m^3/kg and 27.060 kJ/kg. For air return, only the enthalpy values are interesting in this method. They are 43.399 kJ/kg and 42.284 kJ/kg for the first and second stage of evaluation, respectively.

Considering the 515g refrigerant charge for the system studied and adopting this as reference, the 10.7% decrease in R-22 caused the COP to decreased by 0.9%. According to KIM and BRAUN (2010), undercharging or overcharging in fixed orifice systems can reduce refrigeration capacity, and this was corroborated with our results.

After the analysis of the results obtained, it was found that the refrigerant charge application proposed by DIMITRIYEV and PISARENKO (1984) and adapted to an air conditioner in this study led to a 3.5% reduction in electricity consumption when compared with the equipment working with the refrigerant charge suggested by the manufacturer. In contrast, the cooling power and the COP presented a reduction of 4.3% and 0.9% respectively.

Contradictory evidence was found in VJACHESLAV et al. (2001), which points out that a overcharging causes a slight decrease in COP, because of flooding in the condenser that may result in higher system pressure. Consequently, an increase in the work required from the compressor is expected when charge is increased, this time compatible with the results in Table 1. This shows a 3.5% rise in the amount of electricity consumed, from 460 g to 515g.

According to GRACE et al. (2005) and BJORK and PALM (2006), the graphics summarize the results of this experiment. For a slight overcharge, irrespective of the ambient temperature, there is also a slight increase in the system COP and in the compressor power consumption.

To sum up, the method applied works when is adapted to air conditioner (window type) with R-22 as a refrigerant because the COP almost is kept at the same value together with the slight, but not insignificant, electricity consumption reduction. In addition, it provides an economy of 10.7% of refrigerant. It is useful to add the refrigerant charge in this kind of equipment, which no longer have the original label specifying the refrigerant charge. This procedure saves time and reduces the work of adding charge gradually when it is also necessary to measure pressure values.

CONCLUSION

In order to reduce the costs and environmental impacts caused by the excessive use of HFC refrigerant, this study investigates calculating the charge using a referenced method when the nominal charge specified is unknown. The method of calculation has been adapted from refrigerators to an air conditioner (window type) that operates with a fixed orifice expansion device. By analyzing the influence of the refrigerant charge on COP and energy efficiency within the studied system, we may conclude that the replacement of the nominal for the calculated charge caused a 3.5% reduction in the energy consumption of the compressor and an insignificant fall of 0.9% of the COP. Furthermore, there was an economy of 10.7% of R-22.

With these results, we have collected evidence that the nominal charge suggested by manufacturer does not make the operation of the equipment studied so discontinued when compared to the operation with the calculated charge proposed by the method referenced. The best advice is to maintain the nominal charge for equipment that comes with it and apply the calculated charge method in the case of maintenance or installation when this information is unknown or difficult to obtain.

From the analysis in this case study, the conclusion is that the suggested method in practice, is optimal for the maintenance of the COP and the refrigerating power without the risks of excessive use of refrigerant, which is common nowadays in such equipment.

Todos os autores declararam não haver qualquer potencial conflito de interesses referente a este artigo.

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