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FLOODED EVAPORATORS VERSUS DRY EVAPORATORS: IN WHICH CONDITIONS?

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ABSTRACT

This work has as main objective an analysis of the validity of the implementation of a flooded evaporator in a vapor compression refrigerant cycle, the working fluid being the R134a. To achieve this goal, it was used a simulation software, the Pack Calculation Pro. A comparison of the annual energy consumption of the refrigeration system with a flooded evaporator was carried out having as reference the same system with a dry evaporator and working in different situations. In this study, the advantages and disadvantages of using the two types of evaporators, the flooded and dry one, having the system used for situations equal cooling capacity and the possible presence of overheating for the dry evaporator and the presence of the pump in the flooded evaporator was analyzed. It was concluded that the advantage in the implementation of flooded evaporator is directly proportional to the degree of overheating at the exit of the dry evaporator. Also an economic analysis were carried out.

Keywords: refrigeration systems, flooded evaporators, dry evaporators, energy utilization.

INTRODUCTION

Currently, the use of refrigeration systems is indispensable (Afonso, 2012). They play a fundamental role in areas ranging from the preservation of perishable products, the pharmaceutical industry or air conditioning. In fact, uncommon is the house where there are no refrigeration systems installed, be it air conditioner or the refrigerator itself. The scale of applications increases significantly when, instead of considering only domestic applications, it is taken in account industrial, commercial, transportation, among others.

In recent years, with the concept of sustainable development (Bulletin of IIR, 2002), it became clear that changes would have to be made to conventional refrigeration systems trying to increase their efficiency to the maximum, and so, reducing the energy consumed without compromising the cooling effect.

The energy consumption of a refrigeration system is mainly due to the power consumed by the compressor(s), which is responsible for forcing the fluid flow through the system. Components such as the evaporator also influence the energy consumption since the more efficient they are in the absorption of heat, the greater will be the cooling capacity of the entire system, or else, for the same cooling capacity the lower will be the energy consumption (Neto,2013).

A comparison of the annual energy consumption of the refrigeration system with a flooded evaporator was carried out having as reference the same system with a dry evaporator and working in different situations. In case of the dry evaporator, it presents an unnecessary superheat and so this system presents a lower COP, being then feasible the inclusion of a flooded evaporator, when the medium / long term system is energetic analyzed. In this case, the system has a lower annual energy utilization. It was possible to conclude that the relevance of the flooded evaporator implementation is directly proportional to the degree of overheating at the exit of the dry evaporator.

SISTEMS AND METHODOLOGY

Fig. 1 is a diagram of the refrigeration system with a dry evaporator and with a flooded evaporator. In the second situation it was also simulated the possibility of use a circulation pump to feed the evaporator. In both systems it was used two compressors. Both systems have an internal heat exchanger,

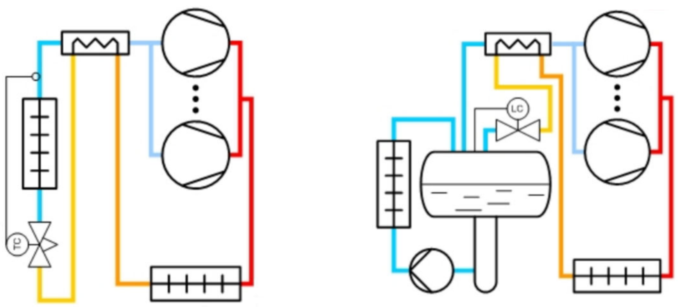

Fig. 1 - Refrigeration system with a dry evaporator (left) and with a flooded evaporator (right)

The methodology used for the simulations is as follow:

- Equal cooling capacity and the temperatures of evaporation and condensation fixed;
- Addition of a pump to carry out forced circulation of the flooded evaporator;
- Regarding the first point, it was also considered an unnecessary overheating in the evaporator.

Table 1 displays the common characteristics of both systems.

Table 1 - Common characteristics of both systems.

T_e	-11 °C
T_c	48 °C
Compressors	Bitzer OSK 8561 50 Hz [1] (2x)
Power of the pump	0.029 kW
Cooling effect	200 kW

It was also considered the use of another type of compressors of the same company, the Bitzer OSK 8551 (Bitzer, 2014).

The city chosen in the simulations is Oporto, Portugal.

Regarding costs, and based on current tariffs, the energy costs were 0.14 €/kWh. Regarding equipment’s, the compressors costs are 20 000 € for Bitzer OSK 8561 and 19 000 € for the Bitzer OSK 8551.The price of the dry evaporator for a cooling capacity of 200 kW is 7000 € (Pricelist, 2014) and of the flooded evaporator is considered 25% higher (Neto,2013). It was admitted a lifetime for both systems is 10 years.

RESULTS

Dry evaporator without overheating vs flooded evaporator by gravity (without pump)

In Fig.2 it is show the energy consumption per month of both systems for all equipment's used.

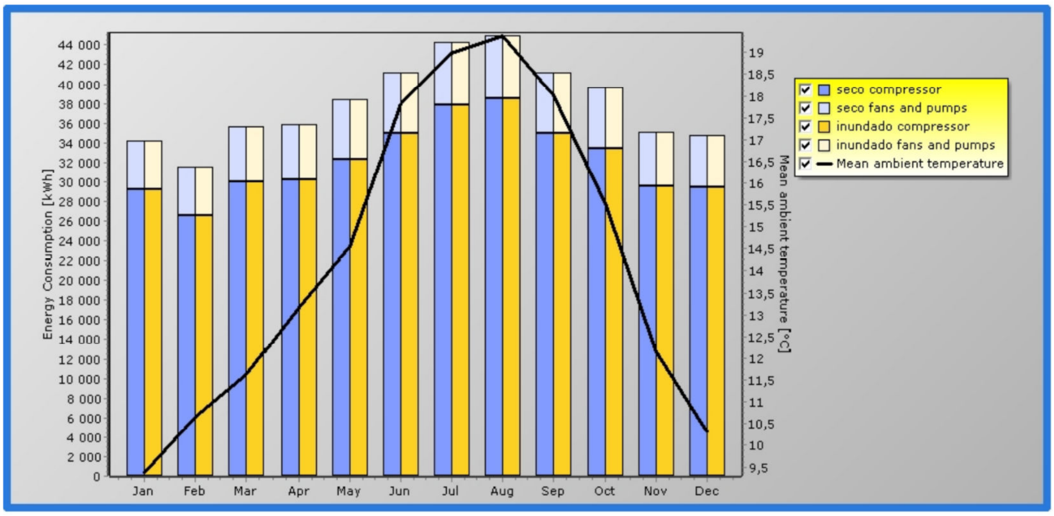

Fig. 2 - Monthly energy consumption for all equipment's used in both systems.

Table 2 displays, for the same year, the global energy used.

Table 2 - Annual energy consumption for both systems.

	Dry evaporator	Flooded evaporator
COP (average)	3,39	3,39
Energy consumption		
Fans and pumps (kWh)	69 535	69 535
Compressors (kWh)	386 847	386 847
Total (kWh)	456 382	456 382
Savings		
Anual savings (kWh)	-	-
Anual savings (kWh)	-	-

It was also calculated the lifetime of both systems as shown in Table3.

Table 3- Lifetime costs

	Dry evaporator	Flooded evaporator
Cost of equipments (€)	47500	49365
IRR (%)	-	-100
Total anual costs (€)	64 259	64 259
Pay back period (years)	-	Inf
Energy costs (kWh)	578 394	578 394
Lifetime costs (€)	625 894	627 759

Based on the results obtained for the refrigeration cycle with dry evaporator without overheating and flooded evaporator by gravity it is visible that the running costs of the two systems are all identical. This information is supported by table 2. Taking in account that the working fluid enters exactly in the same thermodynamic state in both evaporators, such behaviour would be expected.

Dry evaporator without overheating vs flooded evaporator with pump

Considering the need to use a circulation pump it is expected that energy consumption increases compared to the previous condition of the flooded evaporator.

In Fig.3 it is show the energy consumption per month of both systems for all equipment's used.

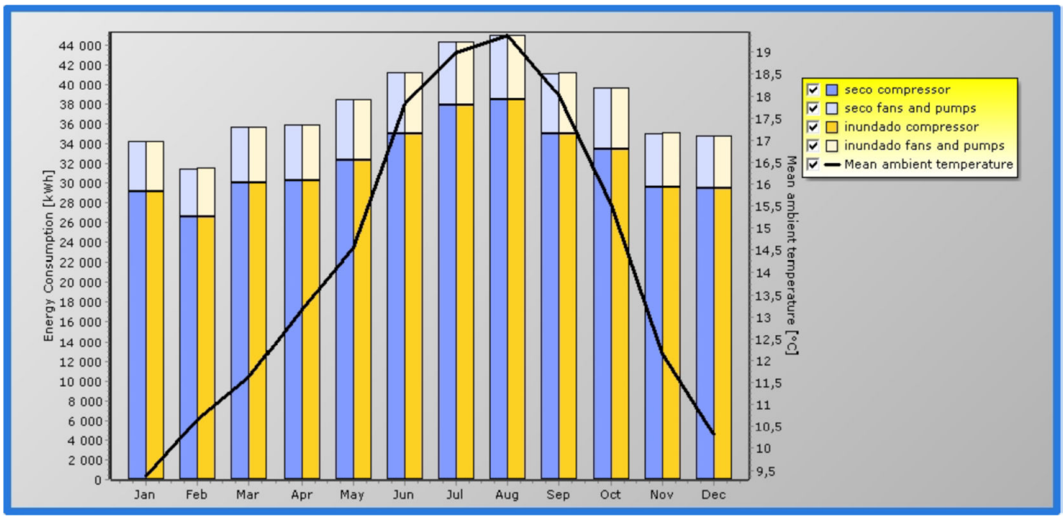

Fig. 3 - Monthly energy consumption for all equipment's used in both systems.

Table 4 displays, for the same year, the global energy used.

Table 4 - Annual energy consumption for both systems.

	Dry evaporator	Flooed evaporator
COP (average)	3,39	3,39
Energy consumption		
Fans and pumps (kWh)	69 535	69 759
Compressors (kWh)	386 847	386 847
Total (kWh)	456 382	456 606
Savings		
Anual savings (kWh)	-	-224
Anual savings (kWh)	-	-

It was also calculated the lifetime of both systems as shown in Table5.

Table 5 - Lifetime costs

	Dry evaporator	Flooded evaporator
Cost of equipments (€)	47500	49365
IRR (%)	-	-100
Total anual costs (€)	64 259	64 259 (+31)
Pay back period (years)	-	-59
Energy costs (kWh)	578 394	578 678
Lifetime costs (€)	625 894	628 043 (+2 149)

The need for the inclusion of a circulating pump in the flooded evaporator implies a higher consumption in the system. Thus, and analysing the information regarding the annual energy consumption of the systems, it is clear that this element is responsible for an increase of 224 kWh in energy consumed annually.

Dry evaporator with useless overheating vs flooded evaporator by gravity (without pump)

The presence of unnecessary overheating is very common in cycles with dry evaporators, since from the exit of the evaporator to the inlet of the compressor, due to the piping length (which may be long), absorbs heat from the environment, which results in an increase in the compression work.

Considering the presence of unnecessary overheating of 6°C at the inlet of the compressor, the following results were obtained.

In Fig.4 it is show the energy consumption per month of both systems for all equipment's used.

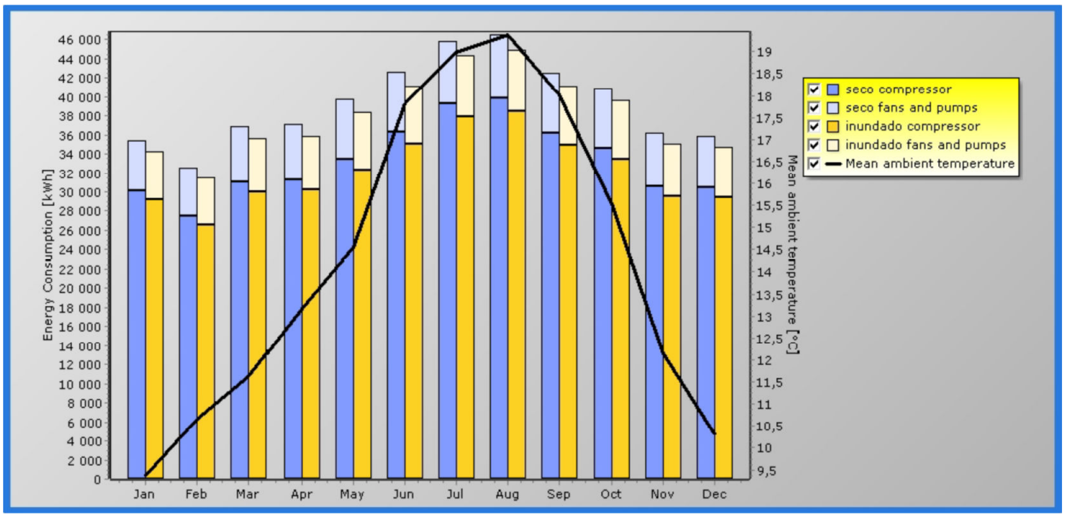

Fig. 4 - Monthly energy consumption for all equipment's used in both systems.

Table 6 displays, for the same year, the global energy used.

Table 6 - Lifetime costs

	Dry evaporator	Flooed evaporator
COP (average)	3,28	3,39
Energy consumption		
Fans and pumps (kWh)	71 494	69 535
Compressors (kWh)	400 469	386 847
Total (kWh)	471 963	456 382
Savings		
Anual savings (kWh)	-	15 581
Anual savings (kWh)	-	3,3

It was also calculated the lifetime of both systems as shown in Table7.

Table 7 - Lifetime costs

	Dry evaporator	Flooded evaporator
Cost of equipments (€)	47500	49365
IRR (%)	-	117,58
Total anual costs (€)	66 452	64 259 (-2 194)
Pay back period (years)	-	0,9
Energy costs (kWh)	598 141	578 394
Lifetime costs (€)	645 641	627 759 (-17 882)

CONCLUSIONS

It was concluded that introduction of a flooded evaporator reduces the annual energy consumption having, however, a higher initial investment cost.

In fact, when considering the presence of useless overheating in the dry evaporators, the cost difference of annual operation reaches 2194 € (the higher the greater the useless overheating), revealing that the flooded evaporators is a more economical solution even with a higher initial cost (the payback time in less than one year). Regarding energy consumption, with the flooded evaporator, and for the same situations, a reduction of 15581 kWh was obtained.

With a direct comparison of a dry and a flooded evaporator it can be concluded that the latter is more efficient than the first. The reason is due to the fact that the heat conduction is higher in liquid fluids than in fluids in the vapour state. Thus, as in a flooded evaporator the amount of liquid inside it is higher, it is expected a greater heat absorption therein.

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