ISSN 2176-5480

22nd International Congress of Mechanical Engineering (COBEM 2013)
November 3-7, 2013, Ribeirão Preto, SP, Brazil

REDUCTION OF ELECTRICITY CONSUMPTION IN A COOLING SYSTEM THROUGH REDUCTION OF DISCHARGE PRESSURE - CASE STUDY

Jair Eduardo Alves Mendes
Pedro Magalhães Sobrinho
Universidade Estadual Paulista – UNESP, Ariberto Pereira da Cunha Avenue, 333; Pedregulho; Zip Code: 12.516-410 - Guaratinguetá, SP
jairedu@uol.com.br
sobrinho@feg.unesp.br

Abstract. *The study and work realized were to reduce electricity consumption in an industrial cooling system at a beverage industry. Anhydrous ammonia (NH_3) is the main refrigerant in this system, which has three chillers with screw compressors to supply all thermal load demand in the plant.*
The methodology applied in this case study was to evaluate the cooling system, its consumption and limitations. This evaluate helped to identify an opportunity to improve the efficiency in cooling system and to saving electricity consumption by reducing the discharge pressure, cleaning of plate heat exchangers and reforming cooling towers.
The premise used was that cooling capacity increases 1% and power consumption reduces of 2% to 3% for each 1 °C of reduction in discharge temperature.
Results after improvements achieved more than 1 MWh / year of reduction in electricity consumption, compared to the initial measured.

Keywords: *cooling system, plate condenser, water treatment, discharge pressure, electricity*

1. INTRODUCTION

Energy is an important and fundamental item for company or country development. There is no substitute for energy and it impacts directly in the cost of the product (Marques et al., 2007; Mesquita, 2009; Tassini, 2012).

In a large cooling system, there are a lot of items to check to help to improve the efficiency of this system and to reduce power consumption, especially in beverage industries, where the cooling system is about 40% of the total consumption of the plant. The discharge pressure is one of these items.

Venturini and Pirani (2005a) assert that the cooling capacity increases by about 1% and reduces power consumption from 2% to 3% for each 1 °C reduction in the discharge temperature.

The refrigeration system studied is composed of three chillers, whose operating principle is shown in figure 1.

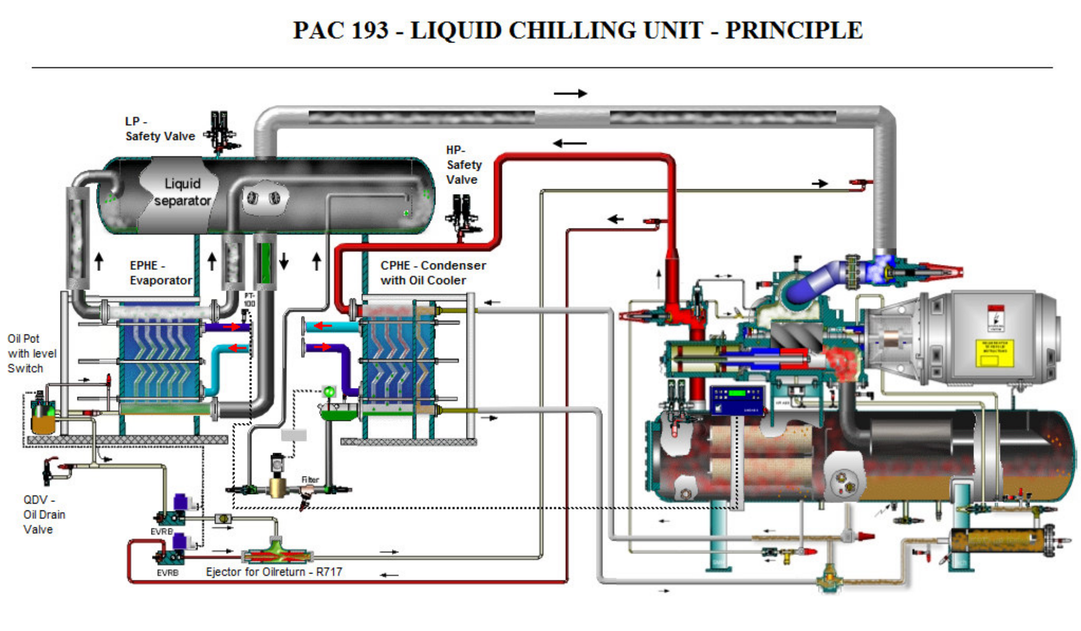

Figure 1. Liquid Chilling Unit - Chiller (York Training and Developing DK, 2011)

ISSN 2176-5480

The chillers use plate and frame condensers cooled by cooling towers. Plate and frame heat exchangers are compact, can be extended, have high efficient, are lightweight and operate with less ammonia (NH_3), comparing with other kinds of condensers. Moreover, this type of condenser is very sensitive to dirt buildup and non-condensable gases, in other words, the efficiency of the equipment reduces a lot when it is very dirty or when there are non-condensable gases in the system, increasing significantly the discharge pressure (Lopez, 2005; Venturini and Pirani, 2005a).

Figure 2 shows a plate and frame condenser used in the industry.

Figure 2. The plate and frame condenser used in the industry

The water of cooling towers requires effective treatment to prevent problems in the plate and frame condensers and in the cooling towers. Organic materials, solids and dissolved salts in the water facilitates the formation of algae, bacteria and fungi, which accumulate in the cooling tower filling, for example, or clog spray nozzles, encrusting plate and frame condensers, decreasing dramatically the efficiency of equipment. The objective of water treatment is to prevent or, at least, minimize corrosion and fouling in heat exchangers and / or pipes, in addition, the correct treatment of the water will prevent loss of efficiency of both, plate and frame condensers and cooling towers, and it increases the useful life of such equipment (Cortinovis and Song, 2012; Lopez, 2005; Tassini, 2012; Venturini and Pirani, 2005b).

2. DEVELOPMENT

The case study happened in a plant with a large cooling system that contained three compact liquid chilling unit (chillers) of different sizes, one model PAC 100 W with motor of 300 HP in the screw compressor, called chiller 1, another model PAC 177 W with motor of 500 HP, called chiller 2 and the third, model PAC 177 W with motor of 600 HP, called chiller 3. All of them have plate and frame condensers supplied by three cooling towers, two of them SEMCO BAC model VXT-525, with two fans, whose motors of 30 HP, for chillers 1 and 2, and another SEMCO BAC model VXT - 750 with two fans, whose motors of 40HP, for chiller 3.

There was a crack in the heat exchanger of condenser in the chiller 2, causing water contamination, in the two identical cooling towers, with ammonia. The water treatment was not good and there was much delay for detection of the problem and the cause of this problem. As a result, cooling towers, that are interconnected and which supplied plate and frame condensers of chillers 1 and 2, began to loosen the paint and form a lot of sludge due to the release of nitrogen in the water. This sludge clogged filters and spray nozzles of the cooling towers, also accumulated in the filling and encrusted heat exchangers condensers, reducing the efficiency of cooling towers and of heat exchangers. The discharge pressure of operation in the chillers was very high, reaching more than 15.0 bar, depending on the thermal load, this way chillers operated limited by high discharge pressure and several times they disarmed. The consequences of the problem are presented in Fig. 3.

ISSN 2176-5480

Figure 3. Clogging of filters and spray nozzles of the cooling towers

The first procedure after detection of the causes of the problem was to replace the plate that had the crack and the next step was intensifying water treatment. Cooling towers were reformed, filters and heat exchangers were cleaned through backwashing and cleaning chemicals. During the cooling towers reform it was made the option of replacing the modules of centrifugal fans by axial fans, because, according to the supplier, the capacity of the equipment is the same, but the electrical required power of axial fans is half that of centrifugal. The nomenclature of the cooling towers has changed, SEMCO BAC model VXT-525, turned VXMT-525 with three fan with motors of 10 HP, and SEMCO BAC model VXT - 750, turned VXMT-750 with four fans with motors of 10 HP. Figure 4(a) shows one of the towers before reform, figure 4(b) shows the same tower after reform, moreover figure 4(c) shows the backwash procedure.

Figure 4. Reform of the cooling towers: (a) cooling tower before reform; (b) cooling tower after reform; (c) backwash in a plate and frame condenser

Figure 5 shows the distribution of water in the spray nozzles before and after the reform of the cooling towers.

Figure 5. Distribution of water in spray nozzles before and after the reform

Figure 6 compares the operation of chiller 1 before and after the reform. In the first part of the figure it appears limited to 84.8% of loading, discharge pressure is 14.8 bar and the electric current, 422 A. The discharge pressure is a high value because, besides reducing the heat exchange area of the plate and frame condenser, because of incrustation, the water inlet temperature of the heat exchanger was 30.69 °C, while the design temperature was around 24.0 °C, taking the value of average wet bulb temperature as 21.0 °C. The fact that the temperatures get so high on the plate and frame condenser means that the heat exchange inside it is not efficient. The water comes out with 30.93 °C, ie, the difference between output and input is minimal, proving the inefficiency of heat transfer inside of the heat exchanger. The second part presents the system data corrected after the reform and cleanings. In this case, the same chiller 1 operates at 100% of capacity with an electric current of 363 A. There is a greater temperature difference between the inlet and outlet water in the condenser and the discharge pressure is 10.70 bar. With the reform and improvements increased cooling system capacity in general, mainly in the compressor and in the cooling towers.

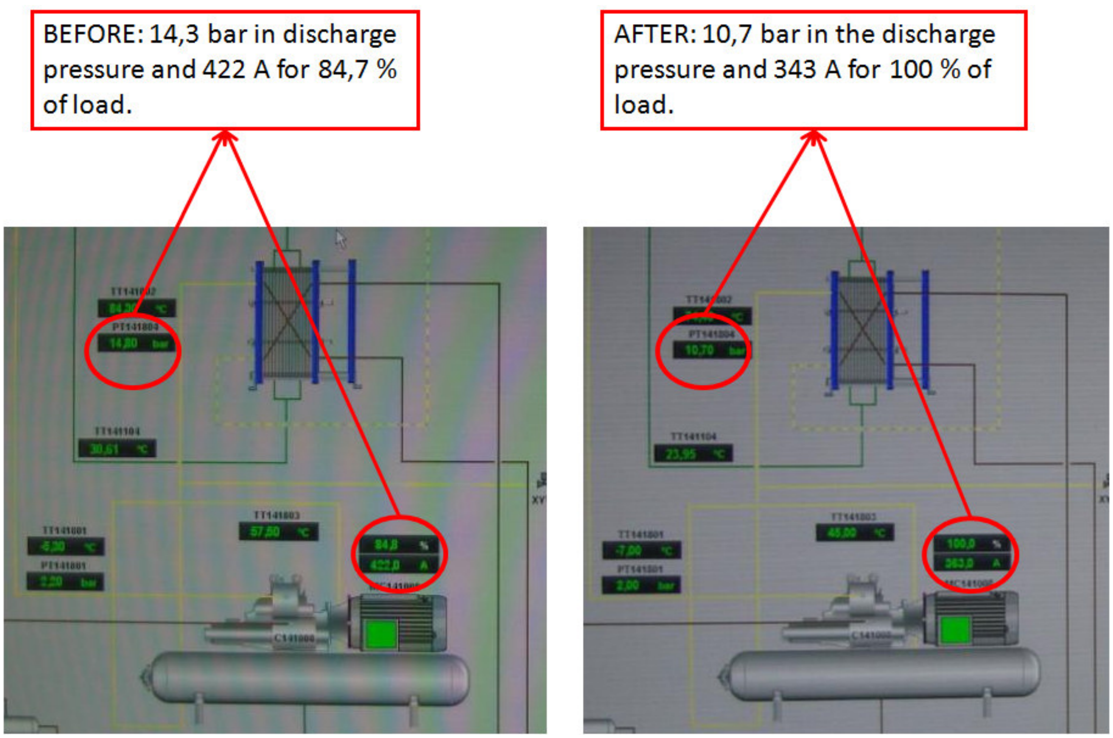

Figure 6. Measurement data of chiller 1 before and after the reform

ISSN 2176-5480

As stated, premise used is that the cooling capacity increases by about 1% and power consumption reduces from 2% to 3% for each 1 °C reduction in the discharge temperature (Venturini and Pirani, 2005a). According Table 1, the gauge pressure and temperature saturated ammonia, reducing the discharge pressure of 14.80 bar to 10.70 bar, meant to reduce the condensing temperature of approximately 10.5 °C. Therefore, in accordance with the premise adopted, the cooling capacity increased more than 10% and power consumption decreased from 20% to 30%.

Table 1. Gauge pressure and temperature of saturated ammonia

Pressure (bar)	Temperature (°C)
10,20	28,62
10,30	28,92
10,40	29,21
10,50	29,50
10,60	29,79
10,70	30,08
10,80	30,37
10,90	30,65
11,00	30,94
11,10	31,22
14,30	39,41
14,40	39,64
14,50	39,87
14,60	40,11
14,70	40,34
14,80	40,57
14,90	40,80
15,00	41,02

Some measurements were made before and after the implementation of the project to verify earnings. In supervisory software it was possible to monitor the cooling capacity of the system. For similar cooling capacities, the average power reduced was 160 kW after the project, equivalent to 20% of the total power of the cooling system. The cooling capacity increased by 9% measured after the improvements. This capacity increased because chillers operated limited before modifications.

The gains were as expected according to the premises.

3. CONCLUSION

The energy efficiency project that was realized in this cooling system reduced electricity consumption significantly. It was necessary an investment for the maintenance and cleaning of equipments that were very inefficient, plate and frame condensers and cooling towers, but the payback through energy savings enabled the project.

The life cycle of compressors and motors were also benefited, because load in them became smaller.

The payback of the project was one year and eleven months and the implementation of it was six months.

The annual reduction of electricity, in this plant, due to this project was around 1,400,000 kWh. Both chillers and cooling towers returned to work at full capacity and there were no more disarms due to high discharge pressure. The economy, only from the reduction of electricity consumption was approximately US$ 170,000.00 per year.

4. REFERENCES

Cortinovis, G. F.; SONG, T. W., “Cooling towers operation”. 27 Nov. 2012. <http://www.hottopos.com/regeq14/giorgia.pdf >.

López, R. G., 2005. *Industrial Refrigeration 2 - Maintenance and services to production of medium and higher cycles*.

Marques, M. C. S. et al., 2007. *Energy Efficiency: Theory and Practice*. Itajubá, 1st edition.

Mesquita, R. P., 2009. *Technical and economic analisys for feasibility the application of variable frequency drive for low power pump systems*. Master's thesis, UNESP. Guaratinguetá, Brazil.

Tassini, J. O., 2012. *Energy Efficiency in Industrial Refrigeration Systems: Case Study*. Master's thesis, UNESP. Guaratinguetá, Brazil.

ISSN 2176-5480

Venturini, O. J.; Pirani, M. J., 2005a. *Energy Efficiency in Industrial and Commercial Refrigeration Systems*. Rio de Janeiro, Brazil.

Venturini, O. J.; Pirani, M. J., 2005. *Energy Efficiency in Industrial and Commercial Refrigeration Systems - Practical Handbook*. Rio de Janeiro, Brazil.

York Training and Developing DK. PAC 193 – Liquid Chilling Unit – Principle, 2011.