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Solutions for Calculating Cooling Towers for Industrial Refrigeration Systems

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ABSTRACT: Nowadays, with the advancement of science and technology, equipment manufacturers always provide the market with products serving refrigeration systems with outstanding features. To choose the right equipment for the purpose and cooling needs of each specific system, it is necessary to calculate the most optimal design, ensuring both the cooling coefficient and the safety and reliability of the system, while ensuring the optimal performance of the equipment. Cooling towers are a very important part of cooling the condenser of industrial refrigeration systems. They are used to lower the temperature of the refrigerant by using water to absorb heat from the refrigerant and release it into the environment. To choose the right type of tower for the capacity used inside the system, the user must determine the temperature of the inlet and outlet water and the circulating water flow. Therefore, it is very necessary to apply software to calculate and select a cooling tower suitable for the cooling performance of the business, factory...

KEYWORDS: Refrigeration systems, cooling towers, Compressors, control.

I. INTRODUCTION

Refrigeration is a technique that creates an environment with a temperature lower than the normal temperature of the environment. There are many different views on the limit between cold temperature and normal temperature, but in general, the limit is the environment. Cold is an environment with a temperature below 20^{0}C. In the cold environment, it is divided into two temperature zones. That is the low positive temperature zone, this zone has a temperature from 0 ÷ 20^{0}C and the remaining temperature zone is called the freezing temperature of the product. Because this temperature range is the freezing temperature of water, the freezing temperature will be different depending on the type of product. Refrigeration technology has been applied in many important fields. One of the important applications is in the food technology industry. According to statistics, about 80% of refrigeration technology is used in food technology. Preserved foods such as meat, fish, milk … are foods that are easily damaged by the effects of microorganisms and enzymes inherent in the food, so they need to be refrigerated. In general, a refrigeration system is a device used to lower the temperature of an object to serve other objects.

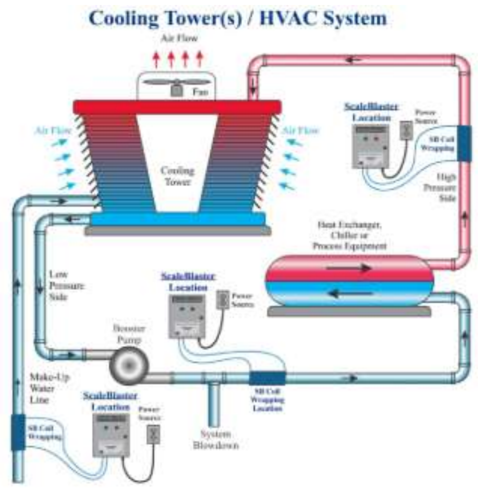

Figure 1. The cooling tower in refrigeration system

Currently, many different refrigeration systems are commonly used in factories, industrial enterprises, especially industrial product warehouses. Therefore, with many different technological requirements for the refrigeration system, designing the system to ensure optimal cooling coefficient, quick and accurate calculation and choosing the most suitable equipment is very necessary. In particular, with an industrial refrigeration system, cooling the condenser is extremely important. After the compressor, the refrigerant is pushed to high pressure, at the same time the temperature of the refrigerant also increases significantly. If the condenser does not

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work well, the reduction of the temperature of the refrigerant is not guaranteed, which will lead to an explosion due to pressure exceeding the allowable threshold. Therefore, in addition to wind and air, industrial refrigeration systems are often designed with additional water cooling systems. The application of technology in the calculation and design of cooling towers is extremely necessary. This article will apply software to the design process to calculate and select cooling towers for industrial refrigeration systems to improve accuracy and reliability in the design process.

Figure 2. The cooling tower picture

Choosing working parameters for the refrigeration system is very important because if a reasonable and correct working mode is chosen, it will bring high economic efficiency. The working mode of the refrigeration system is characterized by the following 5 temperature parameters:

- Boiling temperature of the medium t_o (°C).
- Condensation temperature of the medium t_k (°C), such as $t_k = 40^oC$
- Supercooling temperature of the liquid after the condenser: $\Delta t_{ql} = 10°C$
-Suction steam temperature to the compressor (superheat temperature): $\Delta t_{qn} = 10°C$
- Ambient temperature: $t = 28^oC$

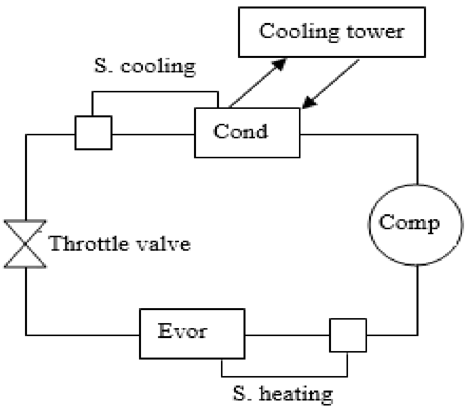

Figure 3. The block diagram of the refrigeration system

The refrigerant vapor at the evaporator outlet has temperature t_o, pressure p_o and is superheated at the superheater to the superheated vapor state $t_{1'}$. The superheated steam is sucked into the compressor suction head by the compressor and adiabatically compressed to a high temperature, high pressure state then follows the pipeline into the oil separator. At the oil separator, the oil will be separated from the medium because the medium vapor changes direction suddenly. The separated oil is returned to the compressor while the refrigerant vapor continues through the pipeline to the condenser. Here, the refrigerant vapor is released heat to the environment thanks to devices that support the cooling process, condensing into liquid the refrigerant is brought to a high-pressure tank, the refrigerant changes its vapor state to a liquid state. The liquid refrigerant continues to be supercooled to a low temperature $t_{3'}$, then the refrigerant liquid from the high-pressure tank passes through the filter pin, then continues through the expansion valve to reduce temperature and pressure t_o, p_o, the refrigerant transfers from high temperature, high pressure state to low temperature, low pressure state. The liquid medium goes from the expansion valve into the evaporator, where the liquid medium receives heat from the environment that needs to be cooled, meets the boiling temperature, will boil and evaporate. The medium changes from the liquid state to the vapor state. The refrigerant vapor escaping from the evaporator is fed into the superheater to perform the superheating process, passing through the liquid separator and then being used by the compressor to close the cycle.

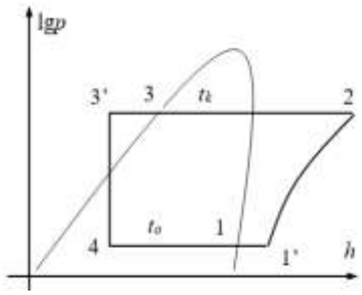

Figure 4. The working graph

The working graph in Figure 4 shows the working cycle of a simple single-stage compression refrigeration system. The graph also shows the basic parameters of the working process corresponding to each main device in the structure diagram of Figure 3 including temperature, pressure, specific volume of refrigerant vapor sucked into the compressor, temperature too cold,

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too hot temperature, enthalpy to use in calculating heat output, heat gain, adiabatic compression work, cooling capacity of the system.

II. BITZER SOFTWARE APPLICATION FOR DEVICE SELECTION

Bitzer software is used in calculating and selecting main equipment of the refrigeration system such as compressors.

With Bitzer software, you can choose a single compressor, choose a condenser compressor cluster, choose a one-stage compressor, two-stage compressor, choose different compressor types, different media from which you can choose the optimal type to meet your needs. meet technology requirements.

The interface of Bitzer software is described in Figure 5:

Figure 5. Bitzer software interface

Click to select the type of compressor that matches the technological requirements of the refrigeration system, select the SI system and update the parameters according to the required problem data.

Without losing generality, consider a refrigeration system with the following parameters:

Refrigerant: R134a

Straight-line, 1-stage Freon compressor.

Refrigeration capacity of compressor:

Q_o = 10(kW)

Look up Bitzer software with the software parameters:

Machine model: Standard type

Compressor type: Single compressor

Refrigerant: R134a

Cooling capacity: 10(kW)

Saturated evaporation temperature: -10^{o}C

Condensing temperature: 40^{o}C

Liquid gas temperature: 30^{o}C

Suction gas temperature: 0^{o}C

Load reduction condition: 100%

Power frequency: 50Hz

After entering the data, press the Run key, the system displays the results.


Figure 6. Results from running the software

Figure 6 shows the results obtained for two types of compressors 4DES-5Y-40S and 4CES-6Y-40S.

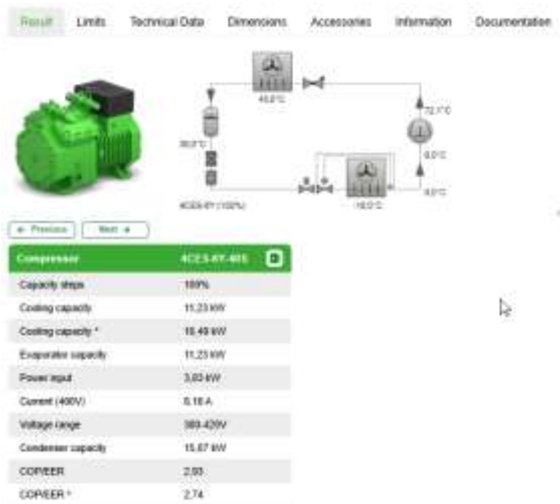

Figure 7. Parameters of the 4CES-6Y-40S compressor

The boiling temperature of the medium depends on the temperature of the cold storage.

The condensation temperature depends on the temperature of the condenser's cooling medium.

We can observe the boiling temperature and condensation temperature right on the structure diagram described in Bitzer software, figure 7.

From the results obtained from the software, we can choose the half-kin piston compressor 4CES-6y-40S with the following parameters:

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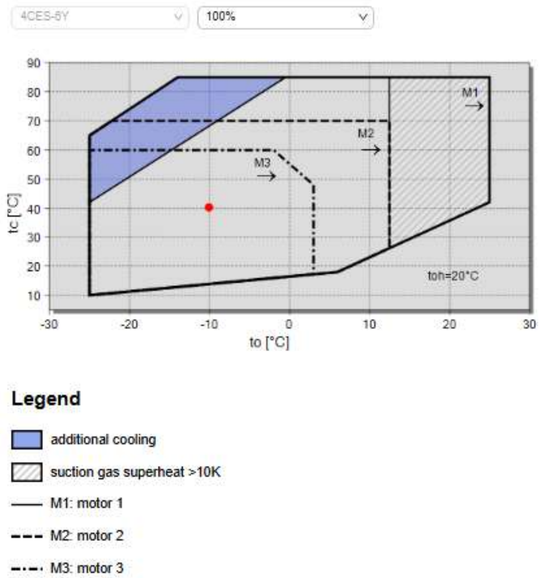

Figure 8. Limit indicators of the 4CES-6Y-40S compressor

Cooling capacity: 11,23(kW)
Cooling capacity*: 10,48 (kW)
Evaporator capacity: 11,23(kW)
Powerinput: 3,83(kW)
Current: 8,16 (A)
Flow: 249 (kg/h)
Moto data:
Moto version: 2
Motor voltage (more on request): 380-420 (V) – 50 (Hz)
Max operating current: 12,2 (A)
Starting current (Roto locked): 53,5 (A)
Max power input: 6,9 (kW)
Technical Data:
Displaceement (1450 RPM 50Hz): 22,72 (m^3/h)
Displaceement (1750 RPM 50Hz): 27,42 (m^3/h)
No. of cylinder x bore x stroke: 4 x 46 mm x 39,3 mm
Weigh: 84 (kg)
Max. pressure (LP/HP): 19/32 (bar)
Connection suction line: 28 mm-11/8''
Connection dischage line:16 mm-5/8''

III. CALCULATE COOLING TOWERS FOR INDUSTRIAL REFRIGERATION SYSTEMS

Currently, each factory and large building often uses a cooling tower product corresponding to different technical parameters. But before using, people often calculate accurately to choose the right cooling tower, meeting the cooling needs of their unit. If using a tower with a capacity that is too low or smaller than the demand, the cooling tower will be overloaded, leading to damage to the tower, causing production to stagnate. On the contrary, if using a tower with a capacity that is too large, larger than the work requirements, it will cause waste of investment money and fuel in production activities.

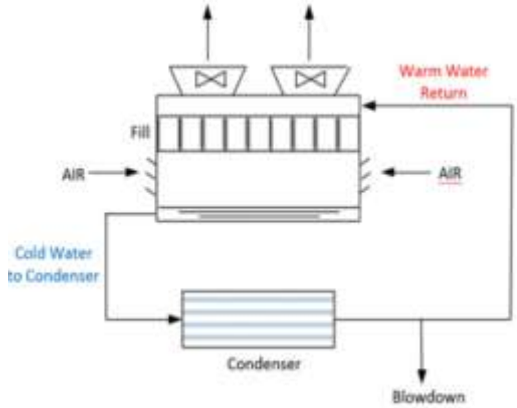

Figure 9. Cooling tower block diagram

Cooling towers can reduce the temperature of the refrigerant more than devices that use only air to reject heat, such as a car radiator, and are therefore more energy and cost efficient. This method is also known as water and air cooling method.

Each industrial refrigeration system uses a cooling tower with different technical parameters, so in the process of designing, using or purchasing a new cooling tower, it is necessary to pay attention to calculating and choosing a cooling tower with accurate technical parameters to meet the cooling needs of the system.

Depending on the requirements for calculating thermal capacity, cooling capacity or circulating water flow, there will be different calculation parameters.

Suppose a refrigeration system considered in section II has the following parameters, figure 10:

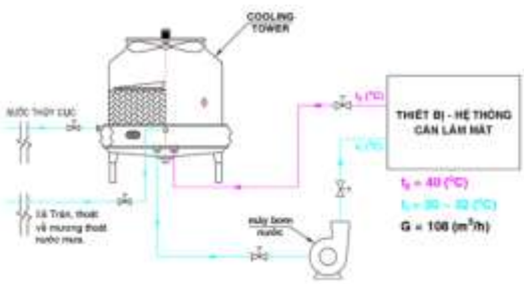

Figure 10. Required parameters of a refrigeration system.

Coolant flow rate: G = 108 m^3/h = 1800 l/p
The condensing temperature is also the outlet temperature of the cooling water: 40^{o}C

The coolant inlet temperature: 30 - 32^{o}C
In there:
Look up the h-x molier graph:at ambient temperature $t = 28^o C$ and humidity 82%.
Wegetwet-bulb thermometer temperature:
$t_u = 26^o C$

Therefore, $t_1 = t_{w1} = t_u + 5 = 26 + 5 = 31^o C$
And, the condensing temperature is also the outlet temperature of the cooling water:
$t_2 = t_{w1} + 9 = 31 + 9 = 40^o C$
The required cooling capacity is:

$$Q_k = G.C.\rho(t_2 - t_1) = \frac{108}{3600}.1000.4,186.9$$
$$= 1130\,kW \approx 320\,RT$$

The software application calculates in figure 11:

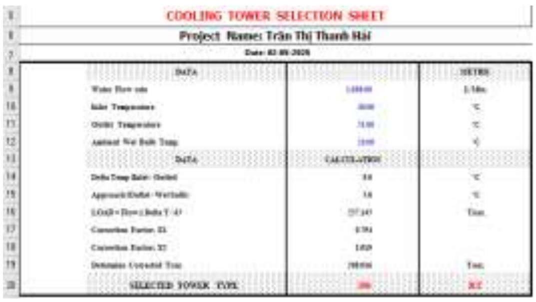

Figure 11. Cooling tower calculation parameter table.

Comparing the required cooling capacity calculation and the software calculation, we see that the difference is negligible. This shows that the software-based calculation is both highly accurate and fast.

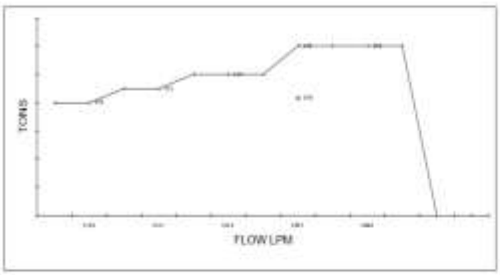

Figure 12. Cooling capacity - flow rate graph

When the cooling water flow rate reaches the value G = 1800 l/p, the cooling capacity reaches the required value Q_k = 300 RT as shown in Figure 12.

IV. CONCLUSION

Calculating and selecting a cooling tower is only a part of the process of calculating and designing a cooling system for a condenser. To ensure safe, reliable operation, fast and good cooling efficiency, it is also necessary to design a good pipeline system, a guaranteed tank, an efficient pump, a combination of natural cooling, forced convection, opening and closing valves ...

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