Designing and implementing an efficient chiller cooling solution for thin film deposition equipment and diffusion vacuum pump for thermal evaporation procedure

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Abstract. This article focuses on improving the thermal evaporation vacuum deposition system already present in the SMARTMAT laboratory at the University of Oradea. The old cooling system was comprised of two inefficient pieces of equipment that were replaced by the system described in this paper. A new design for the piping and connectors was implemented. All of the materials for the piping that were used are cheap and readily available at the hardware store.

1. Introduction

Thin film deposition is a crucial technique in various industries, including electronics, optics, and materials science. Thermal evaporation is a common method for depositing thin films, involving heating a source material in a vacuum chamber to vaporize it, which then condenses onto a substrate to form a thin film. However, the thermal evaporation process generates significant heat, particularly in the diffusion pump, which is essential for creating and maintaining a high vacuum. To ensure optimal performance and longevity of the equipment, efficient cooling is necessary. This article delves into the design and implementation of a chiller cooling solution specifically tailored for thin film deposition equipment and diffusion pumps used in thermal evaporation procedures.

Cooling units, but especially efficient chillers, are indispensable for thermal evaporation equipment. When a diffusion vacuum pump is paired with thin film deposition equipment, the need for cooling equipment becomes significant. To ensure the energy efficiency, temperature stability, and longevity of the thermal deposition equipment and diffusion pump in this system, an efficient chiller is essential. This leads to improved deposition reliability and overall system performance.

2. Designing the system

Before designing a chiller cooling solution, it is crucial to understand the specific cooling needs of the equipment. Key factors to consider include:

1. Heat Load: The amount of heat generated by the equipment, including the diffusion pump, heating sources, and other components.
2. Temperature Requirements**:** The desired operating temperature range for the equipment and the coolant.
3. Flow Rate: The required flow rate of the coolant to effectively dissipate heat.
4. Pressure Drop: The allowable pressure drop across the cooling system to ensure adequate flow.

5. Environmental Conditions: The ambient temperature and humidity, which can affect the cooling system's performance.

Chiller design details that were considered:

1. Chiller Capacity: The chiller's capacity should be sufficient to handle the peak heat load generated by the equipment. We have to consider potential increases in heat load, which are very likely, depending on the material and the system vacuum. Oversizing the chiller can lead to energy inefficiency, while undersizing can compromise performance.
2. Cooling Fluid: Water is the most common coolant due to its high specific heat capacity and availability.
3. Pumping System: A reliable pump is essential to circulate the coolant through the system, while maintaining a stable pressure of 2-3 bar. More important than the pressure is the flow, which has to have a high value. Other important factors are the pump's energy efficiency and noise level, as we have to work inside a laboratory.
4. Piping and Fittings: The piping system should be designed to minimize pressure drop and ensure efficient heat transfer.
5. Heat Exchanger: The heat exchanger transfers heat from the equipment to the coolant and should be sized to handle the heat load and provide efficient heat transfer.
6. Control System: A reliable and digital control system is necessary to maintain the desired temperature and flow rate. The control system should include sensors to monitor temperature, pressure, and flow rate. Alarms and safety interlocks should be implemented to protect the equipment and personnel.

In Figure 1 [1], [2], [3] the diagram of the cooling system is presented.

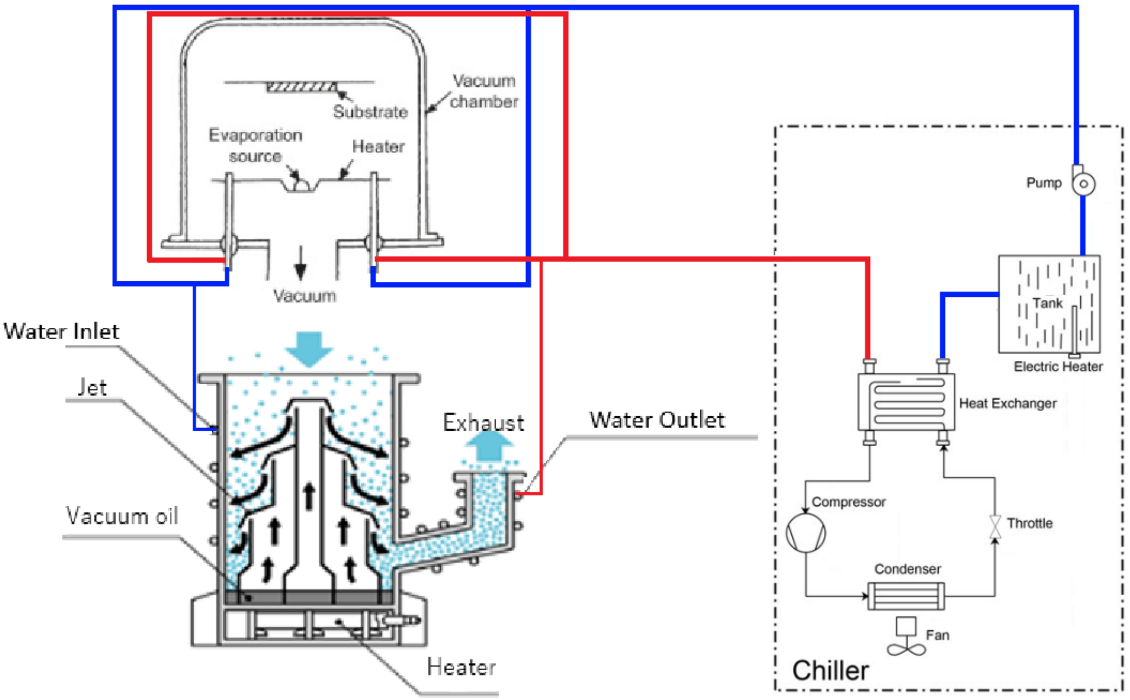

Figure 1. Diagram of the cooling system

3. Implementing the designed system

The whole deposition system is represented in Figure 2.

Figure 2. View of the whole deposition system

From left to right, in Figure 2 we have: Automation box and pressure reader, rough pump and diffusion pump, thermal evaporation equipment and chiller.

As seen in Figure 1, the cold water comes out of the chiller into the main line. There, a T-shaped splitter sends the cold water into a distributor seen in Figure 3B and to the water inlet of the diffusion pump seen in Figure 3A.

Figure 3. Detailed view of the cooling system: A. Connections to and from the diffusion pump cooling coils; B. Distributor for the electrodes; C. T-shaped splitters on the inlet and outlet of the chiller; D. Inlet and outlet of the chiller.

There are two distributors in Figure 3B – one for cold water and one for hot water. The cold water comes directly from the chiller and goes into the electrodes cooling pipes and cools them. Each electrode has a piping system that lets the water pass through it, cooling the electrodes and heating the water. The heated water comes then back into the other distributor, goes into the main collecting line via a T-shaped splitter and into the chiller, where it cools again.

Table 1. Chiller specifications [4]

Specifications	CW-6200 Chiller
Voltage	AC 1p 220V
Frequency	50Hz
Current	2.3~13A
Machine power	2.19kW
Compressor power	1.73kW 2.35HP
Nominal cooling capacity	17623Btu/h 5.17kW 4441Kcal/h
Refrigerant charge	1100g
Pump power	0.37kW
Max. lift	28M
Max. flow	70L/min
N.W.	82Kgs
G.W.	93Kgs
Refrigerant	R-410A
Precision	0.5C
Reducer	Capillary
Tank capacity	15L
Inlet and outlet	Rp1/2"
Dimension	67x47x89 cm (L X W X H)

The distributor attached to the evaporation equipment is necessary as there are at least two electrodes that need to be cooled. The equipment has room for 2 more electrodes if necessary. The heated water that comes out of the diffusion pump water outlet goes into the main collecting line and into the T-shaped splitter. Both T-shaped splitters and the connecting lines can be seen in Figure 3C and Figure 3D.

The chiller is equipped with a temperature controller of type S&A T503[5].

The heat that has to be dissipated is approximately 3,65kw, which is comprised of 0,65kw for the diffusion pump and 3kw for the set of electrodes. Another set of electrodes would bring the total for heat dissipation of the system to 6,65kw, in the event of an expansion of the system. The volume of the chiller tank is 15 liters, plus the water inside the lines and distributors takes the total water volume to about 20 liters. Set pressure is 3 bar with a flow of 70L/min. The technical specifications of the chiller are presented in Table 1. A detailed picture of the chilling equipment is presented in Figure 4.

Figure 4. Chiller equipment

4. Conclusions

The whole system is now slightly over-designed, but room for more equipment and improvements on the thermal deposition system were taken into consideration. It can easily keep the temperature of water at 22-23 degrees Celsius, while the ambient temperature is 25 degrees Celsius. That is more than enough cooling power for the deposition system.

5. References

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