

Options for Semiconductor Process Tool Temperature Control

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- Chiller
- High Flow Rate
- Low Logarithmic Mean Temperature Difference
- SEMI-S2 Certification

Abstract

Traditionally, *Chillers*, i.e. refrigerated temperature control equipment, are viewed as the preferred choice for removing heat from process equipment or for controlling their temperature. Depending upon the application and the degree of control required, however, *Heat Exchangers* can represent a very viable alternative to chillers. The two critical variables enabling the use of heat exchangers are facilities water supply temperature and process fluid temperature stability. When these two variables are sufficiently low, heat exchangers can provide an optimal solution.

Introduction

Optimal temperature control is achieved by equipment that offers stable and reliable performance combined with low cost of ownership. Cost of ownership comprises equipment purchase and operating costs, including maintenance and electricity. While chillers are typically the recommended choice for process cooling applications, they may not always be the optimal equipment.

Both chillers and heat exchangers have recirculation subsystems, but because chillers also have refrigeration subsystems, chillers are inherently more complex and thus potentially less reliable. Also, refrigeration subsystems typically add more expense on a cost-per-heat-load basis. Therefore, if raw heat removal at moderate process fluid temperature stability is permissible, and if the process fluid supply temperature is higher than the facilities water temperature, then heat exchangers become attractive alternatives to chillers.

Because facilities water is prone to fluctuations in quality, temperature and pressure, it is sometimes desirable to isolate the tool from the facilities water supply by using either a chiller or heat exchanger. This promotes better process fluid quality, higher process fluid supply pressures for higher process fluid flow rates, and better control of process fluid supply temperatures.

Example

This application note discusses a case within the semiconductor manufacturing industry. In this specific example, both a heat exchanger and two configurations of chillers were evaluated for support of a 300 mm Physical Vapor Deposition (PVD) tool. The Thermo Scientific NESLAB SWX 100 heat exchanger is shown to best meet the requirements of the tool, including lowest cost of ownership.

Tool Requirements

The PVD tool features two identical left and right halves. Each half has various process chambers, and each process chamber has various components, such as cathodes, stages, walls and pumps, most of which require water cooling.

The water is supplied to these various components via two manifolds, referred to as cathode manifold and module manifold. Both manifolds require a supply pressure between 30 psi(g) and 150 psi(g), a supply temperature between 20°C and 25°C and a supply resistivity of 1/100 MΩcm or 10 kΩcm. Also, the cathode and module manifolds require a flow



Figure 1: Thermo Scientific NESLAB SWX 100 Heat Exchanger

rate of at least 18.5 gal/min and 10 gal/min, respectively. The maximum supply pressure should not be exceeded to prevent damage to the components.

Typical supply and return lines between the temperature control equipment and the cathode and fittings such as elbows and valves, are estimated to introduce a pressure drop of up to 35 psi(d). Thus, the supply pressure at the chiller or heat exchanger typically has to be higher than 65 psi(g) when the return pressure to the chiller or heat exchanger is 0 psi(g). The latter is typically the case in open-loop temperature control equipment that contains reservoirs.

Chiller Performance

Two chiller options were considered as alternatives to the NESLAB SWX 100 heat exchanger in order to meet the requirements of the PVD tool. These were a NESLAB HX 750 chiller, and NESLAB HX 300 and HX 500 chillers used in tandem. While the heat load capability of these two alternatives was sufficient, the inability to provide pressure via one unit and

Parameter	Unit	Tool	HX 750	HX 300	HX 500
Part Number			392205051706	390205051703	391205301701
Pump			CP-75	CP-75	TU-9
Temperature	[°C]	20 ... 25	5 ... 35	5 ... 35	5 ... 35
Heat Load	[kW]	< 25	24	10	15
Pressure	[psi(g)]	30 ... 150	35	60	65
Flow Rate	[gal/min]	>28.5	28.5	10	18.5
Resistivity	[kWcm]	> 10	N/A	N/A	N/A
Stability	[°C]	N/A	+ 0.1	+ 0.1	+ 0.1

Table 1: Tool Requirements and Chiller Performance

the need to provide flow rate via two units were undesirable. The match-up between chiller and tool is shown in Table 1.

Heat Exchanger Performance

The NESLAB SWX 100 heat exchanger is shown in Figure 1. It is rated for a heat load of 100 kW with a 25 gal/min facilities flow rate and a 25 gal/min process flow rate when the temperature difference between process supply and facilities supply is 10°C. The performance can be de-rated with that difference as long as the flow rates remain equal and both remain close to the above process flow rate of 25 gal/min. For example, at a temperature difference of 5°C, the heat load that can be handled by the SWX 100 is only 50 kW.

Therefore, at a typical facilities supply temperature of 60°F or about 15°C, up to 50 kW or 100 kW can be removed from the tool if the process supply temperature is 20°C or 25°C, respectively. This performance does not change substantially as the process and facilities flow rates are increased from 25 gal/min to 28.5 gal/min to accommodate the requirements of this particular tool.

Furthermore, these figures indicate maximum performance. A reduction from these figures is achieved automatically by facilities supply valve modulation.

The CP-13 pump of the NESLAB SWX 100 system can deliver the required process flow rate of 28.5 gal/min at a process supply pressure of about 130 psi(g). In order to establish this flow rate at the predicted supply pressure of no more than 65 psi(g), pressure reduction is necessary. Thus the need for external valves is evident as the NESLAB SWX 100 unit has no internal flow control valves. For reference, the facilities pressure drop within the NESLAB SWX 100 unit at a facilities flow rate of 25 gal/min is 12.5 psi(d). The match-up between heat exchanger and tool is shown in Table 2. Assuming a permissible temperature rise across the tool of 10°C, the tool will be generating 75.3 kW at most, which is likely to result in a process supply temperature of 22.5°C. However, given that a NESLAB HX 750 unit with a heat load capacity of 24 kW was sufficient to handle the heat load, if not the flow rate, the actual temperature rise likely will be no greater than 3.2°C.

Heat Exchanger Features

The NESLAB SWX 100 unit includes a return volume flow transducer, a resistivity meter and a supply pressure gauge. These features permit readouts on the digital controller display not only of supply temperature, but also of process flow rate and of resistivity. The NESLAB SWX 100 unit also provides remote on/off capability and remote resistivity readout, as well as SEMI-S2 certification, which comprises EMO button, earthquake brackets and drip pan.

Other available options are a partial deionization kit comprising a flow control valve, a flow meter, a particle filter and a deionization cartridge; an anti-siphon kit comprising a check valve in the supply line and a solenoid valve in the return line; an auto-refill kit comprising a refill line and a solenoid valve in that refill line; and a smaller CP-9 pump that operates at a process supply pressure of about 85 psi(g) at the required process flow rate of 28.5 gal/min.

Parameter	Unit	Tool	SWX 100
Part Number			603099991603
Pump			CP-13
Temperature	[°C]	20 ... 25	20 ... 25
Heat Load	[kW]	< 25	< 50 ... 100
Pressure	[psi(g)]	30 ... 150	130
Flow Rate	[gal/min]	> 28.5	28.5
Resistivity	[kWcm]	> 10	> 10
Stability	[°C]	N/A	+ 1

Table 2: Tool Requirements and Heat Exchanger Performance

Summary and Conclusion

The combination of a Thermo Scientific NESLAB SWX 100 heat exchanger and the 300 mm PVD tool was deployed at a major memory manufacturer on the East Coast of the US. The NESLAB SWX100 unit was installed such that it provided a process flow rate of up to 35 gal/min at a process supply pressure of up to 85 psi(g) to the tool. The initial resistivity was 12 M Ω cm, which went down to the desired level of >10 k Ω cm as time progressed.

This application more than met the flow requirement, but exceeded the resistivity limit. If simplistic scaling of process supply pressure with the square of process flow rate is assumed, the target process flow rate of 28.5 gal/min could be achieved at a process supply pressure of 56.4 psi(g), falling reasonably close to the predicted number of 65 psi(g). Furthermore, the resistivity could be reduced simply by eliminating the deionization cartridge, thereby also eliminating a maintenance need.

The NESLAB SWX 100 heat exchanger's powerful pump allowed the user to exceed the tool's flow rate requirement, whereas previous attempts to use NESLAB HX chillers in this application had consistently fallen short. Effectively, this qualified the NESLAB SWX 100 unit as support equipment on the tool. Because the tool manufacturer leaves selection of such equipment to the end user, this is particularly significant. The memory manufacturer was able to replace chillers with heat exchangers without further qualification. This option has proven to be an effective alternative for the end user's heat removal application needs.

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