SIZE Really Does Matter

Accurate process temperature control often is the key to minimizing scrap and improving the cost of producing a quality product. Here's how to determine effective sizing of combination heating and cooling systems.

By Jeff Mallon, Mokon

When your operation must perform at its best to meet maximum processing demands, proper sizing of the heating and cooling system for vessels, tanks, reactors and mixers can make the difference. Unfortunately, the individuals involved with the application often overlook the basics when sizing heating and cooling needs because they examine the final product itself rather than the whole process system. Proper collection of the data necessary to perform the calculations is imperative to a successful implementation.

One small biotech company started with the process needs rather than the product when sizing a heating and cooling system. As a result, the system the company selected for its small reactor is delivering successful results. Consider the lessons that can be learned by its experience.

Heating and Cooling Needed

The application involved using water or a glycol/water mix as the liquid heat transfer medium. Glycol can be used to maintain chiller functionality at setpoints below 50°F (10°C) or as a biocide and rust inhibitor when low temperatures are not needed. When the use of glycol is mandated, this must be accounted for in the calculations as glycol inhibits the ability of water to transfer heat efficiently. The amount of glycol in the system will derate the system's heating and cooling capabilities, depending on the percentage of glycol mixed into the water (table 1).

The system the biotech company evaluated was a full-range design that combined a heater and a chiller in a self-contained portable package. The system included a tank as a supply of heat transfer fluid. The company planned to move the temperature control system to a production area following laboratory testing, so a NEMA 4X washdown-compatible design was part of the specification. The company also specified the use of a 15 percent polypropylene glycol/water mix. Because temperatures had to be tightly controlled at the process itself, a stainless steel thermocouple would be located in the reactor and connected to the system for reading the actual process temperature.

Water/Ethylene Glycol Mixture Capacity Losses

Percent Glycol	Percent of Capacity Loss
0	0.0
5	2.1
10	4.2
15	6.3
20	8.5
25	10.6
30	12.7
35	14.8
40	16.9
45	19.0

Table 1. Depending on the percentage of glycol mixed into the water, the amount of glycol in the system will derate the system's heating and cooling capabilities.

After performing the proper calculations, a small biotech company selected a one-ton chiller combined with a 2 kW heater in a NEMA 4X configuration with remote control capabilities and remote thermocouple.

In addition, the biotech company wanted remote-control capabilities so the temperature system operation could be integrated into a computer-controlled automated manufacturing system. To aid this, the temperature control system would be supplied with controller communications via 4 to 20 mA; remote setpoint and retransmission; remote start-stop capabilities via a customer-supplied momentary signal; and run status indication to inform the customer remotely that the system was operating correctly or provide an alarm status in the event of a safety shutdown.

The reactor was physically small and well-insulated, and there were no issues with exothermic or endothermic reactions, so the company was now prepared to calculate the heating and chiller loads (table 2). The calculations for heating and cooling were based on the calculation:

$$Q = W \times C_p \times \Delta T$$

Where Q is the heat required, W is the weight, C_p is the specific heat and ΔT is the temperature differential. The calculations are shown in table 3.

Specifications	
Weight of Reactor/Vessel	53 lb
Reactor Material	Stainless Steel*
Starting Temperature	65°F (18°C)
Maximum Process Temperature	138°F (59°C)
Ending Temperature	65°F (18°C)
Heatup Time	15 min
Cooldown Time	10 min
Specific Heat of the Product	0.5 BTU/lb-°F
Weight of Product Being Manufactured	7 lb
Temperature Difference (ΔT)	73°F (23°C)
Volume in Jacket of Reactor	0.5 gal

*Stainless steel has a specific heat value of 0.12 BTU/lb-°F

Table 2. The biotech company calculated the heating and chiller loads using data specific to its process to ensure the system was properly sized.

Once the kilowatt (kW) requirements are established for the process, surface losses from the temperature control unit must be considered for operating temperatures above 200°F (93°C). (Below this temperature, losses generally are negligible.) This is a function of the surface temperature of uninsulated components and piping; material of construction of the components and piping; the ambient temperature; and the circulating fluid temperature.

Generally, the ambient temperature is assumed to be 70°F (21°C) "still air" (approximately 1 ft/sec). Calculate the total surface area of all exposed piping and components in square feet. Then, refer to the heat loss chart usually found in the technical section of a heater supplier's catalog. The chart typically plots heat loss in watts/square foot vs. surface temperature for various materials such as copper, aluminum and steel. Then, multiply the heat loss per square foot by the surface area to get total watts at the desired operating temperature. Convert it to kilowatts and add it to process requirement. Additionally, a negligible safety factor should be added to the final calculation for assurances of coverage for items and events not previously considered.

Calculating Heat Requirements

Q_{VESSEL} = 53 lb x 0.12 x 73°F = 464.28 BTU/hr

$Q_{MATERIAL}$ = 7 lb x 0.5 x 73°F = 255.50 BTU/hr

Q_{JACKET} = 4.17 lb x 1 x 73°F = 304.41 BTU/hr

Q_{TOTAL} = 1,024.19 BTU/hr

The customer required a 15 min heatup, but Q_{TOTAL} was the BTU required for 1 hr. So, to calculate the total BTU required for the process, it is necessary to take Q_{TOTAL} and calculate it for the required heatup time (one-quarter hour, or 15/60 min).

$Q_{HEATING}$ = 1,024.19 / 0.25 hr = 4,096.76 BTU/hr

To convert the calculation from BTUs to kilowatts, use the value of 1 kW equals 3412 BTUs.

$Q_{HEATING}$ = 4,096.76 / 3,412 = 1.20 kW/hr

Table 3. The heat requirements of the process determined the kilowatt rating of the temperature control system.

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Tips for Sizing Typical Applications

A heating and cooling system can control the process temperature so that the specific sequences or timed stages necessary to develop the end product are managed. However, to be most effective, it must be sized properly. Heat loss and gain are critical factors when sizing a system.

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The biotech company followed these steps to calculate the size of its heating/cooling system. Ultimately, a 2 kW heater was selected after accounting for system surface losses and derating due to the 15 percent glycol/water mix as well as any line losses related to uninsulated, exposed surfaces outside the temperature control system.

The biotech also required cooling in 10 min. Following the calculation steps shown in table 3, the results were:

$Q_{COOLING}$ = 1,024.19 / 0.166 hr
$Q_{COOLING}$ = 6,169.82 BTU

Given that 1 ton of cooling equals 12,000 BTU, and accounting for de-rating due to the glycol, the best selection for a chiller turned out to be a 1 ton size.

The heating and cooling system was configured per the customer's specifications and delivered the desired results. Success was possible because the company started with the process to determine its needs. **PH**

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