GUIDELINES FOR DETERMINING PROCESS HEATING REQUIREMENTS

Often the requirement is simple: a heating element has performed to expectations but has finally failed due to exceeding its useful life-cycle. The catalog number is noted and consideration is given to ordering another one of the same.

In the continuous search for improvement, however, it has been determined that the next element should last longer. Analysis of the watt density, sheath material, and type of control indicates that the entire system needs to be redesigned. More heaters at a lower wattage each would reduce the watt density. The sheath should be upgraded to Incoloy because of the presence of some corrosive materials. Electronic controls could replace the thermostats and the system zoned to improve process control.

But as the heater aged, so had the rest of the equipment. Maintenance costs and down-time were increasing. Product quality was not always what was expected. In addition, not enough material could be processed, cycle times were too long, and overall efficiency was not adequate. As the ultimate solution, the equipment was scrapped. New equipment could be designed to meet all current and future requirements. Specifications needed to include calculations for the amount of wattage necessary in addition to the factors described previously. The available electrical supply, operating environment, mechanical considerations, cost and efficiency also needed to be analyzed. The following method determined the new thermal system design:

Description of System
Calculation of Wattage Required
  1. For Process Start-up
  2. For Process Operation
  3. To Replace Heat Losses
  4. For Contingency Factors
Determine Appropriate Watt Density
Select Type of Heater(s)
Determine Proper Sheath Material
Thermal System Design
Selection of Temperature Control

Assume those responsible for the introductory example successfully accomplished their task. Most materials can be effectively heated by electric heaters. The information presented in the following pages contain the formulas, graphs, definitiions, and other data necessary to apply STS Products in electric heating applications. The step-by-step method described is followed by detailed examples

DESCRIPTION OF SYSTEM

Determine what is to be achieved with a brief statement and a sketch.

CALCULATION OF WATTAGE REQUIRED

Considerations

1. Beginning and final temperatures
2. Time available to reach final temperature
3. Process cycle period
4. Weight and thermal properties of material being processed and of materials added during process cycle
5. Flow rates of liquids or gasses being heated
6. Dimensions, weights and thermal properties of containers, transfer medium, or anything else present that will absorb heat during the process
7. Surface area exposed to ambient where heat losses will occur
8. Effects and properties of insulation

Information for section **1, 2, 3, 5** and **7** is determined by the application requirements as per the Description statements.

Information for section **4, 6** and **8** is found in charts and graphs on the following pages.

See the **Thermal System Glossary** for definitions of the terms used.

Once the above information has been gathered, the formulas can be set-up and the calculations can begin.

$$\mathbf{Qha + Qls + CF = kwh}$$

$$\frac{\textbf{kwh}}{\textbf{Hours allowed for process start-up}} = \textbf{kw}$$

where:

Qha is the heat absorbed

Qls are the heat losses through the system

CF is the contingency or safety factor

A. Qha:

$$\frac{\text{weight (lbs.)} \times \text{specific heat (Btu/lb./°F)} \times \text{(final—starting temperature)}}{3412\ \text{Btu/kwh}} + \frac{\text{weight (lbs.)} \times \text{heat of fusion/vaporization (Btu/lb.)}}{3412\ \text{Btu/kwh}}$$

Both must be calculated for all material present in the system that will absorb heat.

B. Qls:

$$\frac{\text{Exposed surface area (sq.ft.)} \times \text{Watts/sq.ft. loss at final temperature} \times \text{Hours allowed for start-up}}{1000\ \text{w/kw}} \times \tfrac{1}{2}$$

C. CF:

$$\%(\text{Qha} + \text{Qls})$$

10–35% kw additional for unknown or variable factors. 20% is common for most processes. In large thermal systems or in oven applications where the door is opened regularly, 30–35% is added.

$$\textbf{Wattage required for process start-up (kw)} = \frac{\mathbf{A + B + C}}{\textbf{hours allowed for process start-up}}$$

STEP 2: WATTAGE REQUIRED FOR PROCESS OPERATION

$$\mathbf{Qha2 + Qls2 + CF = kw}$$

where:

Qha2 is the heat absorbed by new materials being processed

Qls2 are the heat losses through the system during processing

CF is the contingency or safety factor

D. Qha2:
Apply same calculations as A for all new materials added to system during process operation (weight in lbs./hr.)

E. Qls2:

$$\frac{\text{Exposed surface area (sq.ft.)} \times \text{Watts/sq.ft. loss at final temperature}}{\text{1000 w/kw}}$$

F. CF:

Apply same calculation as **C**.

Wattage Required for Process Operation (kw) = D + E + F

Generally, the greater of **step 1** or **step 2** will be the wattage installed. Often the requirement for start-up will be larger than for operation. Consider lengthening the start-up time to where **step 1** and **step 2** are nearly the same.

The **Heat of Fusion/Vaporization** calculation is required only if the material changes due to melting or evaporation. If the specific heat varies from one state to another, first calculate the kw requirement to the melting/vaporization point. Second, calculate the kw requirement for the heat of fusion or vaporization. Third, calculate the kw requirement to raise the molten or gaseous material to the final desired temperature. See Example 2.

In **step A and step D**, the calculations derived in the numerator are in Btu's. As the ratings of electric heaters are in watts or kilowatts, 3412 (the figure in the denominator) converts Btu's to kilowatts. One kilowatt hour is equal to 3412 Btu's.

If the material to be heated is a flowing liquid or gas, the information will be in gallons per minute for liquids (gpm); cubic feet per minute for air and gases (cfm). This must be converted to weight per hour, and will be determined by the density from chart 7T for liquids (lb./gal.) and by the combination of charts 8T and 9T for air and gasses (lb/cu.ft.). Because the density of a gas changes, air and gas processes also include velocity calculations. For heating forced air in ducts, only the Process Operation kw requirement is necessary. See Example 4. Then substituting:

A. Qha or Qha2:

$$\frac{\text{gpm or cfm} \times \text{60 min./hr.} \times \text{Density} \times \text{specific heat (Btu/lb./°F)} \times \text{(final—starting) temperature)}}{\text{3412 Btu/kwh}}$$

In **step B** and **step E**, the calculations derived in the numerator are in watts. Dividing by 1000 converts watts to kilowatts. For process start-up, as shown in **step C**, an approximate averaging factor of $\frac{1}{2}$ is utilized (heat losses will be 0 at start-up and increase to 100% as the temperature rises from beginning to final temperature). If the requirement for Process Start-Up is greater than two hours, multiply Qls by the approximate averaging factor of $\frac{2}{3}$.