# 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 conduction, convection or radiant energy produced by electric heaters. The information presented in the following pages contain the formulas, graphs, definitions, and other data necessary to apply **OGDEN** 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:**

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

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

**B. Qls:**

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

**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:

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

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**:

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

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 ½ 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 ⅔.

## DETERMINE APPROPRIATE WATT DENSITY

**Watt density** is the rated wattage of an element per unit of surface heated area (usually square inches), and indicates the potential to transmit heat. The formula is as follows:

$$\text{Watt Density} = \frac{\text{Rated Wattage}}{\text{Heated Surface Area}}$$

For example, a **Mighty Watt**, ½" x 12" (MWEJ12A0191) is rated 12000 watts. The standard cold section each end is ⅜" per the specifications in the catalog section. The total cold area is ¾" making the heated length 11¼". Then:

$$\text{Watt Density} = \frac{\text{Rated Wattage}}{\text{Dia. x Heated Length x 3.14}}$$

$$\text{Watt Density} = \frac{1000}{.496 \times 11.25 \times 3.14}$$

$$\text{Watt Density} = 57 \text{ Watts/sq.in.}$$

As the definition indicates, the higher the watt density, the greater the possibility for excessive sheath temperatures. When designing the system, spreading the wattage requirement over more or larger heaters will reduce the operating watt density. Sheath temperatures will be reduced, increasing the heater's length of service. Note that every **OGDEN** heater has watt density and sheath temperature limitations shown in each catalog section.

Recommended allowable ratings for various materials, temperature conditions, and application considerations are also shown in the catalog sections and in the following pages. See Chart 23T. Certain materials such as water, vegetable oils, and metals have high conductivity rates. The heat generated travels quickly from the element and through the medium, allowing these materials to be heated at relatively high watt densities. Fuel oils, lubricating oils, hydraulic fluid, and other materials with low conductivity rates such as sugar syrups and most gasses must be heated at low watt densities. A major concern is to dissipate the heat generated by the element. If attention is not paid to guidelines for both the heater and the material being heated, watt densities too high will result in failure of the elements and possible damage to the material and equipment.

## SELECT TYPE OF HEATER(S)

The type of heater best suited for an application involves the dynamics of the process, space limitations, available electrical supply, cost, and appearance among other considerations. There could be several acceptable heaters for a single application. A water tank could be heated by direct immersion, clamped-on strip or tubular heaters, or even a band heater if the tank is cylindrical.

The following methods of installation are listed in the order of most effective transfer of heat from the element(s):

1. Immersed directly in liquids or gases
2. Inserted into drilled holes
3. Placed in milled slots or grooves
4. Mechanically clamped or wrapped around the surface
5. Spaced away, as a convective or radiant heat source

Most often the application will indicate the obvious selection.

Even though metal sheath heaters are quite durable, physical damage can occur. Protection, such as a shroud or guards might be necessary. In applying surface mounted heaters such as HD Strip Heaters or in some cases tubulars, intimate contact between the heater and the heated part is necessary to facilitate conductive heat transfer. This type of contact is also important in the installation of heaters in drilled holes and the strapping of band heaters to the mounting surface. Air gaps between the element and the heated part will result in higher sheath temperatures, and early failure.

Contamination can be said to be the leading cause of heater failure. Oils, plastics, vapors or other materials around the terminal areas will shorten heater life. Teflon, epoxy, ceramic-to-metal hermetic and other seals will often protect against contamination in some heater designs. Area atmospheric conditions may require complete terminal isolation from the environment by the use of NEMA IV or VII enclosures.

If lead wires are designed, continuous flexing or possible abrasion would call for armor cable or metal braided protection. Temperature and contaminants present also are deciding factors in the lead design and type chosen.

Further along in this section is a discussion on how the placement of heaters will improve heat distribution and heat patterns throughout a thermal system. At this point, the selection should emphasize what would be practical and efficient. Modifying the choice may become necessary in completing the design of the entire system.