Heat Requirement Calculations

There are two basic heat energy requirements to be considered in the sizing of heaters for a particular application:

1. Start-Up Heat is the heat energy required to bring a process up to operating temperature. Start-up heat requirement calculations which include a material change of state should be calculated in three parts:

1) Heat requirement from ambient temperature to change of state temperature

2) Heat requirement during change of state (latent heat)

3) Heat requirement from change of state temperature to operating temperature

2. Operating Heat is the heat energy required to maintain the desired operating temperature through normal work cycles. The larger of these two heat energy values will be the wattage required for the application.

A safety factor is usually added to allow for unknown or unexpected operating conditions. The safety factor is dependent on the accuracy of the wattage calculation. A figure of 10% is adequate for small systems closely calculated, while 20% additional wattage is more common, and figures of 25% to 35% should be considered for larger systems with many unknown conditions existing.

Start-Up Heat requirements will include one or more of the following calculations, depending on the application:

1. Wattage required to heat material:

$$\frac{\text{Weight of material (lbs)} \times \text{Specific Heat (Btu/lb °F)} \times \text{Temperature rise (°F)}}{\text{3.412 btu/watt hr.} \times \text{Heat-up time (hr.)}} = \text{Watts}$$

See page 16-4 for Properties of Materials

2. Wattage required to heat container or tank:

$$\frac{\text{Weight of container (lbs)} \times \text{Specific Heat (Btu/lb °F)} \times \text{Temperature rise (°F)}}{\text{3.412 btu/watt hr.} \times \text{Heat-up time (hr.)}} = \text{Watts}$$

3. Wattage required to heat hardware in container:

$$\frac{\text{Weight of hardware (lbs)} \times \text{Specific Heat (Btu/lb °F)} \times \text{Temperature rise (°F)}}{\text{3.412 btu/watt hr.} \times \text{Heat-up time (hr.)}} = \text{Watts}$$

4. Wattage required to melt a solid to a liquid at constant temperature:

$$\frac{\text{Heat of fusion (Btu/lb)} \times \text{Weight of material to be melted (lb/hr)}}{\text{3.412 btu/watt hr.}} = \text{Watts}$$

Heat of Fusion (Latent Heat): The amount of heat required to change one pound of a given substance from solid to liquid state without change in temperature is termed the heat of fusion.

It requires 144 Btu to change one pound of ice at 32°F to one pound of water at 32°F, thus the heat of fusion of ice is 144 Btu per pound.

A change of state is usually accompanied by a change of specific heat. The specific heat of ice is 0.5; while that of water is 1.0.

5. Wattage required to change a liquid to a vapor state at constant temperature:

$$\frac{\text{Heat of vaporization (Btu/lb)} \times \text{Weight of material to be vaporized (lb/hr)}}{\text{3.412 btu/watt hr.}} = \text{Watts}$$

Heat of Vaporization (Latent Heat): The amount of heat required to change one pound of a given substance from liquid to vapor state without change in temperature is termed the heat of vaporization.

It requires 965 Btu to change one pound of water at 212°F to one pound of steam at 212°F.

6. Wattage to counteract liquid surface losses: See Graph 3 on opposite page for loss rates of water and oils.

$$\frac{\text{Total liquid surface area (sq. ft.)} \times \text{Loss rate at final temperature (watts/sq. ft.)}}{2} = \text{Watts}$$

7. Wattage to counteract surface losses from container walls, platen surfaces, etc.: See Graph 2 on opposite page for losses from metal surfaces. See Graph 1 for losses from insulated surfaces.

$$\frac{\text{Total surface area (sq. ft.)} \times \text{Loss rate at final temperature (watts/sq. ft.)}}{2} = \text{Watts}$$

Heat Requirement Calculations

***Operating heat** requirements will include one or more of the following calculations. Any additional losses particular to the application should also be estimated and included.*

1. **Wattage to counteract losses from open liquid surfaces:** See Graph 3 for loss rates of water and oils.
   Total liquid surface area (sq. ft.) × Loss rate at operating temperature (watts/sq. ft.) = Watts

2. **Wattage to counteract container or platen surface losses,** either insulated (See Graph 1) or uninsulated (See Graph 2).
   Total surface area (sq. ft.) × Loss rate at operating temperature (watts/sq. ft.) = Watts

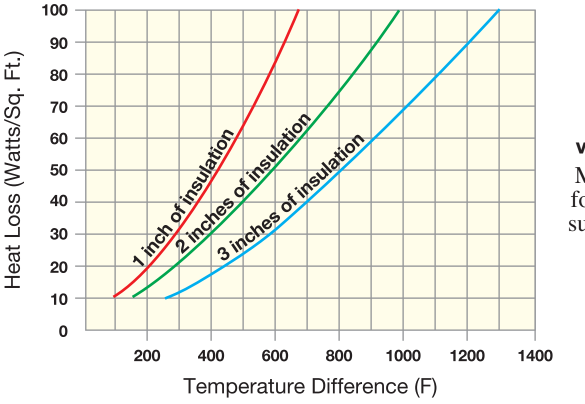
3. **Wattage required to heat material transferred in and out of the system.**
   (Metal dipped in heated tanks, air flows, make-up liquids, etc.)
   $$\frac{\text{Weight of material to be heated (lbs)} \times \text{Specific Heat (Btu/lb °F)} \times \text{Temperature rise (°F)}}{\text{3.412 btu/watt hr.} \times \text{Heat-up time (hr.)}} = \text{Watts}$$

4. **Heat-up of racks of containers, etc. transferred in and out of the system:**
   $$\frac{\text{Weight of items to be heated (lbs)} \times \text{Specific Heat (Btu/lb °F)} \times \text{Temperature rise (°F)}}{\text{3.412 btu/watt hr.} \times \text{Heat-up time (hr.)}} = \text{Watts}$$

Specific Heat: The heat necessary to increase the temperature of all other substances has been referred to water as a standard. The ratio of the amount of heat required to increase the temperature of one pound of any substance by one degree to the amount necessary to increase one pound of water is known as the specific heat of that substance.

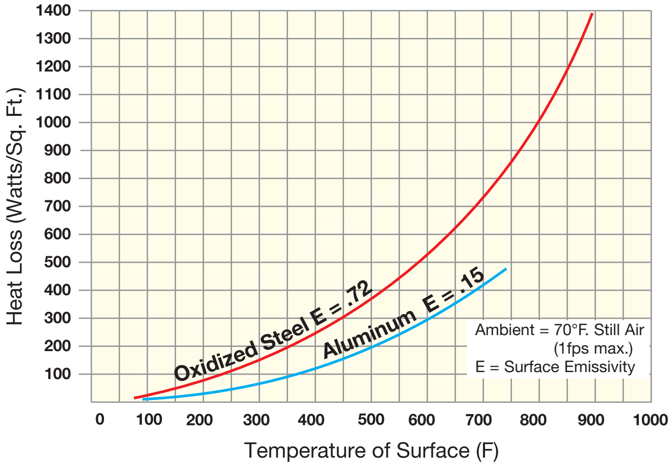
Heat Loss Information

Graph 1 ***Heat Losses through Insulated Walls (based on standard thermal insulations)***



Figures are for vertical surfaces. Multiply by 120% for a horizontal top surface and by 60% for a horizontal bottom surface.

Graph 2 ***Heat Losses from Uninsulated Metal Surfaces***



Graph 3 ***Heat Losses from the Surface of Water and Oil***