## Power Calculations

### *Conduction and Convection Heating*

#### Absorbed Energy, Heat Required to Raise the Temperature of a Material

Because substances all heat differently, different amounts of heat are required in making a temperature change. The specific heat capacity of a substance is the quantity of heat needed to raise the temperature of a unit quantity of the substance by one degree. Calling the amount of heat added **Q**, which will cause a change in temperature **ΔT** to a weight of substance **W**, at a specific heat of material $\mathbf{C_p}$, then $Q = w \times C_p \times \Delta T$.

Since all calculations are in watts, an additional conversion of 3.412 BTU = 1 Wh is introduced yielding:

**Equation 1**

$$Q_A \text{ or } Q_B = \frac{w \times C_p \times \Delta T}{3.412}$$

$Q_A$ = heat required to raise temperature of materials during heat-up (Wh)

$Q_B$ = heat required to raise temperature of materials processed in working cycle (Wh)

$w$ = weight of material (lb)

$C_P$ = specific heat of material (BTU/lb x °F)

$\Delta T$ = temperature rise of material ($T_{Final} - T_{Initial}$)(°F)

This equation should be applied to all materials absorbing heat in the application. Heated media, work being processed, vessels, racks, belts and ventilation air should be included.

**Example:** How much heat energy is needed to change the temperature of 50 lbs of copper from 10 to 70°F?

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

$$= \frac{(50 \text{ lbs}) \times (0.10 \text{ BTU/[lb x °F]}) \times (60°F)}{3.412} = 88 \text{ (Wh)}$$

#### Heat Required to Melt or Vaporize a Material

In considering adding heat to a substance, it is also necessary to anticipate changes in state that might occur during this heating such as melting and vaporizing. The heat needed to melt a material is known as the latent heat of fusion and represented by $\mathbf{H_f}$. Another state change is involved in vaporization and condensation. The latent heat of vaporization $\mathbf{H_v}$ of the substance is the energy required to change a substance from a liquid to a vapor. This same amount of energy is released as the vapor condenses back to a liquid.

**Equation 2**

$$Q_C \text{ or } Q_D = \frac{w \times H_f}{3.412} \quad \text{OR} \quad \frac{w \times H_v}{3.412}$$

$Q_C$ = heat required to melt/vaporize materials during heat-up (Wh)

$Q_D$ = heat required to melt/vaporize materials processed in working cycle (Wh)

$w$ = weight of material (lb)

$H_f$ = latent heat of fusion (BTU/lb)

$H_V$ = latent heat of vaporization (BTU/lb)

**Example:** How much energy is required to melt 50 lbs of lead?

$$Q = w \times H_f$$

$$= \frac{(50 \text{ lbs}) \times (9.8 \text{ BTU/lb})}{3.412 \text{ BTU/(Wh)}} = 144 \text{ (Wh)}$$

Changing state (melting and vaporizing) is a constant temperature process. The $\mathbf{C_p}$ value (from Equation 1) of a material also changes with a change in state. Separate calculations are thus required using Equation 1 for the material below and above the phase change temperature.