The *Salamander* News

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Sizing & Layout

The Information - Once a customer has decided to change over to or use ceramic heaters, their next question usually concerns sizing and layout. The engineering staff at Mor Electric Heating does this as routine and all distributors should be competent in providing this service. There are initially some basic questions to be answered:

1. Is this going to be a drying/evaporating application or does the product need to be heated for processing?
2. Which type of oven is needed: stationary, "batch", or conveyorized?
3. If it is a drying application, how much water or solvent needs to be evaporated?
4. What temperature does the product need to be heated to?
5. How fast does the heating process need to be?

Additional product information is also needed such as, **physical size**, **weight**, **material**, **color**, and the ambient or **"starting" temperature** of the product, including **specific heat** and **emissivity**, if known.

Using this information, a heat loss may be calculated to determine the power required by using this basic formula:

Step 1

$$\frac{w/hr}{in^2} = \frac{(weight)\ (spec\ heat)\ (\triangle T)}{3.412\ Btu/w}$$

However, knowing the power requirement is not enough. For radiant applications the emissivity must be factored in. Using the emissivity of the product and the estimated emissivity of the emitter in the following formula allows you to establish the "effective" or average emissivity between the two points.

Step 2

$$e = \frac{1}{(1/e_1 + 1/e_2 - 1)}$$

e_1 = emissivity of the source
e_2 = emissivity of the target

Once the effective emissivity is know, the Stefan-Boltzmann Law is used to determine the source temp. of the emitter:

Step 3

$$T_1 = \sqrt[4]{\frac{Watt/in^2}{(e)(36.58072 \times 10^{-12})} + (T_2)^4} \quad {}^{\circ}K$$

T_1 = source temperature, e = effective emissivity, watt/in^2 = the amount of kW needed

This information, combined with the space required, determines the number and wattage of the individual heaters required. Spacing between emitters is typically 1/4" (6mm) to 1" (25mm), and the emitters are placed in the heated area according to the zoning requirements of the application and the need to balance 3 phase loads. On the back of this newsletter is an example application done using these steps.

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The Example - A request was received for heating information on an application requiring evaporating water from water-based adhesive applied to a wooden board before being able to adhere the finished surface to the board. Following the steps outlined on the previous page, the following is the how we arrived at the required information.

Information received from the customer:

1. This is obviously an evaporating application.
2. The oven will need to be conveyorized to the point that it will be shuttling back and forth in front of a stationary product.
3. The amount of water needed to be evaporated is 2.5 grams per sq. ft.
4. Because we are evaporating water, it needs to be heated to 212° F.
5. 2.5 grams of water needed to be evaporated every 4 seconds.

Physical size: 5 ft. x 8 ft., heating the 5 ft. area with the length determined by the wattage required.
Heated area: 5 ft. x 30 in.
Weight: 2.5 grams
Material: water

Color: n/a
Starting Temperature: 65° F
Specific Heat: 1 Btu/lb/°F
Emissivity: .93

Before going into step 1, the weight in grams had to be converted to pounds per square inch.

Step 1 $\frac{w/hr}{in^2} = \frac{38.27 \times 10\text{-}6\ (1.0)(212\text{-}65)}{3.412}$ $\frac{w/hr}{in^2} = 1.65 \times 10^{-3}$

When doing applications involving water evaporation the latent heat of vaporization must be considered and is determined by the following formula:

$\frac{965Btu/Lb(38.27 \times 10^{-6})}{3.412} = 10.82 \times 10^{-3}$ = Latent heat evaporation

Add the wattage required to raise the heat with the latent heat of evaporation to find the

Total Power Required = $(1.65 \times 10^{-3}) + (10.82 \times 10^{-3}) = 12.47 \times 10^{-3}$ (watt/hr) / in^2

Now that we have the power required we must adapt it to how fast the waters need to be evaporated, which was stated as every 4 seconds, by using the following formula:

warm up time = $\frac{watt\text{-}hour/in^2 \times 60\ min.}{watt/in^2}$

$4/60 = \frac{12.47 \times 10^{-3}(60)}{watt/in^2}$ $watt/in^2 = \frac{12.47 \times 10^{-3}(60)}{4/60} = 11.223\ watt/in^2$

Now that we have this information we are ready to solve for emissivity.

Step 2 $e = \frac{1}{(1/.9 + 1/.93\text{-}1)}$ e =.84

Using the emissivity we move to the Stefan Boltzmann formula.

Step 3

$$T_1 \sqrt[4]{\frac{11.223}{(.84)(36.58072 \times 10^{-12})} + (332.5)^4} \quad {}^{\circ}K$$

T2 = (65+212)/2 = 332.5 Deg. K

A graph may be used to determine the element wattage required to reach the identified source temperature. Graphs such as this can be found in our Technical Manual or on our Internet website. In this case our 951°F indicates that we use 800-1000 watt FTE size elements. I chose to specify FTE-1000 elements knowing that they are a standard and typically stocked element.

Working with our heated area of 5 ft. x 30”, and using FTE-1000 elements, spaced as recommended, we would need 91 elements. The customer stated no special zoning was required. Are you ready for the **challenge**?