Temperature vs. Heat Loss In a Heater

We often get questions regarding how much power (or wattage) is needed to maintain a process at a certain temperature. That is a complex question. In this article, we will discuss the general concepts that are used to determine wattage needs.

Energy Balance

First, we start with a simple energy balance.

$$\dot{E}_{in} = \dot{E}_{out}$$

$\dot{E}_{in}$ is the rate of energy coming into the system. This is the wattage that is generated by the heater when an electrical current is passed through a resistance element inside the heater. Every heater is stamped with a wattage and a voltage. So energy coming into the system is a variable that can be controlled.

$\dot{E}_{out}$ is the rate at which energy that leaves the system. $\dot{E}_{out}$ is often what we want to determine because we can control $\dot{E}_{in}$ (the rate of energy coming in) and set it equal to this value. This consists of energy that is input into the process and leaves the system e.g., plastic is melted, formed into a part, and then ejected from a machine. The heat that is absorbed by that plastic leaves the system. $\dot{E}_{out}$ also consists of power that is lost to the surroundings and is not used by the process. We call this *waste heat*. So we need to determine both of those components. Power lost to the atmosphere can be approximated using heat loss graphs that are readily available online. In most cases, a wide variety of surface conditions, temperatures, insulation thicknesses are plotted on these graphs. The end result of this calculation should yield a rate of energy loss (typically in Watts) that is lost to the surroundings.

Rate of Energy Consumption

Next, we'll look at the rate of energy consumption of the process. This is often much more complicated to determine.

For Example…

Let's look at a process where we heat a chunk of Polypropylene plastic from a temperature of 100^0C to melting temperature (175^0C). We are going to process one of these blocks of plastic every 15 minutes.

The correct equation is :

$$\dot{E} = \frac{m\, c_p\, \Delta T}{t}$$

where,

$\dot{E}$ = power required (Watts)

m = mass (kg) [25 in our example]

c_p = specific heat (Joules/kg ^{0}C) [1,920 in our example]

ΔT = change in temperature (^{0}C) [75 in our example]

t = time (seconds) [900 in our example]

Using the numbers above, we calculate that E = 4,000 which means we need 4,000 watts for this process. We can now add this 4,000W to the heat lost to the surroundings that we found on the appropriate heat loss curve. That will give us a total steady-state wattage that we need to keep our process functioning.

Some Important Notes

- Start up time is often an important consideration for selecting heaters.
    - Using the simple example above if we wanted to heat the same mass of polypropylene from room temperature to melting temperature in the same amount of time we would need more wattage.
- No matter what the calculations say, it is a good idea to add 20% to this power requirement as a "safety factor" when sizing heaters. Why?
    - It is always good to allow for some error in the calculations.
    - Heater lifetime is improved if the heater does not run 100% of the time. 75-80% run time using a short cycle time is ideal.

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