

DETERMINING PROPER HOLE SIZE FOR **HIGH DENSITY CARTRIDGE HEATERS**



One of the primary uses of High Density Cartridge (HDC) heaters is inserting them into holes machined into a metal block. Determining the proper hole size for an HDC heater is an important design consideration in any application that will use an HDC heater. This article will explain the physical and thermal considerations when determining the proper hole size.

PHYSICAL CONSIDERATIONS WITH HOLE SIZE

The important physical consideration with determining appropriate hole size is making sure that it is possible for the heater to be inserted and removed from the hole. If the hole is machined too small, it will not be possible to insert a heater.

There are two dimensions that must be considered to determine the minimum hole size to accommodate an HDC heater:

1 The maximum OD of the HDC heater

2 The maximum camber of the HDC heater

Additionally, it is recommended to add an extra 0.002" to the hole size to ensure not too much force is required to insert and remove the HDC heater. The minimum hole size can be calculated with the following equation:

$$\textit{Minimum Hole Size} = \textit{Maximum OD} + \textit{Maximum Camber} + 0.002''$$

Below is a sample calculation for a 6" long, 1/2" nominal OD HDC heater:

- **Maximum Camber for a 6" long HDC heater:** 0.005"
- **Actual OD for a 1/2" HDC heater:** 0.496" ±0.002"

$$\textit{Minimum Hole Size} = 0.498'' + 0.005'' + 0.002'' = 0.505''$$

From this it is determined that the minimum hole to accommodate this heater is 0.505".

THERMAL CONSIDERATIONS IN HOLE SIZE

Although having a larger diameter hole is beneficial for easy insertion and removal of an HDC heater, larger holes leave more of an air gap between the HDC heater and the material being heated. This air gap reduces the efficiency of heat transfer between the HDC heater and the material being heated since air is a good insulator. Therefore, it is important to choose a hole size that is appropriate for the operating temperature and watt density of the HDC heater. "Fit" is the parameter used to determine the maximum hole size that can be used with an HDC heater. The "Fit" determines how much of an air gap there is between the heater and the hole and is calculated with the following equation:

$$\textit{Fit} = \textit{Maximum Hole Size} - \textit{Minimum Heater OD}$$

To determine the proper "Fit" to ensure efficient heat transfer, first the watt density of the heater must be calculated with the following equation:

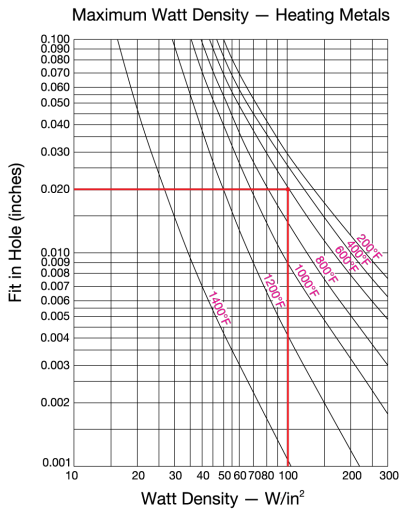
$$\text{Watt Density} = \frac{\text{Heater Wattage}}{\text{Heated Length} \times \text{Heater Diameter} \times \pi}$$

Continuing with the example of a 0.496" ±0.002" OD, 6" long HDC heater, assume the operating temperature will be 600°F, the heater is rated for 800W, the actual heated length is 5", and that the HDC heater is being used to heat a mild steel block.

Using the above formula, the watt density of this example heater would be:

$$\text{Watt Density} = \frac{800W}{5" \times 0.496" \times \pi} = 103 \frac{W}{in^2}$$

Then, utilizing the following chart the watt density and operating temperature of the example heater can be applied to determine a "Fit" of 0.020" is suitable.



NOTE: This chart is based on a heater installed in an oxidized mild steel block, with the thermocouple ½" from the hole. Values need to be adjusted for other materials and sensor locations.

Using the equation for "Fit" the maximum hole size required in this application can be determined:

$$0.020" = \text{Maximum Hole Size} - 0.494"$$

$$0.020" + 0.494" = \text{Maximum Hole Size} = 0.514"$$

Now it has been determined that for the example heater and application a maximum hole size of 0.514" and a minimum hole size of 0.505" would be appropriate. One option to achieve a hole in this size would be to ream a hole to 0.506" ±0.001". This hole size is close to the minimum so it will provide excellent heat transfer since the "Fit" will be smaller than what it required in this case. Another option that might be more economical than reaming a hole would be to just drill a hole. In this case a 13 mm drill, since the 13 mm size translates to 0.5118", would also work.

SOLUTIONS IF REQUIRED HOLE SIZE IS IMPRACTICAL

In some cases, especially if the operating temperature and watt density of an HDC heater are high, a very tight "Fit" might be required for proper heat transfer. In these cases, it may be impractical to machine the hole size for the HDC heater that satisfies both the thermal and physical requirements of the application. Some solutions in this case would be:

- Centerless grind the HDC heater to a tighter OD tolerance
- Lower the HDC heater wattage and allow for a longer heat up time
- Lower the HDC heater wattage and increase the number of heaters used
- Increase the size of the HDC heater to lower the watt density

In conclusion, choosing the proper hole size is essential for both easy installation and obtaining proper heat transfer when using an HDC heater. Both of these design considerations should be accounted for when designing a system that will use HDC heaters.

This article is dedicated to the original author, Ryan Fulmer.