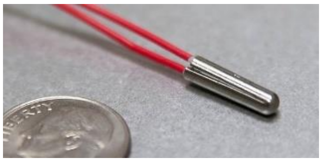
SunRod 1/8" and 4mm Micro Cartridge Heaters



Specifications & Ordering

Voltage, Amperage, Wattage

Size	Max Volts	Max Amps	Wattage Tolerance
1/8" & 4mm	120	4Amps	+/-10%

Electrical Specifications

* Wattage Tolerance for heaters under I" long is+/- 15%

Minimum/ Maximum Wattages by length@ 24 volts*

@Length	I/2"	3/4"	I"	I 1/2"	2"
Min/ Max Wattage*	4 / 100	3 / 100	2 / 100	I / 100	½ / 100

Mechanical Specifications

* Minimum Wattages at Other Voltages
240 Volts: multiply by I00 — 48 Volts: multiply by 4
120 Volts: multiply by 25 — 12 Volts: multiply by .25
See **"SunRod Power Chart"** to determine max wattage at temperature

Standard Features

Diameter and Length

Size / Actual Diameter/ Rec Bore ID	Min Length	**Max** Length
1/8" / .120" to .124" actual / .125"	1/2"	**8"**
4MM / .153" to .1565" actual / .1575	5/8"	**8"**

Length Tolerance: +/-3% of length, with a 3/64" minimum

Lead Configurations and Cold End Length

- **Standard Lead Wires (all insulations rated to 500 degrees°F)**
  - 12" #24 gage stranded nickel, Fiberglas insulated
  - 12" #24 gage stranded nickel, Teflon insulated
  - 2 ½" #24 gage solid nickel, bare or silicon rubber insulated
- **Cold End Length**
  - .25" at lead exit end of heater

To Order SunRod Cartridge Heaters:

Specify:

- **Quantity**
- **Sheath Diameter**
- **Sheath Length**
- **Wattage**
- **Voltage**
- **Lead Length**
- **Lead Insulation**

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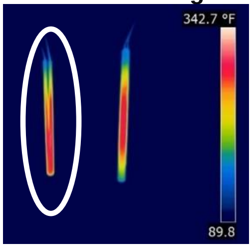
SunRod Micro Cartridge Heaters

Design Guide for Heating Metal Parts



(Backer Hotwatt Patented SunRod split sheath technology, offering temperature uniformity and hot tip)

Using the SunRod Power Chart

Use the SunRod Power Chart at right to determine the temperature/ fit/ watt density parameters for your application.

I. Establish the desired temperature of thepart to be heated.

2. Establish the fit of the heater in the partto be heated by subtracting the minimum heater diameter from the maximum possible bore diameter.

3. Enter the chart with two known parameters (typically, desired Part Temperature and Fit), to determine thethird parameter (maximum watt density).

4. Calculate the actual watt-density of yourheater, based on heater size and actual wattage requirements of your application. (see "Formula for Calculating Watt-Density, below).

5. Read maximum allowable watt-density at the intersection of your application's temperature and fit. For example, the maximum watt-density of a SunRod operating at a Part Temperature of 300 degrees F with a fit of .004 inches is 525watts-per square inch.

6. If your heater's calculated watt-densityexceeds the maximum allowable from the chart, consider using more, longeror larger SunRods to reduce it.

SunRod Power Chart

Part Temp	*Fit in bore of metal part*						
(Deg°F)	.003	.004	.005	.006	.007	.008	.009
200	700	525	425	365	320	275	250
300	660	475	400	340	300	260	225
400	590	440	360	310	270	235	190
500	550	390	325	275	240	225	180
600	460	360	280	245	215	190	160
700	380	320	250	225	190	160	140
800	300	240	210	175	160	145	130
900	250	210	175	160	140	130	115
1000	210	170	145	130	115	105	95
1100	175	145	125	110	*95*	90	82
1200	120	105	95	82	78	72	66
1300	92	I05	78	72	60	*55*	52
1400	58	80	47	42	39	36	34
	Recommended Watt-Density						

Chart Correction Factors

Aluminum or Brass Block: Assume .0015 larger fit
Stainless Steel Block: Assume I00F higher temperature
Cycling more than once a minute: Use 70% of watt-density
Cycling more than once an hour: Use 80% of watt-density

Formula for Calculating Watt-Density

Watt Density = Wattage

Sheath Length - Cold End x Sheath Diameter x 3.14

Cold End = .250 at Conductor End-

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Extending Micro Cartridge Heater Life

Designing cartridge heaters with reduced watt-density multiplies service life.

The industry-standard warranty for electric cartridge heaters is 2000 hours, or one year onsingle shift. This is a reasonable life expectancy for many applications.

But some applications demand much more. Life expectancies of five, seven or even ten years are not unreasonable for some mission-critical applications:

- Blood warmers used in medical theaters must never fail;
  Battery conditioners for EVA spacesuits on the International Space Station must last ten years before replacement, due to payload costs;
- Here on earth, high throughput semiconductor chip testers must operate withoutsignificant downtime for the 5 year life of the equipment.

For these applications, a service life of 50000 to 90000 hours is a requirement that is bothreasonable and attainable.

How can it be done?
For every heater power loading (See "Calculating Watt-Density", at bottom) there is a maximumoperating temperature that will guarantee 2000 hours life. This is the "Critical Temperature" for that power loading. (See chart below)

Power Chart - System Temperature versus Maximum Watt-Density

Critical Temperature	200	300	400	500	600	700	800	900	1000
Maximum Watt-Density	365	345	310	275	245	225	170	150	130

Go above the Critical Temperature by I00 degrees and life will be cut to a third, to 666 hours. But go *below* it by I00 degrees and heater life will be tripled, to 6000 hours! We can use this relationship to determine the watt-density at a given system temperature that will yield thousands of hours of extra life.

For Example...
Let's suppose that your system requires a processing temperature of 500 degrees F with an input power of 80 watts. A I/8" by I" cartridge heater could provide the necessary wattage and would have a power density of 270 watts-per-square-inch. As can be seen from the power chart,a heater with a power loading up to 275 watts per square inch would be acceptable. Heater life would be a respectable 2000 hours.

Processing Temperature ↓

Critical Temperature (F)	200	300	400	500	600	700	800	900	1000
Maximum Watt-Density	365	345	310	275	245	225	170	150	130

Maximum Watt-Density ↑

But what happens if we use a utilize a 1 ¼" heater, just a¼" longer? The heater's power loading is lowered to 210 watts-per-square-inch. The Critical Temperature is raised by 200 degrees. The heater is now operating 200 degrees *below* the new Critical Temperature and heater life is increased to 18000 hours (2000 hours x 3 to the 2^{nd})!

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Processing Temperature ↓ -200 F ↓ New Critical Temperature

Critical Temperature (F)	200	300	400	500	600	700	800	900	1000
Maximum Watt-Density	365	345	310	275	245	225	170	150	130

Maximum Watt-Density ↑ ↑ Lowered Watt-Density

How Do You Reduce Watt-Density? (First, the Good News...)
Your heater watt density may not have to be reduced. Many miniature heating applications inherently require relatively little wattage, due to their small mass. This often results in a minimal power loading on a 1/8" miniature heater. In these cases, miniature cartridge heaters areoften under-loaded by 200 to 400 degrees, relative to the Critical Temperature. Their 2000 hour life expectancy may be multiplied up to 81 times!

Increasing Surface Area to Reduce Watt-Density

1. Maximize your heater length. Increasing the length of a 1" heater to 1 ¼" (just a ¼") can increase the active area* by 33%, reducing power loading by 25%.
2. Consider using more heaters. Two heaters dividing the load will reduce watt-density by 50%.
3. Take advantage of any available space to install a supplemental heater. Adding a ½" long heater to an existing l" heater can reduce power loading by 25%.

Calculating Watt-Density
Watt-density is the power loading of the heater, expressed in watts-per-square-inch of active heater surface.

*The formula for active area surface is: (Heater Length - Cold End Length) x Diameter x Pi.For a 1/8" diameter by l" long heater it is: (1.00 - 0.25) x .38, or .285 square inches.

The formula for watt-density is: Wattage/ Active Heater Surface
For 1/8" diameter by l" heater at 80 watts, this is: 80 watts/ .285 in sq or 270 watts/sq inch.

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SunRod Micro Cartridge Heater
Technical Brief

Element Resistance and Its Affect on Heater Life

1.0 General

This will describe the causes and effects of resistance changes during the operation of l/8" cartridge heaters. Their affects on heater performance and heater life are described. It also describes methods forensuring acceptable performance and for maximizing heater life.

The type of heater being discussed is a metal-sheathed cartridge heater, electrically insulated with compacted Magnesium Oxide, with a helical resistor embedded within. The resistor is an 80 percentnickel and 20 percent chromium alloy, such as Kanthal-80 or Chromel-A.

Four causes for variable resistance are described:
- Variations in the as-manufactured resistance of the heater;
- Permanent increase on first heat up;
- Transient increase with each heat up;
- Gradual Permanent increase due to "Aging".

Except for variations due to manufacturing tolerances, all of the above affects are directly related to the operating temperature of the heater's internal resistor element. It is important to remember that the temperature of the internal resistor element the temperature can be as much as 200 degrees C higher than the system temperature.

2.0 Variations in As Manufactured Resistance

The resistance of an electric heater is typically subject to a manufacturing tolerance. Miniature cartridge heaters have a standard tolerance of minus 10 percent to plus 15 percent.

Tighter tolerances are available, depending on heater length. With special processing, 1/8" cartridge heaters may have a minimum tolerance of plus / minus 7 percent.

Where heaters are used in pairs, it is often possible to sort them by resistance to create matched pairswhose resistance varies only by one or two percent.

3.0 Permanent Resistance Increase on First Heat Up

The initial heat up of the heater (as received from the factory) results in a permanent increase in resistance, typically between 2 percent and 6 percent. This is due to oxidation of the resistor and to therelieving of stresses created during fabrication of the heater. As a result, a I 00 ohm heater (as manufactured and measured at room temperature) may return to room temperature as a I 04 ohm heater. The exact increase is dependent on the temperature reached.

Subject to manufacturing variations from system to system, this increase is repeatable and can usually be determined by customer testing.

4.0 Transient Resistance Increase

With every heat up, the resistance of the heater will increase as much as 6 percent. This is due to the coefficient of resistivity of the Nichrome resistor. This increase is linear in the range between O degrees C and 500 degrees C, and is superimposed on the permanent increase described in 3.0 above.

As a result, a I04 ohm heater at room temperature may actually have a resistance of I 07 ohms at operating temperature. The amount of change depends on the end operating temperature of the heatingelement within the heater. Subject to manufacturing variations from system to system, it is repeatable and may be determined by determined by customer testing.

5.0 Aging

Aging is a process of oxidation of the resistor alloy within the heater which causes an increase in the resistance of the heater. At elevated temperatures, it can be a key factor determining the service life ofthe heater.

5.1 Aging due to oxidation at elevated temperatures

1/8" cartridge heaters are typically insulated with Magnesium oxide which, when compacted, has a porosity of 10 to 15 percent. Oxygen which finds its way into the insulation combines preferentially with the chromium at the surface of the internal resistor wire. A dense, adherent oxide layer is created, which is designed to protect the underlying metal. The protection provided can be defeated under someoperational circumstances, such as operation at temperatures above 600C, where oxidation of the resistor occurs more aggressively.

5.2 Aging due to Thermal Cycling

Thermal cycling occurs during several points of operation:

- During each heat up and cool down of system;
- During "steady state" operation, as changes in process loading occur;
- During "steady state" operation as the heater controller strives to maintain set point temperature byturning the heater on and off (however rapidly).

The rates of expansion of nickel-chromium alloy and its protective chrome oxide are not identical. Asa result, with each heating/ cooling cycle, cracks may open in the oxide layer, exposing the underlyingmetal to further cycles of oxidation. Additional chromium migrates to the exposed surface to combinewith oxygen. If this continues aggressively, the alloy is locally depleted of chromium and oxygen begins to attack the remaining nickel. Operation at temperatures above 600C accelerates this affect.

6.0 Affect on Heater Serviceability

6.1 Increases in Heater Resistance During Operation

Oxidation causes heater's resistance to progressively increase. During service at extreme temperatures, heating capacity may be reduced until it reaches a point where the demands of the process can no longer be met.

Use conservative power-loadings on the surface of the heater to reduce internal element temperatures. At temperatures below 300 degrees C oxidation occurs very slowly. Additionally, the amount of thermal expansion / contraction of the element is reduced.

Minimize thermal cycling by the use of control methods that energize /de-energize the heater rapidly (typically within a period of a few seconds). This allows the thermal inertia of the heater to dampen temperature changes. Avoid using mechanical relays, which can rapidly wear out at high cycling rates.

Customer testing is recommended. This includes accelerated, "worst case" testing to determine the maximum rate of resistance change during service. Heater manufacturers may also perform life testing on behalf of customer.

6.2 "Hot Spots"

Aging may occur locally, raising the resistance of the internal element in isolated segments of the heater. Areas of severe local over heating are sometimes visible as "hot spots" on the surface of the heater. In larger heaters (cartridge and tubular heaters ¼ inch diameter and up) hot spots may appear onthe surface of the heater and cause uneven heating in the system.

Local overheating can shorten heater life as effectively as overall overheating. Therefore, it is important to ensure consistent temperatures over the entire length of the heater body.

In 1/8 inch diameter cartridge heaters, the localized high temperature at a hot spot may not reach thesurface of the cartridge heater. The greater thermal mass of the heater relative to that of the resistor(typically 30: 1), dampens the local temperature difference. The mass of the system being heated enhances *this* effect. This is especially true for short (3/4" long) cartridge heaters, in which the designed hot zone itself may be just 1/2 inches long.