W A T L O W

FIREROD® CARTRIDGE HEATERS

PROVIDE QUALITY AND ENGINEERING EXPERTISE FOR YOUR MOST DEMANDING APPLICATIONS

Four Questions To Ask When Selecting Your Cartridge Heater Supplier

1. *Does my cartridge heater supplier provide a complete product and service package?*

2. *Can I be sure I'll get the products I need, when I need them?*

3. *Is my cartridge heater supplier building the best product possible?*

4. *Does my cartridge heater supplier provide application assistance to solve my heating problems?*

Selecting cartridge heaters for industrial applications should involve more than just specifying temperature and power requirements. Today's users benefit when their cartridge heater supplier can provide:

- Custom design for specific applications
- On-time delivery
- A quality product for maximum performance
- Expert technical assistance

Watlow began answering these cartridge heater needs in 1954, when we designed and manufactured the first swaged cartridge heater — the FIREROD® — and revolutionized the heating element industry.

We have continued to meet our customer's most challenging needs with ongoing research and technological improvements; solving your toughest heating problems through quality products, engineering assistance and fast delivery.

1. *Does my cartridge heater supplier provide a complete product and service package?*

Watlow does.

- Watlow is the only designer and manufacturer to offer single source thermal system capability with our complete line of heaters, sensors and controllers. You are assured of Watlow quality in each system component.
- Continuous product testing is one way we ensure quality at Watlow. Our commitment to Total Quality and World-Class Manufacturing programs also leads to continual product improvements for the FIREROD heater.
- Prototype testing is often performed for special customer applications, such as unusual zoning, temperature response and special life requirements. Based on test results, Watlow can recommend the proper operating conditions to ensure long heater life while providing optimal performance.
- Watlow is a certified cartridge heater supplier for many major industrial manufacturers, having passed stringent quality and delivery tests.
- Watlow's worldwide sales and distributor networks provide instant access to expert technical advice, application assistance and after-the-sale service.

2. *Can I be sure I'll get the products I need when I need them?*

Watlow says yes.

Product availability is recognized as industry's single biggest problem in maintaining demanding production schedules.

Watlow offers several delivery programs, such as Same Day Shipment, Just-In-Time and Ship-To-Stock, that allow you to reduce heater inventories as well as costly downtime.

Same Day Shipment

Watlow's unique LA — or Lead Adaptor — modification method utilizes a patented lead connection technique permitting same day shipment on more than 150,000 configurations of stock FIREROD heaters and lead combinations. Many orders received by 4 p.m. local time can be shipped same day.

The LA modification begins with a standard FIREROD unit. The heater is stocked on the shelf prior to lead attachment. When the order is received, the stock unit undergoes a patented process and a specially designed cap is swaged onto the FIREROD heater to permanently secure the leads.

Just-In-Time Delivery

Watlow has taken a leadership role concerning your JIT programs. We have special account coordinators who can work closely with your purchasing department to assure that both release and ship dates are closely monitored and met to avoid costly shut downs or delays. Some of our customers send us their production usage schedules and we ensure that the required number of heaters are in their plant, on time.

Ship-To-Stock

Watlow offers ship-to-stock delivery as required by many vendor certification programs. We've established partnerships with a number of customers requiring the quality levels and reliability necessary for these programs to succeed. This has led to instituting specific in-line inspection and test fixtures that duplicate those used by our customers.

Our in-house quality control teams are well equipped to handle your inspection needs.

Emergency Delivery Option (EDO)

Ordering a special or custom-designed cartridge heater doesn't mean you'll have to wait months. Because of our flexible World Class Manufacturing "work cells" for the FIREROD heater line, custom sizes can often be designed and manufactured in three to five working days.

3. Is my cartridge heater supplier building the best product possible?

Watlow is.

FIREROD cartridge heaters from Watlow are built using only the finest materials and construction methods, and are backed with extensive quality assurance programs. The FIREROD's advantages:

Premium Materials

Watlow refuses to take shortcuts. Years of testing have proven certain construction materials and manufacturing methods to yield the best performance for FIREROD cartridge heaters. Following are the standard materials we use.

- The Sheath: Our standard Incoloy® 800 provides high temperature resistance to oxidation and corrosion, proving far superior to 304 stainless steel alloys used by other manufacturers.
- The Insulation: We use only high purity MgO, compacted to a carefully predetermined and closely monitored density. This assures high dielectric strength and efficient, fast heat transfer.
- The Resistance Wire: Our nickel-chromium wire of computer-calculated gauge, length and spacing is wound on a supporting core and precisely centered for uniform temperatures.
- The Lead Wire: Watlow purchases only the finest high temperature wire available from certified suppliers. This ensures wire flexibility and fray resistance, two factors that will reduce lead wire failure and makes installation easier.
- The Pins: High-grade nickel pins assure resistance to corrosion at high temperatures and minimize the chances of embrittlement.

Swaging

Swaging was introduced to the cartridge heater field in 1954 with Watlow's FIREROD heater. This mechanical procedure reduces the diameter of the heater by compacting the unit, directly improving heat transfer efficiency. Swaging compacts the MgO insulation, which increases its thermal conductivity and, also, enhances its dielectric strength.

Swaging also provides these advantages:

- Permits the resistance wire to operate at lower temperatures, a critical factor in longer heater life
- Enables users to achieve process temperatures faster
- Provides more uniform heating to the application
- Reduces energy costs through better heating efficiency
- Makes the heater more durable and more resistant to shock and vibration

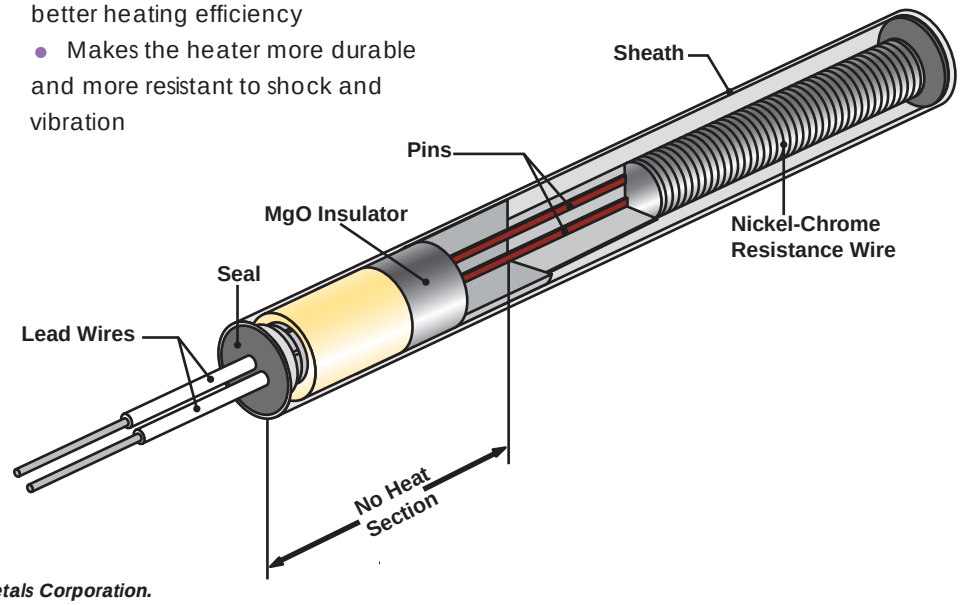
While many cartridge heater manufacturers now swage their products, Watlow has developed its own unique swaging process. This assures consistent heater compaction for longer heater life and uniform temperatures. It also allows us to manufacturer higher watt density heaters.

Smaller "No Heat" Section

Due to our tight manufacturing controls, Watlow can provide the smallest "no heat" section - on both ends of the heater - of any cartridge heater manufacturer. This is true of our stock FIREROD heaters as well.

Various Specifications Available

FIREROD cartridge heaters are available in ⅛-inch to 1-inch diameters and various lengths to cover different applications. Watlow is one of the only companies to offer such a variety of specifications.



Incoloy® is a registered trademark of Special Metals Corporation.

Consistent Quality Standards

Instead of adapting our manufacturing processes to the equipment available, Watlow designs and builds its own manufacturing machinery. As with our customized swaging equipment, this allows more consistent quality and tighter tolerances. It also gives us more freedom when modifying or developing products.

We developed our own MgO fill density equipment, calibrated to our exact needs and designed so that humidity, temperature or other factory conditions will have no effect on the MgO.

Watlow's fill machines are designed to ensure uniform fill thickness which results in better dielectric strength. Our electronic winding machines, engineered and manufactured in-house, provide extremely consistent windings for uniform temperatures.

Consistent quality is also achieved through our own certified supplier programs, which ensure that the materials received meet our standards every time. These "partnerships" with suppliers also allow us to take advantage of advances in materials technology.

4. Does my cartridge heater supplier provide application assistance to solve my heating problems?

Watlow does.

Technical assistance from your cartridge heater supplier can be crucial to the success of your heating application. Premature heater failure often occurs because your supplier doesn't ask the right questions about your application, such as your temperature and watt density requirements, temperature sensing and control systems, even factory environment considerations.

At Watlow, our engineers can help you avoid many of the common causes of cartridge heater failure. We have developed innovative design options to combat the four most common culprits:

- Contamination
- Corrosion
- Overtemperature
- Lead wire failure

CONTAMINATION

1. Overtemperature: The discolored portion indicates part of the heater was operated in open air, rather than being fully inserted in the application.
2. Overtemperature: Resulted in breakdown of insulation, and caused element to short to ground and burn a hole in the sheath.
3. Contamination: External view. Molten plastic has solidified on the heater and the leads.
4. Contamination: Internal view. Notice that more reaction has occurred in the element winding area, where temperatures are highest.
5. Overtemperature of heater and leads: Red insulation boot turned white, and became frayed, which can cause the lead wires to short.

CONTAMINATION

Contamination occurs when foreign materials enter the heater's internal area and cause a breakdown of the element or insulation materials. The contaminants are usually organic and cause either a gross electrical shorting to ground or an accelerated deterioration of the heater's internal elements and/or power leads.

Heaters that are subject to large temperature swings or cycling are most susceptible to ingesting harmful contaminants. When a heater heats up and cools down, it "breathes" air in and out from its surroundings due to the thermal expansion and contraction of the air inside it.

As application temperatures increase, many materials normally considered inert can become quite destructive. Among these are lubrication oils, cleaning solvents, anti-seize lubricants, plastics, fumes, electrical tape adhesives, gases emitted from over-temped lead wire, potting compounds and moisture.

Table 1

Seal Type	Maximum Continuous Operating Temperature
Silicone Rubber	176°C (350°F)
Teflon®	204°C (400°F)
High Temperature Epoxy	260°C (500°F)
Glass Hermetic	315°C (600°F)
Ceramic to Metal Hermetic	537°C (1000°F)
FIREROD HT (high temp.)	593°C (1100°F)
Mineral Insulated Leads	815°C (1500°F)

Teflon® is a registered trademark of E.I. du Pont de Nemours & Company.

Table 2

Sheath Material	Typical Applications
Incoloy® 800 (FIREROD standard)	Excellent for most general applications
304SS	Food and medical; deionized water
Titanium	For highly corrosive atmospheres
Hexoloy® protection tubes	Liquid metals heating/melting

Hexoloy® is a registered trademark of Carborundum Company.

& AND CORROSION

FIREROD heaters can be designed with special seals to resist contaminants. Watlow offers several seal types to handle various application temperatures. (See Table 1).

It is important to realize that the seal or lead end of the heater will not exceed the maximum operating temperature of the seal material. This can be accomplished in one of two ways.

One way is to allow enough natural or forced air convection to cool the area. In other cases, it may be necessary to specify a length of no-heat zone between the heated and the sealed areas of the heater.

Smaller diameter heaters drop in temperature along a no-heat zone at a faster rate than larger diameters. By using Graph A, a good estimate for no-heat zone length can be interpolated for most temperature, seal and heater diameter combinations.

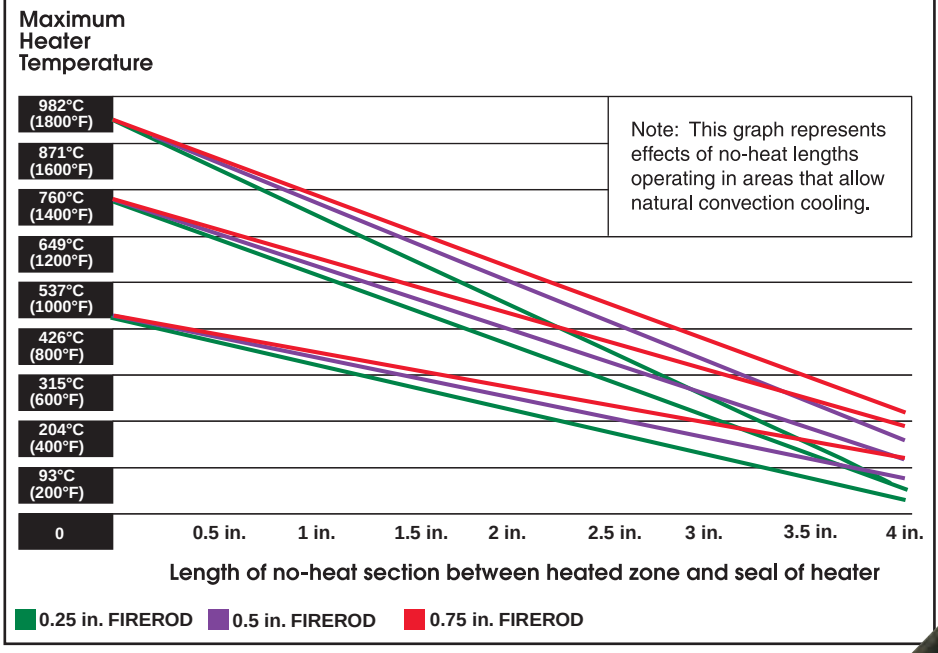
Stored heaters can be protected by keeping the heaters in sealed containers or plastic bags.

CORROSION

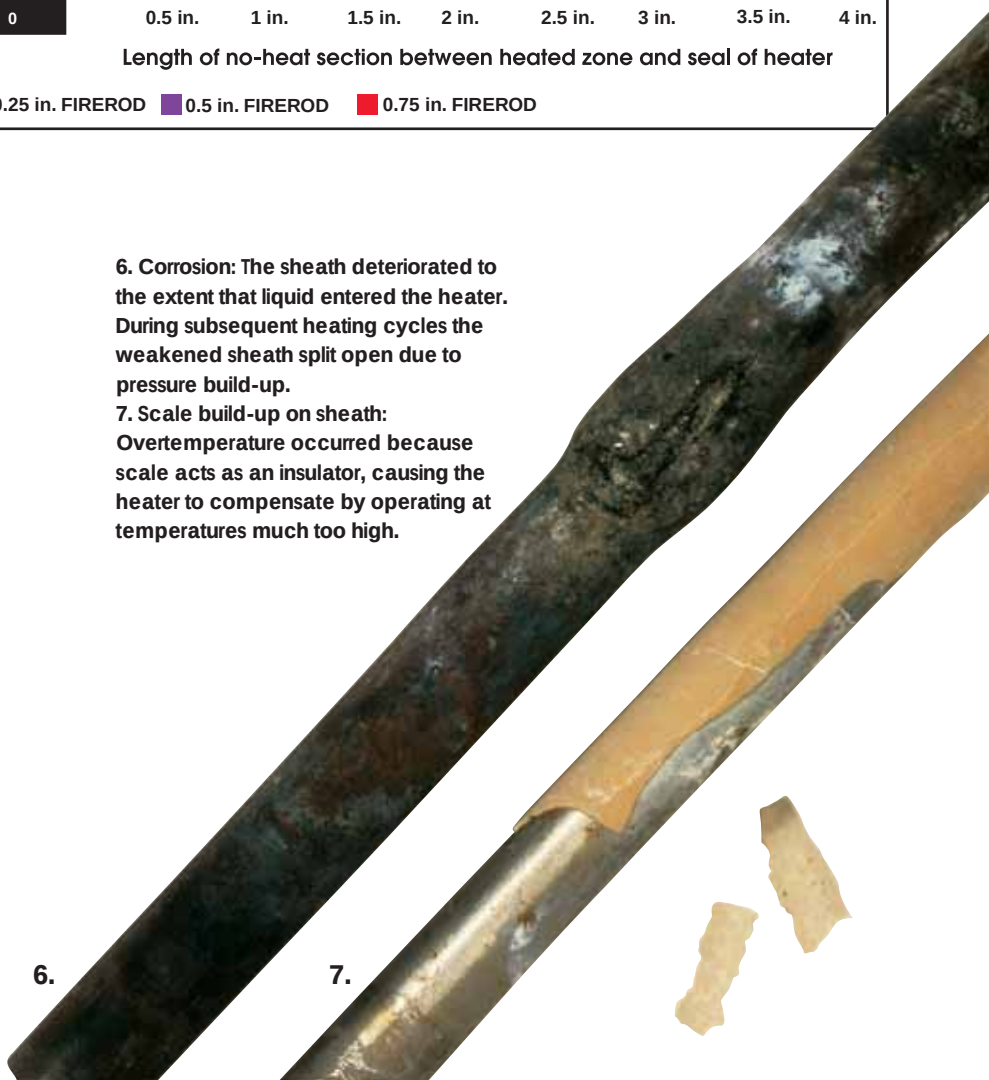
Corrosion occurs when the heater's outer sheath deteriorates, allowing contaminants to enter the heater. Watlow offers several sheath materials to protect the FIREROD from corroding in various environments. (See Table 2).

For certain applications, such as medical and aerospace, Watlow can provide passivated or electropolished heater sheaths.

Graph A: Seal Operating Temperature Versus No-Heat Zone Length



6. Corrosion: The sheath deteriorated to the extent that liquid entered the heater. During subsequent heating cycles the weakened sheath split open due to pressure build-up.
7. Scale build-up on sheath: Overtemperature occurred because scale acts as an insulator, causing the heater to compensate by operating at temperatures much too high.



1204°C (2200°F)
27.29 W/cm² (176.1 W/in²)

1093°C (2000°F)
19.96 W/cm² (128.8 W/in²)

982°C (1800°F)
14.22 W/cm² (91.8 W/in²)

Color Versus Temperature

The chart was created by recreating the colors of Incoloy® sheathed FIRERODs at specific temperatures. Several factors may affect the color, but the chart is a handy reference of color vs. temperature for most metal objects. The power levels indicated were calculated using the Stefan-Boltzman equation for a blackbody source at the temperatures listed.

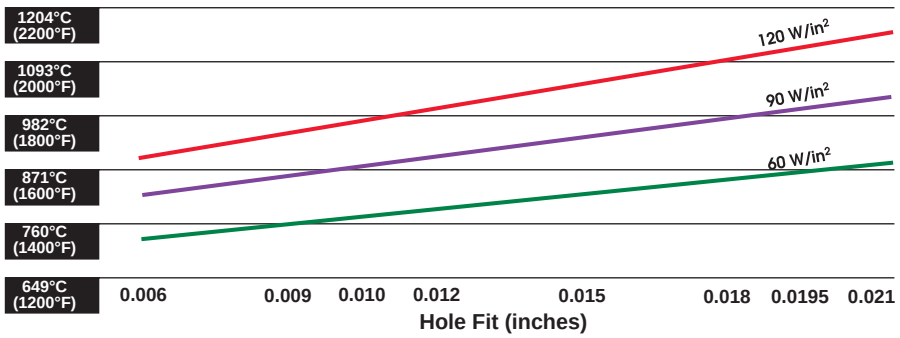
NOTE: Maximum part temperature 760°C (1400°F), maximum watt density 69 W/cm² (400 W/in²).

OVERTEMPERATURE OF THE HEATER

A heater that is forced to operate beyond its maximum operating temperature is destined for premature failure. Extreme overtemperature conditions will cause the heater's internal conductors to melt. Less severe overtemperature conditions will accelerate a heater's normal "aging" process. In fact, operating a heater 37°C (100°F) beyond its maximum recommended temperature can reduce heater life by as much as two-thirds.

Watlow designers optimize the internal construction of your FIREROD based on the wattage and operating temperature you specify. Yet certain conditions can cause the heater to overtemp.

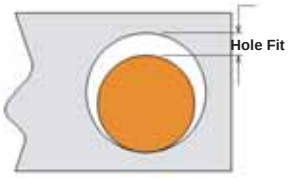
Graph B: How Hole Fit & Watt Density Can Affect Internal Heater Temperature



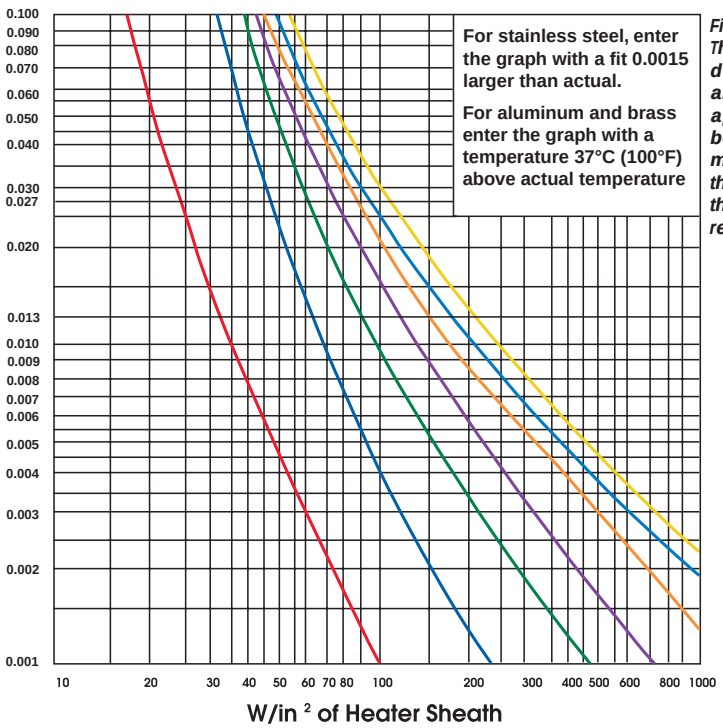
A loose fit causes cartridge heaters to operate at temperatures that are much higher than the part being heated. This is even more dramatic at higher watt densities. Using a tighter hole fit and lowering the watt density will keep the heater's internal temperature low, prolonging life significantly.

HOLE FIT

Overtemperature failure frequently occurs when a heater is placed in a hole that is too large, impeding heat transfer from the heater to the part. Watlow's hole fit graphs (B and C) depict the importance of hole fit, and how dramatically it affects the temperature of the heater's internal components.



Graph C: Recommended Maximum Hole Fit For Heating Metals



Fit = I.D. Hole - O.D. FIREROD
This graph will help you determine the maximum allowable hole fit for your application. Notice that both the heated part maximum temperature and the surface watt density of the heater affect the recommended hole fit.

EXPOSED HEATER SECTION

Allowing part of the heater's heated section to operate in open air can cause the exposed section to rise significantly in temperature, while the part immersed or inserted into the application is kept at the desired temperature.

The solution is to be sure the heated section is fully inserted into your heated part or liquid.

871°C (1600°F)
9.81 W/cm² (63.3 W/in²)

760°C (1400°F)
6.52 W/cm² (42.1 W/in²)

649°C (1200°F)
4.13 W/cm² (26.7 W/in²)

Sensor Location

Poor temperature sensor location is another common cause of overtemperature heater failure. If the controlling thermocouple is placed on the edge of a heated part that runs cooler due to "end effects" of heat losses to atmosphere, the center portions of the heated part can run significantly higher in temperature, forcing the heater to operate well over its maximum recommended temperature. The solution is to place the temperature sensor in the hottest part of the application.

When heating fluids or gases in chambers, the process becomes hotter as it flows through the chamber. Thermocouples at the cooler end of the chamber will be unable to properly control heaters at the hot end, causing early heater failure. One solution is to relocate the thermocouples to the hot end, or to use lower watt density heaters at that end.

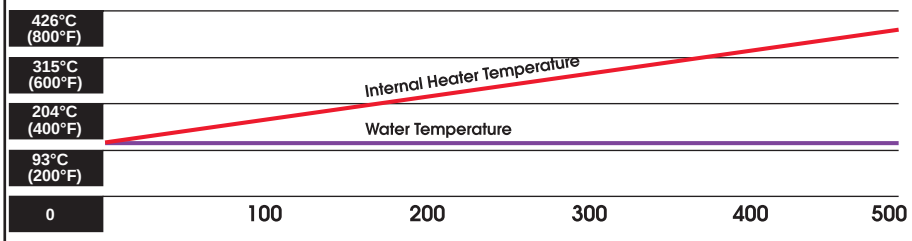
Watlow can also design your FIREROD heater with an internal thermocouple to provide accurate temperature readings. This is especially beneficial for extremely sensitive, zoned or uniform temperature applications. Thermocouples can be located at the disc end of the heater or anywhere along the heater length.

Also, thermostats are available as a high-limit temperature control.

Low Temperature Applications

Surprisingly, overtemperature failure can occur in some low temperature applications such as heating water. Conventional thinking suggests that a heater immersed in liquid should never greatly exceed the boiling temperature of that liquid. But this isn't always the case. (See Graph D).

Graph D: Internal Heater Temperature Versus Watt Density



Sheath Watt Density ($^5/_8$ in. diameter FIREROD in water boiled in ambient conditions)

Graph D shows how water's ability to accept heat from a FIREROD heater changes with watt density. A good rule of thumb for water is to add 1°F for every W/in² of heater surface to the boiling point of water. (Example: On a 200 W/in² heater, internal operating temperature = 200 W/in² + 212° = 412°F).

Heat flow between the heater sheath and liquid can also be impeded by the buildup of mineral deposits on the heater sheath. The heat won't be able to leave the heater, causing its internal temperature to rise dramatically.

Lead Wire Failure

Overtemperature

Placing power leads in a high temperature environment can lead to premature heater failure if the leads aren't properly rated for the application. The binders in the lead wire insulation will bake out and the insulation becomes brittle. Any amount of flexing after this usually causes electrical shorting between the lead wire conductors or a grounded surface.

To combat this problem, Watlow offers six types of insulation for lead wire (see Table 3.)

Table 3

Insulation Material	Maximum Continuous Operating Temperature
Neoprene	93°C (200°F)
Silicone	176°C (350°F
Teflon®	204°C (400°F)
Fiberglass/Silicone (GGS)	249°C (480°F)
Mica/Fiberglass/ Teflon® (MGT)	449°C (840°F)
Ceramic Beads	649°C (1200°F)
Mineral Insulated Leads	815°C (1500°F)

Over-Flexing

Vibration is a frequent cause of lead wire failure. Over-flexing can be prevented by adjusting the lead wires to withstand high vibration, as in a moving or cycling platen or mold die.

To protect the leads, isolate any relative movement of the heater and leads by adding strain reliefs that anchor back to the platen or heated part. You can also allow extra lead length for flexing.

Abrasion

Watlow provides several lead wire types that are ideal for applications requiring abrasion assistance. These include flexible stainless steel overbraid and flexible metal conduit.

Watlow Solutions To Your Heating Problems

Watlow specializes in solving demanding heater applications through customized engineering. Our experience is reflected in our design of over 250,000 different FIREROD heaters for such industries as plastics processing, packaging, medical equipment, aerospace, scientific instruments, semiconductor, foodservice and nuclear power generation.

Solution to complex heating problem

A gas analysis system required a heat source capable of handling temperatures above 649°C (1200°F) and to provide heat to the analyzer head from distances of up to 10 feet. A ¼ -inch diameter, 10 -foot long FIREROD heater was designed with a unique heated zone that included an internal thermocouple and a long no-heat section.

Solution to complex medical standard problem

A manufacturer of blood warming equipment required a heat source with an integral high limit cutoff device as a protective measure for the system. A FIREROD heater was designed to meet UL® specifications for medical equipment. An internal thermostat provided the secondary high limit necessary to prevent the plastic reservoir from melting.

Solution to complex contamination problem

A food processing plant required moisture-proof cartridge heaters that could operate at temperatures higher than Teflon® 204°C (400°F) and potted seals 60°C to 260°C (140°F to 500°F). To eliminate the extra steps required to protect heater leads from moisture contamination during high-pressure hose washdown, Watlow recommended the FIREROD with M.I. lead temperature capability to 815°C (1500°F).

Solution to response time problem

A food packaging machine manufacturer needed to apply heat to an adhesive-backed paper lid and seal it onto the mouth of a plastic container. By concentrating the heat only around the edge of the container, none of the dairy product inside the container would be affected by the sealing process.

UL® is a registered trademark of Underwriter's Laboratories, Inc.

An additional problem with the application involved the high throughput required for the machine, making the duration of heater contact less than one second. A FIREROD heater was designed with a centerless ground sheath for good hole fit and heat transfer, and a special fill material in the heater to greatly increase the heater's thermal conductivity.

Solution to complex military Standard problem

A small, high watt density FIREROD cartridge heater was designed to provide freeze protection on a radar guidance system used on missiles. The application had space limitations, but more importantly, the heat source had to meet pages of military standards. These specifications covered everything from the type of nickel wire to be used to complex test criteria.

Solution to high temperature requirement problem

A custom manufacturer of titanium expanders for the aircraft/aerospace industry required heat in order to form thin walled titanium tubing into missile nose cones. The application required a uniform die temperature operating at 760°C (1400°F). Multiple HT (high temperature) FIREROD heaters with zoned wattage were chosen because of the die and the even higher internal temperatures. Also, a special HT seal reduced the amount of oxidation and corrosion of the resistance wire thus prolonging heater life.

Solution to temperature uniformity problem

Uniform temperature profile is critical for the large sealing bars of vertical and horizontal wrapping machines. Watlow conducted testing to determine the proper heat zoning needed to compensate for heat losses at the ends and at the machinery clamps. A FIREROD cartridge heater with special distributed wattage was designed, providing the extremely tight profiles required by the packaging equipment manufacturer.

Solution to space limitation problem

A commercial sign producer needed a means to apply heat to an extremely small stylus used to cut vinyl. Watlow engineers solved the application using a ⅛-inch diameter FIREROD with an internal thermocouple for temperature control.

Solution to corrosive environment problem

A high-speed photographic film processor required a heat source to maintain stringent developer temperatures, despite the highly corrosive nature of these solutions. In addition, the system design provided limited space. Watlow engineering designed a FIREROD heater with a passivated 316 stainless steel sheath and a unique flanged mounting method.

Solution to low current leakage specifications

A FIREROD heater with its high watt density capabilities was designed for a compact, mobile hyper/hypothermia system. The heater was required to meet UL® specifications for low current leakage under the guidelines for medical equipment.

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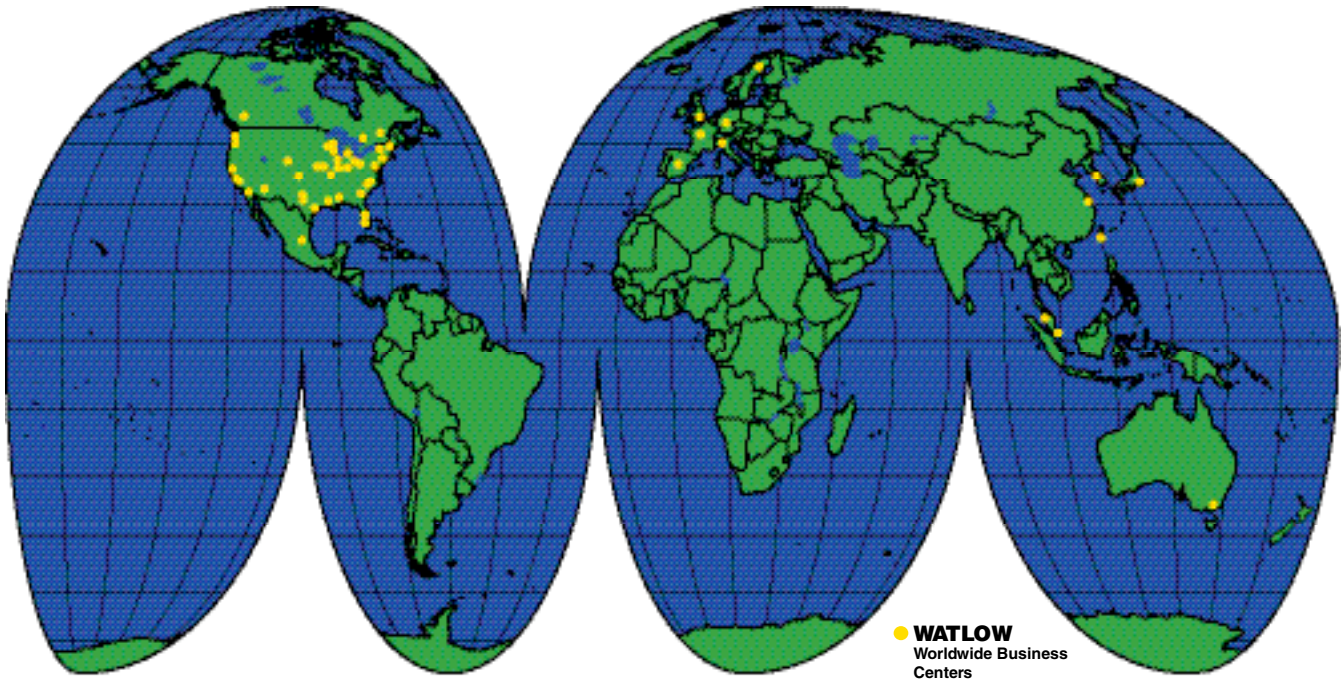

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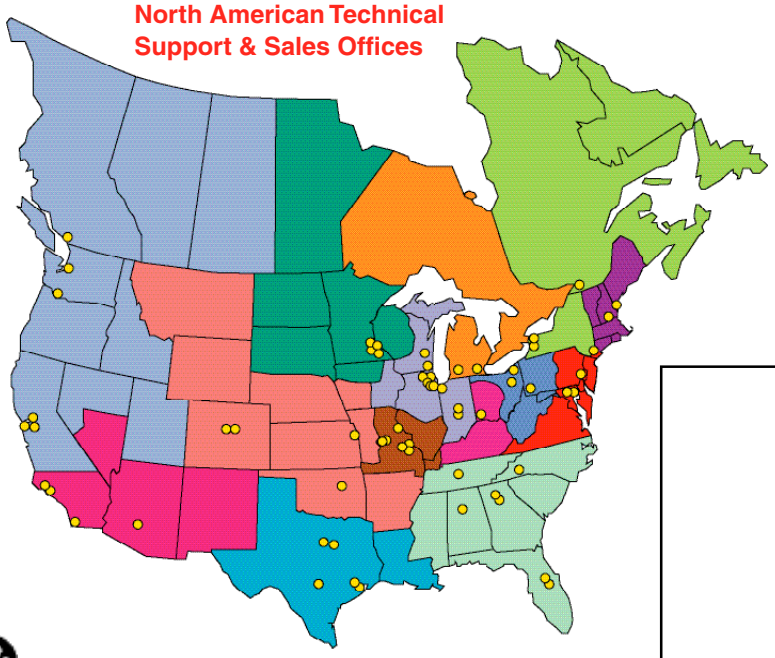

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