

## Cast-In Heaters

### The Heated Part Concept

Watlow's heated part concept can help simplify many complex heating problems.

The heated part is much more than a heater ... it is a functional component of equipment that can be designed in the exact shape and size needed. The heated part from Watlow is available two ways: as a one-piece cast-in aluminum heater assembly, or as an interference fit (IFC) design.

Utilizing Watlow's heated part can alleviate time-consuming tasks such as purchasing, assembly or machining of parts. Customers can concentrate on meeting the other manufacturing challenges.

The heated part consists of a formed cable or tubular heater cast into aluminum. For high temperature applications, Watlow offers an interference fit into other material such as stainless steel. The part is then customized to meet specific application needs including machining, termination, coatings and assembly.

From state-of-the-art CNC machines to the high tech research lab, Watlow invested in the technology necessary to develop high quality custom heat solutions.

Watlow's heated parts are manufactured by Watlow's ISO 9001 registered facility in Batavia, Illinois.

#### Performance Capabilities

- Operating temperatures: up to 752°F (400°C) with 319 or 356 aluminum
- Operating temperatures: up to 842°F (450°C) with 99.7 pure aluminum
- Operating temperatures: up to min. 1112°F (600°C) with stainless steel (IFC) designs

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#### Features and Benefits

- **Watlow's complete foundry capabilities** assure precise and uniform placement of the element in the casting.
- **UL® component recognition** on cast-in heaters is available exclusively from Watlow.
- **ISO 9001** registration at Watlow's Batavia, Illinois, manufacturing plant assures quality management control from product design through production and servicing.
- **Patented pressure-casting system** produces castings with low porosity for better heat transfer. The system also minimizes internal

voids and defects by precisely controlling molten metal temperature and feed rate.

- **Optional cast-in tubing** provides faster cooling or can be used to heat liquids or gases that run through it, functioning as a circulation heater.
- **High thermal conductivity** of aluminum provides extremely uniform surface temperatures to avoid damaging hot or cold spots when operating the heaters.
- **Reusable molds** are economical and provide excellent part-to-part uniformity.

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#### Benefits

- Strong engineering support from concept through production
- Extremely tight tolerances
- Thorough documentation on request
- Quick prototypes
- Superb temperature uniformity due to optimum heater layouts and precision mold design
- Long life
- Single piece construction, eliminating need to assemble several components

### Applications and Technical Data

#### Capabilities include:

- CAD/CAM design
- CNC equipment for precision machining and repeatable results from one order to the next
- Metallurgical expertise in foundry practice as well as machining technology
- Lapping machines for smooth finishes and extremely flat surfaces
- CMM (coordinate measuring machines) for in-process and final inspection with printed reports
- Assembly and termination options
- Services such as FEA (finite element analysis)
- Special coatings including Teflon® anodizing and electroless nickel plating
- X-ray techniques to check for porosity-free castings and proper heater location
- Additional treatment of the heated part such as chemical cleaning, and packaging for cleanroom acceptance
- Specially-designed packaging
- MRP scheduling and planning of your deliveries to meet your needs in a timely manner

#### R&D Efforts

To remain at the forefront of technological advancements in the industry, Watlow's heated part facility features a full lab in which extensive product and process research is conducted. One recent example of our R&D efforts has been the development of casting methods and an alloy to match the stringent contamination requirements of the semiconductor industry. Watlow now offers a 99.7 percent pure aluminum alloy with the same porosity-free characteristics of the more typical casting alloys.

On-going laboratory tests at the heated part facility include

- Temperature uniformity
- Heating and cooling ramp rates
- Structural characteristics
- Coating performance

Watlow has created heated parts for a variety of industries including

- Semiconductor
- Medical
- Glue melt
- Foodservice

#### How to Order

All cast-in heaters are **made-to-order**. Please have the following information available when placing an order or requesting a quote:

- Wattage: (see either the WATROD tubular section, **page 273** or

Cable heater section, **page 57**, for engineering information)

- Voltage: Maximum is 550V~(ac)
- Part design: Provide two drawings with all dimensions and critical tolerances
- Heater exit locations

- Electrical termination: Standard threaded studs will be supplied unless other hardware is specified
- Quantity

#### Availability

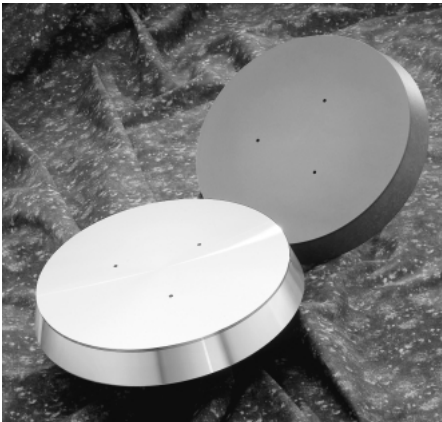
Consult Watlow for design and manufacturing time required.

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## Cast-In Heaters

### The Heated Part Concept

#### Standard Aluminum Pedestal Heater



Watlow now has 200 mm aluminum pedestal heaters in stock to quickly solve wafer fabrication needs. Customers can now save thousands of dollars with off-the-shelf designs since there are no additional costs for engineering, tooling or mold creation. Watlow's pedestal heater design is ideal for prototype machine trials or engineering experiments as well as temporary repairs until custom heaters can be manufactured.

Watlow's pedestal heaters provide a complete turnkey solution available in anodized or bare 356 aluminum with optional add-on features.

The stock anodized cast aluminum pedestal heaters are complete, ready-to-install parts and are available for same day shipment. The bare special configured model can be customized from a list of options and is available with one to two week delivery depending on options selected.

#### Features and Benefits

- **Overnight delivery from stock** reduces downtime and assures a cost effective option for 200 mm wafer processing.
- **Operating temperatures up to 752°F (400°C)** provide world class performance.

- **Temperature uniformity**  $\pm 1.8^\circ\text{F}$  ( $\pm 1.0^\circ\text{C}$ ) at 302°F (150°C) enhances heat transfer.

#### Applications

- Semiconductor processing

#### Specifications

##### Model WR200-1A (Anodized)

- Material: A356 aluminum alloy
- Diameter: 8.93 in (226.8 mm)
- Thickness: 1.25 in (31.75 mm)
- Surface flatness:  $<0.0005$  in (0.0127 mm)
- 3 lift pin holes 0.125 in (31.75 mm) dia. @  $120^\circ$  on 3.25 in (82.55 mm) dia. bolt circle
- 1 thermocouple hole 0.063 in (1.6002 mm) dia.
- 1285W, 208V center exit (1711W/240V max.)
- Temperature uniformity:  $\pm 1^\circ$  @  $150^\circ\text{C}$
- Hard anodize thickness: 0.0015 in (0.0381 mm) per MIL-A-8625, Type III, Class 1
- Cleaning: IPA wipe down

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- Surface flatness:  $<0.0005$  in (0.0127 mm)
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- Temperature uniformity:  $\pm 1^\circ$  @  $150^\circ\text{C}$
- Cleaning: IPA wipe down

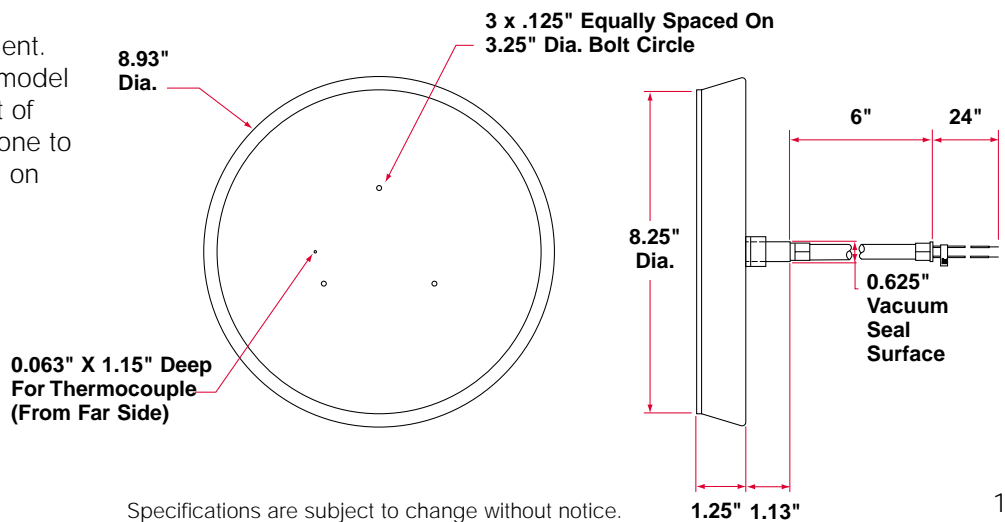
##### Options (available for model WR200-1B)

- 3 proximity pins 0.006 in (0.1524 mm) high
- 3 lift pin holes 0.125 in (31.75 mm) dia. @  $120^\circ$
- 1 thermocouple hole 0.063 in (1.6002 mm) dia.
- Hard anodize thickness: 0.0015 in (0.0381 mm) per MIL-A-8625, Type III, Class 1
- Precision cleaning: backfill  $\text{N}_2$
- Contact your local Watlow sales engineer or the factory to discuss any special options that may be required.

##### Model WR200-1B (Bare)

- Material: A356 aluminum alloy
- Diameter: 8.93 in (226.8 mm)

#### Standard Design

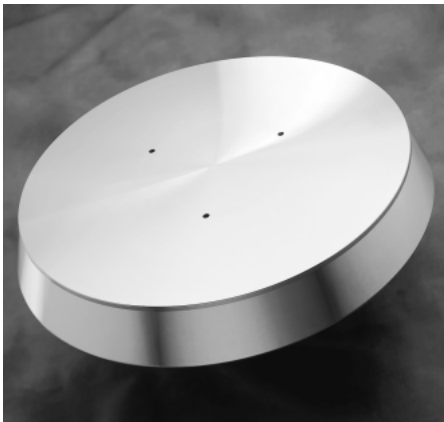


Specifications are subject to change without notice.

# Cast-In Heaters

## The Heated Part Concept

### Pure Aluminum Heated Parts



The need for maintaining an ultra pure environment has led to the development of pure aluminum cast-in heated parts. Watlow now has the capability to cast complex heated shapes in 99.7 percent pure aluminum that limits process contamination and offers increased operating temperatures up to 842°F (450°C).

Pure aluminum cast-in heated parts provide higher maximum operating temperatures over the more typical aluminum casting alloys. This equates to a 25 percent increase in process temperatures, resulting in an additional 194-266°F (90-130°C) operating range. Thermal conductivity is also improved more than A356 alloy.

Designed and engineered to customer specifications, Watlow's low-pressure casting technique and CNC machining ensure consistent quality heated parts. Many types of tubing can be cast-in to produce a circulation heater or add cooling capability for heat/cool applications. With a modern and innovative aluminum foundry on site, and over

75 years of experience in manufacturing heaters, Watlow has refined the technique to allow pure aluminum alloys to be cast with the same precision as more typical aluminum alloys.

Watlow's custom designs are backed by strong engineering support, expert heater knowledge, metallurgical expertise in foundry practice and precision machining using CAD/CAM/CAE and CNC manufacturing techniques.

### Features and Benefits

- **99.7% pure aluminum** allows for increased operating temperatures while reducing the risk of process contamination.
- **Low porosity** provides longer heater life, improved temperature uniformity and fewer defects in machined surfaces.
- **Excellent temperature uniformity** provides better process yields.

### Applications

- Semiconductor processing

## Properties and Characteristics of Aluminum Alloys

AA#	Thermal Properties				Mechanical Properties			
	Solidus Temperature		Thermal Conductivity		Tensile		Yield	
	°C	(°F)	W/m-K	(BTU/ft <sup>2</sup> h°F)	MPa	(ksi)	MPa	(ksi)
<b>Casting Alloys</b>								
319	515	(960)	109	(63)	235	(34)	130	(19)
356	555	(1035)	159	(92)	207	(30)	165	(24)
170.1	646	(1195)	234	(135)	76	(11)	28	(4)

<b>Wrought Alloys</b>								
1100	643	(1190)	222	(128)	90	(13)	34	(5)
5052	607	(1125)	91	(110)	193	(28)	90	(13)
5086	585	(1085)	127	(73.4)	60	(38)	115	(17)
6061	582	(1080)	180	(104)	310	(45)	276	(40)

## Chemical Compositions Comparisons of Common Aluminum Alloys (maximum limits)

AA#	Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Sn	Ti	Other	% Al
<b>Casting Alloys</b>												
319	6.50	1.00	4.00	0.50	0.01	-	0.35	1.00	-	0.25	0.50	85.9
356	7.50	0.60	0.25	0.35	0.45	-	-	0.35	-	0.25	0.15	90.1
170.1	0.05	0.09	0.07	-	0.01	-	-	-	-	0.03	0.10	99.7

<b>Wrought Alloys</b>												
1100	1.0	-	0.05/0.20	0.05	-	-	-	0.10	-	-	0.15	99.0
5052	0.25	0.40	0.10	0.10	2.2/2.8	0.15/0.35	-	0.10	-	-	0.15	96.2
5086	0.40	0.50	-	0.2/0.7	3.5/4.5	-	-	0.25	-	0.15	0.15	94.1
6061	0.4/0.8	0.70	0.15/0.4	0.15	0.8/1.2	0.04/0.35	-	0.25	-	0.15	0.15	96.5

## Cast-In Heaters

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#### IFC Heated Parts



Watlow's new IFC (Interference Fit Construction) heated parts are ideal for applications that require materials other than aluminum or exceed the temperature capabilities of cast aluminum. With FEA (Finite Element Analysis), or if time permits, by an iterative prototyping process, uniformity levels equaling  $\pm 1$  percent of the operating temperature have been achieved. IFC heated parts use the same design logic as cast-in heaters to achieve temperature uniformity. Some important aspects that determine temperature uniformity performance are the material used, the physical shape of the part, the heater placement within the part, and the special shaped groove that is machined into the part to accept a cable or tubular heater. IFC allows the heated part to be customized to meet many specific customer needs over a wide variety of shapes and sizes.

In the past when temperature requirements have exceeded 842°F (450°C), engineers turned to milled groove or brazed assemblies. One of the advantages of the IFC heated part over the milled groove approach or the brazed assembly, is the improved heater life due to the intimate contact of the heater, therefore reducing hot spots. To optimize temperature uniformity and to eliminate the time-consuming iterative prototyping process Watlow offers FEA, which will optimize the design and allow an accurate prediction of the temperature uniformity that can be expected for a specific part.

IFC heated parts may be customized to meet specific customer needs including a multitude of machined shapes, terminations and coating, plus special cleaning. Since Watlow's IFC heated parts are a finished product, no assembly is required. All joints of the IFC heated part can be welded to make it vacuum-tight for use, even in the highest vacuum process levels. Watlow provides strong engineering support from concept through production, quick prototyping and wide range of design parameters.

#### Features and Benefits

- **Wide range of shapes and sizes** allows custom parts to meet specific customer needs.
- **Superior thermal transfer between heater and substrate** provides excellent temperature uniformity and improved heater life.
- **Single piece construction** eliminates the need to assemble several components (no brazing required).
- **Vacuum compatible** for very low contamination (no outgassing).
- **High operating temperatures** greater than 842°F (450°C) (depending on materials used and flatness requirements, consult factory for details).

#### Applications

- Semiconductor processing

#### Available Materials

- Stainless steel
- Nickel
- Inconel®
- Aluminum
- Copper
- Bronze

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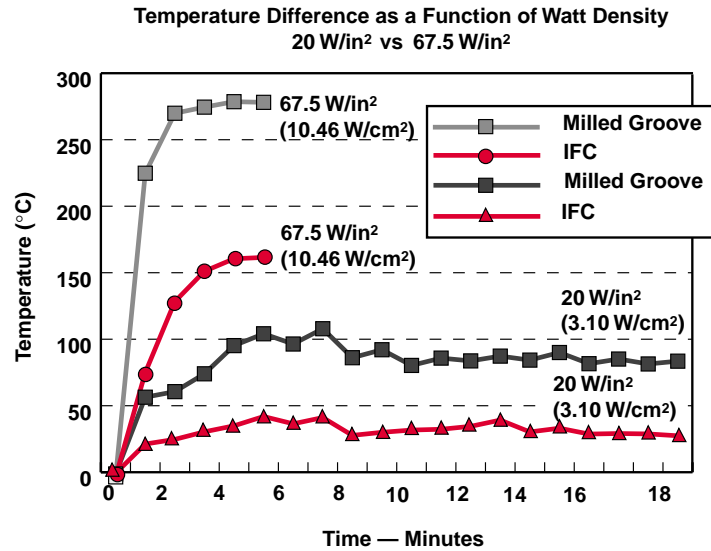
### IFC Heated Parts

Continued

#### IFC Performance Data

IFC heaters improve thermal performance of a heated part by optimizing thermal transfer from heater sheath to the substrate. Testing was performed on two identical platens, one with the heater installed with the IFC method and the other using a typical milled groove construction. The test demonstrated the delta that exists between the heater sheath temperature and the platen substrate temperature at different watt densities. Both heaters were

powered simultaneously and allowed to ramp to the set point of 662°F (350°C) at 120 volts and then again to 932°F (500°C) at 220 volts. The delta value of the IFC was only 86-104°F (30-40°C) while the delta of the milled groove part concluded with +176°F (+80°C) at 20 W/in<sup>2</sup> (3.10 W/cm<sup>2</sup>). This is even more significant at 67.5 W/in<sup>2</sup> (10.46 W/cm<sup>2</sup>) with the IFC delta value at a 302-320°F (150-160°C) rating while at 518°F (+270°C) for the milled groove part. The graph to the right illustrates the test results.



#### IFC Section View

IFC heaters have a proprietary-shaped groove machined into the part that accepts a tubular or cable heater. The heater is pressed into the groove and achieves heat

transfer similar to that of a cast-in design. This method increases heater life when compared to the milled groove approach. The tight contact fit of heater within the machined groove reduces sheath hot spots that could result in heater burnout.

