

High-Temperature Heaters



Ceramic Fiber Heaters

Ceramic fiber heaters offer some of the highest temperature heating element capabilities available in the Watlow family of heaters. Heating units constructed of ceramic fiber insulation isolate the heating chamber from the outside. Ceramic fiber heaters are extremely low mass, high insulation value units with self-supported heating elements. Many applications can benefit from the convenience of the heating element and insulation combined into one package. Its lightweight, low-density properties are ideally suited for high temperature applications requiring low thermal mass.

Performance Capabilities

- Operating temperatures up to 2200°F (1204°C)
- Watt densities from 5 up to 30 W/in² (0.8 to 4.6 W/cm²)
- Uses “radiant” heat transfer exclusively

Features and Benefits

High temperature ICA resistance elements

- Bounds integrally into required position
- Allows five element configurations

Lightweight, low-density alumina-silica composition molded into shape

- Acts as insulation to isolate the heating chamber from the outside
- Provides low shrinkage fiber and inorganic binder
- Ensures a firm, thermal shock resistant, self-supporting unit at all operating temperatures

Operating temperatures up to 2200°F (1204°C)

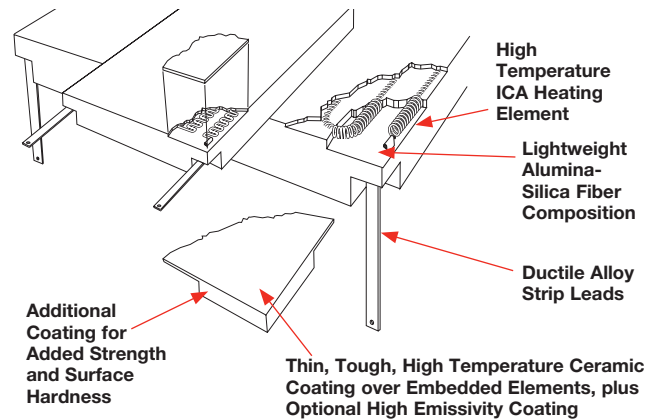
- Provides high temperature performance that is not possible with many other heater types (See page 423 for detailed limits)

Low mass ceramic fiber insulation of 10 to 15 lb/ft³ (160 to 240 kg/m³)

- Allows the heater to reach process temperature quickly
- Allows the energy to heat the load instead of wasting energy on itself

Works directly off of common power line voltages

- Eliminates the need for expensive transformers or complex power control systems
- Enables compatibility with the full range of Watlow temperature controllers and power switching devices



Typical Applications

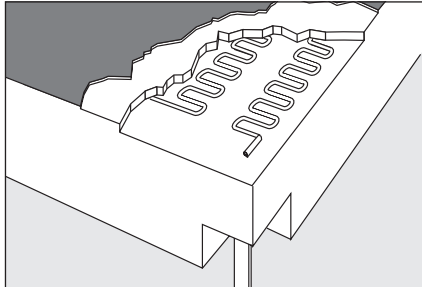
- High temperature furnaces
- Metal melting, holding and transfer
- Semiconductor processing
- Glass, ceramic and wire processing
- Analytical instrumentation



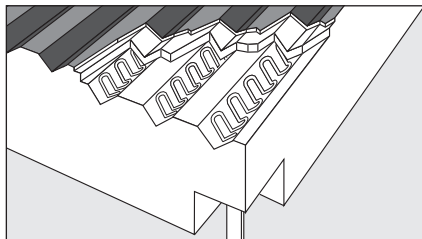
Ceramic Fiber Heaters

Options

Embedded Sinuated Elements



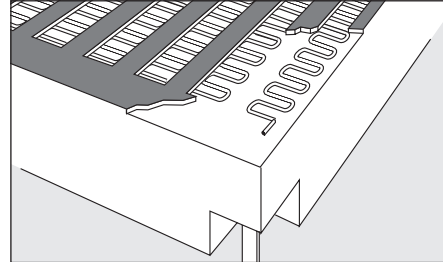
Flat Sinuated



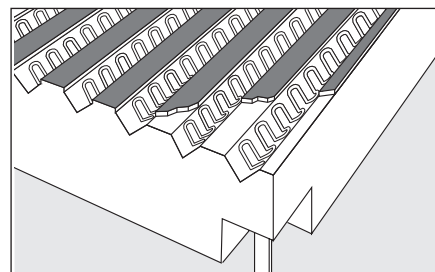
V-Sinuated

- Available in either flat or V-sinuated element configurations
- Advanced V-sinuated element configuration allows up to 27 percent additional watt density over embedded flat sinuated elements
- Performs best at medium to high temperatures at medium watt density power requirements
- Use in partially enclosed to fully enclosed applications
- Especially well suited for large, flat units; semi-cylindrical units above 5 in. (125 mm) I.D.; and full cylinders above 4 in. (100 mm) I.D.
- Offers greater effective insulation thickness than coiled element designs
- Enhances “heated insulation” concept of operational use
- Features high emissivity coating on new high watt density series units. When ordering, refer to charts on pages 438 to 440.

Exposed Sinuated Elements



Flat Sinuated



V-Sinuated

- Available in either flat or V-sinuated element configurations
- Advanced V-sinuated element configuration allows up to 20 percent additional watt density compared to exposed flat sinuated elements
- Offers the lowest possible wire-to-chamber temperature difference for maximum heater life
- Provides optimum heat-up/cool-down and recovery times as well as maximum operational efficiency
- Higher current handling capabilities are possible
- Minimizes the number of circuits and connections in large furnaces
- Especially well suited for large, flat surface area units and large I.D. curved units
- Exposed elements are available on special order as a variation of the embedded sinuated element normally provided on stock and standard units. When ordering, refer to charts on pages 438 to 440.

High-Temperature Heaters

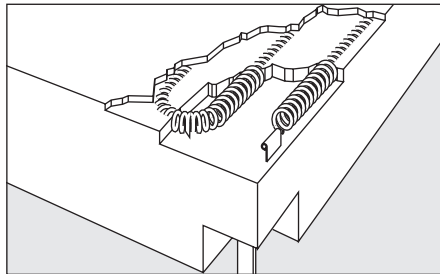


Ceramic Fiber Heaters

Application Hints

Applications

- High temperature furnaces
- Metal melting, holding and transfer
- Semiconductor processing
- Glass, ceramic and wire processing
- Analytical instrumentation
- Fluidized beds
- Laboratory and R&D
- Other high temperature process applications
- Optimum performance for high temperature, enclosed furnace chambers
- Coiled elements readily conform to complex curved surfaces, especially small custom chamber shapes
- Coiled element design works best in higher voltage, lower current situations
- Use where lower watt density requirements and low duty cycle operations are expected
- Available in stock and standard units of medium watt density, rated up to 2000°F (1093°C). When ordering, refer to charts on pages 435 to 437.



Embedded Coil Elements



- Never use ceramic fiber heaters for conduction heating applications. These heaters are designed for **radiant heat transfer only**.

- Use appropriate mounting methods including pins, washers, clamping straps, overlapping edge clamps, interlocking edges, etc. Generally, these methods work better than cementing ceramic fiber heaters, as cementing will not accommodate the expansion and contraction caused by thermal cycling of surrounding metal structures.
- Keep furnace loads free of oils, lubricants and other contaminants that can vaporize at high temperatures. Ceramic fiber heaters have a porosity exceeding 90 percent and cannot be sealed against contamination infiltration and possible damage to the heating element wire.

- Use low mass thermocouples that are responsive to rapidly changing radiant energy transfer conditions. Without proper temperature control, ceramic fiber heaters can generate sufficient heat for self destruction.
- Mount a thermocouple junction directly above an element and within $\frac{1}{16}$ in. (1.6 mm) of the heated surface. Embedded ceramic mounting tubes are available as an option to position 0.125 in. (3.2 mm) diameter thermocouples inside the fiber, directly behind and between the elements. Heater wire operating temperatures are critical and wires should be monitored at the hottest point within the application.
- Electrical connections made in heated portions of the application must be rated for the appropriate currents and anticipate ambient temperatures. To ensure good electrical connections, use compression-type connection devices located as far away from the hottest area of the application. This minimizes the possibility of electrical connection degradation caused by thermal expansion, contraction and high temperature oxidation.
- Ceramic fiber products shrink at high temperatures. During the first 24 hours of operation at temperatures between 1600 and 2200°F (870 to 1204°C), shrinkage of up to four percent can occur. Fill all gaps between units created by shrinkage with loose ceramic fiber insulation. Watlow offers a “pre-firing” process that pre-shrinks and dimensionally stabilizes units before shipping. Contact your Watlow representative for further details.
- Use additional back-up insulation for maximum energy efficiency and appropriate safety considerations. Use only insulation with inorganic fibers and binders to avoid corrosive fumes that could damage heater elements.
- Handle all units and leads with care. Ceramic fiber heaters are very resistant to thermal cycling and thermal shock, but are easily subject to mechanical damage from careless handling.
- Repair of minor mechanical damage, made with unapproved or unknown cements, could damage the wire elements at high temperatures. If unsure, contact your Watlow representative before making repairs. Several accessory items are available from the factory for repair purposes.

High-Temperature Heaters



Ceramic Fiber Heaters

Performance Data

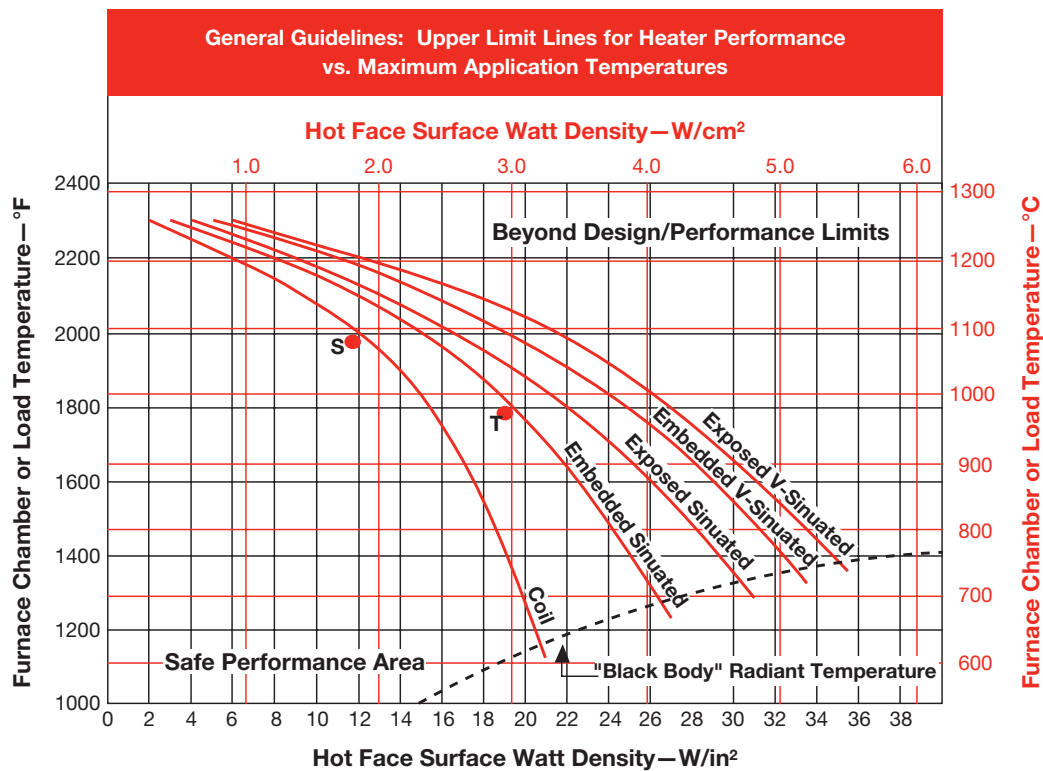
Performance Capabilities

The *Performance* graph shown below represents capabilities of the five heater element configurations. The curves compare upper temperature limits versus permissible design watt densities to achieve a standard heater life expectation of 2,000 hours.

As with all Watlow heaters, the major application concern is the heater's surface watt density as it relates to the application temperature, such as with the furnace chamber temperature or the radiant surface temperature. When evaluating an application for temperature and watt density requirements, it should fall to the left of and below the performance limit lines. If the application falls

into this area, then it is in the safe performance area.

The further into this safe performance area, the higher the life expectancy of the heater. If an application requires temperatures or watt densities that fall into the area to the right of and above the lines, then the application operates beyond the heater's typical design or performance limits. Using a heater required to perform in this area of the graph may result in a shorter life expectancy. For information specific to an application, contact your Watlow representative.



High-Temperature Heaters



Ceramic Fiber Heaters

Performance Data (Continued)

The following graphs provide technical data to help evaluate performance and select the correct ceramic fiber heater for an application.

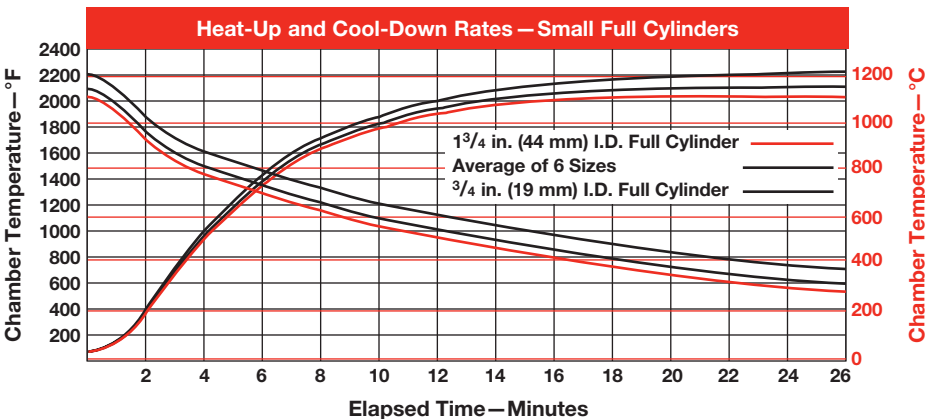
The four graphs shown represent performance data for heat-up/cool-down rates and power requirements

to maintain furnace temperature. This data averages test results performed for two typical types of furnace chambers, and should not be used for specification purposes.

Small, Full Cylinder, Heated Chambers

Test conditions for small, full-cylinder heated chambers are typical of analytical instrumentation furnaces. Several stock sizes are represented. Units tested were 6 in. (150 mm) long, mounted in a vertical orientation. Both ends were capped with 1 in. (25 mm) of ceramic fiber

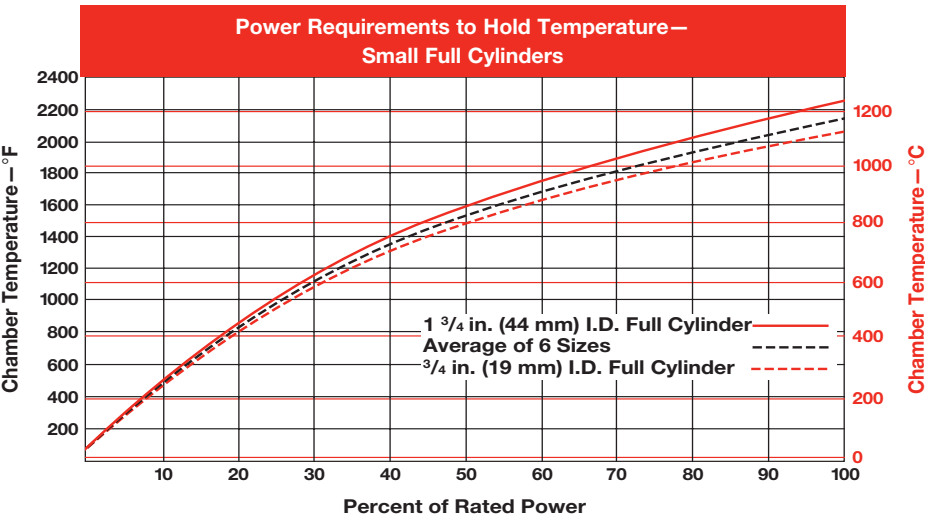
insulation. No additional insulation or metal sheath was added to the outside diameter. Temperature was measured by a thermocouple located in the geometric center of the chamber.



Power Requirements

Shown below are percentages of rated power needed to achieve and hold specific temperatures inside the full cylinder chambers tested.

This represents the efficiency of these heaters in this mounting configuration.



High-Temperature Heaters



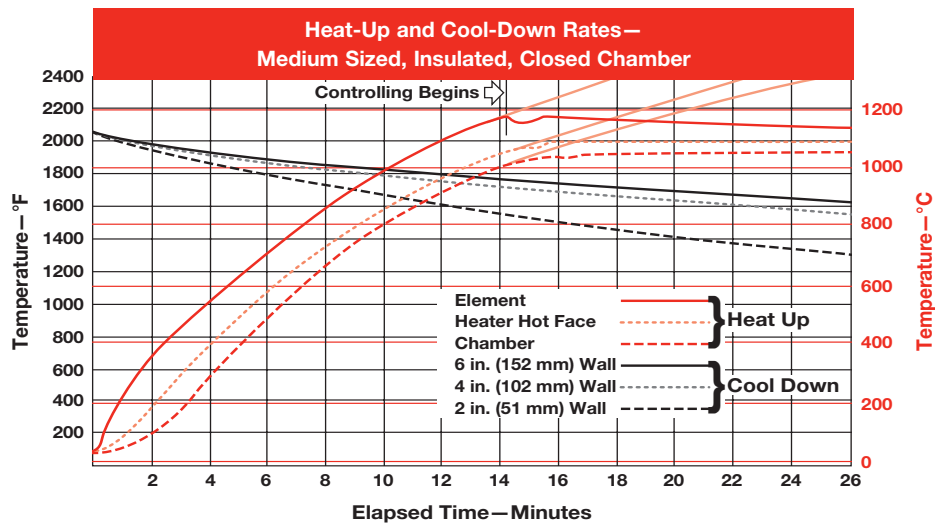
Ceramic Fiber Heaters

Performance Data (Continued)

Medium Sized, Insulated Closed Chambers

Test conditions for medium-sized, insulated chambers are typical of pit and box furnaces, large tube furnaces and pipe and reactor heating. Standard embedded coil units (Watlow part number **VS412A12S**) were used and rated for 2000°F (1093°C). The test chamber size was 12 in. long and 12 in. I.D. (305 X 305 mm). The volume was approximately 0.75 ft³ (0.02 m³).

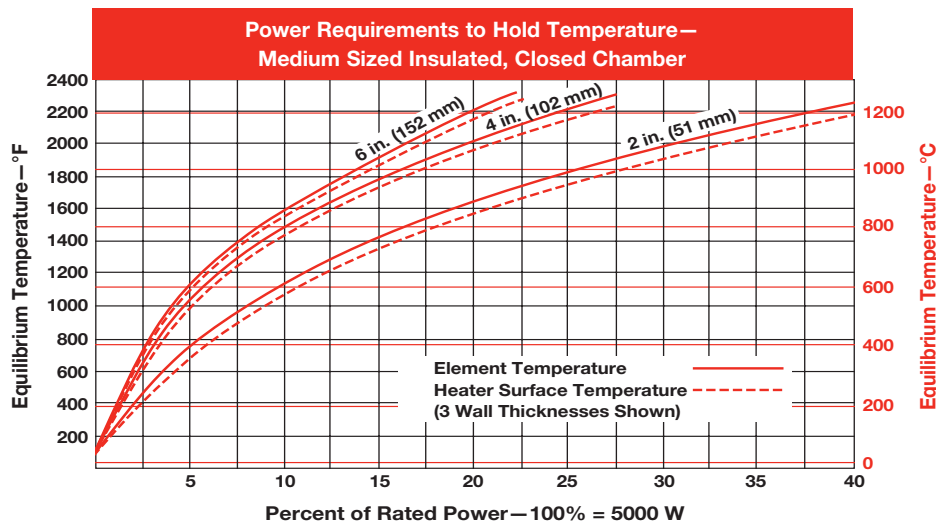
Temperature heat-up rates were measured by thermocouples in three places: at the element, on the heater surface and at the center-of-chamber. Data for various additional wall thicknesses is also shown. This is typical of how large, flat and semi-cylindrical units are used. The chamber was oriented vertically with top and bottom disks of ceramic fiber insulation equal to wall thickness.



Power Requirements

Shown below are the percentages of rated power needed to achieve and hold specific temperatures inside of

medium-sized, insulated chambers. This represents the efficiency of these heaters in this mounting configuration.



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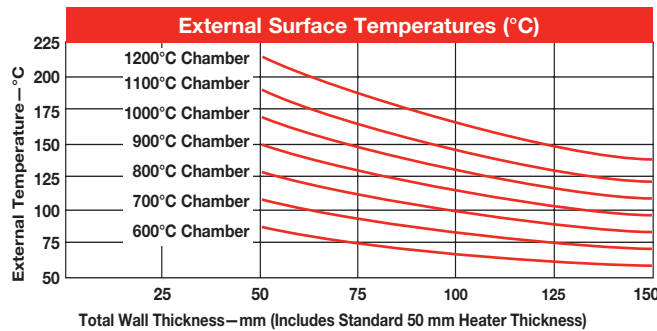
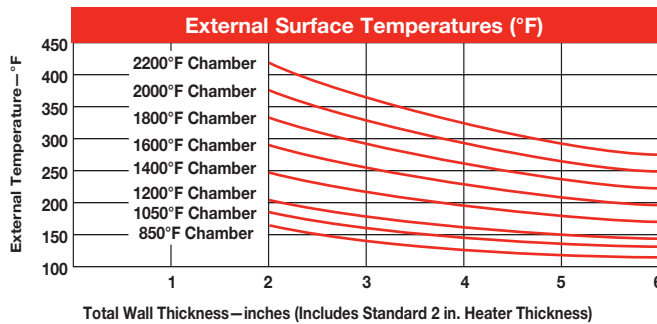


Ceramic Fiber Heaters

Performance Data (Continued)

Insulation Effectiveness

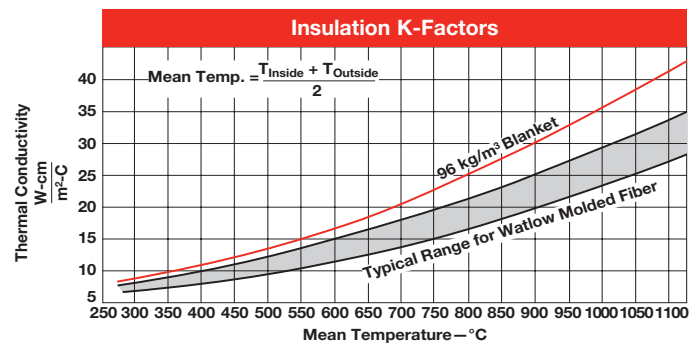
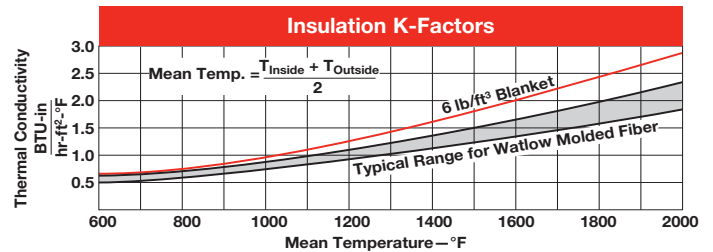
The graphs below illustrate the effectiveness of adding 6 lb/ft³ (96 kg/m³) blanket insulation to the backside of standard 2 in. (50 mm) thick ceramic fiber heaters. Total wall thickness of up to 6 in. (152 mm) is shown. Data is for vertical sides without metal sheathing. Top and bottom surfaces and surfaces with metal sheaths covering ceramic fiber insulation will vary.



Heat Loss and Energy Transfer

For general calculations of heat loss and energy transfer, the *Insulation K-Factors* and *Emissivity* graphs are helpful.

The *K-Factors* graph is for ceramic fiber heaters and the ceramic fiber insulation blanket typically used with the heaters. This blanket is offered as an accessory by Watlow.



Application Hints

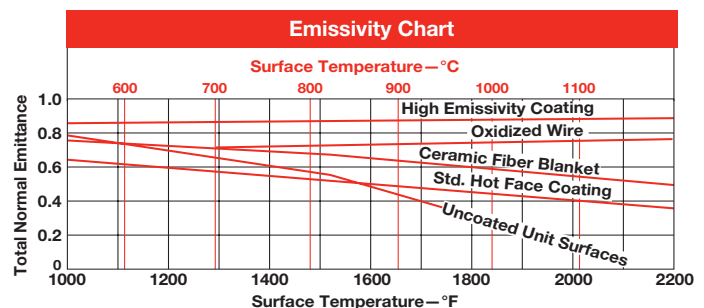
For wall thicknesses (T) in cylindrical situations use the “equivalent thickness” conversion.

$$T_{\text{cyl.}} = r_{\text{out}} \log_e \left(\frac{r_{\text{out}}}{r_{\text{in}}} \right)$$

Where r_{out} is outer radius
 r_{in} is inner radius

Emissivity of Heater Surface

The *Emissivity* graph details the normalized emittance values for the four surfaces most likely to be encountered when planning Watlow ceramic fiber heater applications.



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Termination Options

Watlow offers many variations of electric leads to meet particular wiring requirements. To understand termination options available, it is necessary to understand the various methods for applying electrical leads.

Ceramic fiber heater electrical leads are welded to stubs – the metal parts that interface between the heating element wire and the add-on electrical leads. These stubs exit the heater at the lead pockets. Pockets are small cavities below the cold face plane (outside surface) and usually located at or near the corners.

Watlow ceramic fiber heaters are equipped with either strip leads or double twisted wire leads. Strip leads are most commonly used, unless otherwise specified. The various lead styles refer to the lead's exit orientation relative to the pocket used on a given type of heater. See illustrations for specific details.

Strip Leads

Flat and semi-cylindrical ceramic fiber heaters are available with the termination options shown here. When ordering termination options for catalog units, the specific strip lead **Style** must be specified. To determine the desired style, refer to the following illustrations. If a style is not specified, **Style A** leads, 12 in. (305 mm) in length will be provided. Additional lengths are available using add-on leads which are priced per pair, per inch, for the three different widths. See ordering charts for which lead width is used on a specific heater.

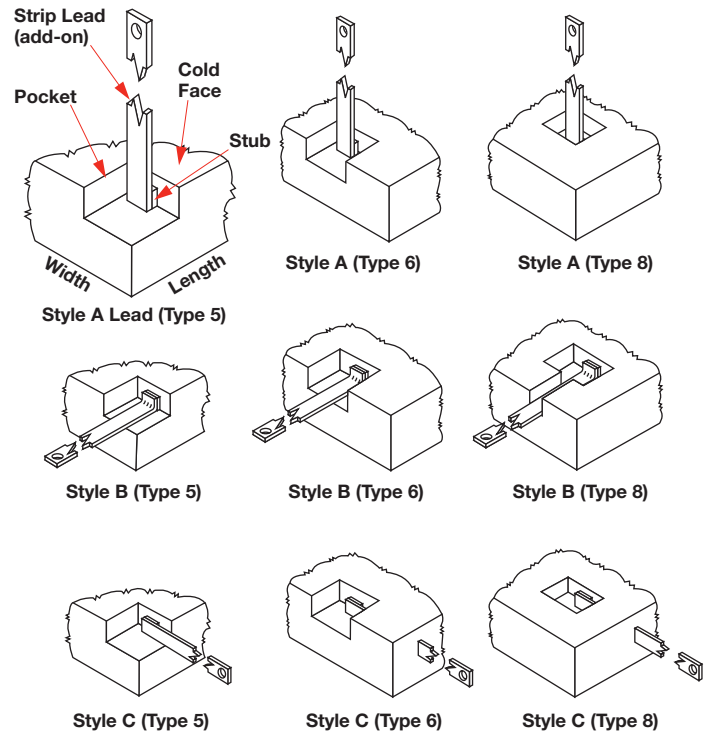
Strip leads are shipped with a $13/64$ in. (5 mm) hole at the end of the lead. Use #10-24 screws, nuts and washers, or other wiring connections. Caution should be exercised when making connections. Leads are susceptible to loosening due to thermal expansion and contraction as the heater cycles.



Important

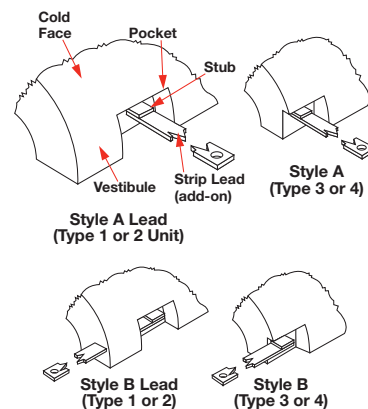
Inspect the carton and its contents for damage prior to discarding packaging material. If there is any damage, contact your Watlow representative immediately for a Returned Material Authorization (RMA) number. All damaged goods are to be returned in the original packaging to reduce the possibility of further damage to the product.

Flat Units



Cold

Semi-Cylindrical Units



High-Temperature Heaters



Ceramic Fiber Heaters

Termination Options (Continued)

Special Lead Orientation

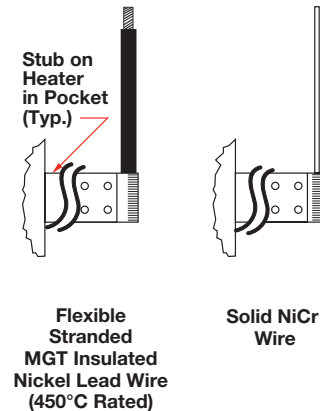
If the various standard strip lead orientations and pocket configurations are not suitable, special designs are available. When ordering, please include drawings that show proposed locations.

Leads Bent 90 Degrees

The double twisted leads of full cylinder heaters can bend 90 degrees to lay into slots and exit to the sides of the unit.

Special Add-On Lead Configurations

The two options illustrated can be welded onto the stub at the heater pocket, or for a better installation, welded to the end of a specified length of the regular strip lead. The strip lead length can vary from zero to the value necessary to distance it from the hot zone. The length of the add-on lead option eliminates the need for a custom product and satisfies a greater range of wiring requirements. Contact your Watlow representative for technical details and price.



Accessories

Ceramic fiber heater orders can include the accessory items described in this section. Please specify the Watlow part number when ordering.

Rigidizer

Rigidizer is primarily used to recoat soft, cut edges of ceramic fiber heaters and ceramic fiber insulation panels. Various degrees of hardening can be achieved with additional applications. Rigidizer can be ordered by the pint (0.47 L) by specifying part number **CFRGDPT** or gallon (3.78 L), part number **CFRGDGL**.

B.T.E. Closed-End Thermocouple Tubes

A horizontal thermocouple tube between the elements is available in two sizes: 0.140 in. (3.6 mm) and 0.265 in. (6.7 mm), both 6 in. (152 mm) long with closed end.

Black Surface Coat

Black high emissivity coating is used to raise emissivity closer to 1.0. The container size is 4 ounces. Order **CFBSC**.

Ceramic Tubes

Ceramic tubes are available in four nominal sizes: 1/8, 1/4, 3/8 and 1/2 in. (3.2, 6, 9.5 and 13 mm) I.D. and lengths including 0.9 in. (22 mm) and 1.9 in. (48 mm) long. Ceramic tubes have several uses, including thermocouple mounting holes, mounting pin sleeves and lead coverings. The table below lists part numbers and exact sizes.

Inside Diameter		Length		Part Number
in.	(mm)	in.	(mm)	
0.140	(3.6)	0.90	(22)	CC405-1
0.265	(6.7)	0.90	(22)	CC405-2
0.390	(9.9)	0.74	(19)	CC405-3
0.515	(13.1)	0.90	(22)	CC405-9
0.140	(3.6)	1.90	(48)	CC405-4
0.265	(6.7)	1.90	(48)	CC405-5
0.390	(9.9)	1.60	(41)	CC405-6
0.515	(13.1)	1.90	(48)	CC405-8

High-Temperature Heaters



Ceramic Fiber Heaters

Accessories (Continued)

Dry Heating Surface Mix

Dry heating surface mix is used to make the hot face of all heaters, including those with the high emissivity coating. It can also be used with rigidizer to make a very high temperature paste for touch ups of the hot face area. Order by the pint (0.47 L), part number **CFHTGSURMX**, or gallon (3.78 L), part number **CFHTGMXGAL**.

Patch Kit

To easily repair small breaks or cracks, the patch kit contains one pint (0.47 L) of powdered ceramic fiber and four ounces (0.118 L) of black surface coat. Order **CFPATCHKIT**.

Ceramic Fiber Insulation Blanket

Additional insulation value for ceramic fiber heaters is available with ceramic fiber insulation blanket. This 6 lb/ft³ (96 kg/m³) ceramic fiber blanket contains no organic binders. It is suitable for applications up to 2300°F (1260°C) and sold in full rolls or cut by the square foot. These blankets are available in the following sizes:

Size (U.S.)	Size (metric)	Part No.
24 in. X 25 ft X 1/4 in.	610 mm X 7.6 m X 6 mm	CFBLKT1/4 ^①
24 in. X 25 ft X 1/2 in.	610 mm X 7.6 m X 13 mm	CFBLKT1/2 ^①
24 in. X 25 ft X 1 in.	610 mm X 7.6 m X 25 mm	CFBLKT-1 ^①

^① Add ...R to end of part number for full roll.

Powdered Ceramic Fiber

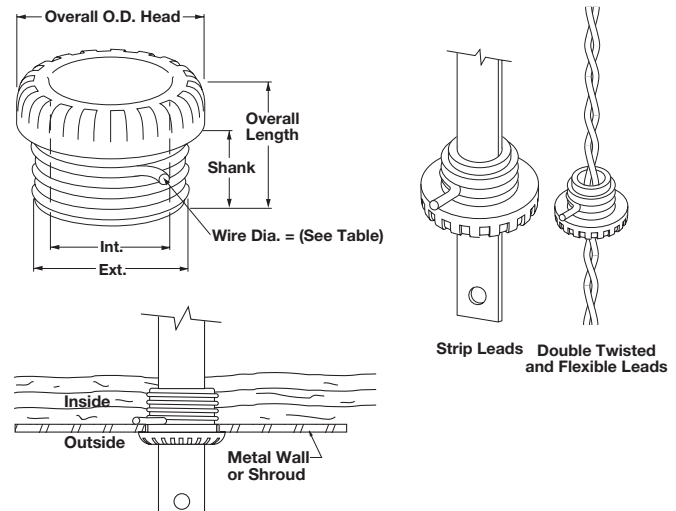
Powdered ceramic fiber is used primarily to improve surface finish in critical areas. It can also be used to fill voids, cracks and broken corners in damaged units. Use powdered ceramic fiber with rigidizer to make an easy to apply paste. A standard container size is one pint (0.47 L). Order part number **CFPDRFPT**.

High Temperature Coating and Electrical Potting Cement

Two different high purity, high temperature cements can be used to mount thermocouple tubes, provide extra surface hardening, bond ceramic fiber gaskets and affix lightweight ceramic fiber insulation blanket to panels, as well as attach edge-spacer blocks and custom vestibules. Potting cement is packaged in a 1/4 pint (116 mL) jar, and may be ordered by specifying part number **CFPTGCMT**. The high temperature coating cement is available in pints or gallons, and can be ordered by using part numbers **CFCTGCMTPT** and **CFCTGCMTGAL**.

Strip Lead Porcelain Bushings

Strip lead porcelain bushings are primarily used to protect heater power leads when passing through metal walls and furnace structures. Bushings are available with inside diameters listed below for use with double twisted leads and the three standard strip lead widths. To select the appropriate inside diameter lead bushing, reference the heater selection tables on pages 435 through 440. The strip lead width for each heater is listed therein.



Porcelain Bushings Specifications

Conduit K.O. Size in. (mm)	Shank Dia. without Wire Nut		Wire Nut Dia. in. (mm)	Shank Length in. (mm)	Overall Length in. (mm)	Overall Head O.D. (Ref.)		Use With:	Part Number
	Int. in. (mm)	Ext. in. (mm)				in. (mm)	(mm)		
3/8 (9.5)	3/8 (9.5)	21/32 (16.7)	0.080 (2.032)	9/16 (14.3)	7/8 (22.2)	7/8 (22.2)	(22.2)	All double twist	CS45-11
1/2 (13.0)	7/16 (11.1)	13/16 (20.6)	0.080 (2.032)	3/4 (19.0)	1 1/8 (28.6)	1 1/8 (28.6)	(28.6)	3/8 (9.5 mm) Strip	CS45-20
3/4 (19.0)	9/16 (14.3)	1 (25.0)	0.106 (2.692)	7/8 (22.2)	1 5/16 (33.3)	1 5/16 (33.3)	(33.3)	1/2 (13.0 mm) Strip	CS45-30

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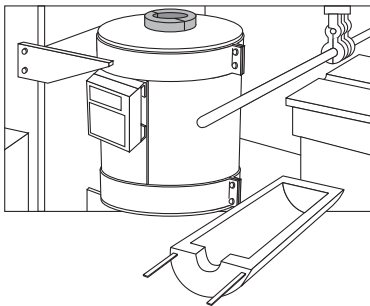
Mounting Methods

The Watlow ceramic fiber heater is available in a wide range of heater shapes and configurations to solve high temperature process applications. The modularity and range of sizes and wattages provide the greatest possible flexibility. Watlow has developed and can recommend many appropriate specific and generalized mounting systems for mounting heaters. Ceramic fiber heaters have been organized into seven major mounting categories or heater system configurations as shown in the following illustrations.

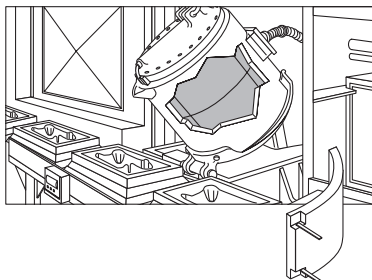
1. Full Cylinder Heaters



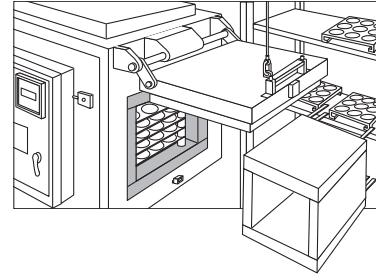
2. Semi-Cylindrical (180° section) Heaters



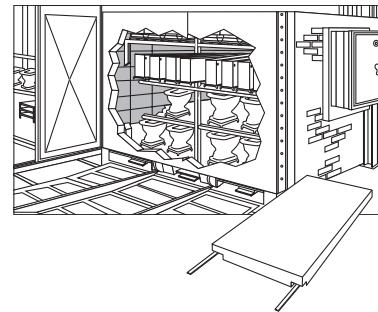
3. Arc-Section Arrays of Heaters (3 or more units of 120° or less each)



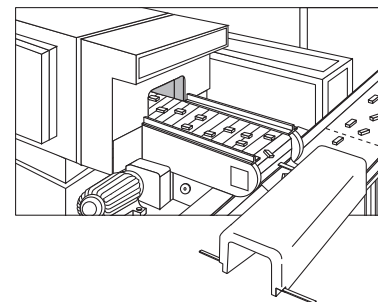
4. Flat Panels, with One Panel on Each Side



5. Flat Wall Array with Minimum Two-by-Two Units per Wall



6. Made-to-Order Molded Shapes with Up to Five Sides of a Box Molded as One Piece, Including Complex Curves



High-Temperature Heaters



Ceramic Fiber Heaters

Molded Ceramic Fiber Insulation Modules

For heating applications requiring insulation panels, Watlow offers many shapes and sizes of molded ceramic fiber insulation modules. These insulation modules are constructed using the same high quality, high temperature, low mass ceramic fiber material used in our heaters.

As a complement to the overall product line, these modules offer additional solutions for high temperature industrial insulation problems. Without heating elements, molded ceramic fiber insulation modules are available in complex shapes to conform to application requirements.

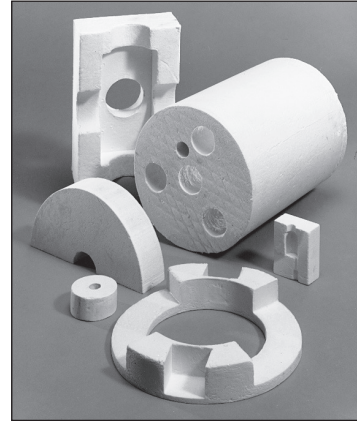
Molded-to-shape insulation modules also make handling and installation easier compared to other insulation methods. Since they are molded to shape, sanding, cutting and grinding of blocks to achieve the desired configuration is not required.

Highly resistant to thermal shock and chemical attack, except for hydrofluoric and phosphoric acids and strong alkalis, insulation modules are unaffected by oil and water. If the insulation becomes wet, physical and thermal properties can be fully restored when dried.

Note: If using molded ceramic fiber insulation modules along with other Watlow ceramic fiber heaters, oil, water and other contaminants will negatively affect the heating element portion of the ceramic fiber heater.

Molded insulation modules are rated for up to 2300°F (1260°C) continuous duty. The inorganic binder eliminates smoke or combustion during initial heating to 300°F (150°C) and higher. Vacuum molded density is 10 to 15 lbs/ft³ (160 to 240 kg/m³), the same as the ceramic fiber heaters.

Size Limits: Maximum flat size is 34 x 52 in. (860 x 1320 mm) with a molded thickness of more than 4 in. (102 mm). Maximum inside diameter for semi-cylindrical modules is 24 in. (610 mm). For applications requiring curved insulation pieces in excess of 180 degrees, consider using multiple arc-section modules or an array system of multiple flat units.



Application and Technical Data

The same insulation performance and technical data for ceramic fiber heaters applies to molded ceramic fiber insulation modules. For specific information on insulation performance properties, see the *Heat Loss and Energy Transfer* portion of the ceramic fiber heaters section on page 425.

Accessories

Where appropriate, many of the same accessories available for ceramic fiber heaters are available for use with molded ceramic fiber insulation modules. Accessories can be used to modify, provide mounting options and for minor repairs and maintenance.

Ordering Information

Molded ceramic fiber insulation modules are available in exactly the same sizes and shapes as the ceramic fiber heaters listed in the ordering tables. In general, the ordering part numbers are derived by replacing the second alpha character in the heater part number (i.e., F, S, C, R, etc.) with **N** to designate **no-element**.

Extended Capabilities: Watlow representatives can work with your customers to design and manufacture modules to meet specific insulation needs.

High-Temperature Heaters



Ceramic Fiber Heaters

Molded Ceramic Fiber Insulation Modules

Legacy Part Number Scheme

VN - No-Heat Panels

Part Number

①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪	⑫	⑬	⑭
Base Code Nbr.	Base Code Nbr.	Base Code Nbr.	Base Code Nbr.	Base Code Nbr.	Base Code Nbr.	Base Code Nbr.	Base Code Nbr.	Base Code Nbr.	Modification Options				
V	N	5	1	2	A	1	2	A		0	0	0	0

① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨ Base Code Number

⑩	Modification Options
0 =	None
A =	0.140 thermocouple tube I.D. center on unit
B =	0.265 thermocouple tube I.D. center on unit
E =	Black surface coat one side
F =	Black surface coat 0.140 thermocouple tube I.D. center on unit
G =	Black surface coat 0.265 thermocouple tube I.D. center on unit

High-Temperature Heaters



Ceramic Fiber Heaters

Modifications

It is possible to order certain special modifications for catalog units prior to shipment. Some of these are listed below, with a brief description.

Beveled and trimmed edges: The unheated edges of Type 6, 7 and 8 units can be factory modified to provide in-between overall sizes, and can be angle cut to form regular polygon shapes around objects. Angles between zero degrees and 45 degrees can be accommodated.

Black surface coating: Improves the emissivity of the heater's hotface. See the graph on page 425 for emissivity values, contact the factory for pricing adders.

Leads: See page 427 for other "Special Add-On Lead" configurations.

Thermocouple holes: Ceramic tubes on page 427 are used to make electrically isolated holes through heaters. To order, the inside **diameter** and **location** must be specified. A special "behind-the-element" horizontal thermocouple tube is available to very closely track element temperature for over-temperature protection and improved heater life.

Notches or long slots in no-heat areas of

units: Rectangular and semi-circular notches can be cut into no-heat areas and vestibules on most units. Usually, a sketch or drawing that specifies exact location must be included with your order. Fax numbers to send drawings to are available.

Shortened vestibule lengths: Modified vestibule lengths require retention of at least 1/2 in. (13 mm) of insulation for adequate strength or complete removal ("0" length) to make Type 1 units into left vestibule (i.e., Type 2) or right vestibule (i.e., Type 3) units.



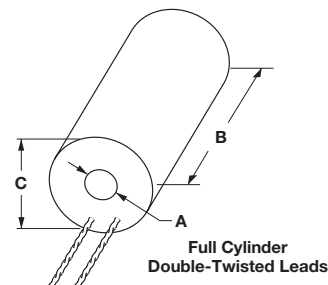
Warning

This product contains refractory ceramic fibers (RCF) which have been identified by the International Agency for Research on Cancer (IARC) as a possible human carcinogen (class 2B). Before using these products, read the material data safety sheet (MSDS) which includes the detailed precautionary measures and handling instructions.

High-Temperature Heaters

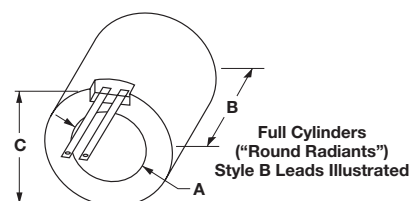
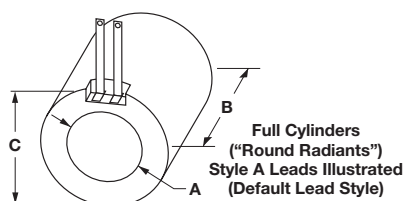


Ceramic Fiber Heaters



Full Cylinder Units

Dimensions, in. (mm)			Electrical Ratings				
Heated Area		Overall					
I.D. (A) in. (mm) ± ¹ / ₁₆ (±1.6)	Length (B) in. (mm) ± ¹ / ₁₆ (±1.6)	O.D. (C) in. (mm) ± ¹ / ₈ (±3.2)	Volts	Power (Watts) ±5%	Surface Loading ^① W/in ² (W/cm ²)	Lead Width	Approx. Net Wt. oz (kg)
1/2 (13)	6 (152)	2 (51)	60	175	18.6 (2.9)	Double Twisted Leads	5 (0.14)
1/2 (13)	12 (305)	2 (51)	120	350	18.6 (2.9)		10 (0.28)
3/4 (19)	6 (152)	3 (76)	60	200	14.2 (2.2)		8 (0.23)
3/4 (19)	12 (305)	3 (76)	120	400	14.2 (2.2)		13 (0.37)
1 (25)	6 (152)	3 (76)	60	220	11.7 (1.8)		9 (0.26)
1 (25)	12 (305)	3 (76)	120	440	11.7 (1.8)		13 (0.37)
1 1/4 (32)	6 (152)	3 1/2 (89)	60	275	11.7 (1.8)		11 (0.31)
1 1/4 (32)	12 (305)	3 1/2 (89)	120	550	11.7 (1.8)		18 (0.51)
1 1/2 (38)	6 (152)	3 1/2 (89)	60	300	10.6 (1.6)		12 (0.34)
1 1/2 (38)	12 (305)	3 1/2 (89)	120	600	10.6 (1.6)		20 (0.57)
1 3/4 (45)	6 (152)	4 (102)	120	350	10.6 (1.6)		12 (0.34)
1 3/4 (45)	12 (305)	4 (102)	120	700	10.6 (1.6)		23 (0.65)
2 (51)	6 (152)	4 (102)	120	425	11.3 (1.8)	13 (0.37)	
2 (51)	12 (305)	4 (102)	120	850	11.3 (1.8)	25 (0.71)	



Full Cylinder Units

Dimensions, in. (mm)			Electrical Ratings					
Heated Area		Overall						
I.D. (A) in. (mm) ± ¹ / ₁₆ (±1.6)	Length (B) in. (mm) ± ¹ / ₁₆ (±1.6)	O.D. (C) in. (mm) ± ¹ / ₈ (±3.2)	Volts	Power (Watts) ±5%	Surface Loading ^① W/in ² (W/cm ²)	Lead Width in. (mm)	Approx. Net Wt. lbs (kg)	
3 (76)	6 (152)	7 (178)	120	650	11.5 (1.8)	³ / ₈ (10)	2.5 (1.1)	
4 (102)	6 (152)	8 (203)	120	900	11.9 (1.8)	¹ / ₂ (13)	3.1 (1.4)	
4 (102)	6 (152)	8 (203)	120	1100	14.6 (2.3)	³ / ₈ (10)	3.1 (1.4)	
5 (127)	6 (152)	9 (229)	120	1250	13.7 (2.1)	¹ / ₂ (13)	3.5 (1.6)	
5 (127)	6 (152)	9 (229)	120	1400	14.9 (2.3)	³ / ₈ (10)	3.6 (1.6)	
6 ¹ / ₂ (165)	6 (152)	10 ¹ / ₂ (267)	120	1500	12.2 (1.9)	³ / ₄ (19)	4.9 (2.2)	
6 ¹ / ₂ (165)	6 (152)	10 ¹ / ₂ (267)	120	2000	16.3 (2.5)	¹ / ₂ (13)	4.9 (2.2)	
8 (203)	6 (152)	12 (305)	120	1800	11.9 (1.8)	³ / ₄ (19)	5.7 (2.6)	
8 (203)	6 (152)	12 (305)	120	2600	17.2 (2.7)	³ / ₄ (19)	5.8 (2.6)	

① Units with watt densities between 10.6 to 14.2 W/in² (1.6 to 2.2 W/cm²), are coil designs suitable for use up to 2000°F (1093°C) maximum surface temperature. Units with watt densities between 14.6 to 17.2 W/in² (2.3 to 2.7 W/cm²) are "round radiants" with sinuated element designs and high emissivity coating that are suitable for use up to 1800°F (982°C) maximum surface temperature.

For unheated insulation tubes, select the appropriate size during quoting process.

High-Temperature Heaters



Ceramic Fiber Heaters

Legacy Part Number Scheme

VC - Full Cylindrical

Part Number

①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪	⑫	⑬	⑭
Base Code Nbr.	Base Code Nbr.	Base Code Nbr.	Base Code Nbr.	Base Code Nbr.	Base Code Nbr.	Base Code Nbr.	Base Code Nbr.	Base Code Nbr.	Modification Options			Lead Options	Lead Length
V	C	4	0	5	A	0	6	A		0	0		

① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨ Base Code Number

⑩	Modification Options
0 =	None
A =	0.140 thermocouple tube I.D. opposite leads, centered on height
B =	0.140 thermocouple tube I.D. lead side, centered on height
E =	Black surface coat
F =	Black surface coat 0.140 thermocouple tube I.D. opposite leads, centered on height
G =	Black surface coat 0.140 thermocouple tube I.D. lead side, centered on height

⑬	Lead Options
0 =	Fixed (built-in) standard double-twisted*
1 =	601 Alloy 600 strip A style
2 =	601 Alloy 600 strip B style
9 =	Flex NI, MGT A style
A =	Flex NI, MGT B style
E =	Chromel® A / NI, A style
F =	Chromel® A / NI, B style

* Double -twisted leads are only available on 1/2 thru 2 in. I.D. heaters.

⑭		Lead Length	
A =	0 in.	T =	14 in.
B =	1 in.	U =	15 in.
E =	2 in.	V =	16 in.
F =	3 in.	W =	17 in.
G =	4 in.	X =	18 in.
H =	5 in.	Y =	19 in.
J =	6 in.	1 =	20 in.
K =	7 in.	2 =	21 in.
L =	8 in.	3 =	22 in.
M =	9 in.	4 =	23 in.
N =	10 in.	6 =	24 in.
P =	11 in.	7 =	30 in.
R =	12 in.	8 =	36 in.
S =	13 in.	9 =	42 in.

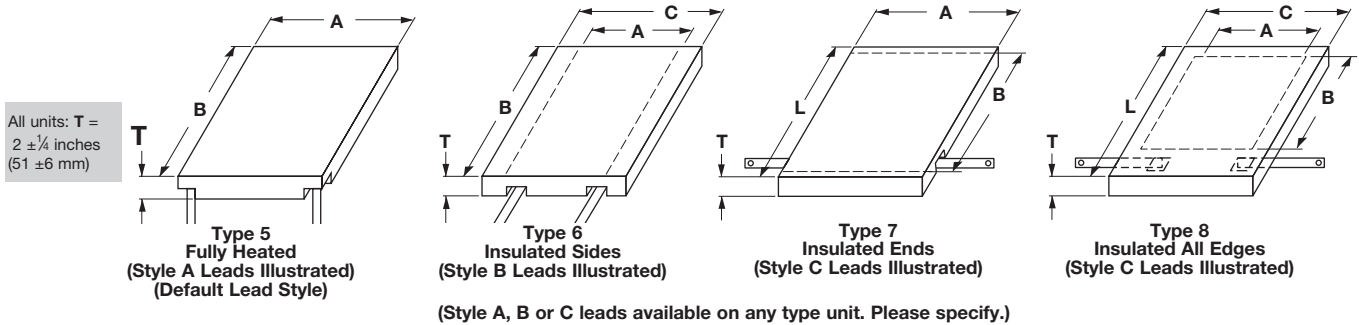
Notes:

- If the order is placed before 11:00 AM CST, heaters with standard leads (...0R) ship the same day. Heaters with non-standard leads ship the next day.
- The BTE (between-the-element) is NOT covered in this system yet. Please contact your Watlow representative for availability.

High-Temperature Heaters



Ceramic Fiber Heaters



Flat Units — Embedded Coiled Elements (see page 421)

Dimensions in. (mm)				Electrical Rating			Strip Lead Width in. (mm)	Approximate Net Wt.		
Heated Size		Type 6 & 8	Type 7 & 8					Type 5	Type 6 & 7	Type 8
Width (A) in. (mm) <small>+1/16 -1/8 (1.6-3.2)</small>	Length (B) in. (mm) <small>+1/16 -1/8 (1.6-3.2)</small>	Width (C) in. (mm) <small>+1/16 -1/8 (1.6-3.2)</small>	Length (L) in. (mm) <small>+1/16 -1/8 (1.6-3.2)</small>	Volts	Power (Watts) ±5%	Surface Loading W/in ² (W/cm ²)		lbs (kg)	lbs (kg)	lbs (kg)
4 (102)	6 (152)	8 (203)	10 (254)	60	275	11.5 (1.8)	3/8 (10)	0.6 (0.3)	1.1 (0.5)	1.7 (0.9)
	12 (305)	8 (203)	16 (406)	60	550	11.5 (1.8)	1/2 (13)	1.2 (0.5)	2.2 (1.0)	2.8 (1.3)
	18 (457)	8 (203)	22 (559)	120	750	10.4 (1.6)	3/8 (10)	1.9 (0.9)	3.4 (1.5)	4.6 (2.0)
	24 (610)	8 (203)	28 (711)	120	1100	11.5 (1.8)	1/2 (13)	2.4 (1.1)	4.4 (2.0)	5.6 (2.5)
6 (152)	6 (152)	10 (254)	10 (254)	60	375	10.4 (1.6)	3/8 (10)	0.9 (0.4)	1.5 (0.7)	2.4 (1.1)
	12 (305)	10 (254)	16 (406)	120	750	10.4 (1.6)	3/8 (10)	1.8 (0.8)	2.8 (1.3)	3.7 (1.7)
	18 (457)	10 (254)	22 (559)	120	1250	11.6 (1.8)	1/2 (13)	3.0 (1.4)	4.1 (1.9)	5.0 (2.3)
	24 (610)	10 (254)	28 (711)	240	1500	10.4 (1.6)	3/8 (10)	3.5 (1.6)	5.2 (2.4)	6.2 (2.8)
	30 (762)	10 (254)	34 (864)	240	2000	11.2 (1.7)	1/2 (13)	4.5 (2.0)	6.6 (3.0)	8.4 (3.8)
	36 (914)	10 (254)	40 (1016)	240	2500	11.6 (1.8)	1/2 (13)	6.1 (2.8)	8.3 (3.8)	10.2 (4.6)
8 (203)	12 (305)	12 (305)	16 (406)	120	1100	11.5 (1.8)	1/2 (13)	2.5 (1.1)	3.2 (1.5)	4.1 (1.9)
	18 (457)	12 (305)	22 (559)	240	1500	10.4 (1.6)	3/8 (10)	3.6 (1.6)	4.7 (2.1)	5.6 (2.5)
	24 (610)	12 (305)	28 (711)	240	2200	11.5 (1.8)	1/2 (13)	4.8 (2.2)	6.5 (2.9)	7.4 (3.4)
	30 (762)	12 (305)	34 (864)	240	2500	10.4 (1.6)	1/2 (13)	6.2 (2.8)	8.0 (3.6)	9.7 (4.4)
	36 (914)	12 (305)	40 (1016)	240	3000	10.4 (1.6)	3/4 (19)	7.8 (3.5)	10.0 (4.5)	11.8 (5.4)
10 (254)	12 (305)	14 (356)	16 (406)	240	1250	10.4 (1.6)	3/8 (10)	2.6 (1.2)	3.9 (1.8)	5.0 (2.3)
	18 (457)	14 (356)	22 (559)	240	1800	10.0 (1.6)	1/2 (13)	4.2 (1.9)	5.4 (2.4)	6.5 (2.9)
	24 (610)	14 (356)	28 (711)	240	2500	10.4 (1.6)	1/2 (13)	5.2 (2.4)	7.7 (3.5)	8.8 (4.0)
	30 (762)	14 (356)	34 (864)	240	3000	10.0 (1.6)	3/4 (19)	7.0 (3.2)	9.5 (4.3)	11.7 (5.3)
	36 (914)	14 (356)	40 (1016)	240	3600	10.0 (1.6)	3/4 (19)	9.1 (4.1)	11.5 (5.2)	13.7 (6.2)
12 (305)	12 (305)	16 (406)	16 (406)	240	1500	10.4 (1.6)	3/8 (10)	3.2 (1.5)	4.6 (2.1)	5.8 (2.6)
	18 (457)	16 (406)	22 (559)	240	2200	10.2 (1.6)	1/2 (13)	4.9 (2.2)	6.5 (2.9)	7.7 (3.5)
	24 (610)	16 (406)	28 (711)	240	3000	10.4 (1.6)	3/4 (19)	7.5 (3.4)	9.5 (4.3)	10.7 (4.9)
	30 (762)	16 (406)	34 (864)	240	3600	10.0 (1.6)	3/4 (19)	9.1 (4.1)	11.7 (5.3)	12.9 (5.9)
	36 (914)	16 (406)	40 (1016)	240	4400	10.2 (1.6)	3/4 (19)	12.4 (5.6)	15.5 (7.0)	16.7 (7.6)
14 (356)	12 (305)	18 (457)	16 (406)	240	1750	10.4 (1.6)	1/2 (13)	4.7 (2.1)	6.1 (2.8)	7.6 (3.4)
	18 (457)	18 (457)	22 (559)	240	2550	10.6 (1.6)	1/2 (13)	6.8 (3.1)	8.5 (3.9)	10.0 (4.5)
	24 (610)	18 (457)	28 (711)	240	3500	10.4 (1.6)	3/4 (19)	10.0 (4.5)	11.9 (5.4)	13.4 (6.1)
	30 (762)	18 (457)	34 (864)	240	4300	10.2 (1.6)	3/4 (19)	12.5 (5.7)	15.0 (6.8)	16.5 (7.5)
	36 (914)	18 (457)	40 (1016)	240/240 ^①	5200	10.3 (1.6)	1/2 (13)	14.2 (6.4)	17.2 (7.8)	18.7 (8.5)
16 (406)	12 (305)	20 (508)	16 (406)	240	2100	10.9 (1.7)	1/2 (13)	5.2 (2.4)	6.7 (3.0)	8.4 (3.8)
	18 (457)	20 (508)	22 (559)	240	3000	10.4 (1.6)	3/4 (19)	8.2 (3.7)	9.9 (4.5)	11.6 (5.3)
	24 (610)	20 (508)	28 (711)	240	4200	10.9 (1.7)	3/4 (19)	11.9 (5.4)	13.8 (6.3)	15.5 (7.0)
	30 (762)	20 (508)	34 (864)	240/240 ^①	5000	10.4 (1.6)	1/2 (13)	15.2 (6.9)	17.7 (8.0)	19.4 (8.8)
	36 (914)	20 (508)	40 (1016)	240/240 ^①	6000	10.4 (1.6)	3/4 (19)	17.9 (8.1)	20.9 (9.5)	22.6 (10.3)

All units in this table are suitable for use up to 2000°F (1093°C) maximum surface temperature.

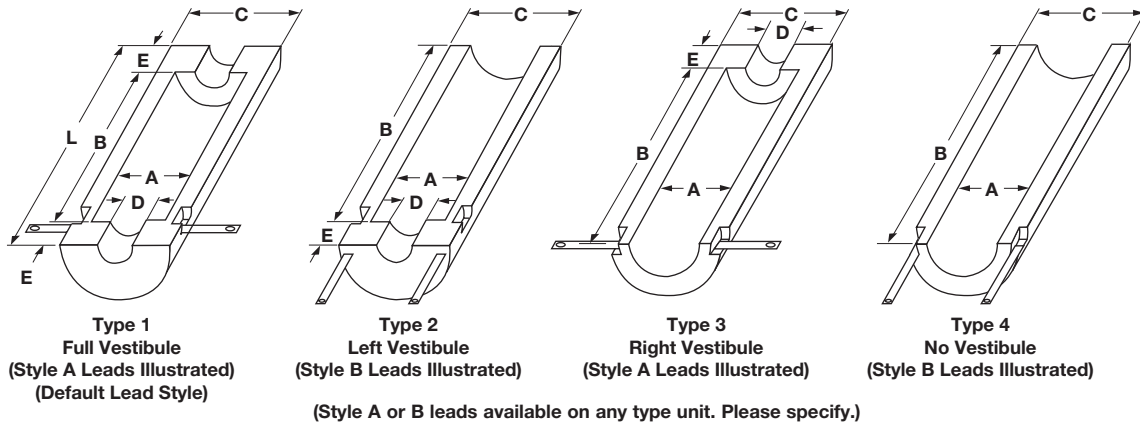
For unheated units, see catalog page 430.

① These units have dual elements to use in "parallel" for 240V usage. Alternate designs are available for 480V, 277V and three-phase (internally wired). Contact your Watlow representative.

High-Temperature Heaters



Ceramic Fiber Heaters



Semi-Cylindrical Units — Embedded Coiled Elements (see page 421)

Dimensions in. (mm)						Electrical Rating			Strip Lead Width in. (mm)	Approximate Net Wt.	
Heated Size			Type 1, 2 & 3 Sizes								
			Vestibule Sizes							Volts	Power (Watts) ±5%
I.D. (A) in. (mm) +1/8 (+3.2)	Length (B) in. (mm) +1/16 -1/8 (1.6-3.2)	O.D (C) in. (mm) (Ref)	Length (L) in. (mm) +1/16 - 1/8 (1.6-3.2)	Dia. (D) in. (mm) ±1/8 (±3.2)	Length (E) in. (mm) +1/16 -1/8 (1.6-3.2)						
2 (51)	6 (152)	6 (152)	8 (203)	1 (25)	1 (25)	60	275	14.6 (2.3)	3/8 (10)	1.1 (0.5)	1.1 (0.5)
	12 (305)	6 (152)	14 (356)	1 (25)	1 (25)	120	550	14.6 (2.3)	3/8 (10)	1.8 (0.8)	1.8 (0.8)
	18 (457)	6 (152)	20 (508)	1 (25)	1 (25)	120	750	13.3 (2.1)	3/8 (10)	2.3 (1.0)	2.3 (1.0)
	24 (610)	6 (152)	26 (660)	1 (25)	1 (25)	240	1100	14.6 (2.3)	3/8 (10)	3.5 (1.6)	3.5 (1.6)
3 1/2 (89)	6 (152)	7 1/2 (191)	9 1/2 (241)	2 (51)	1 3/4 (45)	60	450	13.6 (2.1)	1/2 (13)	2.0 (0.9)	1.5 (0.7)
	12 (305)	7 1/2 (191)	15 1/2 (394)	2 (51)	1 3/4 (45)	120	900	13.6 (2.1)	1/2 (13)	3.1 (1.4)	2.6 (1.2)
	18 (457)	7 1/2 (191)	21 1/2 (546)	2 (51)	1 3/4 (45)	120	1250	12.6 (2.0)	1/2 (13)	4.5 (2.0)	4.0 (1.8)
	24 (610)	7 1/2 (191)	27 1/2 (699)	2 (51)	1 3/4 (45)	240	1800	13.6 (2.1)	1/2 (13)	5.4 (2.4)	4.9 (2.2)
5 (127)	6 (152)	9 (229)	11 (279)	2 1/2 (64)	2 1/2 (64)	60	625	13.3 (2.1)	1/2 (13)	3.4 (1.5)	2.5 (1.1)
	12 (305)	9 (229)	17 (432)	2 1/2 (64)	2 1/2 (64)	120	1250	13.3 (2.1)	1/2 (13)	4.9 (2.2)	4.0 (1.8)
	18 (457)	9 (229)	23 (584)	2 1/2 (64)	2 1/2 (64)	240	1775	12.6 (2.0)	1/2 (13)	5.7 (2.6)	4.8 (2.2)
	24 (610)	9 (229)	29 (737)	2 1/2 (64)	2 1/2 (64)	240	2500	13.3 (2.1)	1/2 (13)	7.9 (3.6)	6.9 (3.1)
	30 (762)	9 (229)	35 (889)	2 1/2 (64)	2 1/2 (64)	240	3100	13.2 (2.0)	3/4 (19)	10.9 (4.9)	9.2 (4.2)
	36 (914)	9 (229)	41 (1041)	2 1/2 (64)	2 1/2 (64)	240	3550	12.6 (2.0)	3/4 (19)	13.2 (6.0)	11.5 (5.2)
6 1/2 (165)	6 (152)	10 1/2 (267)	12 (305)	5 (127)	3 (76)	120	750	12.2 (1.9)	3/8 (10)	3.8 (1.7)	2.6 (1.2)
	12 (305)	10 1/2 (267)	18 (457)	5 (127)	3 (76)	240	1500	12.2 (1.9)	3/8 (10)	5.4 (2.4)	4.2 (1.9)
	18 (457)	10 1/2 (267)	24 (610)	5 (127)	3 (76)	240	2100	11.4 (1.8)	1/2 (13)	7.5 (3.4)	6.2 (2.8)
	24 (610)	10 1/2 (267)	30 (762)	5 (127)	3 (76)	240	3000	12.2 (1.9)	3/4 (19)	10.9 (4.9)	8.9 (4.0)
	30 (762)	10 1/2 (267)	36 (914)	5 (127)	3 (76)	240	3750	12.2 (1.9)	3/4 (19)	13.5 (6.1)	11.4 (5.2)
	36 (914)	10 1/2 (267)	42 (1067)	5 (127)	3 (76)	240	4200	11.4 (1.8)	3/4 (19)	16.4 (7.4)	14.3 (6.5)
8 (203)	6 (152)	12 (305)	12 (305)	6 1/2 (165)	3 (76)	120	900	11.6 (1.8)	1/2 (13)	5.0 (2.1)	2.8 (1.3)
	12 (305)	12 (305)	18 (457)	6 1/2 (165)	3 (76)	240	1800	11.6 (1.8)	1/2 (13)	7.6 (2.9)	5.0 (2.3)
	18 (457)	12 (305)	24 (610)	6 1/2 (165)	3 (76)	240	2500	11.1 (1.7)	1/2 (13)	10.5 (4.3)	8.1 (3.7)
	24 (610)	12 (305)	30 (762)	6 1/2 (165)	3 (76)	240	3500	11.6 (1.8)	3/4 (19)	13.9 (5.3)	12.4 (5.6)
	30 (762)	12 (305)	36 (914)	6 1/2 (165)	3 (76)	240	4200	11.1 (1.7)	3/4 (19)	16.6 (7.0)	14.1 (6.4)
	36 (914)	12 (305)	42 (1067)	6 1/2 (165)	3 (76)	240/240 ^①	5000	11.1 (1.7)	1/2 (13)	18.0 (8.2)	15.6 (7.1)

CONTINUED

All units have 2 ±1/4 inch thick walls.

All units in this table are suitable for use up to 2000°F (1093°C) maximum surface temperature.

For unheated units, see catalog page 430.

Overall length applies only to the full vestibule (Type 1) units. Types 2 and 3 are shorter by one vestibule length. Type 4 length equals (B).

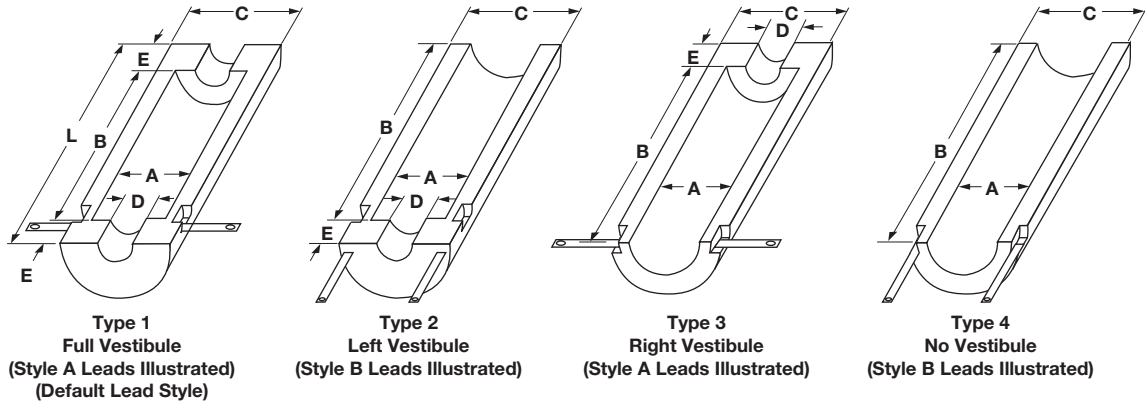
Type 2 (left vestibule) and Type 3 (right vestibule) style units are not stocked. They are, however, still standard units and designs are kept on file.

① These units have dual elements to use in "parallel" for 240V usage. Alternate designs are available for 480V, 277V and three-phase (internally wired). Contact your Watlow representative.

High-Temperature Heaters



Ceramic Fiber Heaters



(Style A or B leads available on any type unit. Please specify.)

Semi-Cylindrical Units — Embedded Coiled Elements (Con't.) (see page 421)

Dimensions in. (mm)						Electrical Rating			Strip Lead Width in. (mm)	Approximate Net Wt.	
Heated Size			Type 1, 2 & 3 Sizes								
			Vestibule Sizes			Volts	Power (Watts) ±5%	Surface Loading W/in² (W/cm²)			
I.D. (A) in. (mm) +1/8 (+3.2)	Length (B) in. (mm) +1/16 -1/8 (1.6-3.2)	O.D (C) in. (mm) (Ref)	Length (L) in. (mm) +1/16 - 1/8 (1.6-3.2)	Dia. (D) in. (mm) ±1/8 (±3.2)	Length (E) in. (mm) +1/16 -1/8 (1.6-3.2)						
10 (254)	12 (305)	14 (356)	18 (457)	8 (203)	3 (76)	240	2100	11.1 (1.7)	1/2 (13)	9.2 (4.2)	6.5 (2.9)
	18 (457)	14 (356)	24 (610)	8 (203)	3 (76)	240	3000	10.6 (1.6)	3/4 (19)	13.3 (6.0)	10.6 (4.8)
	24 (610)	14 (356)	30 (762)	8 (203)	3 (76)	240	4200	11.1 (1.7)	3/4 (19)	15.5 (7.0)	12.8 (5.8)
	30 (762)	14 (356)	36 (914)	8 (203)	3 (76)	240/240 ^①	5000	10.6 (1.6)	1/2 (13)	18.7 (8.5)	15.4 (7.0)
	36 (914)	14 (356)	42 (1067)	8 (203)	3 (76)	240/240 ^①	6000	10.6 (1.6)	3/4 (19)	22.6 (10.3)	19.3 (8.8)
12 (305)	12 (305)	16 (406)	18 (457)	10 (254)	3 (76)	240	2500	11.1 (1.7)	1/2 (13)	9.9 (4.5)	6.8 (3.1)
	18 (457)	16 (406)	24 (610)	10 (254)	3 (76)	240	3500	10.6 (1.6)	3/4 (19)	13.0 (5.9)	9.9 (4.5)
	24 (610)	16 (406)	30 (762)	10 (254)	3 (76)	240	4200	9.3 (1.4)	3/4 (19)	18.5 (8.4)	15.4 (7.0)
	30 (762)	16 (406)	36 (914)	10 (254)	3 (76)	240/240 ^①	6000	10.6 (1.6)	3/4 (19)	22-5 (10.2)	18.6 (8.4)
	36 (914)	16 (406)	42 (1067)	10 (254)	3 (76)	240/240 ^①	7000	10.6 (1.6)	3/4 (19)	26.9 (12.2)	23.6 (10.5)
14 (356)	12 (305)	18 (457)	18 (457)	12 (305)	3 (76)	240	3000	11.4 (1.8)	3/4 (19)	12.6 (5.7)	9.0 (4.1)
	18 (457)	18 (457)	24 (610)	12 (305)	3 (76)	240	4200	10.6 (1.6)	3/4 (19)	15.3 (6.9)	11.7 (5.2)
	24 (610)	18 (457)	30 (762)	12 (305)	3 (76)	240/240 ^①	6000	11.4 (1.8)	3/4 (19)	18.8 (8.5)	15.2 (6.9)
	30 (762)	18 (457)	36 (914)	12 (305)	3 (76)	240/240 ^①	7000	10.6 (1.6)	3/4 (19)	26.7 (12.1)	22.2 (10.1)
	36 (914)	18 (457)	42 (1067)	12 (305)	3 (76)	240/240 ^①	8400	10.6 (1.6)	3/4 (19)	31.8 (14.4)	27.3 (12.4)
16 (406)	12 (305)	20 (508)	18 (457)	14 (356)	3 (76)	240	3500	11.6 (1.8)	3/4 (19)	14.0 (6.4)	10.2 (4.6)
	18 (457)	20 (508)	24 (610)	14 (356)	3 (76)	240	4200	9.3 (1.4)	3/4 (19)	16.9 (7.7)	13.1 (5.9)
	24 (610)	20 (508)	30 (762)	14 (356)	3 (76)	240/240 ^①	7000	11.6 (1.8)	3/4 (19)	20.8 (9.4)	17.0 (7.7)
	30 (762)	20 (508)	36 (914)	14 (356)	3 (76)	240/240 ^①	7600	10.1 (1.6)	3/4 (19)	30.1 (13.7)	24.2 (11.0)
	36 (914)	20 (508)	42 (1067)	14 (356)	3 (76)	240/240 ^①	9000	9.9 (1.5)	3/4 (19)	34.4 (15.6)	28.5 (12.9)

All units in this table have 2 ±1/4 inch thick walls.

All units in this table are suitable for use up to 2000°F (1093°C) maximum surface temperature.

For unheated units, see catalog page 430.

Overall length applies only to the full vestibule (Type 1) Units. Types 2 and 3 are shorter by one vestibule length. Type 4 length equals (B).

Type 2 (left vestibule) and Type 3 (right vestibule) style units are not stocked. They are, however, still standard units and designs are kept on file.

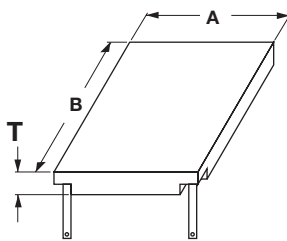
① These units have dual elements to use in "parallel" for 240V usage. Alternate designs are available for 480V, 277V and three-phase (internally wired). Contact your Watlow representative.

High-Temperature Heaters

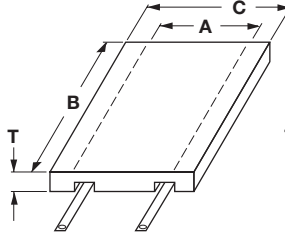


Ceramic Fiber Heaters

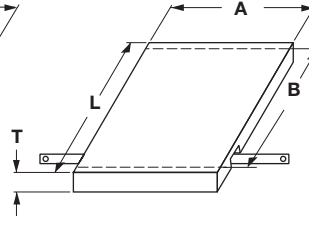
All units: T =
2 ± 1/4 inches
(51 ± 6 mm)



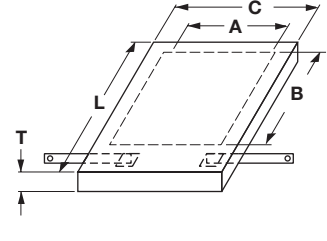
Type 5
Fully Heated
(Style A Leads Illustrated)
(Default Lead Style)



Type 6
Insulated Sides
(Style B Leads Illustrated)



Type 7
Insulated Ends
(Style C Leads Illustrated)



Type 8
Insulated All Edges
(Style C Leads Illustrated)

(Style A, B or C leads available on any type unit. Please specify.)

Flat Units—High Watt Density Sinuated Elements (see page 420)

Dimensions in. (mm)				Electrical Rating			Strip Lead Width in. (mm)	Approximate Net Wt.		
Heated Size		Type 6 & 8	Type 7 & 8							
Width (A) in. (mm) <small>+1/16 -1/8 (1.6-3.2)</small>	Length (B) in. (mm) <small>+1/16 -1/8 (1.6-3.2)</small>	Width (C) in. (mm) <small>+1/16 -1/8 (1.6-3.2)</small>	Length (L) in. (mm) <small>+1/16 -1/8 (1.6-3.2)</small>	Volts	Power (Watts) ±5%	Surface Loading W/in² (W/cm²)		Type 5 lbs (kg)	Type 6 & 7 lbs (kg)	Type 8 lbs (kg)
6 (152)	12 (305)	10 (254)	16 (406)	60	1250	17.4 (2.7)	1/2 (13)	1.7 (0.8)	2.7 (1.6)	3.6 (1.2)
	18 (457)	10 (254)	22 (559)	120	2000	18.5 (1.6)	1/2 (13)	2.6 (1.2)	3.7 (2.1)	4.6 (1.7)
	24 (610)	10 (254)	28 (711)	120	2500	17.4 (2.7)	1/2 (13)	3.2 (1.5)	5.0 (2.7)	5.9 (2.3)
	24 (610)	10 (254)	28 (711)	240	2500	17.4 (2.7)	1/2 (13)	3.2 (1.5)	5.0 (2.7)	5.9 (2.3)
	30 (762)	10 (254)	34 (864)	240	3400	18.9 (2.7)	1/2 (13)	4.5 (2.0)	7.1 (3.6)	7.9 (3.2)
	36 (914)	10 (254)	40 (1016)	240	4000	18.5 (2.9)	1/2 (13)	5.5 (2.5)	8.5 (4.2)	9.3 (3.9)
8 (203)	12 (305)	12 (305)	16 (406)	60	1800	18.7 (2.9)	3/4 (19)	2.3 (1.1)	3.0 (1.8)	3.9 (1.4)
	18 (457)	12 (305)	22 (559)	120	3000	20.8 (3.2)	3/4 (19)	3.5 (1.6)	4.6 (2.5)	5.5 (2.1)
	24 (610)	12 (305)	28 (711)	120	3600	18.7 (2.9)	3/4 (19)	4.4 (2.0)	6.1 (3.2)	7.0 (2.8)
	30 (762)	12 (305)	34 (864)	240	5000	20.8 (3.2)	1/2 (13)	6.1 (2.8)	8.7 (4.4)	9.7 (4.0)
	36 (914)	12 (305)	40 (1016)	240	6000	20.8 (3.2)	3/4 (19)	7.0 (3.2)	10.0 (5.0)	11.0 (4.5)
10 (254)	12 (305)	14 (356)	16 (406)	120	2000	16.7 (2.6)	1/2 (13)	2.4 (1.1)	3.7 (2.2)	4.8 (1.7)
	18 (457)	14 (356)	22 (559)	120	3600	20.0 (3.1)	3/4 (19)	4.0 (1.8)	5.2 (2.9)	6.3 (2.4)
	24 (610)	14 (356)	28 (711)	240	4500	17.9 (2.8)	1/2 (13)	4.7 (2.1)	7.2 (3.8)	8.3 (3.3)
	30 (762)	14 (356)	34 (864)	240	6000	20.0 (3.1)	3/4 (19)	6.7 (3.0)	9.3 (4.8)	10.5 (4.3)
	36 (914)	14 (356)	40 (1016)	240	7200	20.0 (3.1)	3/4 (19)	8.5 (3.9)	11.5 (5.8)	12.7 (5.2)
12 (305)	12 (305)	16 (406)	16 (406)	120	2500	17.4 (2.7)	1/2 (13)	2.9 (1.3)	4.3 (2.5)	5.5 (2.0)
	12 (305)	16 (406)	16 (406)	240	2500	17.4 (2.7)	3/8 (10)	2.9 (1.3)	4.3 (2.5)	5.5 (2.0)
	18 (457)	16 (406)	22 (559)	240	4000	18.5 (2.9)	1/2 (13)	4.5 (2.0)	6.1 (3.3)	7.3 (2.8)
	24 (610)	16 (406)	28 (711)	240	6000	20.8 (3.2)	3/4 (19)	6.6 (3.0)	8.6 (4.4)	9.8 (3.9)
	30 (762)	16 (406)	34 (864)	240	7200	20.0 (3.1)	3/4 (19)	8.6 (3.9)	11.2 (5.7)	12.6 (5.1)
	36 (914)	16 (406)	40 (1016)	240/240 [Ⓢ]	8400	19.4 (3.0)	1/2 (13)	10.2 (4.6)	13.2 (6.6)	14.6 (6.0)
14 (356)	12 (305)	18 (457)	16 (406)	120	3500	20.8 (3.2)	3/4 (19)	4.2 (1.9)	5.3 (3.0)	6.7 (2.4)
	18 (457)	18 (457)	22 (559)	240	4900	19.4 (3.0)	1/2 (13)	6.1 (2.8)	7.6 (4.1)	9.1 (3.4)
	24 (610)	18 (457)	28 (711)	240	7000	20.8 (3.2)	3/4 (19)	8.5 (3.9)	10.5 (5.4)	11.9 (4.8)
	30 (762)	18 (457)	34 (864)	240/240 [Ⓢ]	8400	20.0 (3.1)	1/2 (13)	10.7 (4.9)	13.2 (6.6)	14.6 (6.0)
	36 (914)	18 (457)	40 (1016)	240/240 [Ⓢ]	9800	19.4 (3.0)	1/2 (13)	12.2 (5.5)	15.2 (7.5)	16.6 (6.9)
16 (406)	12 (305)	20 (508)	16 (406)	120	3550	18.5 (2.9)	3/4 (19)	4.7 (2.1)	5.7 (3.4)	7.4 (2.6)
	18 (457)	20 (508)	22 (559)	240	5750	20.0 (3.1)	3/4 (19)	7.1 (3.2)	8.6 (4.7)	10.3 (3.9)
	24 (610)	20 (508)	28 (711)	240	7100	18.5 (2.9)	3/4 (19)	9.5 (4.3)	11.5 (6.0)	13.2 (5.2)
	30 (762)	20 (508)	34 (864)	240/240 [Ⓢ]	9600	20.0 (3.1)	1/2 (13)	11.7 (5.3)	14.2 (7.2)	15.9 (6.4)
	36 (914)	20 (508)	40 (1016)	240/240 [Ⓢ]	11500	20.0 (3.1)	3/4 (19)	14.2 (6.4)	17.2 (8.6)	18.9 (7.8)

All units in this table are suitable for use up to 1800°F (982°C) maximum surface temperature.

For unheated units, see catalog page 430.

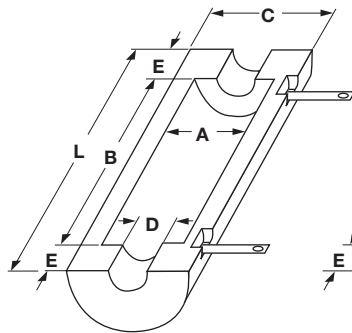
Sinuated wire, high watt density units are provided with embedded sinuated elements and high emissivity coating unless exposed sinuated is specified when manufactured. (These are not stocked.) Contact your Watlow representative.

① These units have dual elements to use in "parallel" for 240V usage. Alternate designs are available for 480V, 277V and three-phase (internally wired). Contact your Watlow representative.

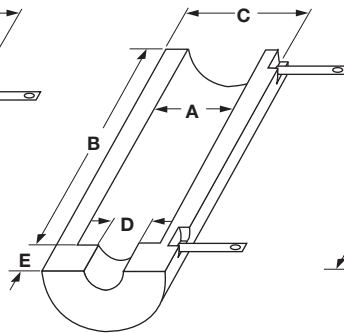
High-Temperature Heaters



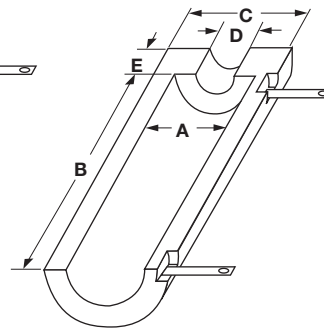
Ceramic Fiber Heaters



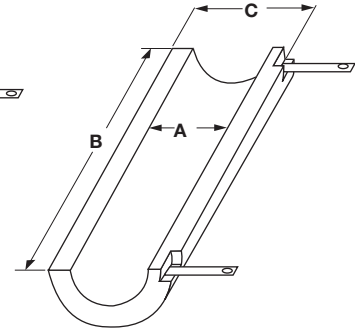
Type 1
Full Vestibule
(Style A Leads Illustrated)
(Default Lead Style)



Type 2
Left Vestibule
(Style A Leads Illustrated)



Type 3
Right Vestibule
(Style A Leads Illustrated)



Type 4
No Vestibule
(Style A Leads Illustrated)

Semi-Cylindrical Units—High Watt Density Sinuated Elements (see page 420)

Dimensions in. (mm)						Electrical Rating			Strip Lead Width in. (mm)	Approximate Net Wt.	
Heated Size			Type 1, 2 & 3 Sizes								
			Vestibule Sizes							Volts	Power (Watts) ±5%
I.D. (A) in. (mm) + ¹ / ₈ (+3.2)	Length (B) in. (mm) + ¹ / ₁₆ - ¹ / ₈ (1.6-3.2)	O.D (C) in. (mm) (Ref)	Length (L) in. (mm) + ¹ / ₁₆ - ¹ / ₈ (1.6-3.2)	Dia. (D) in. (mm) ± ¹ / ₈ (±3.2)	Length (E) in. (mm) + ¹ / ₁₆ - ¹ / ₈ (1.6-3.2)						
5 (127)	6 (152)	9 (229)	11 (279)	3 ¹ / ₂ (89)	2 ¹ / ₂ (64)	60	750	15.9 (2.5)	³ / ₈ (10)	3.1 (1.4)	2.3 (1.0)
	12 (305)	9 (229)	17 (432)	3 ¹ / ₂ (89)	2 ¹ / ₂ (64)	60	1400	14.9 (2.3)	³ / ₄ (19)	4.5 (2.0)	3.6 (1.6)
	18 (457)	9 (229)	23 (584)	3 ¹ / ₂ (89)	2 ¹ / ₂ (64)	120	2100	14.9 (2.3)	¹ / ₂ (13)	5.2 (2.4)	4.3 (2.0)
	24 (610)	9 (229)	29 (737)	3 ¹ / ₂ (89)	2 ¹ / ₂ (64)	120	2800	14.9 (2.3)	³ / ₄ (19)	6.9 (3.1)	6.0 (2.7)
	30 (762)	9 (229)	35 (889)	3 ¹ / ₂ (89)	2 ¹ / ₂ (64)	240	3500	14.9 (2.3)	¹ / ₂ (13)	8.3 (3.8)	7.4 (3.4)
	36 (914)	9 (229)	41 (102)	3 ¹ / ₂ (89)	2 ¹ / ₂ (64)	240	4200	14.9 (2.3)	¹ / ₂ (13)	9.6 (4.4)	8.7 (3.9)
6 ¹ / ₂ (165)	6 (152)	10 ¹ / ₂ (267)	12 (305)	5 (127)	3 (76)	60	1000	16.3 (2.5)	¹ / ₂ (13)	3.6 (1.6)	2.4 (1.1)
	12 (305)	10 ¹ / ₂ (267)	18 (457)	5 (127)	3 (76)	120	2000	16.3 (2.5)	¹ / ₂ (13)	5.1 (2.3)	3.9 (1.8)
	18 (457)	10 ¹ / ₂ (267)	24 (610)	5 (127)	3 (76)	120	3000	16.3 (2.5)	³ / ₄ (19)	6.8 (3.1)	5.6 (2.5)
	24 (610)	10 ¹ / ₂ (267)	30 (762)	5 (127)	3 (76)	240	4000	16.3 (2.5)	¹ / ₂ (13)	9.5 (4.3)	7.4 (3.4)
	30 (762)	10 ¹ / ₂ (267)	36 (914)	5 (127)	3 (76)	240	5000	16.3 (2.5)	³ / ₄ (19)	11.0 (5.0)	9.3 (4.2)
	36 (914)	10 ¹ / ₂ (267)	42 (1067)	5 (127)	3 (76)	240	6000	16.3 (2.5)	³ / ₄ (19)	12.4 (5.6)	11.2 (5.1)
8 (203)	6 (152)	12 (305)	12 (305)	6 ¹ / ₂ (165)	3 (76)	60	1300	17.2 (2.7)	¹ / ₂ (13)	4.1 (1.9)	2.6 (1.2)
	12 (305)	12 (305)	18 (457)	6 ¹ / ₂ (165)	3 (76)	120	2600	17.2 (2.7)	³ / ₄ (19)	6.9 (3.1)	5.4 (2.4)
	18 (457)	12 (305)	24 (610)	6 ¹ / ₂ (165)	3 (76)	240	3900	17.2 (2.7)	¹ / ₂ (13)	8.5 (3.9)	7.0 (3.2)
	24 (610)	12 (305)	30 (762)	6 ¹ / ₂ (165)	3 (76)	240	5200	17.2 (2.7)	¹ / ₂ (13)	12.0 (5.4)	10.5 (4.8)
	30 (762)	12 (305)	36 (914)	6 ¹ / ₂ (165)	3 (76)	240	6250	16.7 (2.6)	³ / ₄ (19)	13.8 (6.3)	12.3 (5.6)
	36 (914)	12 (305)	42 (1067)	6 ¹ / ₂ (165)	3 (76)	240/240 ^①	7800	17.2 (2.7)	¹ / ₂ (13)	15.6 (7.1)	14.1 (6.4)

CONTINUED

All units in this table have 2 ±1/4 inch thick walls.

All units in this table are suitable for use up to 1800°F (982°C) maximum surface temperature.

For unheated units, see catalog page 430.

Sinuated wire, high watt density units are provided with embedded sinuated elements and high emissivity coating unless exposed sinuated is specified when manufactured. (These are not stocked.) Contact your Watlow representative.

Overall length applies only to the full vestibule (Type 1) units. Types 2 and 3 are shorter by one vestibule length. Type 4 length equals (B).

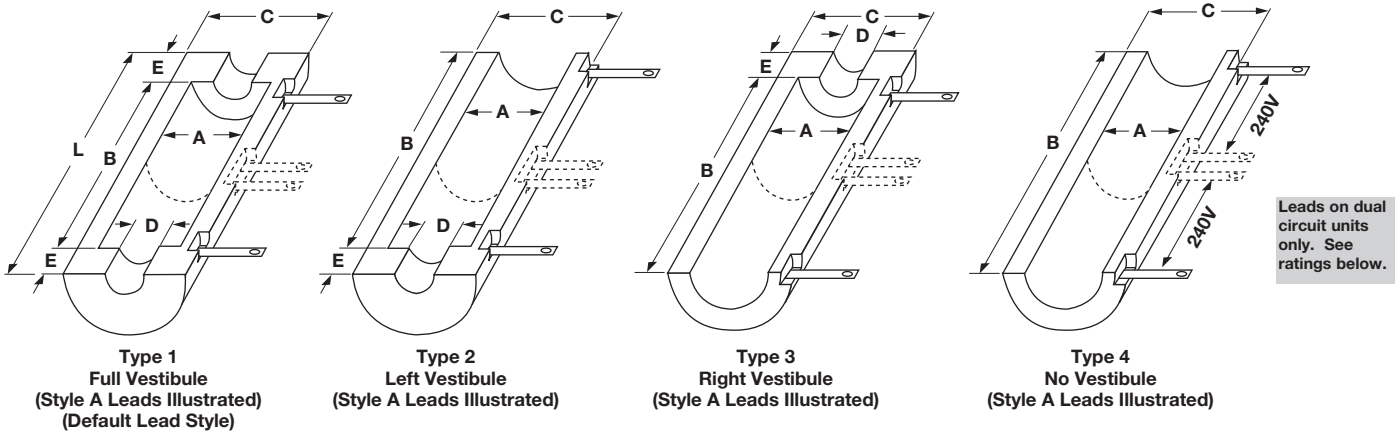
Type 2 (left vestibule) and Type 3 (right vestibule) style units are not stocked. They are, however, still standard units and designs are kept on file.

① These units have dual elements to use in "parallel" for 240V usage. Alternate designs are available for 480V, 277V and three-phase (internally wired). Contact your Watlow representative.

High-Temperature Heaters



Ceramic Fiber Heaters



Semi-Cylindrical Units—High Watt Density Sinuated Elements (Con't.) (see page 420)

Dimensions in. (mm)						Electrical Rating			Strip Lead Width in. (mm)	Approximate Net Wt.	
Heated Size			Type 1, 2 & 3 Sizes								
			Vestibule Sizes							Volts	Power (Watts) ±5%
I.D. (A) in. (mm) + ¹ / ₈ (+3.2)	Length (B) in. (mm) + ¹ / ₁₆ - ¹ / ₈ (1.6-3.2)	O.D (C) in. (mm) (Ref)	Length (L) in. (mm) + ¹ / ₁₆ - ¹ / ₈ (1.6-3.2)	Dia. (D) in. (mm) ± ¹ / ₈ (±3.2)	Length (E) in. (mm) + ¹ / ₁₆ - ¹ / ₈ (1.6-3.2)						
10 (254)	12 (305)	14 (356)	18 (457)	8 (203)	3 (76)	240	3200	17.0 (2.6)	1/2 (13)	8.5 (3.9)	5.8 (2.6)
	18 (457)	14 (356)	24 (610)	8 (203)	3 (76)	240	4800	17.0 (2.6)	1/2 (13)	12.0 (5.4)	9.3 (4.2)
	24 (610)	14 (356)	30 (762)	8 (203)	3 (76)	240	6400	17.0 (2.6)	3/4 (19)	13.8 (6.3)	11.1 (5.0)
	30 (762)	14 (356)	36 (914)	8 (203)	3 (76)	240/240 ^①	8000	17.0 (2.6)	1/2 (13)	17.6 (8.0)	14.9 (6.8)
	36 (914)	14 (356)	42 (1067)	8 (203)	3 (76)	240/240 ^①	9600	17.0 (2.6)	1/2 (13)	21.3 (9.7)	18.6 (8.4)
12 (305)	12 (305)	16 (406)	18 (457)	10 (254)	3 (76)	240	3800	16.8 (2.6)	1/2 (13)	8.9 (4.0)	5.9 (2.7)
	18 (457)	16 (406)	24 (610)	10 (254)	3 (76)	240	5700	16.8 (2.6)	3/4 (19)	11.2 (5.1)	8.1 (3.7)
	24 (610)	16 (406)	30 (762)	10 (254)	3 (76)	240	7600	16.8 (2.6)	3/4 (19)	16.7 (7.6)	13.6 (6.2)
	30 (762)	16 (406)	36 (914)	10 (254)	3 (76)	240/240 ^①	9600	17.0 (2.6)	1/2 (13)	18.0 (8.2)	14.9 (6.8)
	36 (914)	16 (406)	42 (1067)	10 (254)	3 (76)	240/240 ^①	11400	16.8 (2.6)	3/4 (19)	19.2 (8.7)	16.1 (7.3)
14 (356)	12 (305)	18 (457)	18 (457)	12 (305)	3 (76)	240	4400	16.7 (2.6)	1/2 (13)	11.4 (5.2)	7.7 (3.5)
	18 (457)	18 (457)	24 (610)	12 (305)	3 (76)	240	6600	16.7 (2.6)	3/4 (19)	12.9 (5.9)	9.4 (4.3)
	24 (610)	18 (457)	30 (762)	12 (305)	3 (76)	240/240 ^①	8800	16.7 (2.6)	1/2 (13)	16.2 (7.4)	12.7 (5.8)
	30 (762)	18 (457)	36 (914)	12 (305)	3 (76)	240/240 ^①	11400	17.3 (2.7)	3/4 (19)	19.4 (8.8)	15.8 (7.2)
	36 (914)	18 (457)	42 (1067)	12 (305)	3 (76)	240/240 ^①	13200	16.7 (2.6)	3/4 (19)	22.4 (10.2)	18.8 (8.5)
16 (406)	12 (305)	20 (508)	18 (457)	14 (356)	3 (76)	240	5000	16.6 (2.6)	3/4 (19)	11.8 (5.4)	8.0 (3.6)
	18 (457)	20 (508)	24 (610)	14 (356)	3 (76)	240/240 ^①	7500	16.6 (2.6)	1/2 (13)	15.1 (6.8)	11.3 (5.1)
	24 (610)	20 (508)	30 (762)	14 (356)	3 (76)	240/240 ^①	10000	16.6 (2.6)	1/2 (13)	18.1 (8.2)	14.3 (6.5)
	30 (762)	20 (508)	36 (914)	14 (356)	3 (76)	240/240 ^①	12800	16.8 (2.6)	3/4 (19)	18.1 (10.1)	18.5 (8.4)
	36 (914)	20 (508)	42 (1067)	14 (356)	3 (76)	240/240 ^①	15000	16.6 (2.6)	3/4 (19)	22.3 (12.0)	22.6 (10.3)

All units in this table have 2 ±1/4 inch thick walls.

All units in this table are suitable for use up to 1800°F (982°C) maximum surface temperature.

For unheated units, see catalog page 430.

Sinuated wire, high watt density units are provided with embedded sinuated elements and high emissivity coating unless exposed sinuated is specified when manufactured. (These are not stocked.) Contact your Watlow representative.

Overall length applies only to the full vestibule (Type 1) units. Types 2 and 3 are shorter by one Vestibule length. Type 4 length equals (B).

Type 2 (left vestibule) and Type 3 (right vestibule) style units are not stocked. They are, however, still standard units and designs are kept on file.

① These units have dual elements to use in "parallel" for 240V usage. Alternate designs are available for 480V, 277V and three-phase (internally wired). Contact your Watlow representative.

High-Temperature Heaters



Ceramic Fiber Heaters

Legacy Part Number Scheme

VF - Flat

VS - Semi-Cylindrical

Part Number

①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪	⑫	⑬	⑭
Base Code Nbr.	Base Code Nbr.	Base Code Nbr.	Base Code Nbr.	Base Code Nbr.	Base Code Nbr.	Base Code Nbr.	Base Code Nbr.	Base Code Nbr.	Modification Options			Lead Options	Lead Length
V	F	5	1	2	A	1	2	S		0	0		

① ② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨ Base Code Number

⑩	Modification Options
0 =	None
A =	0.140 thermocouple tube I.D. center of heated length of unit
B =	0.265 thermocouple tube I.D. center of heated length of unit
E =	Black surface coat
F =	Black surface coat 0.140 thermocouple tube I.D. center of heated length of unit
G =	Black surface coat 0.265 thermocouple tube I.D. center of heated length of unit

⑬	Lead Options
0 =	None
1 =	601 Alloy 600 strip A style
2 =	601 Alloy 600 strip B style
3 =	601 Alloy 600 strip C style
9 =	Flex NI, MGT A style
A =	Flex NI, MGT B style
B =	Flex NI, MGT C style
E =	Chromel® -A / NI, A style
F =	Chromel® -A / NI, B style
G =	Chromel® -A / NI, C style

⑭	Lead Length
A =	0 in.
B =	1 in.
E =	2 in.
F =	3 in.
G =	4 in.
H =	5 in.
J =	6 in.
K =	7 in.
L =	8 in.
M =	9 in.
N =	10 in.
P =	11 in.
R =	12 in.
S =	13 in.
T =	14 in.
U =	15 in.
V =	16 in.
W =	17 in.
X =	18 in.
Y =	19 in.
1 =	20 in.
2 =	21 in.
3 =	22 in.
4 =	23 in.
6 =	24 in.
7 =	30 in.
8 =	36 in.
9 =	42 in.



Ceramic Fiber Heaters

How to Order

Made-to-Order

Ordering Information

Quantity: When ordering, specify quantity of units desired. Semi-cylindrical units are sold as “each half.” Two halves to make a pair are usually required. Please include the number of desired spares or extras in the total quantity.

Part number: Use the legacy part number if an exact re-order of a previously designed made-to-order unit is needed. Please reconfirm volts and watts, lead orientation and length. Most heaters allow selection of several stock modifications (see page 432) and termination options (see pages 426 and 427).

Dimensions for made-to-order units: Include a drawing if possible. Specify the heated area, width and length, overall width/length, thickness, electrical ratings, etc.

Wattage: 6.5 to 25 W/in² (1.0 - 3.9 W/cm²) on the heating surface is the recommended watt density range for operation in the 1500 to 2200°F (815 - 1204°C) range. (Note: At the higher temperatures, lower watt densities must be employed.) Please provide operating temperatures and conditions. Contact your Watlow representative for higher watt densities at other temperatures. Generally, for higher operating temperature limits, lower watt densities must be used.

Voltage: 60, 120 and 240VAC are offered on units. However, up to 600 volts is possible with extended capabilities. Internally connected three-lead, three-phase units are also available on made-to-order units (these are normally internally wye-connected). Contact your Watlow representative on special voltage requirements.

Leads: Lead length and orientation (i.e. **Style A, B or C**). Lead **Style A**, 12 in. (305 mm) long.

Shipping weight: The product listing tables show net weights per unit. To estimate gross shipping weight, add 30 percent to the total. Additional shipping/packaging charges may be incurred for certain large orders. Due to the light weight but large size of these heaters, dimensional box weighting may occur on expedited air shipments.

Ordering Hints

Ordering ceramic fiber heaters is easy. However, it is very important to pay attention to part numbers and special modifications details.

- Always provide the correct Lead Style letter. (See suggested illustrations above the charts, but Style A-12 will be the default lead if not otherwise specified.)
- Supply a drawing or sketch whenever possible to eliminate confusion.
- When ordering Type 6, 7, 8 units, be certain of the heated area and no-heat area orientations desired.
- When planning to order Type 2 and/or Type 3 units (left or right vestibule), there are three options to consider—two of which could be used on the Type 1 items:
 1. Order the appropriate full vestibule unit. The customer can carefully remove the unneeded vestibule.
 2. Order the full vestibule unit. Prior to shipping Watlow will remove the unneeded vestibule as a stock modification. There is a small additional charge for this.
 3. Special order the desired Type 2 or 3 unit. This requires extended manufacturing of the heater and increases delivery time, but will minimize costs.