

THICK FILM TECHNOLOGY

LOW-PROFILE

EFFICIENT

HEATING



THICK FILM HEATERS PROVIDE LOW-PROFILE AND HIGH PERFORMANCE



Watlow's new thick film heater technology provides you with an innovative new way to deliver heat to various applications that require a compact heating solution. You can now achieve greater control of your heating applications with this breakthrough technology that offers a high-performance, low-profile design that can be intimately fitted to flat and cylindrical surfaces.

HEAT EXACTLY WHERE YOU WANT IT

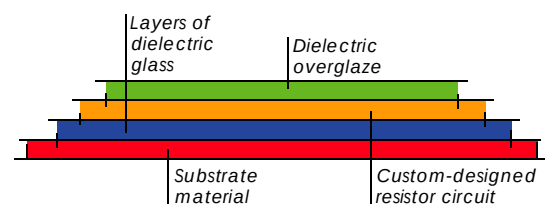
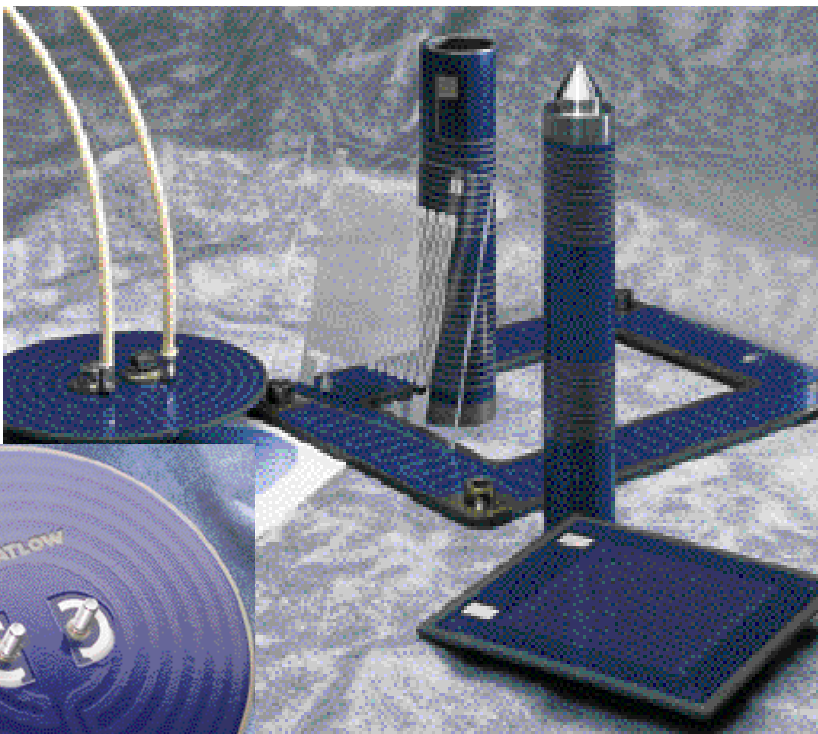
The direct surface contact of the thick film heater lets you put the heat precisely where it is needed. The heater also provides you with superior heat transfer and fast thermal response, while glass-based films provide a non-porous surface that prevents moisture absorption.

Because of the unique nature of the thick film circuit, this heater can be designed to vary heat output across the entire unit.

THE THICK FILM PROCESS

Layering several different film coatings onto a conductive surface produces the thick film heater. After each layer is printed, it is dried to evaporate solvents and then fired at high temperatures. This firing cycle bonds the multiple layers together and to the base material; it melts glass frit materials into multiple cohesive dielectric layers; and allows metal oxides present to form the conductive lattice that carries the current and generates heat. Optional temperature sensors are available and can be integrated into the heater design to meet your application needs.

Watlow utilizes different dielectric and resistor ink combinations depending upon thermal expansion and electrical conduction characteristics of the substrate material. The material



The construction of Watlow's thick film heaters comes from layering different film coatings directly onto conductive surfaces.

Look inside pocket for detailed product information.

chosen is determined by your process' compatibility, operating temperature and cycle rates. A poor match will result in delamination of the heater film.

Accelerated life testing of thick film heaters has demonstrated significantly longer life than with infrared (radiant) methods or other types of conduction heating technologies. Watlow's thick film heaters are manufactured to meet the requirements of NEC codes and is a UL® recognized component and conforms with applicable CE directives. Consult the factory for specific details.

BENEFITS OF THICK FILM HEATERS

- Low profile, compact size
- Fast response with low thermal mass
- Even thermal profile to $\pm 5^\circ\text{F}$ ($\pm 2^\circ\text{C}$)
- High watt densities from 35 to 125 W/in² (dependent upon application and temperature)
- 1025°F (550°C), maximum operating temperature (dependent upon application demands and substrate material)
- Corrosion resistant; long heater life
- Application-specific distributed wattages available

Ceramic, quartz and stainless steel substrates provide low thermal expansion, high temperature tolerance, lower dielectric constant, rigidity and dimensional stability; while accommodating mounting holes and notches.

AVAILABLE SUBSTRATES

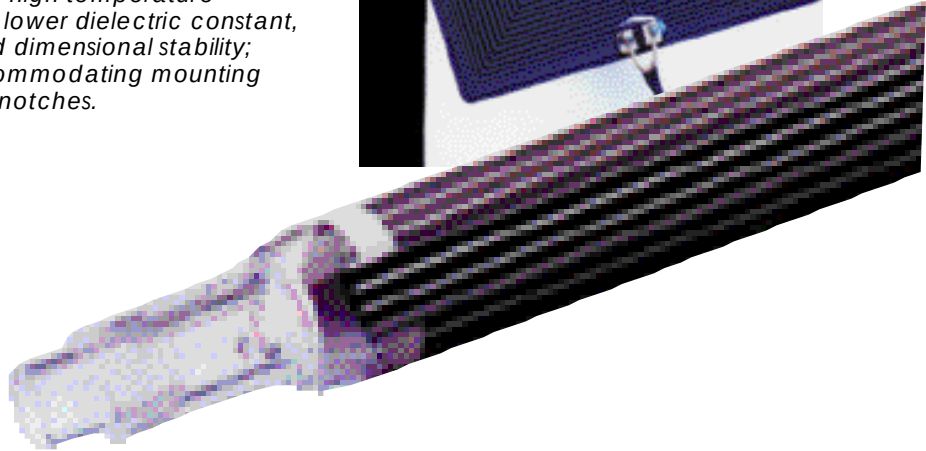
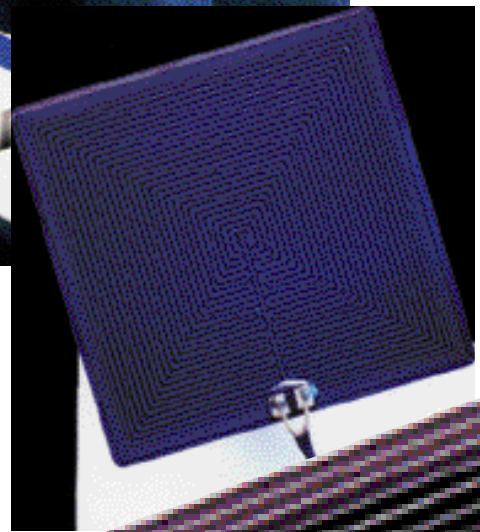
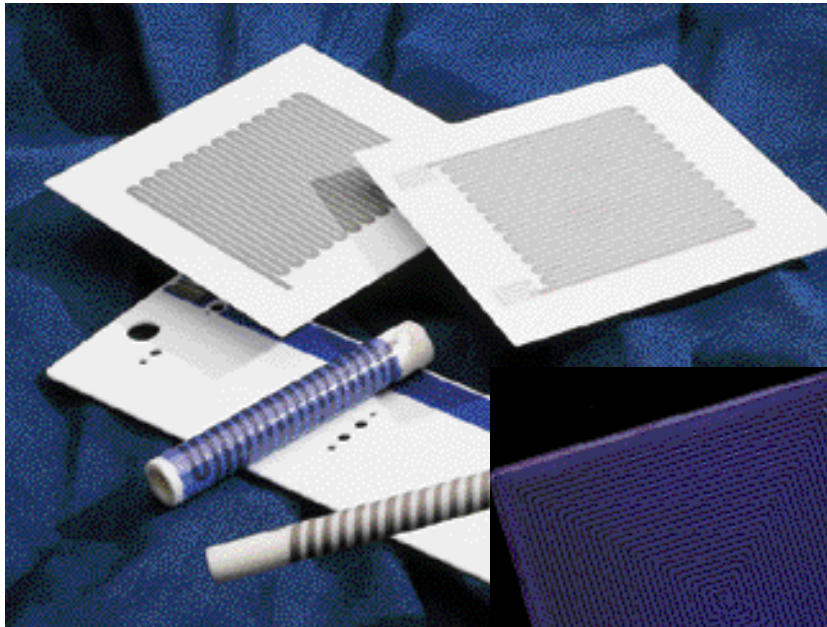
The combination of low thermal mass coupled with fast response, high watt density, compact size and conductive heat technology makes Watlow's thick

film heaters an excellent solution for your applications that require heat, but have minimum height clearances.

Contact your local Watlow sales engineer for available substrates.

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Inconel® is a registered trademark of Special Metals Corporation.



Ultra Pure Thick Film Quartz Heater Modules Are Ideal for Aggressive Chemical Heating

Watlow thick film quartz heater modules are intended for use in deionized (DI) water and aggressive chemical heating applications. This product employs Watlow's patented thick film on quartz technology to significantly advance the state-of-the-art in ultra pure process heating. The primary benefits of thick film heating include:

- Reduction in size of the heater modules over other heating technologies, therefore saving space in expensive tools, cleanrooms and wafer fabs
- Elimination of the need for clean-dry-air (CDA) purge required in most infrared (IR) heating systems
- Reduction of the possibility of quartz devitrification that can occur in high temperature IR heating systems
- Elimination of potential metal contamination associated with Teflon® (PFA) heating systems
- Reduction of preventative maintenance (PM) and increased tool uptime
- Reduced cost of ownership

These superior thick film heaters can be applied in areas where space is at a premium or where conventional heaters cannot be used because the voltage and wattage combination precludes using other types of resistive heaters. Due to the unique nature of a thick film circuit, these heaters can be designed to vary heat output across the entire surface.

U.S. Patent # 6,037,574



Applications

Heating aggressive chemicals such as:

- Ammonium chloride
- Deionized water (DI)
- Hydrobromic acid
- Hydrochloric acid
- Hydrogen peroxide
- Nitric acid
- Phosphoric acid
- Piranha etch (Sulfuric acid + hydrogen peroxide)
- RCA standard clean 1 (SC1) (DI + ammonium hydroxide + hydrogen peroxide)
- RCA standard clean 2 (SC2) (DI + hydrochloric acid + hydrogen peroxide)
- Sulfuric acid
- TMAH (Tetra Methyl Ammonium Hydroxide)



WATLOW

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



Features

- High purity semiconductor grade GE 214 quartz
- Single tube power ratings up to 11kW, multi-tube systems up to 32.4kW
- Glassware fluid pressures up to 75 psi*
- 30 liters (8 gallons) per minute, maximum flow rate
- 0.95 liters (0.25 gallon) per minute, minimum flow rate (for vertically oriented units)
- 11.4 liters (3.0 gallons) per minute, minimum flow rate (for horizontally oriented units)
- Primary element over-temperature sensor available as an RTD or thermocouple
- Redundant mechanical over-temperature snap switch
- Single- and multi-phase power forms 120-480V~(ac)
- UL® recognized - thick film heater on glassware level
- UR®, C-UR®, VDE, CE (pending)
- Options including enclosure materials, electrical interconnection and mounting configurations
- Quartz heater modules utilize materials that have been FM approved in a different geometric form
- Horizontal or vertical orientations available

Benefits

- Eliminates risk of metal contamination
- Reduced preventative maintenance (PM) cycles
- Reduced cost of ownership
- Longer life
- Reduced element size; reduced system size
- Maximum efficiency in differing flow conditions
- Fast recovery due to direct heater contact
- Low element temperature, <450°C (842°F), no CDA-purge required
- Watt densities up to 15.5 W/cm² (100 W/in²)
- Fast response
- Compact package size
- Wattages to 21.6 kW for dual fluid paths
- 200°C (390°F) maximum process fluid temperature

***Note:** Refer to Flaretek® or Flarelock® II for manufacturer's pressure vs. temperature rating charts on external fittings. Use a surge suppressor and/or pressure regulator in applications exceeding manufacturer's ratings.

Thick Film Quartz Heaters Outperform Traditional Heating Solutions

In-line thick film quartz tube heaters are the building blocks of thick film quartz heater modules, Watlow's state-of-the-art solution for aggressive chemical heating. Designed for applications with up to 15.5 W/cm² (100 W/in²), thick film quartz heaters are an excellent solution resulting in a smaller footprint, faster response to dynamic changes in flow and pressure and longer heater life than traditional technologies.

Problems With Traditional Heating Technology vs. Watlow Thick Film Solutions

Wet Chemistry Heating - Teflon® vs. Quartz

Quartz glass is the preferred material for most semiconductor high purity wet processes due to its chemically stable and inert characteristics. Historically, Teflon® has also seen extensive service in wet chemistry processes due to its chemical resistance and inert properties. For example, Teflon® has been used to cover metallic heating elements in an effort to make them compatible with the purity requirements of semiconductor processes. Teflon®, however, has absorption and permeation characteristics which allow particulate migration from the heater sheath through the Teflon® cover, contaminating the process. Quartz does not exhibit these characteristics making it a superior material for insuring process purity in wet chemistry heating.

Thick Film Quartz Heating Technology vs. IR

Infrared (IR) heaters use a lamp element operating at an extremely high temperature to radiate energy through the quartz. IR heaters offer a good compromise between performance and size, however, these are less efficient and have a relatively short lamp life, typically about six months. The high operating temperature of the IR lamp represents an operating hazard and requires external cooling means to keep the enclosure and IR lamp termination area at safe limits. The efficiency of IR transmission through quartz is a function of the source (lamp) temperature. To achieve IR heat transfer efficiencies in the +90 percent range requires a source temperature of >2000°C (3632°F).

Watlow thick film quartz heating technology utilizes a specially formulated conductive ink which is permanently fused to, and becomes an actual part of, the quartz surface. This results in an element temperature many times less than that of the IR heater; no CDA purge is required for a touch safe package.

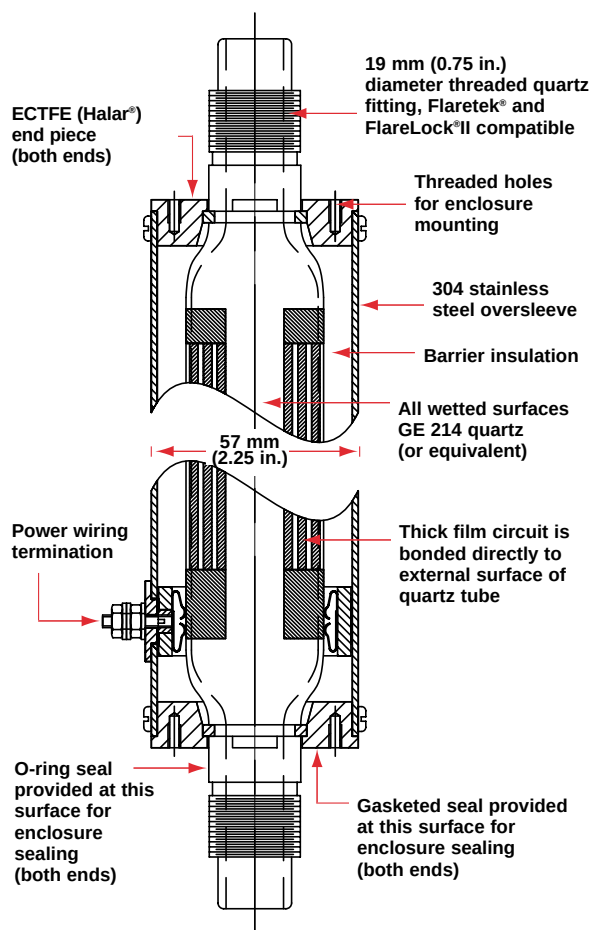
This packs an incredible amount of heat into a small package. The versatile nature of the design and manufacturing process allows Watlow engineers to put power virtually anywhere on the quartz surface. The thick film element itself adds an insignificant amount of mass to the parent quartz material so heat up and response time performance is equally impressive.

Construction of Thick Film Quartz Heaters Provides High Heater Efficiencies and Design Flexibility

The construction of Watlow's single quartz heater module employs a standard 38 mm (1.50 in.) diameter heated quartz tube surrounded by an insulating barrier and a 300 series stainless steel oversleeve. An FM 4910 compliant end piece is used to provide the module mounting interface. Sealing provisions are provided in order to isolate the heater components from the operational environment when the module is incorporated into a heating system design.

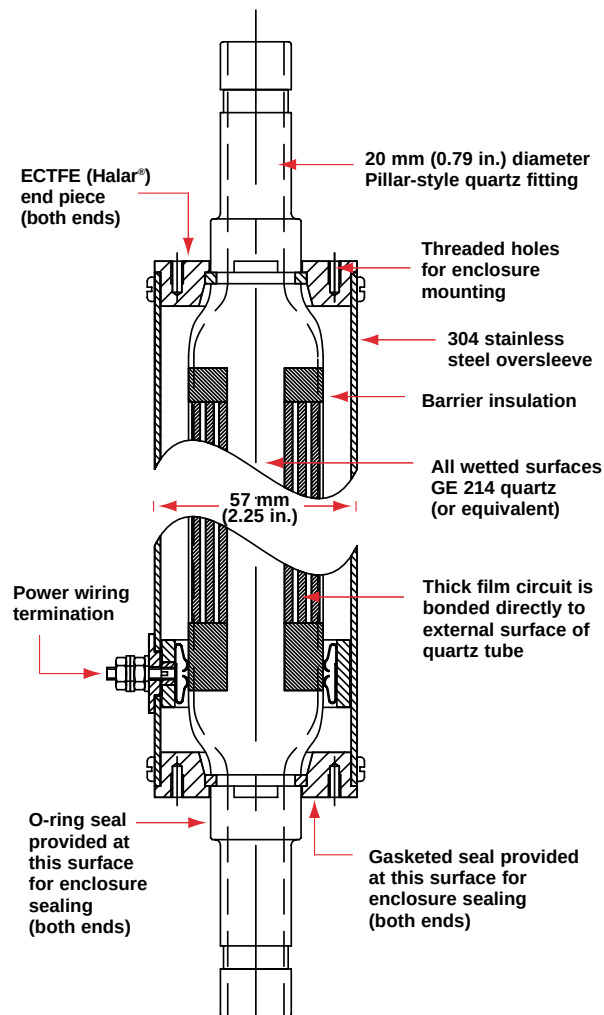
Power ratings and lengths may be varied as required to support virtually any combination of voltages and application requirements by combining multiple modules into a single array package. This modular approach allows higher capacity systems to be offered by combining the necessary configuration of heater modules with controllers and other customer options.

Quartz Tube with Flaretek®-Style Fitting



Flaretek®-Style Fitting

Quartz Tube with Pillar-Style Fitting



Pillar-Style Fitting

Thick Film Quartz Heater Modules Available in Single, Dual, and Triple Configurations

Quartz heater modules can be stand-alone units or interconnected to form systems for DI water or acid applications.

Depending upon the process need, the design of the quartz module allows application requirements to drive not only the electrical and thermal solution, but also the physical size of the equipment.

Watlow quartz modules are designed for both vertical and horizontal applications.



Fully assembled, single-tube, vertical unit with Pillar-style fitting.

Standard Features

- Single-phase voltage
- Quartz end fittings compatible with standard 19 mm (0.75 in.) Flaretek® and Flarelock® II fittings
- 1828 mm (6.00 ft) long Teflon® lead wires within flexible Teflon® sleeve
- Redundant safety high limit - Pilot duty (dry contact mechanical switch)
- High limit sensor - Type J or K thermocouple

Options

- Quartz end fitting compatible with standard 19 mm Pillar-style fitting available
- 3-phase voltage
- Leak detector - Non-contact electro-optical switch (open collector)
- Teflon® (PFA) interconnects for arrays
- Kynar® 740 (PVDF) rated 130°C (266°F) - Recommended for acid applications other than hot phosphoric
- Halar® 901 (ECTFE) - Recommended for hot phosphoric applications
- Process sensor
- Fitting assembly also available
- High limit sensor - 100Ω RTD for dry-fire condition (set limit control for 400°C (752°F))

Dual Quartz Module

Thick film quartz modules are also available as dual modules. The dual module can provide up to double the wattage without doubling the size of the package. The dual quartz modules are available in horizontal or vertical orientation, see page 6.



Two-tube horizontal unit



FLARETEK®-style inlet and outlet fittings on a dual module unit

Triple Quartz Module

Many applications requiring higher kW can also be addressed using module assemblies configured with three fluid paths.

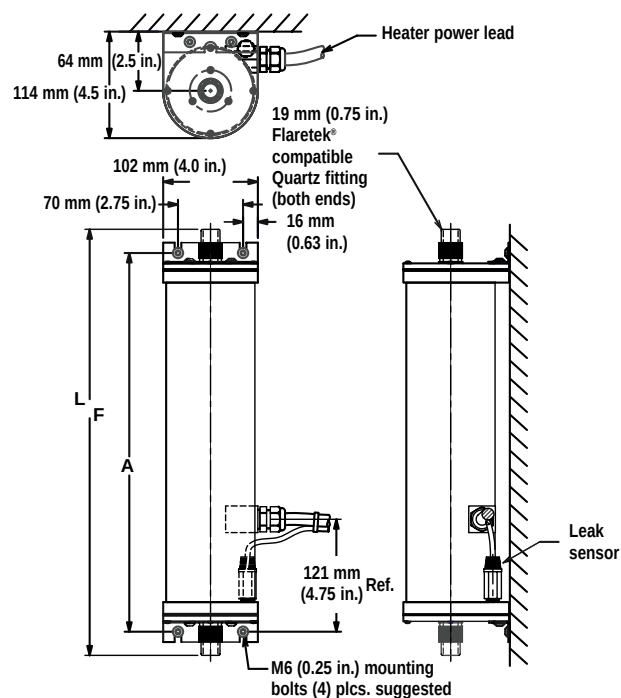
Wattages of up to 32.4 kW can be supplied, but all inquiries should be made to the factory on these custom designs.



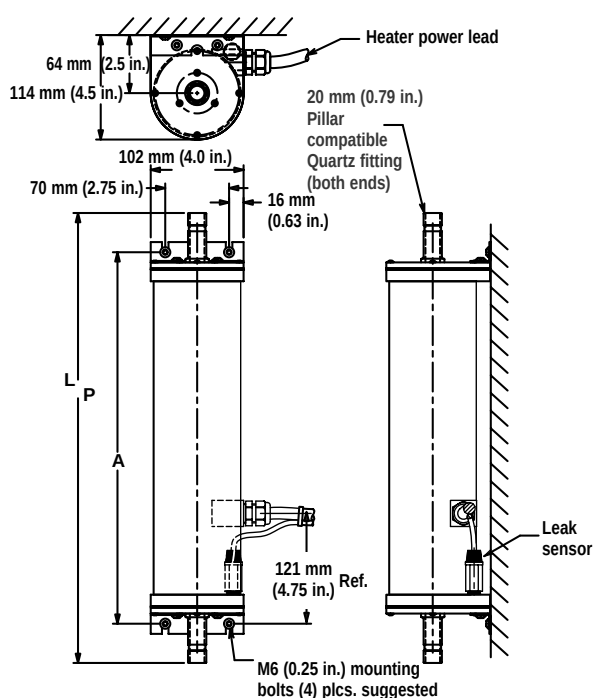
Three-tube vertical unit

Flaretek® and FlareLock® II are registered trademarks of Entegris, Inc. Halar® is a registered trademark of Ausimont USA. Kynar® is a registered trademark of ELF Atochem.

Single Tube Vertical Unit with Flaretek®-Style Fittings



Single Tube Vertical Unit with Pillar-Style Fittings

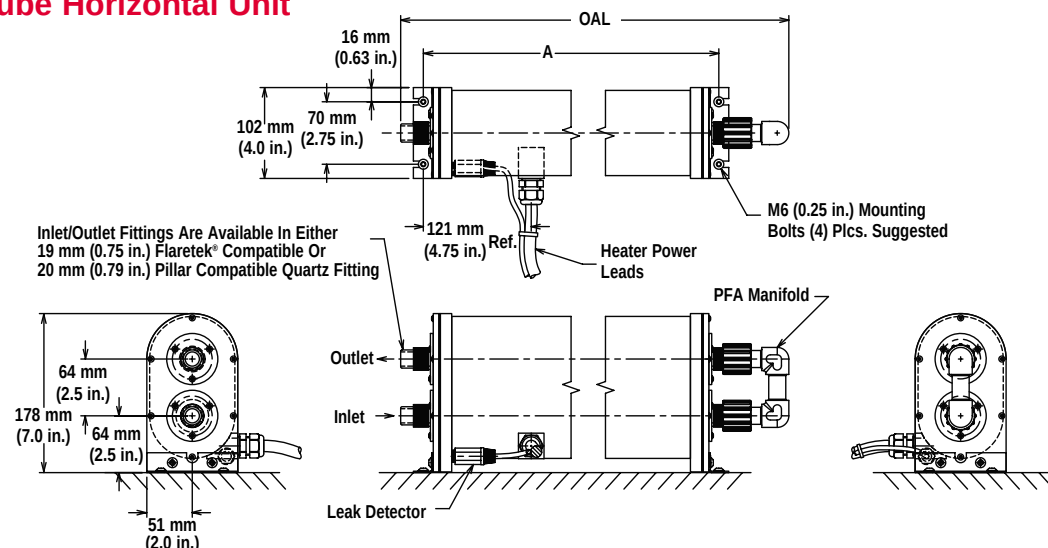


Maximum Available Power (kW)

Minimum Overall Fluid Path Length							
Flaretek®		Pillar		Power (kW)		A	
Lf mm	Lf (inch)	Lp mm	Lp (inch)	Horizontal Orientation	Vertical Orientation	mm	(inch)
305	(12)	340	(13.38)	2.0	2.4	254	(10)
381	(15)	416	(16.38)	3.2	3.8	330	(13)
457	(18)	492	(19.38)	4.4	5.2	406	(16)
533	(21)	568	(22.38)	5.6	6.6	483	(19)
610	(24)	645	(25.38)	6.8	8.0	559	(22)
686	(27)	721	(28.38)	8.0	9.4	635	(25)
762	(30)	797	(31.38)	9.2	10.8	711	(28)
1016	(40 [Ⓢ])	Consult Factory		10.0	11.8	965	(38)
1092	(43 [Ⓢ])	Consult Factory		11.2	13.2	1041	(41)
1168	(46 [Ⓢ])	Consult Factory		12.4	14.6	1118	(44)
1245	(49 [Ⓢ])	Consult Factory		13.6	16.0	1194	(47)
1321	(52 [Ⓢ])	Consult Factory		14.8	17.4	1270	(50)
1397	(55 [Ⓢ])	Consult Factory		16.0	18.8	1346	(53)
1473	(58 [Ⓢ])	Consult Factory		17.2	20.2	1422	(56)
1549	(61 [Ⓢ])	Consult Factory		18.4	21.6	1499	(59)

Notes: ① Fluid path length includes a 19 mm (0.75 in.) Flaretek®- compatible all-PFA tube union.
 Minimum flow rate: 11.4 LPM (3.0 GPM) for horizontal; 0.95 LPM (0.25 GPM) for vertical.
 Consult factory for available voltage forms.

Two Tube Horizontal Unit

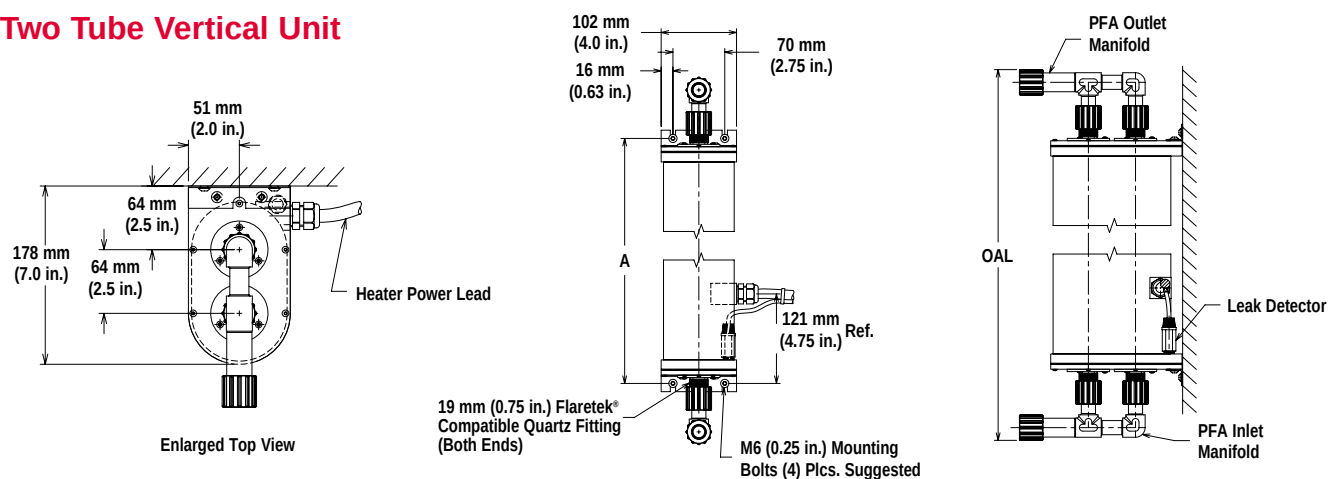


Maximum Available Power for Two Tube Horizontal Enclosure

Horizontal Two Tube Enclosure										
Flaretek® Inlet/Outlet Fittings			Pillar Inlet/Outlet Fittings			Power (kW)	A			
Quartz Weldment Length		OAL		Quartz Weldment Length					OAL	
mm	(inch)	mm	(inch)	mm	(inch)		mm	(inch)		
305	(12)	358	(14.1)	340	(13.38)	376	(14.8)	4.0	254	(10)
381	(15)	434	(17.1)	416	(16.38)	452	(17.8)	6.4	330	(13)
457	(18)	511	(20.1)	492	(19.38)	528	(20.8)	8.8	406	(16)
533	(21)	587	(23.1)	568	(22.38)	605	(23.8)	11.2	483	(19)
610	(24)	663	(26.1)	645	(25.38)	681	(26.8)	13.6	559	(22)
686	(27)	739	(29.1)	721	(28.38)	757	(29.8)	16.0	635	(25)
762	(30)	815	(32.1)	797	(31.38)	833	(32.8)	18.4	711	(28)

Note: Minimum flow rate is 11.4 LPM (3.0 GPM) @ 10 psig minimum. Consult factory for available voltage forms.

Two Tube Vertical Unit



Maximum Available Power for Two Tube Vertical Enclosure

Vertical Two Tube Enclosure								
Flaretek® Inlet/Outlet Fittings				Pillar Inlet/Outlet Fittings		Power (kW)	A	
Quartz Weldment Length		OAL		Quartz Weldment Length				
mm	(inch)	mm	(inch)	mm	(inch)		mm	(inch)
305	(12)	425	(16.8)	Consult Factory		4.8	254	(10)
381	(15)	502	(19.8)	Consult Factory		7.6	330	(13)
457	(18)	578	(22.8)	Consult Factory		10.4	406	(16)
533	(21)	654	(25.8)	Consult Factory		13.2	483	(19)
610	(24)	730	(28.8)	Consult Factory		16.0	559	(22)
686	(27)	806	(31.8)	Consult Factory		18.8	635	(25)
762	(30)	883	(34.8)	Consult Factory		21.6	711	(28)

Note: Minimum flow rate (on a per tube basis) is 0.95 LPM (0.25 GPM) @ 10 psig minimum. Consult factory for available voltage forms.

Thick Film Quartz In-Line Heater Modules Stock List

Part Number	Module Size	Wattage	Voltage	Orientation	Fitting Style	Lead Length	List Price
TQ-117-8-1	18" Single	5.2 kW	208, 1ph	Vertical	¾" Flaretek® compatible	36"	Consult factory
TQ-117-9-1	18" Single	5.2 kW	208, 1ph	Vertical	19 mm Pillar	1000 mm	Consult factory
TQ-117-10-1	30" Single	9.2 kW	480, 3ph	Vertical or Horizontal	¾" Flaretek® compatible	36"	Consult factory
TQ-117-11-1	15" Double	6.4 kW	208, 1ph	Horizontal	¾" Flaretek® compatible	36"	Consult factory
TQ-117-13-1	24" Single	6.8 kW	480, 3ph	Vertical or Horizontal	¾" Flaretek® compatible	36"	Consult factory*

* Includes leak detector

Common features include:

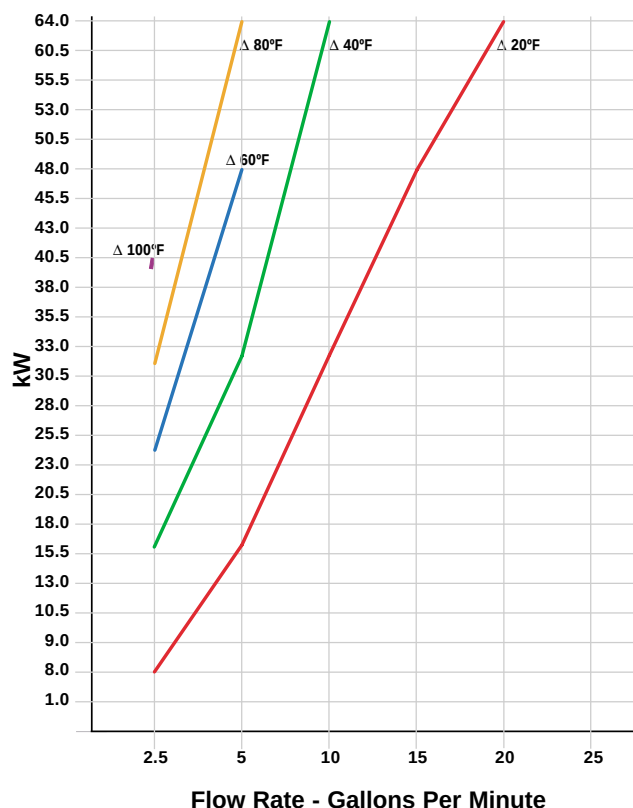
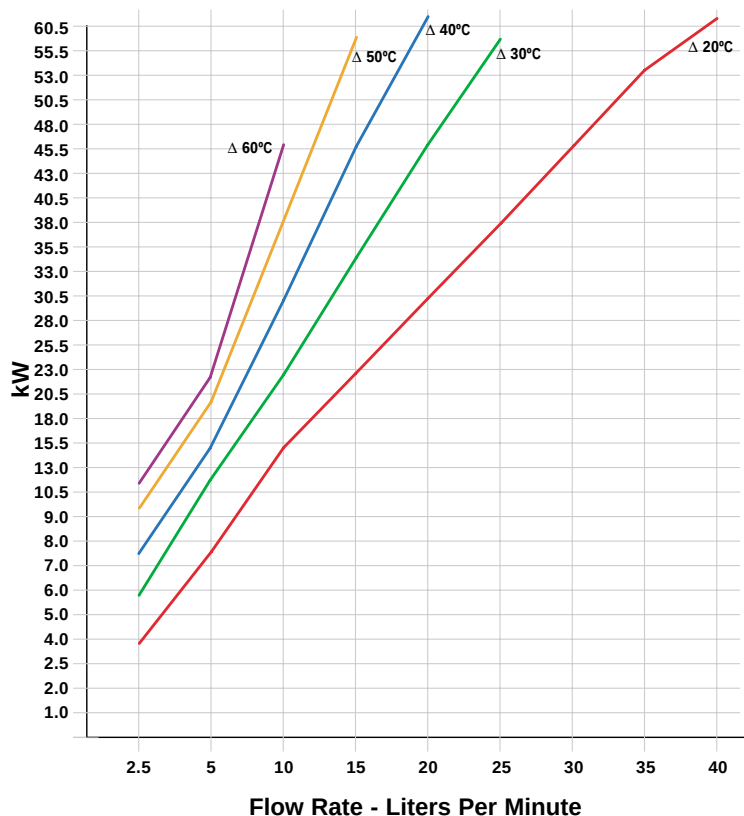
- Pilot duty 24V thermostat
- ANSI Type J high limit T/C
- Kynar® (PVDF) enclosure

Options:

(to be specified at time of order)

- leak detector
- process sensor

Quick Estimates of Wattage Requirements (for Deionized Water)



Note: Locate the application flow rate on x-axis of the appropriate chart and follow the vertical line upward until it intersects the target temperature rise. At that point move left, horizontally, to the y-axis to capture the approximated wattage requirement.

Quick Estimates of Wattage Requirements

For heating flowing water, simply calculate:

$$\text{kW} = \text{GPM} \times \text{temperature rise (°F)} \times 0.16$$

or

$$\text{kW} = \text{Liters/minute} \times \text{temperature rise(°C)} \times 0.076$$

For heating recirculation applications heating water in baths, simply calculate:

$$\text{kW} = \frac{\text{Gallons} \times \text{temperature rise (°F)}}{375 \times \text{Heat up time (hours)}}$$

or

$$\text{kW} = \frac{\text{Liters} \times \text{temperature rise(°C)}}{790 \times \text{Heat up time (hours)}}$$

Performance and Reliability Testing—IR vs. Thick Film—Proves Superiority of Thick Film Quartz Modules

Performance Testing

Watlow's quartz heater module was tested in direct comparison to an IR heater to provide evidence of the performance and efficiency advantages of thick film technology.

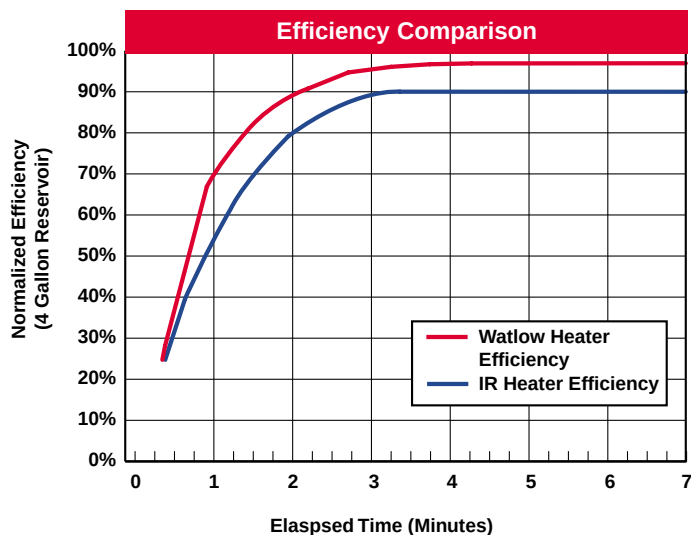
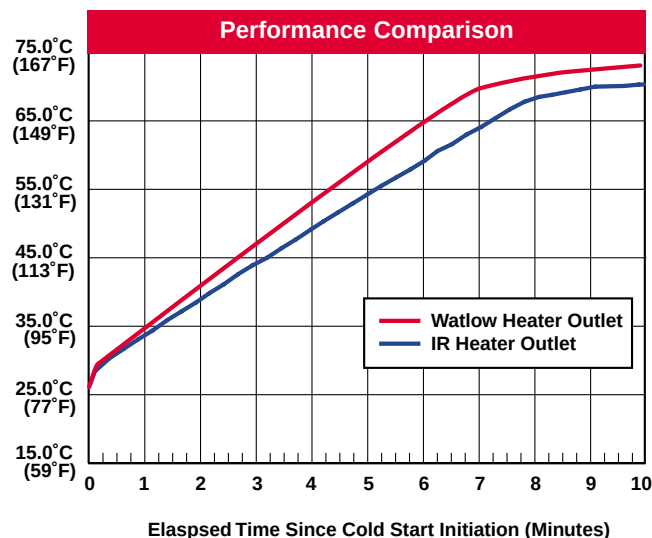
Testing was performed on a wet bench heating DI water. The normalized performance comparison graph illustrates the thermal response of the system using each heater. The thermal load consisted of 15.1 liters (4 gallons) of water circulating through a diaphragm pump, the in-line heater, a diverter valve and back to a holding tank (reservoir). Temperatures were sensed at the outlet of the in-line heater and the bulk tank. The Watlow heater provided a faster heat up time. It outperformed the IR heater by achieving the process set point of 65°C (149°F) in 6.5 minutes; whereas, the IR heater required 7.25 minutes.

This efficiency comparison was created by normalizing the nominal power outputs of the respective heaters and calculating the efficiency based upon the work performed at the reservoir. Elapsed time for the efficiency test was equal for both systems at which both were at 100 percent power.

As shown in the efficiency comparison graph the Watlow heater demonstrated a five to 10 percent improvement in efficiency.

Reliability Testing

Reliability testing of the core technology used in the thick film quartz heater module has been conducted. Reliability targets of three years or 9,000 hours of continuous operation were validated through this testing.



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THICK FILM NOZZLE HEATING TECHNOLOGY

Improve Part Quality and Reduce Cycle Time with Thick Film Nozzle Heating Technology

Because the hot runner nozzle is the final melt path between the hot runner manifold and the gate area, temperature uniformity is critical to avoid differences in melt viscosity. Whether it's hot spots causing thermal degradation of the plastic, or cold spots causing flow restrictions, both affect the final part quality and consistency from shot to shot. Watlow's innovative thick film heating technology provides the injection molding industry with a patented (U.S. patent number 5,973,296) high-performance, low profile hot runner nozzle heater. The direct surface contact of the thick film material to the cylindrical stainless steel sleeve creates optimal heat transfer while the non-porous glass film prevents moisture absorption which results in dielectric failure in cable heaters.

Unlike coiled cable heaters, the design of Watlow's thick film nozzle heater allows the thermocouple to be immersed directly into the hot runner nozzle. This provides a distinct advantage over the design of commonly used coiled cable heaters, which have internal thermocouples; therefore the actual nozzle temperature is measured, not the heater temperature.

Thick Film Heating Technology

Thick film heating technology allows you to put the heat precisely where it is needed. The heater also provides you with greater control and the ability to customize the nozzle temperature profile.

Thick film resistance heaters consist of a sandwich of several different materials. These layers include a metal substrate, a layer of glassy dielectric material, a resistor layer, and a final dielectric layer.

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



Features and Benefits

Uniform thermal profile and ability to pattern heater layout

- Uniform melt temperature for equal cavity filling and improved part quality. Eliminates hot and cold spots.

Low thermal mass

- Allows quicker heat up and less thermal lag between the heater and the nozzle

Extremely low radial profile

- Allows closer pitch—center-to-center distance—between nozzles for higher nozzle density and more parts per mold

Moisture-resistant non-porous glass film construction

- Eliminates need for soft starting
- Minimizes current leakage
- Ultimately reduces cost by eliminating special need for GFCI protection

Agency Approvals

- UL® recognized
- CSA and CE pending



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Substrate I.D.

Standard substrate I.D.s include:

- 6.0 mm (0.238 in.)
- 10.0 mm (0.396 in.)
- 12.0 mm (0.474 in.)
- 12.7 mm (0.502 in.)
- 14.0 mm (0.553 in.)
- 15.9 mm (0.627 in.)
- 19.0 mm (0.752 in.)
- 22.2 mm (0.877 in.)
- 25.4 mm (1.02 in.)
- 28.0 mm (1.104 in.)
- 38.1 mm (1.502 in.)

Substrate Length

- Lengths available starting from 12 mm (0.5 in.). Since development of new length capabilities are ongoing, please consult factory for maximum length.

Voltage

- Voltages ranging from 100 to 240V are available.

Thick Film Nozzle with Metallic Oversleeve

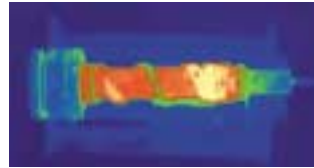


Watlow is also developing a thick film nozzle heater configured with a low-profile, protective metallic oversleeve. This metal sleeve allows for internal lead terminations resulting in a heater thickness unmatched in the marketplace. It also provides additional protection of the dielectric glass material as well as further improving mechanical resistance and enhanced thermal efficiency by directing more heat transfer through the heater substrate directly into the nozzle itself. This added heat transfer (or reduced heat loss to the outside) results in a more efficient heater and overall less energy consumption.

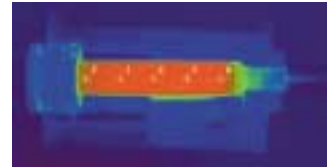
Consult factory for more details on the metallic oversleeve option. *Patent pending.*

Precise Wattage Distribution

Thick film nozzle heaters rated to 500°C (932°F) provide superior temperature uniformity by putting the energy exactly where it is needed.



Temperature distribution using standard coiled cable heater.

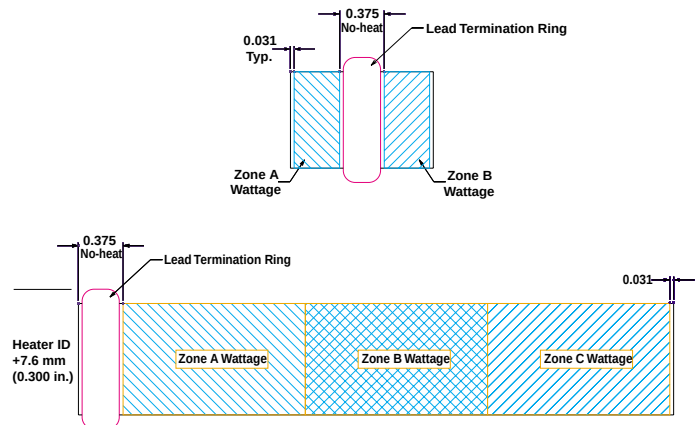


Temperature distribution using thick film heating technology.

Watlow thick film technology heaters offer distinct competitive advantages over cable heater technology:

1. Uniform temperature profile
2. No requirement for clamping of the heater
3. High dielectric barrier with agency approvals eliminates need for soft start
4. Lower heater operating temperatures
5. Precise and repeatable wattage distribution
6. Increased controllability of system
7. Increased productivity through decreased set-up time

Distributed Wattage



Note: Specific items in stock. Consult factory for sizes and quantities.

Installation

The thick film nozzle heaters can be designed to provide a "sliding clearance fit" with the nozzle to deliver optimal heater performance. This clearance fit allows for easy insertion and removal of the heater and excellent heat transfer without the need for clamping, anti-seize or heat sink compound. **Do not use anti-seize or heat sink compound with the thick film nozzle heater.**

Low Profile Heaters Available on Various Substrates

Thick film heaters can be applied in areas where space is at a premium or where conventional heater technology cannot be used due to the voltage and wattage combination typical of other types of resistive heaters.

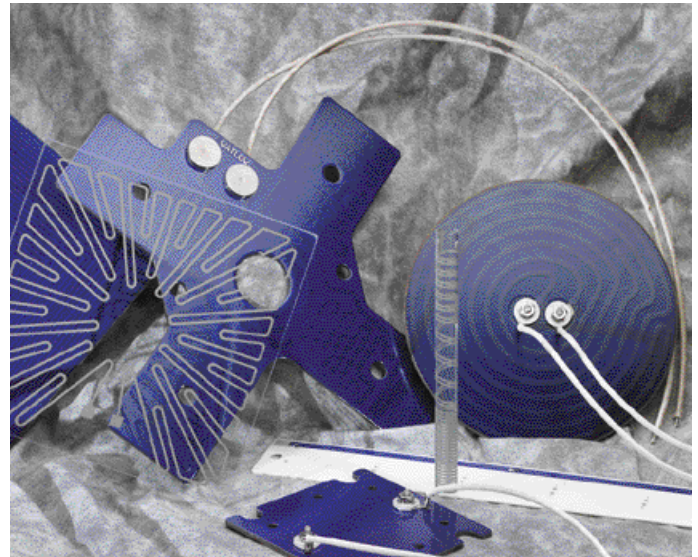
Due to the unique nature of a thick film circuit, these heaters can be designed to vary heat output across the entire surface. This feature will correct virtually any temperature uniformity problem that may be inherent to other heater technologies.

Specifications

- Maximum substrate temperature of 550°C (1025°F) (dependent upon application and temperature)
- Watt densities are application dependent over entire substrate surface
- 35 W/in² for radiant heating applications
- 65 W/in² for conduction heating applications
- Depending on the application, up to 240 volts, three-phase
- Termination options include contact pad, stud or soldered

Applications

- Life sciences: thermal cycling, sterilizers and sample analysis
- Gas chromatography and spectroscopy
- Foodservice equipment: steamtables, griddles and food processing
- Packaging: seal bars and seal rams
- Semiconductor: aggressive chemical heating, susceptor plates and flat panel display



Features and Benefits

Low profile package

- Ideal for applications with limited space
- Can be designed to fit around mounting holes, notches, sensors, etc.

Bonded RTDs, thermistors and thermocouples

- Inhibits moisture penetration

Low thermal mass

- Fast response to power

Variety of substrate materials offered

- Offers excellent corrosion resistance

Infrared thermal scanning technology and finite element analysis

- Results in extremely uniform temperature distribution

High watt densities

- Improves process quality and yields
- Provides precise, repeatable wattage distribution
- Places heat directly where required

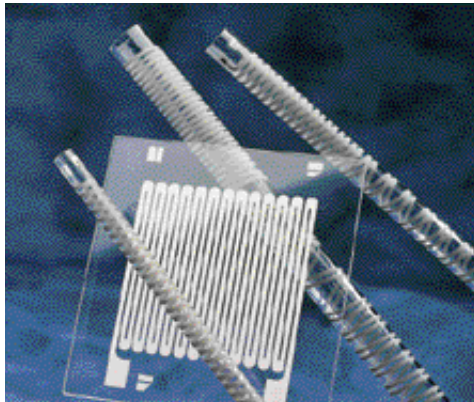


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Quartz



Thick film on quartz glass is ideal for use in many applications where visibility and corrosion resistance are required. The quartz substrate provides a low-profile heater that can be cut or blow molded to fit a variety of shapes and sizes.

Specifications

- Material: Quartz Type GE 214
- Density: 2.2g/cc (0.0795 lb/in³)
- Thermal conductivity: 1.4 W/m-K (9.72 BTU-in/hr-ft²-°F)
- Heat capacity: 0.67 J/g-°C (0.16 BTU/lb-°F)
- Thermal expansion coefficient: 0.4µm/m-°C (0.222 µin/in-°F)
- Notes: Excellent corrosion resistance; no dielectric coat available; choice material for corrosive liquids; except hydrofluoric.

Stainless Steel

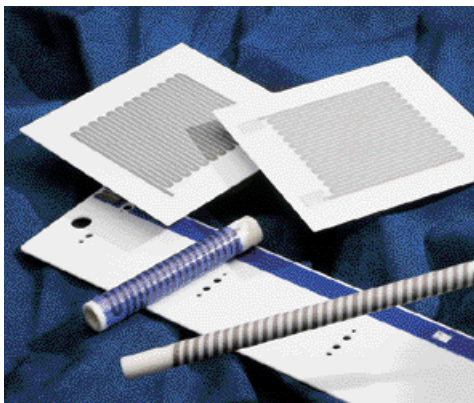


Thick film heaters on stainless steel are ideal for use in many applications where fast response and uniformity are essential. Thick film on stainless steel provides a low-profile heater that has the ability to be laser cut or machined to fit any CAD-generated, two-dimensional shape.

Specifications

- Material: Type 430 SS (W.Nr. 1.4016)
- Density: 7.8 g/cc (0.282 lb/in³)
- Thermal conductivity: 26.1 W/m-K (181 BTU-in/hr-ft²-°F)
- Heat capacity: 0.46 J/g-°C (0.11 BTU/lb-°F)
- Thermal expansion coefficient: 10.4 µm/m-°C (5.78 µin/in-°F)
- Notes: Ensures greater heat transfer through thermally stable substrates.

Ceramics



Thick film on ceramic substrates provide low thermal expansion, high temperature tolerance, lower dielectric constant, rigidity and dimensional stability. Due to the direct surface contact, these thick film heaters ensure greater heat transfer through the thermally stable ceramic substrates than other types of heaters.

Specifications

- Material: Aluminum Oxide or Alumina (Al₂O₃) 96% purity
- Density: 3.72 g/cc (0.134 lb/in³)
- Thermal conductivity: 24.7 W/m-K (171 BTU-in/hr-ft²-°F)
- Heat capacity: 0.88 J/g-°C (0.21 BTU/lb-°F)
- Thermal expansion coefficient: 8.2 µm/m-°C (4.56 µin/in-°F)
- Notes: Can be cut or cast as needed; excellent low cost ceramic.

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THICK FILM CONDUCTION HEATERS

In-Stock Thick Film Heaters Ideal for Clamp-On Applications

Watlow's 14 gauge, 430 stainless steel thick film conduction heaters are ideal for use in many applications where fast response and uniformity are essential. These high performance heaters use thick film technology to provide maximum temperature response in a compact package.

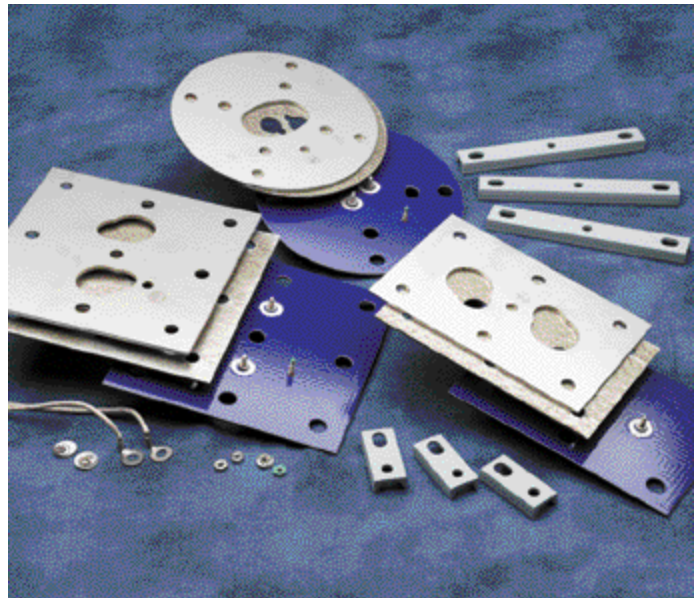
A clamp-on thick film heater provides the best possible combination of heat transfer, thermal efficiency and temperature uniformity. For example, clamping the thick film conduction heater on to a 316 stainless steel pan or aluminum griddle in foodservice applications results in uniform cooking or heating.

This technology can be applied in areas where space is at a premium or where conventional heaters cannot be used because of limited voltage and wattage combinations.

Thick film conduction heaters provide a low-profile heater in a variety of shapes. These shapes include two-dimensional circular, rectangular and square forms. Due to the direct surface contact, thick film heaters ensure greater heat transfer through thermally stable substrates and precise heater patterns.

Applications

- Foodservice
- Industrial machines
- Life sciences
- Plastics
- Semiconductor



Features and Benefits

550°C (1025°F) maximum substrate temperature (dependent upon application demands and substrate material)

- Allows for higher process temperatures than most conduction heater technologies

UR® File #E52951 CSA

- Consult factory for current status of agency recognitions
- Also conforms with applicable CE directives

High watt densities for clamp-on applications

- Allow for precise, repeatable wattage distribution and uniform temperature distribution

Threaded stud termination

- Produces strong, trouble-free connections, see Termination Assembly drawing on back page



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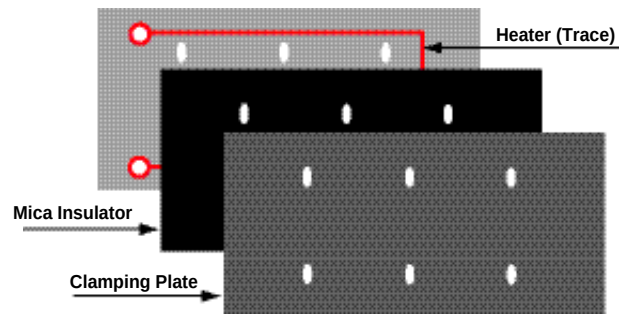
Construction

Thick film conduction heaters, designed for clamp-on applications, are supplied as a multi-part assembly: heater, mica insulator, clamping plate and mounting hardware.

The mica insulator acts as a thermal barrier to more effectively force the heat into the part being heated, as well as an additional protective layer for the heater.

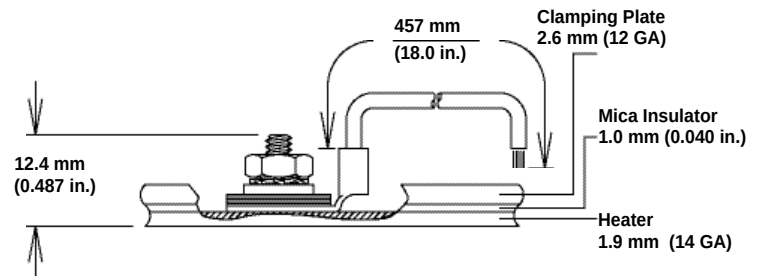
The clamping plate distributes the pressure loading evenly across the entire surface of the heater to promote intimate contact between the thick film heater and the part being heated.

The mounting hardware has been designed to provide the most effective means to clamp the heater to the part being heated, based on the size of the heater.



Termination Assembly

To install, mount the heater to the surface being heated and assemble mounting hardware. Standard measurements of assembly hardware is illustrated in the Termination Assembly drawing to the right. Please refer to the Installation & Maintenance Manual (316-42-32-1) that is supplied with the heater for proper mounting instruction.



Stock Product List

Heater Size mm (inch)	Voltage	Wattage	W/cm ²	W/in ²	Approximate Assembly Weight kg (lbs)	Watlow Code Number
Round						
114 dia. (4.5)	120	325	3.2	(20.4)	0.50 (1.10)	TFA004JA03EL18B
152 dia. (6)	120	850	4.7	(30.1)	1.24 (2.74)	TFA006AA08KL18C
152 dia. (6)	240	1125	6.1	(39.8)	1.24 (2.74)	TFA006AE11EL18C
203 dia. (8)	240	2000	6.1	(39.8)	2.23 (4.91)	TFA008AE200L18C
254 dia. (10)	240	3000	6.04	(39.0)	3.28 (7.24)	TFA010AE300L18C
Square						
57 X 57 (2.25 X 2.25)	120	100	3.9	(25.0)	0.12 (0.27)	TFA2E2EA010L18B
76 X 76 (3 X 3)	120	225	4.03	(26.0)	0.23 (0.5)	TFA3A3AA02EL18B
102 X 102 (4 X 4)	120	400	3.9	(25.0)	0.73 (1.61)	TFA4A4AA040L18C
152 X 152 (6 X 6)	120	1250	5.4	(34.7)	1.70 (3.74)	TFA6A6AA12KL18C
152 X 152 (6 X 6)	240	1450	6.6	(40.3)	1.70 (3.74)	TFA6A6AE14KL18C
203 X 203 (8 X 8)	240	2500	6.1	(39.1)	2.88 (6.36)	TFA8A8AE250L18C
Rectangle						
51 X 102 (2 X 4)	120	240	4.7	(30.0)	0.21 (0.47)	TFA2A4AA02HL18B
102 X 152 (4 X 6)	120	725	4.7	(30.0)	1.12 (2.46)	TFA4A6AA07EL18C
152 X 203 (6 X 8)	240	1920	6.2	(40.0)	2.27 (5.01)	TFA6A8AE19DL18C

Note: Size and wattage may vary with future design enhancements. Please consult factory for current wattage information and pricing.

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Thick Film Heaters on Ceramic Now Available Aluminum Nitride and Alumina

Watlow's thick film heaters on ceramic provide superior thermal characteristics, small heater profile, chemical compatibility and ultra-pure materials which are critical to successful wafer processing, testing, and packaging. Aluminum Nitride (AlN) and Alumina (Al_2O_3) are preferred heater materials for many semiconductor applications.

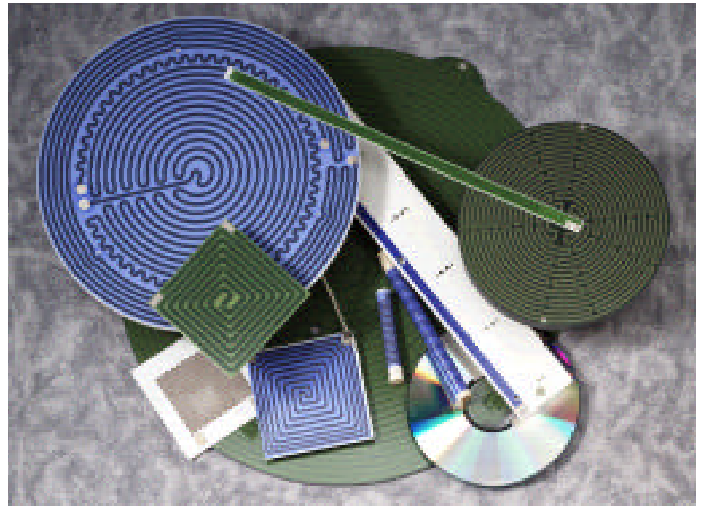
Watlow has developed specialized processes using hybrid thick film materials to manufacture precision heater circuits on Aluminum Nitride and Alumina substrates. Thick film heaters on ceramics can now be designed with multiple circuits and ramp rates of up to 40°C (104°F) per second depending on the substrate material and application details. Thick film on ceramic is capable of high operating reliability at temperatures of 300°C (572°F) for Aluminum Nitride and 500°C (932°F) for Alumina. Contact the factory for details of ongoing extensions to both of these capabilities.

Temperature uniformity, rapid response and thickness down to 1.27 mm (0.050 in.) for 300 mm pedestal heaters make Aluminum Nitride the preferred heater material for many semiconductor applications. Watlow thick film technology gives designers the capability of multi-zoning the heater for optimum temperature performance.

Alumina, a widely used semiconductor material due to availability, relatively low cost and stable physical properties is a well established material for use in demanding semiconductor applications. It is relatively easy to fabricate into a range of shapes while remaining strong at high temperatures. It is available in purity levels of 96 percent.

Specifications

- Maximum operating temperatures of 300°C (572°F) for Aluminum Nitride and 500°C (932°F) for Alumina
- Voltages of up to 480V~(ac)
- Watt densities up to 23.25 W/cm^2 (150 W/in^2) for Aluminum Nitride and 3.56 W/cm^2 (23 W/in^2) for Alumina
- Ramping capabilities of up to 40°C (104°F) per second
- Flat shapes of up to 355.6 mm (14.0 in.) square
- Cylindrical shapes of up to 50.8 mm (2.0 in.) in diameter
- Thickness from 0.5 mm (0.025 in.) up to 12.5 mm (0.500 in.)
- 5000V~(dc) dielectric strength



Features and Benefits

Multiple circuit design capability and heater patterning

- Able to provide a method to optimize heater design for a specific application and precise temperature profile

Reliable thick film manufacturing techniques

- Heaters will perform to specification
- Multi-zone capability

High thermal conductivity materials

- Rapid thermal response in applications requiring fast temperature ramps

Thin ceramic substrate

- Allows heater to be designed with a lower profile
- Reduces heater mass for faster thermal cycling

High dielectric material and thick film system

- Ideal for applications requiring high isolation resistance

Material compatibility

- Ideal for most ultra-pure semiconductor applications
- Ideal for use in demanding applications

Applications

- Wafer pre-heat bake stations
- Photolithography track systems
- Annealing
- Wafer probers
- Wafer bonding
- IC test
- Atmospheric rapid thermal processing



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Case History

Thick Film Heaters Provide High Temperature Ramping

Application: Atmospheric Rapid Thermal Processing (RTP) for Wafer Processing

A Semiconductor OEM was redesigning a single wafer-processing tool for improved performance. One key step in the process was the annealing of a copper ECD layer onto the wafer surface. This customer was attempting to:

- Minimize wafer processing cycle time in order to improve process reliability
- Maximize output while also achieving thermal uniformity on the wafer

The wafer needed to be loaded at a low temperature, quickly heated to 250°C (482°F) for approximately 30 seconds in a controlled environment, then cooled utilizing a thermal reactor capable of rapidly heating and cooling the wafer. Maximum temperature capability was specified at 450°C (842°F).

Solution:

Watlow's answer to this challenge was a low mass thick film heater printed on a aluminum nitride substrate. Aluminum nitride was a particularly good substrate choice because coefficient of thermal expansion closely matches that of silicon while the thermal conductivity is close to that of aluminum. Multiple thick film heater circuits were specially designed to provide optimal thermal uniformity during transient and steady state conditions.

Reasons for Success:

- Low profile product design minimized space requirements
- Very fast thermal response (higher watt density)
- Excellent thermal uniformity on the wafer
- Substrate and Watlow films were compatible with the customer's process.
- Greater operating efficiency
- High product reliability
- Innovative technology

Ceramic Substrates Material Comparison Chart

	Aluminum Nitride (AlN)	Alumina (Al ₂ O ₃) 96 Percent Purity	Type 430 Stainless Steel
Description	Good strength and thermal conductivity; excellent thermal stability and dielectric properties	High mechanical strength and temperature resistance; high chemical and wear resistance	Ferritic stainless steel; moderate cost; good thermal stability
Dielectric Constant	8.9	9.8	N/A
Dielectric Strength (V/in) @ 25°C	3.18E+05	2.39E+05	N/A
Electrical Resistivity (ohm ft) @25°C	3.28E+13	3.28E+13	1.96E-06
Specific Heat (BTU/lb °F)	9.60	11.41	0.11
Thermal Conductivity (BTU/ft hr °F)	98	17.91	15.08
Coefficient of thermal expansion (ppm/°C for ceramics, cm/cm°C for stainless steel)	4.3	10.2	5.8

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THICK FILM MANIFOLD HEATERS

Thick Film Manifold Heaters Help Deliver Hot Runner Precision

Watlow's thick film manifold heaters allow hot runner operations to gain more control over temperature uniformity while reducing overall cycle times.

Thick film manifold heaters are designed to clamp directly to the outer surface of the hot runner manifold. This clamp-on design provides many advantages to hot runner molds including:

- Uniform heat distribution
- Smaller-mass hot runner manifolds, since the extra steel required for the tubular heaters is eliminated; smaller manifolds will heat up more quickly, reducing the overall start-up time of the injection molding machine
- Design flexibility
- Shape of the heater matches the shape of the manifold allowing the heater to adapt to any hot runner geometry
- Simpler manufacturing, as the grooves that were traditionally machined in the steel manifold to accept tubular or cable heaters are eliminated

Thick film manifold heaters are manufactured utilizing Watlow's thick film heating technology on stainless steel plates. The basis for the low profiles lies in its unique sandwich design. Watlow's thick film resistance heaters are made of several layered materials. A glassy dielectric film coats the substrate and is then covered with a custom-designed resistor circuit and a final dielectric overglaze. The thick film circuitry allows the heater to vary heat output across the entire surface of the heater helping to control and correct virtually any temperature uniformity issues caused by conventional heaters.

Specifications

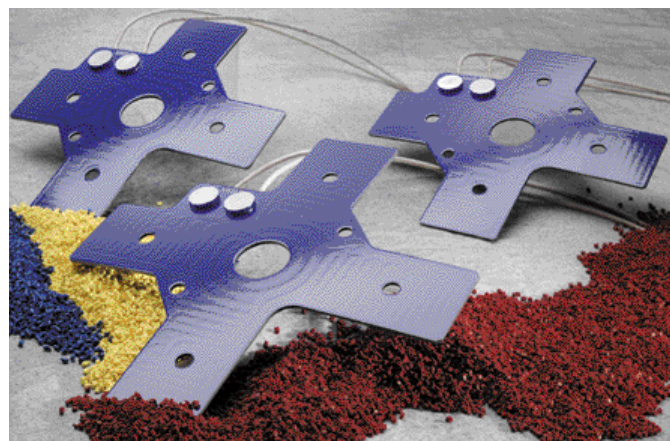
- Maximum substrate temperature of 550°C (1025°F)
- Watt densities are application dependent over entire substrate surface
- 5.43 W/cm² (35 W/in²) for radiant heating applications
- Up to 240 volts, three phase
- Termination options include contact pad, soldered lead wire or welded stud/lead wire (standard)

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Features and Benefits

Low profile package

- Allows heater to be designed to fit around mounting holes, notches, sensors, etc.

Quick thermal response within manifold during start-up and operation

- Allows for a more efficient system

Heaters not affected by plastic resin leakage and are easily replaced

- Reduces machine downtime

Elimination of milled channel required for cartridge, cable or tubular heaters

- Reduces overall mold height and costs

Lower overall thermal mass in manifold

- Reduces power consumption
- Allows for faster thermal response

Superior thermal profile in the manifold

- Generates higher part quality and yield
- Allows for shorter recovery between cycles

Applications

- Hot runner manifold systems



HAN-TFM-0902

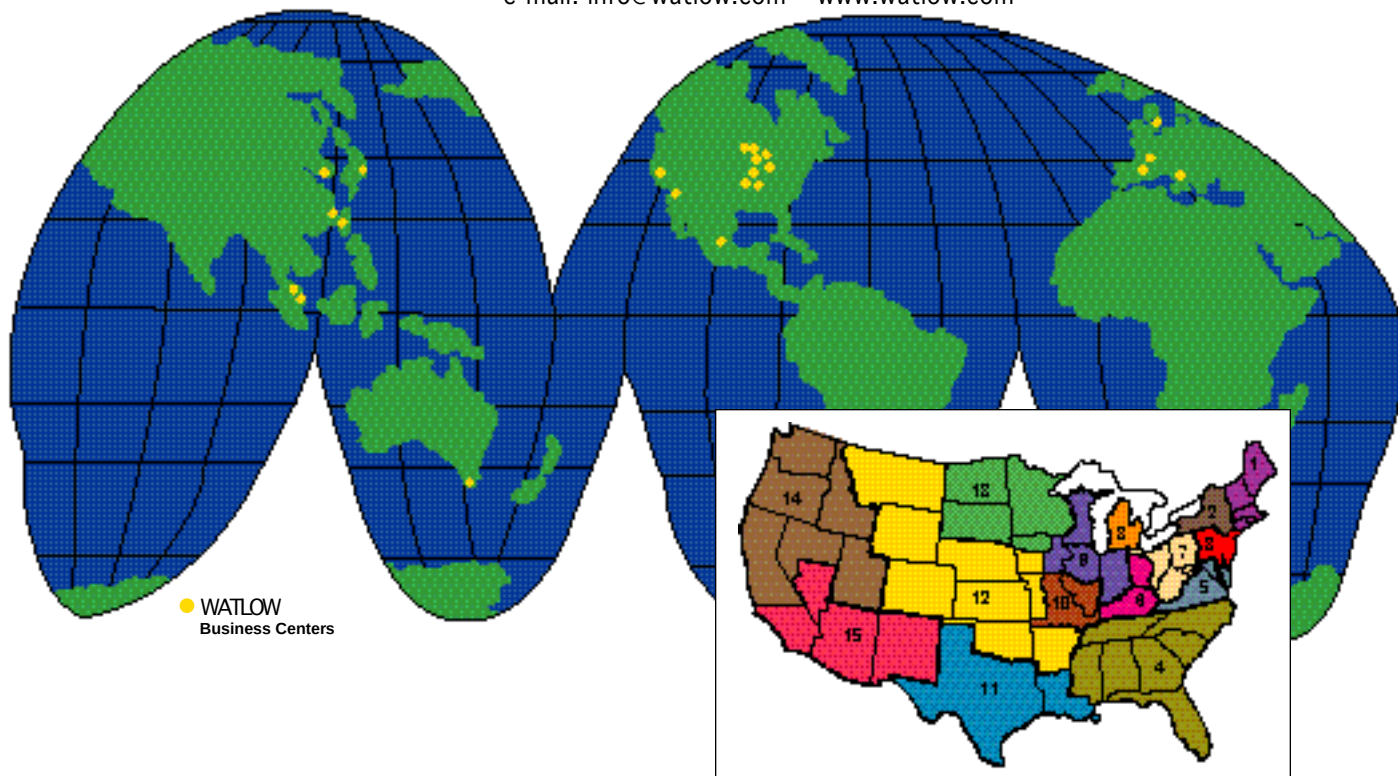
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