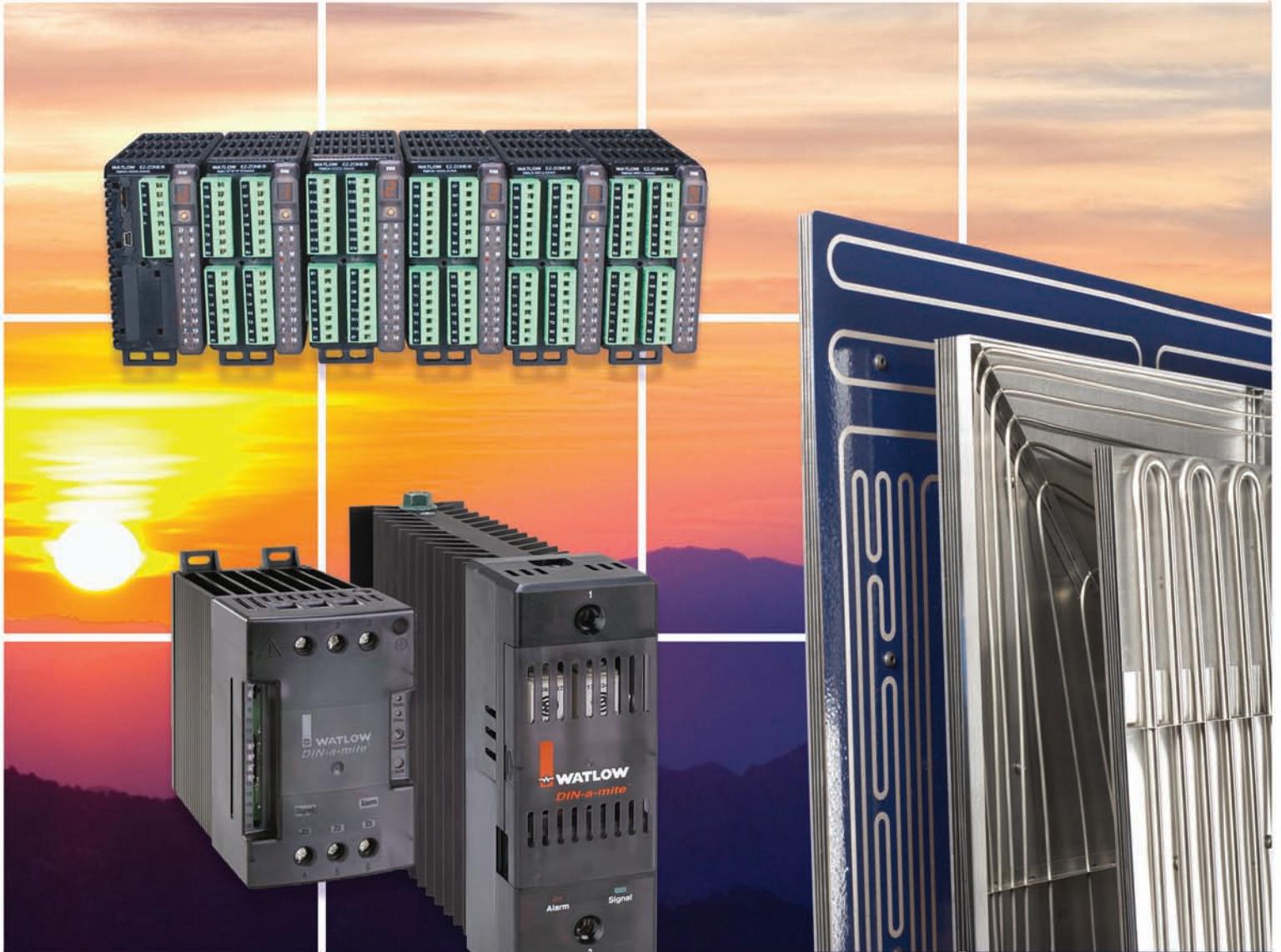


# Thermal Solutions for Photovoltaic Processing Equipment



heaters | sensors | controllers



## Designing Thermal Solutions for Photovoltaic Processing Equipment

Watlow's thermal solutions start at the beginning with silicon ingot production and are found all the way through manufacturing and test of photovoltaic cells and modules. Watlow® products can be found in a variety of thin-film processes including those used to produce a-Si, CdTe and CIGS solar modules. As an extension of your internal engineering resources Watlow can provide engineering teams dedicated to solving your most complex thermal problems.

The rapid evolution of photovoltaic tool design and manufacturing processes combined with steady advancement toward grid parity has created an environment where businesses need to identify and focus on their core competency while partnering with other companies that have complementary skill sets. Watlow's core competency is thermal applications expertise with emphasis on delivery of innovative solutions at an accelerated pace. Watlow's ability to understand thermal interactions at the system level as well as a thorough understanding of the role heat plays in a variety of photovoltaic cell manufacturing processes is what differentiates Watlow from thermal component suppliers. To complement its thermal expertise Watlow also employs disciplined project managers to assure that the optimum combination of performance, schedule and cost is brought to each development project.

### What can Watlow do for you?

- Develop a thermal system from concept through validation and start up
- Optimize existing designs with respect to cost and performance
- Create a complete thermal solution that includes heaters, sensors, controllers and subassemblies
- Improve your market position and market share with innovative, patentable designs
- Offer insight into emerging heating, sensing and control technologies
- Provide the expertise to reduce development risk and improve time-to-market
- Employ computer modeling techniques including finite element analysis (FEA) and computational fluid dynamics (CFD) to simulate thermal system performance
- Provide complete "build-to-print" heater assemblies and thermal components

# Heater Solutions

## Radiant Heater Panels

Watlow's custom radiant heater panels can be used to provide uniform heat to both single piece and web style substrates. With custom panel sizes up to 47 in. (1.2 m) x 86 in. (2.2 m) and a choice of heating technologies to choose from, these radiant panels can be designed to meet your thermal processing needs.

Custom engineered panels are fitted with appropriate heat shielding to maximize process efficiency by providing more heat where you need it and less where you do not. The entire package is then assembled to a structural frame that can be easily mounted into your processing chamber. An additional consumable or cleanable shield may be employed to minimize cleaning complexity and reduce downtime. All assemblies are designed to accommodate thermal expansion and minimize deflection during operation. Most include provisions to accommodate vacuum wall pass-through.

### Features

- Custom circuit configurations to achieve your thermal uniformity needs
- Vacuum compatible construction materials
- Choice of heat "engine" to meet your specific requirements
- Modular construction for easy installation and maintenance
- Integrated sensors for process and high limit feedback

## Conductive Heater Plates

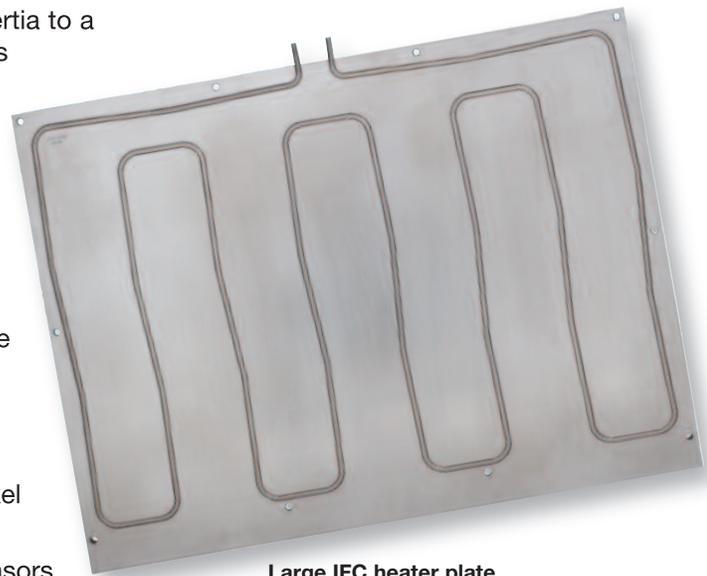
Watlow's heater plates are ideal for applications that require the substrate to sit directly on or be pressed against a flat hotplate. By allowing heat to be transferred by conduction, high levels of thermal uniformity can be achieved. This can occur at a rapid rate without excessive temperature deltas between the heat source and substrate. Thick heater plates can also add considerable thermal inertia to a system in order to minimize temperature droop when new substrates are introduced. Watlow heater plates can be manufactured from materials such as nickel, stainless steel, Incoloy®, aluminum and copper and may operate up to 1292°F (700°C). Depending on the type of heating technology required, several methods of affixing the heater element to the plate are available. These range from a simple mechanical sandwiching of the element between a set of plates to Watlow's patented interference fit construction (IFC) to casting the heater element directly into the hot plate. Watlow heater plates can also be used as a radiant heat source in vacuum or where high levels of thermal uniformity are required.

### Features

- Performance up to 1292°F (700°C)
- Materials including Inconel®, 304 and 316 stainless steel and nickel
- Choice of heat "engine" to meet your specific requirements
- Can be customized to include features for lift pins, integrated sensors and optimized thermal profile
- Flatness better than 0.02 in. (0.5 mm) on plates 0.2 to 0.7 in. (6 to 19 mm) thick
- Flatness better than 0.01 in. (0.2 mm) on plates greater than 0.7 in. (19 mm) thick



Variety of flat panel radiant heaters



Large IFC heater plate

# Heater Solutions

## Heater Technologies for use in Radiant Panels and Conductive Plates

The following table illustrates the relationship between various heater technologies and their capabilities:

Heater Technology	Continuous Max. Temperature <sup>2</sup>	Max. Voltage Input <sup>3</sup>	Circuit Customization
Foil Circuit <sup>1</sup>	428°F (220°C)	400V	High
Thick Film	842°F (450°C)	400V	High
Cable	1202°F (650°C)	220V	Med
Tubular	1598°F (870°C)	600V	Low
High Temp. Tubular	1652°F (900°C)	480V	Low

<sup>1</sup> Foil circuit technology for use in conductive plates only

<sup>2</sup> Temperature shown is continuous maximum temperature of heater element's outer surface

<sup>3</sup> Voltage input is based on heater construction. Termination type and vacuum level could de-rate voltage input capability

### Foil Circuit Heaters

These rugged, yet thin, lightweight and highly customizable foil circuits can put heat where it is needed. Fiberglass-reinforced insulator layers give this heating technology dimensional stability without sacrificing flexibility. The heater circuit can be custom designed and tuned to provide a highly uniform heater plate.

#### Features

- Designed in the exact shape and size you need to provide easy installation and temperature uniformity
- Moisture- and chemical-resistant material provides longer heater life
- Vulcanizing adhesives or fasteners easily bond heaters to your part
- Peak temperature up to 482°F (250°C)

### Cable Heaters

Watlow's cable heaters are small diameter, high-performance units. This versatile heater element can be formed to a variety of shapes for incorporation into any heater panel or conductive plate. Cable heater powered radiant panels and conductive plates are a prominent heating solution in both microcrystalline and thin-film processing equipment.

#### Features

- High ductility allows unlimited coiling geometries
- Diameters as small as 0.4 in. (10 mm) to fit in tight spaces
- Low mass for quick response to both heating and cooling
- Peak temperature up to 1202°F (650°C)
- 304, 316 stainless steel or Incoloy<sup>®</sup> for high temperature corrosion and oxidation resistance
- Internal thermocouples for high-limit protection or process control



Foil circuit heaters

Cable heaters



# Heater Solutions

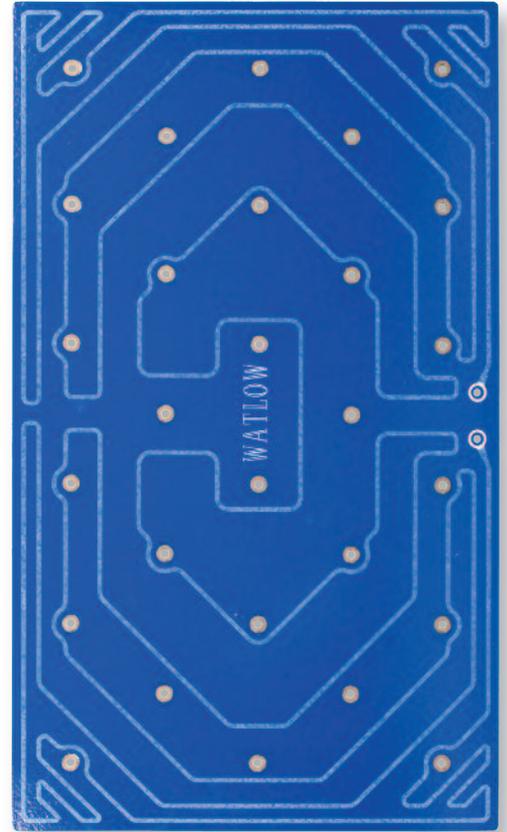
## Thick Film Heaters

Watlow layers thick film resistor and dielectric materials on stainless steel to produce high performance industrial heaters. The thick film heaters provide very fast temperature response and uniformity on a low-profile heater. Thick film heaters are ideal for applications where space is limited, where conventional heaters can not be used, when heat output needs to vary across the surface or in ultra-clean or aggressive chemical applications.

Watlow's large flat panel heaters were developed to address customers' growing processing requirements. These large panel thick film heaters with stainless steel construction provide uniform heating up to 842°F (450°C). Using thick film technology, overall weight of the assembly is greatly reduced and the single piece heater construction results in a very thin profile heater.

### Features

- Provides excellent cleanliness for ultra-pure applications
- Vacuum compatible including heater-to-power lead terminations
- Thick film heater trace circuit for optimal circuit layout
- Low profile and low mass for quick thermal response
- High emissivity glass coating for excellent radiative heat transfer



Large panel thick film heater

## Tubular Heaters

When your process calls for more power and higher source temperatures, Watlow tubular heaters are the technology to call. This highly robust time-proven technology can provide the extra heating capacity for your higher temperature processes. These heaters are used in both radiant and convection modes to provide uniform temperature profiles. Tubular heaters are available in many sheath materials including aluminum, 316L stainless steel and Inconel® to meet your process compatibility requirements. High temperature tubular heaters are commonly used in heated vacuum chamber assemblies and conveyor ovens.

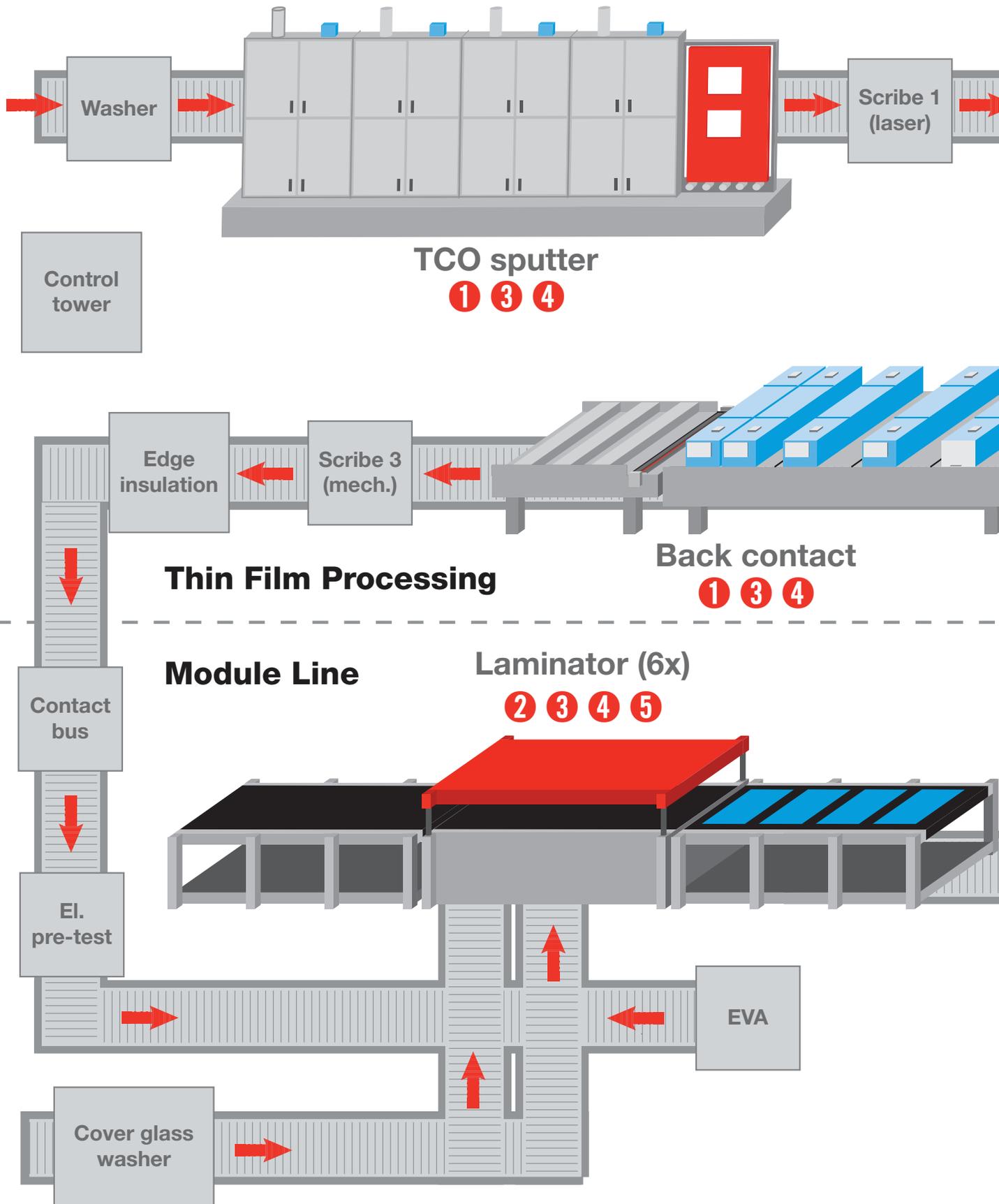
### Features

- Tubular heater sheath temperature up to 1598°F (870°C) depending on sheath materials
- Precision bending for maximum design efficiency and temperature uniformity
- Sheath materials available in aluminum, stainless steel and Inconel®
- High-limit internal thermocouple reduces assembly costs and is more responsive and accurate
- High temperature moisture-resistant seals protect against moisture contamination
- Agency approvals: cRU®, CE and RoHS

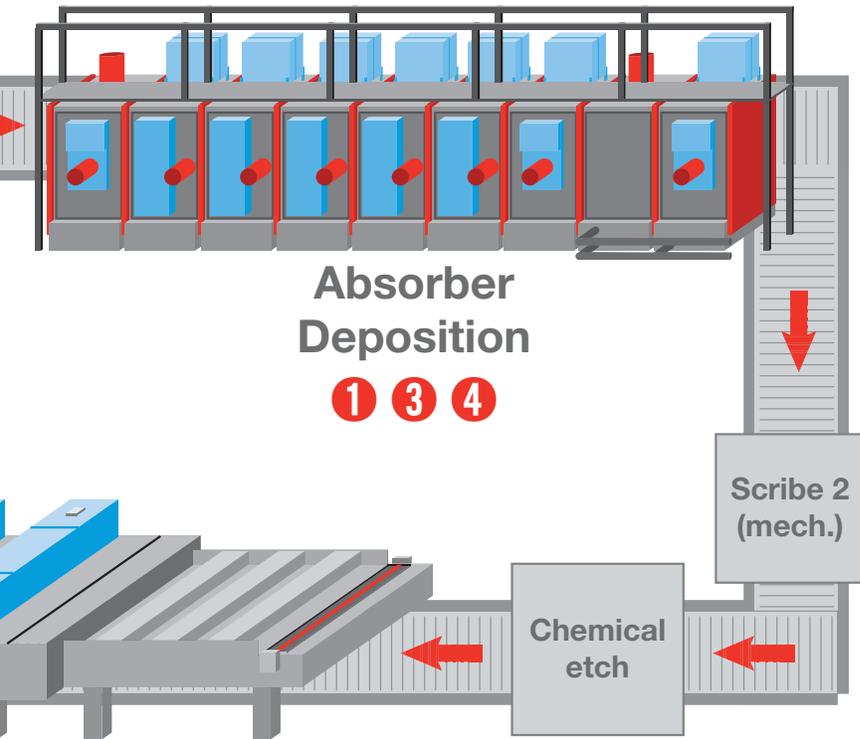


Tubular heaters

# Application Solutions



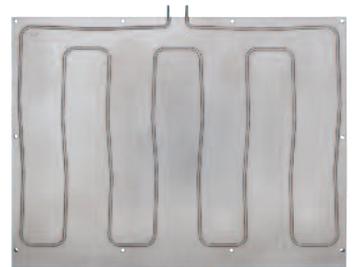
# Application Solutions



**1**  
Radiant  
Heater  
Panels



**2**  
Conductive  
Heater  
Plates



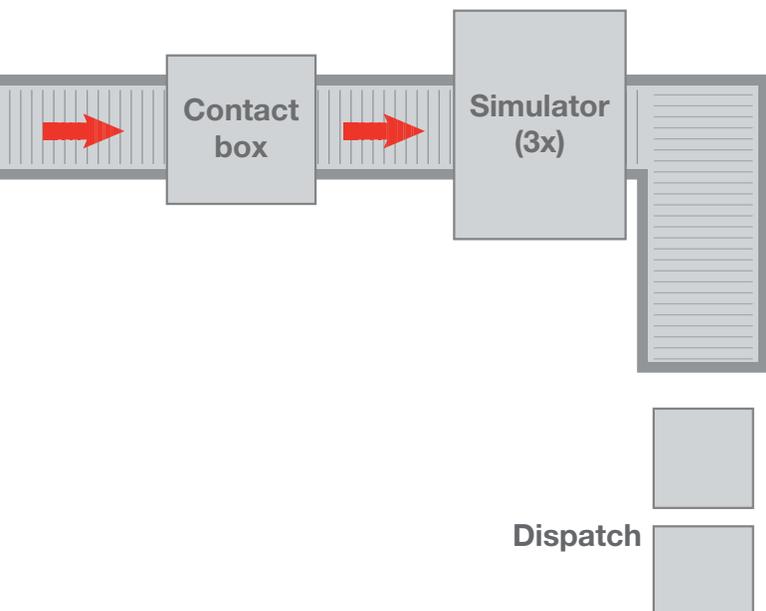
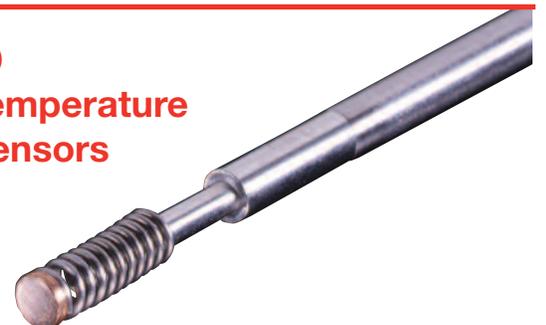
**3** EZ-ZONE® Controllers



**4**  
DIN-A-MITE®  
Power  
Controllers



**5**  
Temperature  
Sensors



# Heater Solutions

## Additional Heating Systems

### MULTICELL™ Heaters

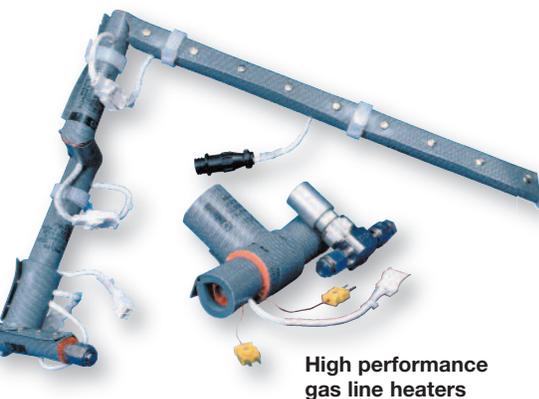


The MULTICELL™ heater from Watlow offers independent zone control for precise temperature uniformity during photovoltaic applications. Its loose fit design makes it easy for insertion in and removal from the equipment and has extreme process temperature capability. The heaters are available with up to eight independently controllable zones and one to three internal thermowells for removable sensors. Custom assemblies are available.

#### Features

- Extreme process capability up to 2050°F (1200°C)
- Oxidized sheath provides high emissivity which improves as oxidation increases
- Quick disconnect plug and jack provides fast replacement of individual elements while equipment stays at operating temperature
- Multiple, independently controllable zones allow precise process temperature uniformity

### High Performance Gas Line Heaters



Precision heating of valves, mass flow controls (MFC), filters and other gas line components is critical to process performance. Watlow's high uniformity temperature solutions start with thermal profiling of the gas lines in order to understand the thermal gradients resulting from component mass, material and physical orientation. The standard and custom modeled silicone rubber gas line heater solution results in a thermal system that meets thermal and mechanical specification.

#### Features

- Even heating up to 392°F (200°C) for uniform temperature profiles
- Insulated straight fillers for 100 percent line coverage
- Cleanroom compatible silicone rubber construction
- Fire-safe UL® 94-HB or UL®-VO material
- UL®, CE, Semi S2

# Temperature Controllers

## EZ-ZONE® Family Comparison Chart

	EZ-ZONE ST	EZ-ZONE PM Express ½ and ⅙ DIN	EZ-ZONE PM ½ DIN	EZ-ZONE PM ⅙ DIN	EZ-ZONE PM ⅙ and ¼ DIN	EZ-ZONE RM
PID Loops	1	1	1	1	1 to 2	0 to 64
Profile Ramp/Soak	40 total steps		40 total steps	40 total steps	40 total steps	400 total steps
Integrated Over/Under Limit Loops	1	1 Ordered as separate device	1 Ordered as separate device	1	1	0 to 64 Any combination of limit or PID
Digital Inputs/Outputs	0 to 2		0 to 2	0 to 2	0 to 8	0 to 300+
Number of Outputs	1 to 2	1 to 2	1 to 4	1 to 6	1 to 12	1 to 300+
Integrated Current Measurement	✓			Accepts 0-50mA signal	Accepts 0-50mA signal	Accepts 0-50mA signal or integrated single or shared system versions
Integrated On-Board Datalogging						✓
Field Bus Communications	Modbus® RTU 485		Modbus® RTU 485	Modbus® RTU 232/485, Ethernet/IP™, Modbus® TCP, DeviceNet™, PROFIBUS DP	Modbus® RTU 232/485, Ethernet/IP™, Modbus® TCP, DeviceNet™, PROFIBUS DP	Modbus® RTU 232/485, Ethernet/IP™, Modbus® TCP, DeviceNet™, PROFIBUS DP
Integrated Timers and Counters						✓
Integrated Math and Logic Operators						✓
Mounting Method	Behind panel screws or DIN-rail	Front panel	Front panel	Front panel	Front panel	Behind panel screws or DIN-rail

## EZ-ZONE ST Integrated Temperature Controllers

EZ-ZONE ST integrates temperature control, power control, safety shut-down and power disconnect in a single package. It features a PID temperature controller already connected to a high amperage solid state relay (SSR) with the option of adding a properly sized heat sink, current measurement, over/under temperature limit, a definite purpose mechanical contactor and digital communications in one package.

The integrated control loop is an excellent solution for photovoltaic applications such as wet processing stations, laminators and integrated circuit (IC) test and other types of equipment that require precision temperature control while benefiting from space and manufacturing simplicity of an integrated control system.

### Features

- Back panel or DIN-rail mount
- PID temperature controller with standard and advanced TRU-TUNE+ algorithms
- Compact package and touch-safe package reduces panel size and complies with IP2X
- Available with zero cross and phase angle firing
- Agency approvals: UL® listed, CSA, CE, RoHS, W.E.E. FM, SEMI F47-0200, Class I, Div. 2 rating on selected models
- Solid state relay output up to 75 amperes

EZ-ZONE ST integrated temperature controller



# Temperature Controllers



**EZ-ZONE PM**  
panel mount  
controllers

## EZ-ZONE PM Panel Mount Controllers

Watlow's EZ-ZONE® PM panel mount controller offers control options to reduce system complexity and the cost of thermal loop ownership. The controller is available as a PID controller, an over/under limit controller or these functions can be combined into an integrated controller. Other options include integrated high amperage power controller output with a high-performance PID controller and an over/under limit controller in one space-saving, panel mount package. This controller is available in  $\frac{1}{32}$ ,  $\frac{1}{16}$ ,  $\frac{1}{8}$  or  $\frac{1}{4}$  DIN panel mount packages.

### Features

- Advanced PID control algorithm including TRU-TUNE+ adaptive control
- Integrated PID and limit controller for over/under temperature conditions
- Serial communication capabilities provides a wide range of protocol choices including Modbus® RTU, EtherNet/IP™, Modbus® TCP, and DeviceNet™
- High-amperage power control output for up to 15 ampere resistive loads
- Current monitoring provides alarm indication of a failed output device
- Agency approvals: UL® listed, CSA, CE, RoHS, W.E.E.E. FM, SEMI F47-0200, Class I, Div. 2 rating on selected models
- Sealing system complies to NEMA 4X, IP66 for cleaning and washed down
- Touch-safe package increases safety for installer/operator and complies to IP2X requirements
- Ramp/soak programming with four files and 40 total steps



**EZ-ZONE RM rail**  
mount controller

## EZ-ZONE RM Rail Mount Controllers

The EZ-ZONE RM integrated multi-loop controller can be used as a PID temperature/process controller, an over/under limit controller or these functions can be combined into an integrated controller. Other control functions can be integrated such as high amperage power controller output which creates a complete integrated thermal loop controller all in one space-saving, DIN-rail mount integrated package. The EZ-ZONE RM is designed so you only pay for what you need.

### Features

- 1 to 64 PID loop controller
- Advanced PID control algorithm
- Current monitoring for entire system
- Communications capabilities
- Function block capabilities for arithmetic and boolean operations
- SPLIT-RAIL control, AUTO CLONE and SENSOR GUARD

# Temperature Controllers

## DIN-A-MITE® Power Controllers

Watlow's DIN-A-MITE® family of solid state power controllers provide silicon controlled rectifiers (SCR) control, heat sink, wiring and touch-safe exterior in one package. With zero cross and burst fire switching DIN-A-MITE controller are an excellent solution for most current switching applications. DIN-A-MITE is also available for applications with high in-rush such as vertical and horizontal diffusion furnaces that phase fired control

### Features

- Zero cross burst firing for optimum temperature control and reduced electrical noise
- Phase fired controller for systems with high in-rush current
- Integrated power controller for easy installation with no separate components
- Reduced space requirements for power switching components
- Rugged, back-to-back SCR design ensures long term reliability
- UL® 508 Listed, C-UL® Approved, VDE 0160, License #91623 and CE

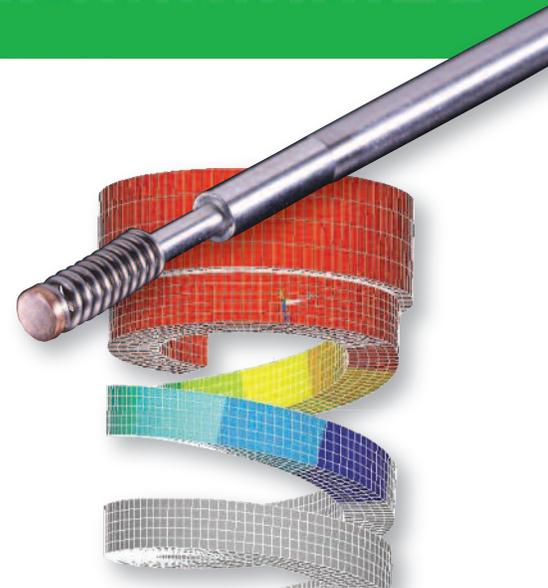


# Temperature Sensor Technologies

Temperature sensor accuracy, repeatability and stability over operating life are critical for photovoltaic processing. Designing the best sensor for an application requires knowledge of material science, thermodynamics, electrical properties, process specification and connectivity. Watlow's advanced sensor technologies and understanding of the application gives us the capability to design sensor assemblies that support new innovations in cell processing. Thermocouple, RTD and thermistor sensor assemblies are specially designed to ensure precise and repeatable temperature characteristics

### Features

- Isothermal design increases temperature response and accuracy
- Repeatable and traceable to U.S. National Institute of Standards and Technology (NIST)
- Interchangeably allows probes from different lots to be substituted without recalibration
- Small size and low mass enables very fast response to small changes in process temperature



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Find out more about Watlow and how we can provide thermal solutions for your company:

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## About Watlow

Watlow designs and manufactures industrial heaters, temperature sensors, controllers and system assemblies – all of the components of a thermal system. Designing and manufacturing the complete thermal system allows Watlow to recommend, develop and deliver the optimum thermal solution for our customers' equipment and process heat requirements.

Watlow manufactures thermal systems for a broad range of industries including but not limited to: semiconductor processing, photovoltaic, aerospace, analytical instrumentation, medical equipment, packaging, foodservice equipment and plastics processing. Watlow customers receive the highest level of technical engineering combined with exceptional customer service.

Since 1922, Watlow has grown in product capability, market experience and global reach. We hold more than 200 patents and employ 2,000 employees working in 12 manufacturing facilities in the United States, Mexico, Europe and Asia. We also have sales offices in 15 countries around the world. Our company has grown at an exponential rate but our commitment remains the same – to provide our customers with superior products and services for their individual needs.

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