



**HIGH PERFORMANCE COMPONENT HEATING SOLUTIONS FOR
LARGE, HIGH TEMPERATURE INDUSTRIAL APPLICATIONS**



Joe Podge, Global Vice President of Component Technologies
Steve Doyle, Director of Specialty Components

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Challenges with compact, high-temperature heating sources in mid-to-large scale heavy industrial applications

There are very few elegant solutions for mid-to-large scale heavy industrial applications that require compact, high-temperature heating sources capable of delivering precise heat energy to a targeted location. While steam and gas fired heating are options, both are very difficult to work into complex environments and require complex system infrastructure to install and support. This white paper uncovers the need for high performance component heating solutions in large, high temperature industrial applications and discusses the benefits of multiple zone heating element technology.

Most engineers appreciate the relative ease of designing and installing discreet electric heating elements into a system, but inherent design and construction drawbacks such as lower operating temperatures, relatively low aggregate wattage capabilities, concerns about resistance to environmental factors and service life have caused many to dismiss electric heating elements as a viable option for large, challenging industrial applications. When used in demanding high temperature industrial projects, conventional electric heating elements often present the shortcomings below:

- **Tubular Heating Elements:** Smaller diameters coupled with lower watt density and ampacity constraints can limit overall wattage output. Construction is not overly robust, which affects life expectancy in extreme operational environments.
- **Cartridge Heaters:** These are conductive heating sources exclusively when used at elevated temperatures and require extremely tight fit and bore tolerances. Modest length and diameter constraints govern the size of area that can be addressed, which is cumbersome unless multiples of units are used.
- **Strip Heaters:** Modest length constraints govern the size of area that can be addressed, which can be cumbersome unless multiples of units are used. Strip heaters are rarely capable of operating in environments that are not reasonably clean and they do not exhibit long life spans in contaminate intensive environments.
- **Cast-In Heaters:** Cast-In Heaters have very limited size capabilities due to the manufacturing process constraints, which makes it challenging to use in large scale applications. They tend to be high mass, especially bronze or brass alloys, which leads to challenging installation and maintenance.

In addition, when selecting the optimal heating source for large-scale applications that possess inhospitable operating environments, most or all of the below factors must be considered simultaneously, which makes selection and design of the proper heating element solution challenging:

- Operating temperatures required
- Time to reach operating temperature
- Mass of target object to be processed
- Heating method (conduction, convection or radiation)
- Process temperatures of the media being heated
- Environment of process: corrosion and thermal resistance
- Available voltage and current draw required for the heating system
- Watt density VS operating temperature limitations
- Temperature uniformity requirements
- Temperature, power controls and sensor requirements

A practical heating technology solution for extreme industrial applications?

Is there a solution to the challenges above? The answer is yes. Multiple Zone Technology (MZT) heating elements were developed to provide practical solutions for demanding applications, including:

- Large scale industrial environments at power plants and chemical processing plants
- Thermal remediation of contaminated soil at oil & gas well heads and fracking sites
- Aircraft manufacturing for titanium forming and bonding that requires extremely high operating temperatures with exceptionally closely controlled thermal profiles across the press platens

MZT is ideally suited for high temperature press platens because the element's independent heating zones enable individual zone control that yields tight temperature profiles on the platen surface.

MZT heating elements can be made up to 16 feet (4.88 m) in length and be designed with wattages up to 10 kW, which is ideal for applications in energy focused projects, chemical processes or metal and glass processing that require large heat sources – both in physical size and aggregate wattage output. MZT Technology opens new dimensions for industrial processors requiring high temperature heating sources in very challenging locations and sizes. Large vessels, tanks, furnaces and reactors can be readily outfitted with discreet and easy to install robust heating elements that operate in a convective, radiant or conductive heating mode. Elements can be installed as a single heating device or in large arrays wired in simple or sophisticated control schemes to facilitate precise temperature and power controlling profiles.

A full list of differences between MZT and conventional heating elements is further outlined below.

MZT heating elements are resistant to variety of environmental challenges.

Based upon the design and construction characteristics described above, Maxi-Zone heaters are perfectly suited to operate in the most challenging environments. They can be used as convective, conductive or radiant heat source. The Inconel 600 outer sheathing material enables them to function in corrosive environments – liquids or gasses, and resists excessive sheath oxidation at elevated temperatures.



The physical sizes, structural rigidity and aggregate wattage capabilities of MZT elements are ideal for tough industrial applications.

While there are three available diameters - 0.495" (12.57mm), 0.685" (17.4mm) and 0.935" (23.75mm) - the length capabilities are very conducive to a large array of tough industrial applications. Lengths range from a minimum of 8" (0.2m) to a maximum of 190" (4.25 m). Because the elements are swaged to ensure excellent heat transfer efficiency, they tend to be quite rigid, yet enable some elasticity over longer lengths. In open air environments these elements are typically supported at intervals along the length of the heater and with wattage concentration capabilities of between 30 - 50 watt per square inch, aggregate wattages can exceed 10kW.



MZT is capable of withstanding very high temperatures.

These heaters are designed to operate temperatures as high as 2050°F (1121°C), whether in Fluidized Bed Reactors, Super Plastic Forming/Diffusion Bonding or Glass Forming applications. The heaters are designed with individual high temperature elements that are then surrounded by high purity magnesium oxide and swaged into a heavy wall Inconel 600 alloy tube. This robust construction enables exceptional heat transfer from the base resistance wire to the element sheath without excessive oxidation of the resistance wire or introducing dielectric breakdown of the refractory material.

Individual temperature zoning capabilities provide precision.

MZT elements can be designed with one, two or three individual circuits. Each of these circuits can be individually zoned and controlled to provide very precise temperature profiling in thermally demanding applications.

Integral temperature/hi-limit sensors provide risk mitigation.

A variety of thermocouple calibrations can be integrated into the heater for risk mitigation and monitoring of heater temperatures. This can be used to merely monitor heater sheath temperatures as a reference reading or to be used in conjunction with Hi-Limit Temperature Controls.

Operating voltage capabilities and wiring are flexible.

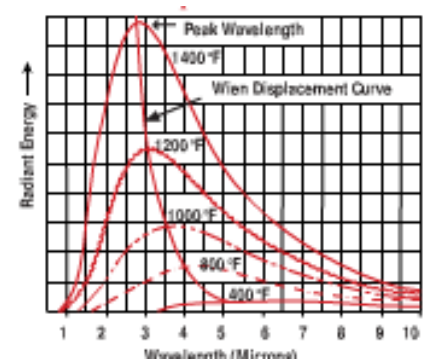
MZT elements can be designed for use with operating voltages between 110 to 480 volts single or three-phase.

Operational cost savings are present in Conductive, Convective or Radiant applications.

Providing users the flexibility to use MZT heating element technology in any of the three fundamental heating sources is a major benefit as it enables users to optimize their installed and operational costs for a project. Depending on the application the use of conduction, convection or radiation can offer many cost savings depending on the environmental challenges presented.

Black Oxide Finish yields excellent emissivity, which improves with usage.

This is an especially important technical feature particularly when using as a radiant heat source. The black oxide finish yields shorter wavelength emissivity, which is a more efficient means of transferring radiant energy to the target medium.



Additional construction benefits that include:

- A high temperature insertion heater that produces sheath temperatures to 2050 °F (1121° C) and provides exact, uniform temperatures with 2, 3 or 6 independently controllable zones; along with 2 to 6 individual metal sheathed tubular heating elements that are arranged and swaged in place with an Inconel 600 outer sheath (Standard Diameters 0.495”(12.57mm), 0.685”(17.4mm) and 0.935”(23.75mm))
- 0.495” (12.57mm) diameter single zone only
- 0.685”(17.4mm) and 0.935” (23.75mm) diameters have an internal over-temperature thermocouple option
- Minimum heated lengths on all diameters 8”(0.2m)
- Maximum heated lengths up to 190” (4.25m)
- Diameters designed to be undersized in platen hole for radiant heat transfer and ease of removal (note: insertion hole to be coated with black radiant emissivity receiver)
- Mounting bracket, tab or stop washer attached to hold heaters in place
- Extra unheated section (optional) to get lead wires out of the heated zone and insulation
- Cinch multi-blade electrical connectors for ease of wiring and heater replacement

Conquering Customer Pain Points Through MZT Technology

In addition to the product benefits listed above, MZT technology provides cost savings (both installation and operation related) and risk mitigation for high temperature applications.

No longer are engineers limited to expensive, gas fired combustion options when designing a heating system for large, high temperature industrial process heating. Because MZT is integrated into the process design itself and is not required as a stand-alone, bolt-on auxiliary system, it is more cost effective. In addition, the solution is more efficient in plant space conservation because it requires a much smaller footprint for installation. *MZT is less expensive both in terms of system-to-system price comparison and the installation and start up costs and support required.*

Operationally, MZT possesses an extremely high energy transfer efficiency rating. In most cases the electric elements are in direct contact with the process, or in very close proximity, which results in a ratio of energy input very close to the amount that is output as heat energy. *The electric heating technology allows for ease of maintenance and protection against shutting down.* Because there are multiple heaters that can be configured in multiple circuits, the system can continue to operate if one element should fail.

Although high temperature applications may reduce life expectancy, maintenance engineering teams are able to *monitor heater health and predict a planned replacement cycle* rather than react to emergency outages. Specifically, part of the Preventative Maintenance program consists of measuring and logging resistance and insulation values over time. For example, when the results indicate sudden changes in these values or that a resistance has passed the nominally specified resistance value, it may be logical to conclude a failure is imminent and Maintenance Teams can develop a predictive schedule for replacement planning and *avoid costly downtime situations.*

Extreme industrial applications that benefit from MZT Advanced Thermal Technology solutions

Specific MZT applications and usage examples are listed below to further demonstrate the installation, operational and environmental benefits of MZT technology in extreme industries.

Fluidized Bed Reactors and Fluidized Beds

Fluidized Beds and Fluidized Bed Reactors run at process temperatures of 1500°F (815°C), up to 1800°F (982°C) and have heaters that are typically mounted in a protection tube in a process vessel that are then filled with metallic media (beads or pellets) so they can be heated and transfer heat uniformly throughout the vessel. Once the vessel reaches operating temperature, the operator will begin to flow the Gas/Media to be processed from the bottom of the vessel. The heated metallic media will then react and can either crack the gas molecule or carbonize the specific pollutant (NOX/VOC's) being processed within the vessel. Clean and EPA safe gasses are then sometimes sent through a secondary air scrubber to filter out the oxidized bi-product of the reactor. In the case of Fluidized Bed Reactors the heaters are heating the contents of the reactor vessel to very high temperatures, 1800°F (982°C), to affect phase state changes and generate a reaction between the compounds, resulting in a new by-product.



Clean Burning Coal Processes

A large group of 277VAC 3 Phase construction MZT Heaters are inserted in very long platens. Coal is then placed on platen and baked at 1112°F (600° C) for a set number of hours. SO₂ and VOC's bake out from coal yielding clean burning coal that is used in coal fired power generators, thereby meeting EPA regulations in cost effective manner as heaters are temperature profiled and controlled through independent zones.

Super Plastic Forming/Diffusion Bonding (SPF/BD)

Titanium and Aluminum alloys require platen temperatures from 1350°F (732°) and up to 2050°F 1121°C. MZT Heaters were specifically designed for these precision thermal applications and supply the necessary temperature uniformity for such extremely demanding processes. This process is used on almost every commercial airliner currently being used today and is an integral part of Jet Engine/fan blade manufacturing/forging.

Soil Remediation for Chemical, Oil/ Gas and Waste Water Treatment

MZT Heaters are typically placed in directly in very long screw-like augers, which convey contaminated soil or sludge that has been removed from the work site. The heaters can reach as long as 15 feet (5m) and feature multiple heat zones through the length to provide very precise temperature profiles required to bake out the volatiles and contaminants resident in the affected soil.

Aluminum Extruding and Forging Dies and/or Presses

In many high temperature applications, loose fit heaters are designed so that the outside diameter to bore inside diameter relationship is superior in thermal properties as well as removal and installation processes. MZT heaters take advantage of the loose fit radiant design and can easily heat extrusion/forging dies to forming temperatures of 1100-1300°F (593-704°C) or more. They also are easily removed and replaced due to their loose fit radiant design. This solves the problem of heaters seizing in one of the many holes in a die, enabling users to replace the heater quickly and efficiently preventing costly down

time. These heaters are also ideal for applications that require ease of replacement (even while equipment remains at operating temperatures).

Architectural Glass Forming/Tempering and Auto Glass Production

MZT heaters are inserted into the bottom of the forming oven into radiant tubes and operate in radiant mode so they can be zoned for precise heat distribution across the glass substrate. Should a heater fail during an ongoing process, it can be removed from the radiant tube and replaced with a new one without terminating the process.

****note:** a suitable quick disconnect (such as a Cinch Blade type) must be used on each heater to achieve this safely. Flat Panel Ceramic Fiber Heaters were used previously and the MRO could take as long as 3 days due to system cool-down requirements before maintenance personnel could enter the heated structure to replace the failed heater and do other necessary repairs.

Complete, Turn-Key Thermal Solutions and the Total Thermal Loop

Most large-scale, high temperature industrial applications require a considerable amount of kW energy to accomplish the thermal task. Beyond that, the applications typically require heating objects of substantial size and mass to elevated temperatures, therefore, selecting the correct heating source is critical. That said, however, engineering the correct temperature sensing, temperature controlling and power controlling system is equally important because the heaters and controlling system are totally interdependent upon one another to meet the application's operational parameters. Hence, when engineering and specifying a heating and controlling system for a large industrial project, it is an enormous benefit to select a vendor that can provide a complete and turn-key thermal solution consisting of the heat source, temperature sensing, and temperature and power controls – "a Total Thermal Loop."

Typically these large, high temperature applications are not suitable for basic temperature and power controller schemes and the wrong temperature sensor will create havoc in the process. To mitigate project risk and assure optimal performance, the entire thermal loop must be designed so that every component operates synergistically with its corresponding components. The End User will typically realize a benefit in process performance, as well as reductions in installed and operating costs from a single thermal expert engineering the entire thermal solution.

Overall, utilizing sophisticated Ramp/Soak DIN Standard and/or Rail Mount Multi-Loop Controls/Limits, Programmable SCR Power Controls and bundled temperature sensors needed for total thermal loop feedback and precise heating, will have a dramatic positive outcome on mid and long term operational cost and performance of the system. By utilizing the SCR Power control, the heating elements can easily run in "Soft Start" mode, and gradually increase the voltage these heaters were designed for so they can go through a "Bake Out" period to expel any moisture that may have been accumulated during the time they were stored or not being used. In addition, the "Power Limiting" feature in the SCR Power Controllers limits available current to each of the heated zones. In doing so, the heaters will supply continuously reliable precision heating for years to come, and the new "Total Thermal Loop" approach means better Temperature Control, More Uniform Temperature distribution and Ease of Programming.

Conclusion

Multiple Zone Technology (MZT) heating elements provide breakthrough and practical solutions for extreme high temperature industrial applications, while cutting costs and mitigating overall risk through a Total Thermal Loop approach.

About Chromalox:

Chromalox is a thermal technology company. We engineer thermal solutions for the world's toughest industrial heating applications. Our Heat Trace segment delivers temperature management solutions for piping systems, valves, and tanks. Our Industrial Heaters and Systems segment delivers process heating solutions for revenue-generating industrial processes, and our Component Technologies segment delivers component heating solutions for industrial equipment manufacturers. Chromalox was founded in 1917 and is headquartered in Pittsburgh, PA.

Chromalox, Inc.
103 Gamma Drive
Pittsburgh, PA 15238
1-800-443-2640
www.chromalox.com