

**industry:** energy and environmental technologies

**author:** scott boehmer & mike bange



**WATLOW**<sup>®</sup>

*Powered by Possibility*

**subject:**

Better predicting terminal enclosure temperature to improve heater reliability



**summary:**

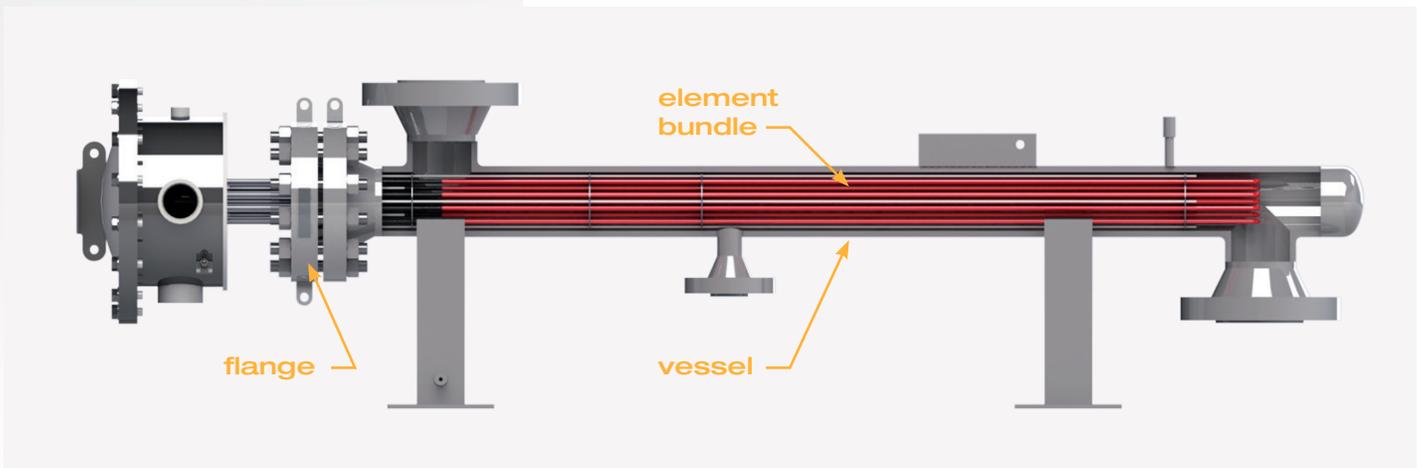
One of the most common failures in electric process heaters used in various industrial applications involves electrical terminations and not the heating elements. Engineers at Watlow<sup>®</sup> believe designers across the industry are underestimating the temperature profile from the heater flange to terminal enclosure in these thermal systems.

Research into the impact of terminal pins, incoming electric supply cables, internal electrical wiring and heating element termination/bussing has shown dramatic levels of unexpected heat generation. This underprediction is leading to designs that will contribute to more rapid degradation and failure of heater electrical termination/bussing inside the terminal enclosure. Watlow engineers have a new temperature prediction tool based on extensive research and testing intended to guide design decisions to improve heater operation and minimize process downtime.



## electric process heaters:

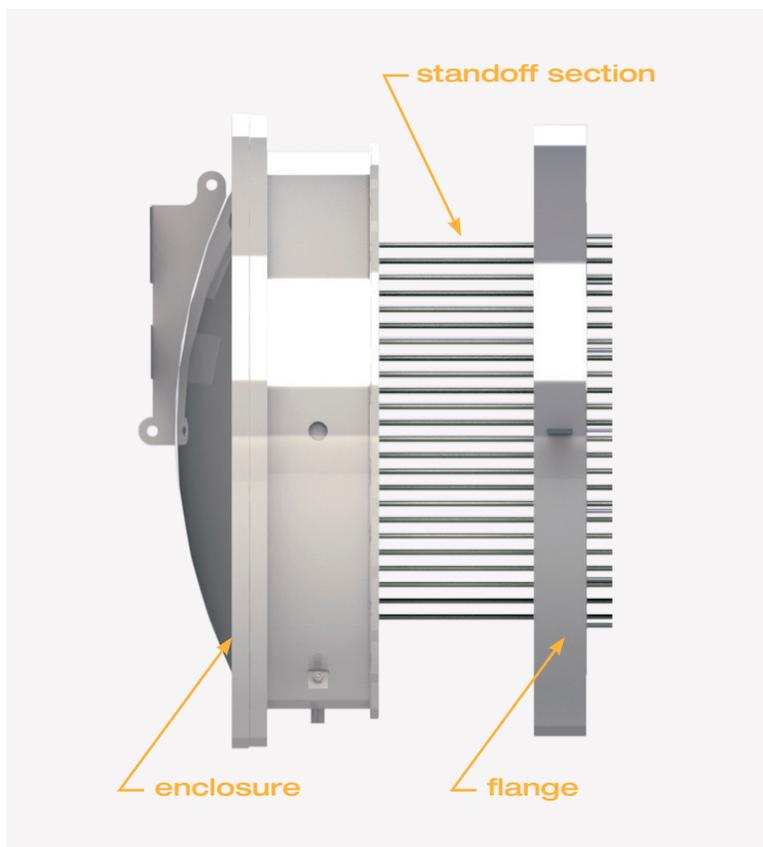
Electric process heaters provide ready-made means to install electric heating with a minimal amount of time and labor. This is done by combining heating elements, a flange, and a terminal enclosure into a heater assembly. This heater is then usually mated with a pressure vessel or tank. These heaters are designed to heat forced-circulation air, gases or liquids.



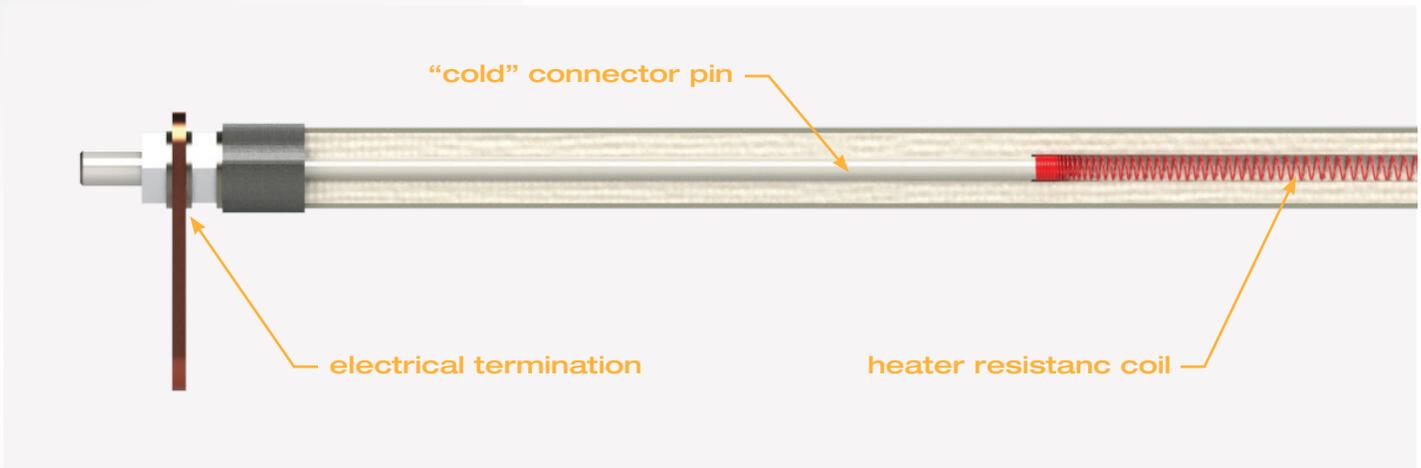
These assemblies direct fluids past tubular heating elements to deliver fast response and even heat distribution. Applications using these heaters include hydrocarbon refining, power generation and natural gas processing. The tubular heating elements are held in place by a metal flange. On the other side of the flange away from where the process heating is intended is the wiring of the heater connecting the customer's power source to the heating elements. Typically, there will be a standoff section incorporated into the design to cool the electrical enclosure from the process heat.

## flange to electric enclosure:

The heater flange is an end closure on the vessel, completing the pressure boundary. The flange conducts heat, and if the flange temperature will exceed electrical component ratings within the enclosure, then the elements are extended to provide for natural convection cooling and a longer conduction path. The goal is to get them away from the hot surface. This natural convection cooling area in the heater is called the standoff.



Within the standoff section are low resistivity terminal pins used to carry power to the resistor coil. These are often called “cold pins” because it might be assumed that no heat was produced by the amperage flowing through them. The section is relatively cold compared to the intended heated section of the process heater. The pins are connected to the electrical termination inside the enclosure. In this area, various termination components, such as busbar, secondary lead wires and distribution blocks, connect to the customer’s incoming power. All of these can be negatively affected by increased temperature in the enclosure as well as the element end seal, typically an epoxy.



## old design approach

For the past 20-30 years, engineers across the industry have relied on more simplistic calculations to predict the terminal enclosure temperature for these kinds of heaters. Engineers believed they understood the heat generated in this part of the equipment. Previously, the temperature modeling was too simple in that it did not take into account all of the heat generation points in the

termination assembly. These heat generation points include the cold pins and the various lead wire joint connections. With the cold pins, there has historically been no design options for them. There was only one standard configuration with no variations in diameter or material to compensate for higher amperage levels.

For years, high temperature in the electrical enclosure was usually not seen as a risk and wires were not seen as individual heaters. Over time, these kinds of heaters have gotten larger and larger with higher wattage and higher amperage. At that point, temperature in the enclosure became a concern because the higher the temperature of an electrical component, the more likely it is to fail. Thermal expansion and contraction happens in the electrical joints causing them to loosen over time. Resistivity builds up in the joints causing temperatures to steadily increase to the point of device failure. Higher operating temperatures also lead to more rapid oxidation corrosion of the electrical bussing and terminations.

new  
technology  
learning:

Watlow's OPTIMAX<sup>®</sup> heat exchanger is a next generation electric process heater combining optimal fluid dynamics, efficient heat transfer, low pressure drop, and a compact and reliable package to create a world-class system solution. OPTIMAX is a game changer. It provided a chance for Watlow engineers to reevaluate the heater design process. They quickly saw that the improvement in heat transfer coefficient created different conditions in the heaters.

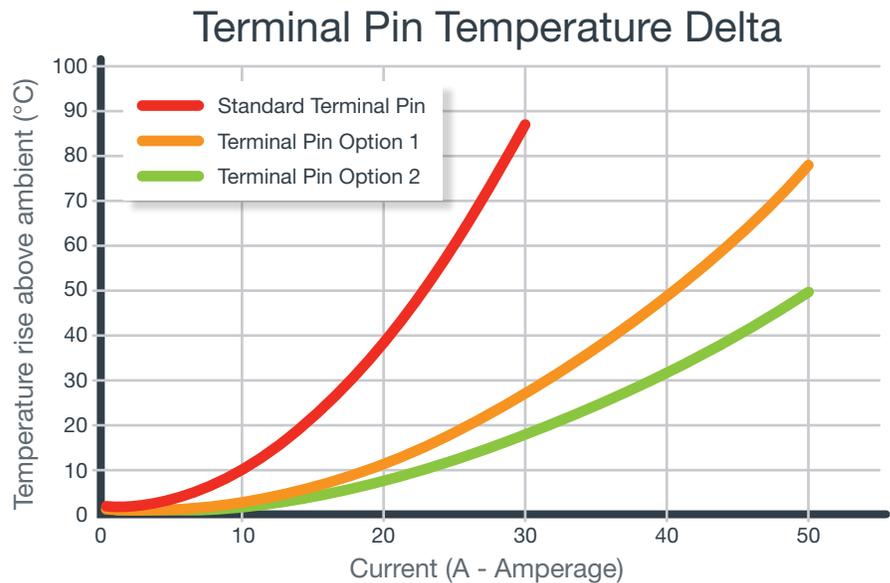
OPTIMAX allowed for higher watt densities for a given temperature per element. That meant a reduction in the number of heating elements required in heaters, which raised the amperage per element. In order to understand more thoroughly the heat generation impacts due to the increased amperage, Watlow engineers began testing various cold pin configurations at different ambient temperatures and amperage levels.

After testing, there were some easy to see conclusions. The traditional cold pin configuration — cold pins made with the standard diameter and metal — creates a much steeper and higher temperature rise. Even though standard cold pins have a very low resistivity, if enough current or amperage flows through them, they will then produce enough power and will act as small heaters on their own.

Watlow engineers developed tradeoff curves for the different cold pin diameter/material configurations that can be used for design optimization at various amperage levels. The tradeoff curves predict how changing the cold pins will affect the enclosure temperature.



## terminal pin temperature delta:



It was clear heat generation was happening in the cold pins raising the temperature in the enclosure, possibly reducing the reliability of the electrical termination components. The lesson here is that the combination of all of the heating elements and electrical components in a heater assembly need to be analyzed as a complete thermal system within the equipment.

From a theoretical perspective and using the equation for Electrical Resistivity, the resistance can be determined for a terminal pin based on its material resistivity ( $\rho$ ), the cross-sectional area ( $A$ ), and its length ( $L$ ).

$$R = \rho \frac{L}{A} \quad \frac{\rho}{A} = \text{(Specific to Watlow's various terminal pin material options)}$$

Once resistance is known, then basic Ohm's Law can be used to calculate the power for each terminal pin.

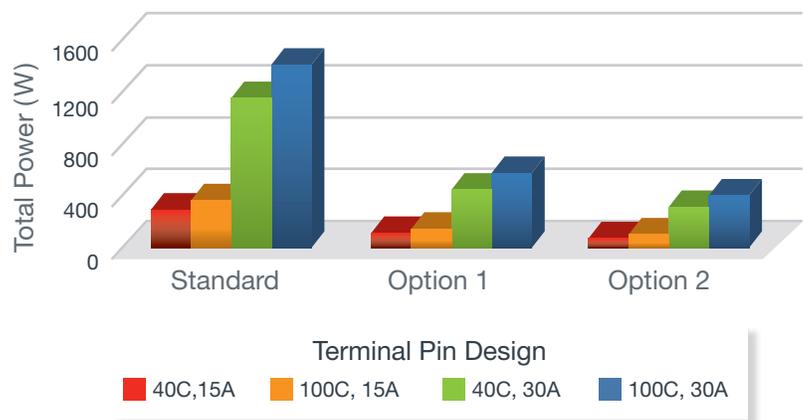
$$P = I^2 R$$

The total power for a heater assembly will vary as shown in the following graph. A significant amount of power can be produced in the standoff area depending on the design and application variables (temperature, amperage, etc.). This power will be converted into heat energy within the standoff element legs of the heater bundle and transferred to the baseplate of the enclosure.

In three test cases, a standard cold pin was used as well as two different design options. Each were tested under similar conditions with enclosure temperatures at 40 and 100 degrees Celsius and with 15 amps and 30 amps. The temperature rise was significant with the standard cold pins and greatly reduced with the two other options.

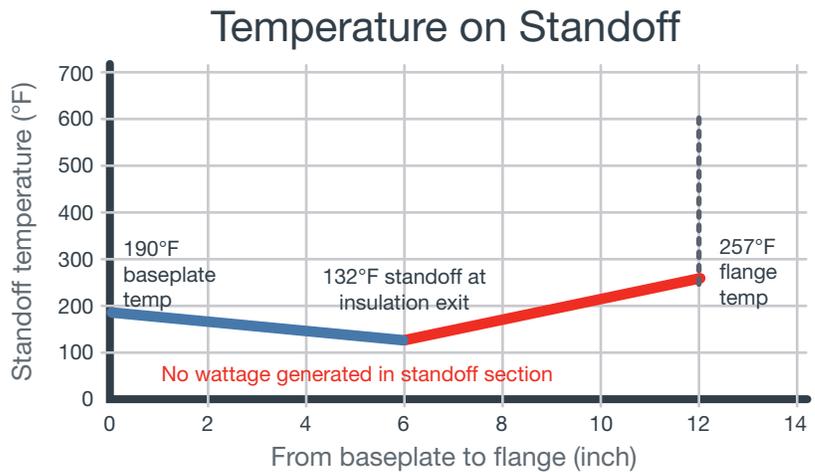
### Total Power Generated in Standoff Element Legs

*24" Heater w/ 216 elements  
Various Temperature and Amperage Levels*

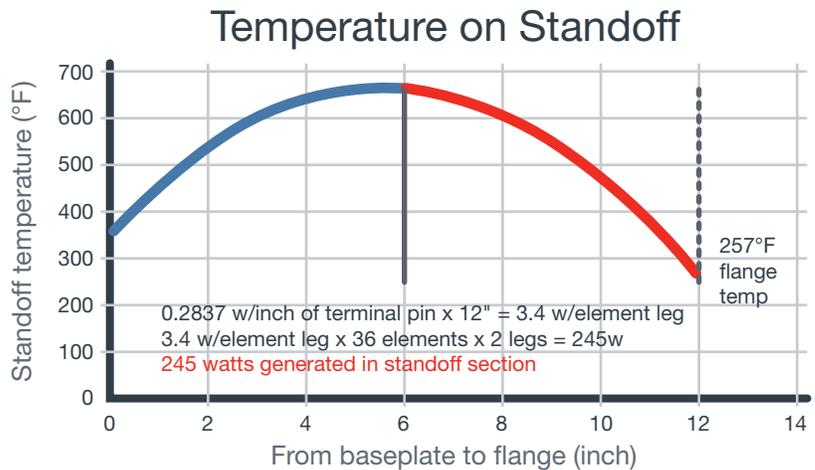


As a case study, an existing design was evaluated to determine the impact on the standoff temperature profile using the old and new calculation methods. This example is for a 10" w/ 36 element flange heater with 21A/element, 12" standoff length, 6" flange insulation, and standard termination.

old method:



new method:



The wattage that is actually generated in this heater design results in much higher temperatures within the standoff section and at the baseplate of the enclosure than previous determined.

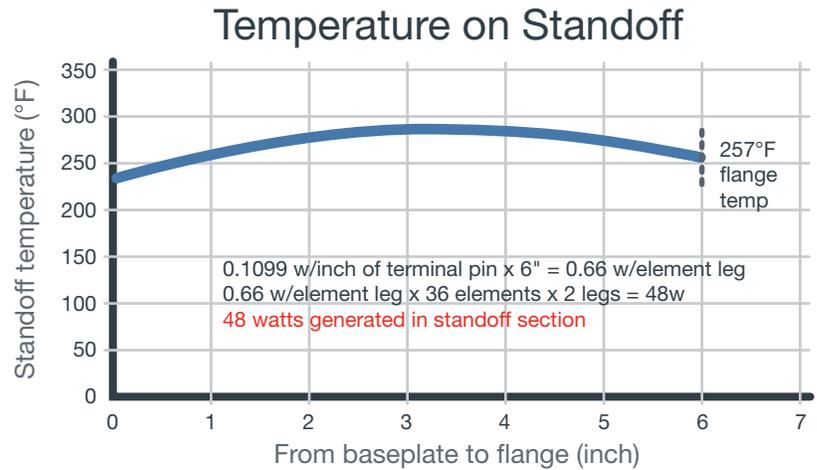
## heater design changes:

Going forward, Watlow engineers have made changes to their process of designing new electric process heaters. Now, the design tool incorporates the impact of the heat generated by the resistance of the cold pins and the various termination joints. That more complete and thorough understanding is built into Watlow's next generation terminal enclosure prediction tool. It provides design options that will ensure that the temperatures will not exceed the electrical components' ratings for reliability and for maximum external allowed surface temperature in hazardous locations.

For example, changing the diameter and the metal in the cold pin can greatly reduce the temperature rise in the electrical enclosure. Depending on the amperage and application, choices can be made in a heater's design to maximize its reliability and better ensure uptime usage.

On the case presented above, the temperatures needed to be reduced to improve the reliability of the electrical enclosure termination components. Watlow used its new terminal pin options to lower the wattage that is generated within the standoff section, thereby significantly reducing the temperatures.

improved  
design  
method:



The temperature prediction tool can also provide the minimum standards for the wire size for the customer to install and power the electric process heater. It is important that the field installation wire meets or exceeds the tool's recommendation to ensure the accuracy of the analysis and not making the incoming power wire a contributing factor to increasing temperature in the electrical termination enclosure.

## takeaways:

Watlow engineers believe the electric process heater industry has been underestimating the temperature in the electrical termination enclosures for decades. Heat was being generated in the cold pins and other electrical wiring and connections in that area of the equipment. Increased temperatures are more likely to lead to failures. Testing found that changing the diameter and the metal used for cold pins connecting heating elements to the heater's power can dramatically reduce temperatures in the enclosure.

Watlow has developed the industry's leading enclosure temperature prediction tool that enables better designs which result in more reliable electric process heaters. Because of a better understanding of all the heat generation points customers should expect to see higher reliability and less downtime for their processes.