Minco SmartHeat™ WP | Inrush Current

Achieving Optimal Heater Performance and Controlling Inrush Currents in SmartHeat SLT™ Heaters

Abstract

Precise temperature control is a vital part of many important mechanical, chemical and biological processes. In the depths of frigid outer space or at a patient's bedside, engineers use precise heating systems to keep critical devices at optimal operating temperature—from de-icing important in-flight sensors to humidifying respiratory equipment for patient safety and comfort. SmartHeat SLT's™ patented polymer compound delivers a thin film heater that provides precise, responsive temperature control in each of these high-reliability applications—without the added bulk and fail points associated with external sensor solutions.

In applications where particularly cold temperatures (-55°C or lower) are common, the instantaneous maximum current draw through the control circuitry of the SmartHeat heater has led some product design teams to seek out additional inrush current protections as an added precaution for system reliability and safety. While self-limiting features built into the SmartHeat component prevents it from overheating or exceeding the designed safety temperature, the additional inrush current remediation methods laid out in this whitepaper can provide that added precaution from power on to power off.

A Breakthrough in Precise Temperature Control

When it comes to maintaining optimal temperature of an important device or system, a typical heater rig requires both a temperature sensor and controller to be used in tandem with the heater to ensure it reaches the desired temperature—and stays at that temperature.

While this three-part heating system tends to get the job done, it's not a perfect solution—especially in mission-critical devices where small variations in temperature across the heating surface can lead to damage, wear-and-tear or even catastrophic system failure. Additionally, the multiple-component construction of these solutions creates new fail points that can impact system reliability throughout the entire device.

In real-world applications such as de-icing aircraft wings, defrosting displays for clarity and readability, or avoiding condensation buildup in batteries—end customers continue to prioritize products that can help minimize these types of system malfunction with the highest possible reliability.

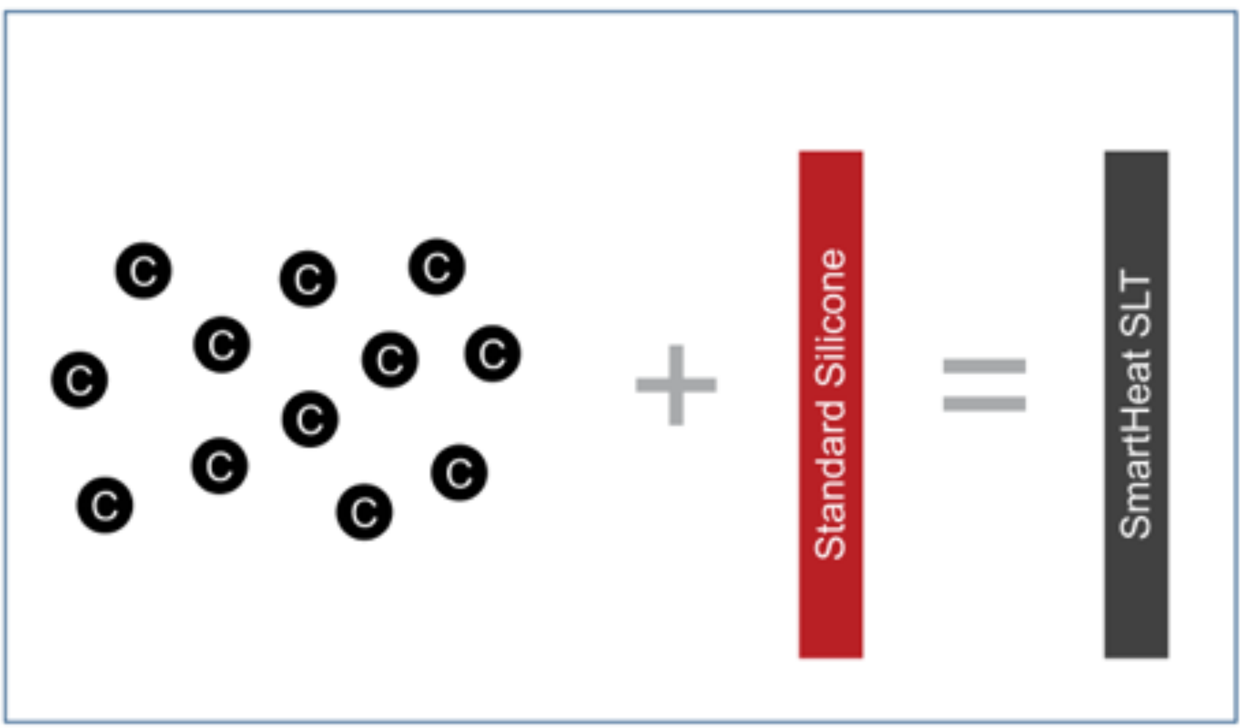
4 CHALLENGES ASSOCIATED WITH COMMON HEATING SOLUTIONS

1. External sensors and controllers increase cost and weight.
2. Connection points and assemblies complicate the solution and become potential points of failure in the system.
3. Delamination issues can cause dangerous overheating.
4. Unable to respond to local changes in temp—unless additional design work is added to include multiple temperature sensor "zones."

SmartHeat SLT solves for these challenges—freeing engineering and design teams to build, innovate and imagine more reliable products. Compared to traditional heater rigs, SmartHeat's simple 3-in-1 design includes the heater, sensor and controller all in one package. Not only does this reduce the common points of system failure between each component, but it also introduces more localized sensing that helps achieve more stable, accurate thermal equilibrium.

How It Works

SmartHeat SLT uses carbon particles diffused through a thin silicone matrix. As electrical current moves between the carbon particles and warms the matrix, thermal expansion drives the carbon particles farther apart and increases resistance point-by-point across the surface of the heater. If one section of the silicone reaches the designed set point it no longer produces heat to maintain the set-point temperature. However, as one section cools, the carbon particles pull together which drives new current flow and produces heat at the specific location on the silicone matrix. The self-limiting nature of SmartHeat functions as a built-in controller, allowing the device to approach the designed temperature set point, without ever exceeding it.



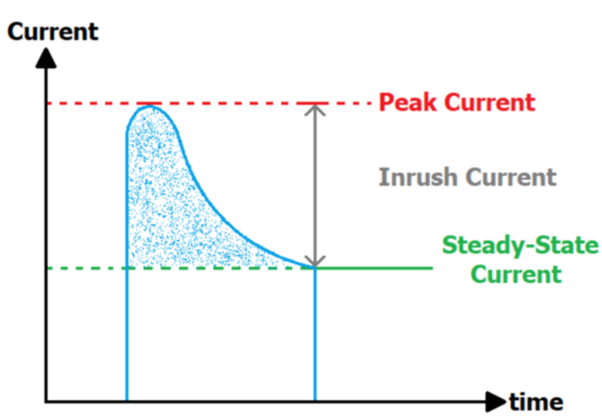
Protecting Against Inrush Currents in Frigid Environments

Every application is different. But when it comes to operating SmartHeat SLT in particularly cold applications—in the -55°C range or colder—some engineering teams will require additional precautions to guard against the potential for damaging inrush currents as a device or system powers on.

While inrush current-related malfunctions have not been documented in SmartHeat applications and remain only a theoretical concern, Minco tested and measured SmartHeat's response to three different inrush current remediation strategies to provide additional support to designers who want to control the inrush current effect in their systems without sacrificing the solution benefits associated with SmartHeat heaters.

The three inrush current remediation methods explored in this whitepaper include:

- Inline Inductors
- Inline NTC thermistors
- Inline etched foil heaters



THE INRUSH CURRENT CONUNDRUM

Inrush currents describe the phenomenon that occurs during a device's power on sequence, when maximum power is drawn to quickly achieve the operating temperature, before it tapers off as it approaches the steady-state current. These starting currents often range from 5x to 20x the steady state current in any given application.

For particularly cold applications, inrush currents approaching 20x the steady state have the potential to trip circuit breakers or short out critical electronic devices entirely. While this creates instant safety concerns, the additional reliability, maintenance and costs associated with routine inrush current damage also pose ROI and uptime challenges for manufacturers—and their end users.

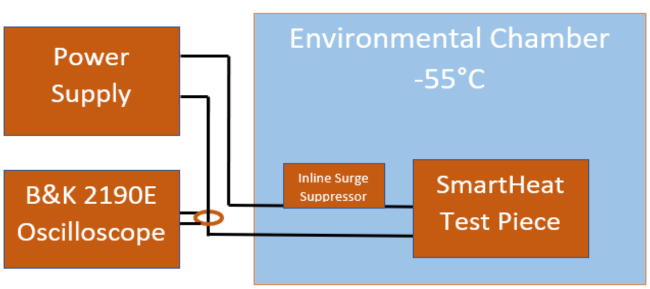
Staging the Experiment

In order to explore these strategies for their efficacy in remediating inrush current concerns, Minco engineers calibrated the environmental circumstances to match that of a common aerospace application. The test environment measured at -55°C and each surge-compressing component was wired in-between a power supply and the test piece. A 400hz power supply was used due to its common application in aircraft.

EXPERIMENT VITALS:

- -55°C test environment
- Input Voltage 120V at 400Hz
- Input Voltage 60V at 400Hz
- 3 inrush current remediation techniques

Two voltage levels were used to test each solution, including a 60V setting and a 120V setting. A clamp-on probe was used to determine the inrush current in both cases. This probe detected the electromagnetic field induced by current flow through the wire, which then passed to an oscilloscope that displayed a voltage waveform. Knowing the current to volt ratio setting of the oscilloscope was 10mV per amp, we calculated the peak current level in each case.



The SmartHeat with remediation component sits in the CSZ16 test chamber that was used to mimic -55°C aerospace conditions.

To better illustrate the initial surge and subsequent power reduction as the test device approached steady state, "trigger levels" were set on the oscilloscope to capture a voltage waveform starting with the instant at which 120V was applied to the circuit. The waveforms from each experiment can be found with the test results included in this whitepaper.

In the control scenario, the 120V test produced an inrush current that measured **17.4 Amps**. The same test performed at 60V produced an inrush current of **8.8 Amps**.

Two Remediation Strategies That Work—And One That Doesn't

During Minco's controlled tests, two inrush current surge protection strategies emerged as successful solutions to reduce the current level at power on. These strategies included the use of (1) NTC thermistors in series and (2) etched foil heaters in series. The third strategy, using a series of inductors, did not produce a strong enough reduction in current level to be considered a practical remediation solution.

EXPERIMENT #1: NTC THERMISTORS

In this first scenario, two thermistors were placed inside the environmental chamber with the heater. The hypothesis for this scenario was that NTC thermistors' high resistance characteristics in cold temperatures would limit the initial current when power was applied.

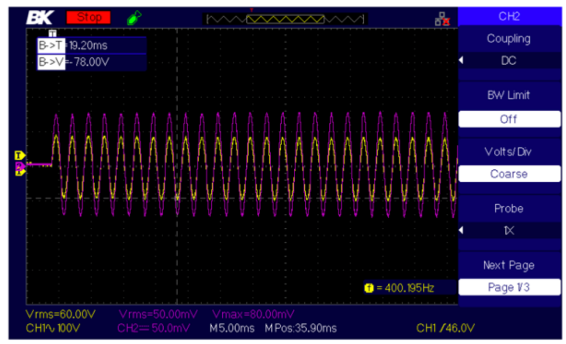
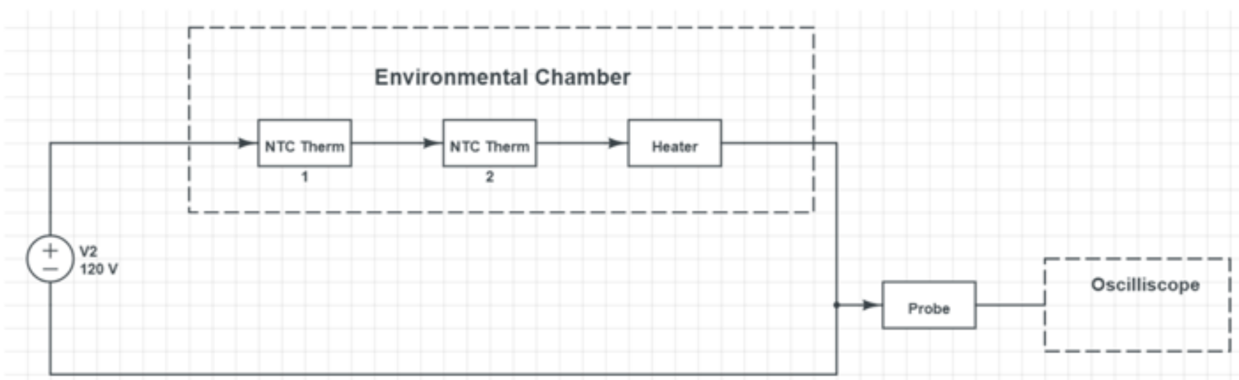


Figure 2: Two NTC thermistors in series, 8.0 Amps inrush current



Results: **Success!** Due to the NTC thermistors resistance characteristics at low temperatures, the solution delivered significant inrush current protection—reducing the inrush current from 17.5 Amps in the control environment to 8 Amps in the test environment at 120V.

Why Choose this solution: An NTC thermistor solution offers a less expensive and more universal method to limit inrush current, compared to the other solutions included in this whitepaper. However, the integration of an NTC thermistor into your existing system will require additional design work that could lead to other concerns relating to reliability, performance and longevity. It is also important to note that the NTC thermistor will self-heat at initial startup, which may require additional experimentation to assess the long-term implications of this side effect.

EXPERIMENT #2: ETCHED FOIL HEATERS

In this second scenario, three etched foil heaters wired in a series worked as a fixed resister to reduce the inrush current. These etched foil heaters were applied directly to the SmartHeat component in an overlay configuration.

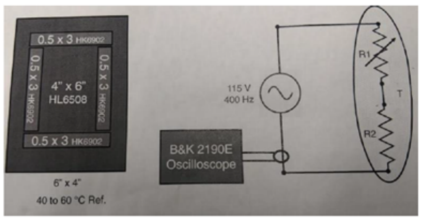
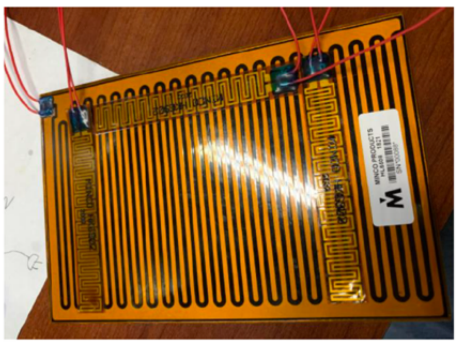


Figure 1: Etched Foil Setup



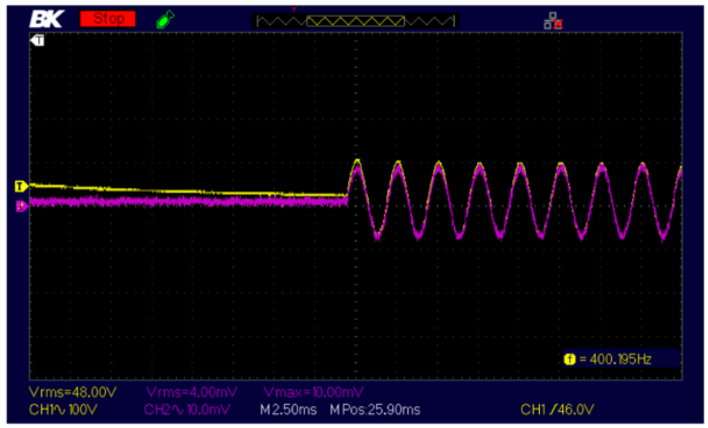


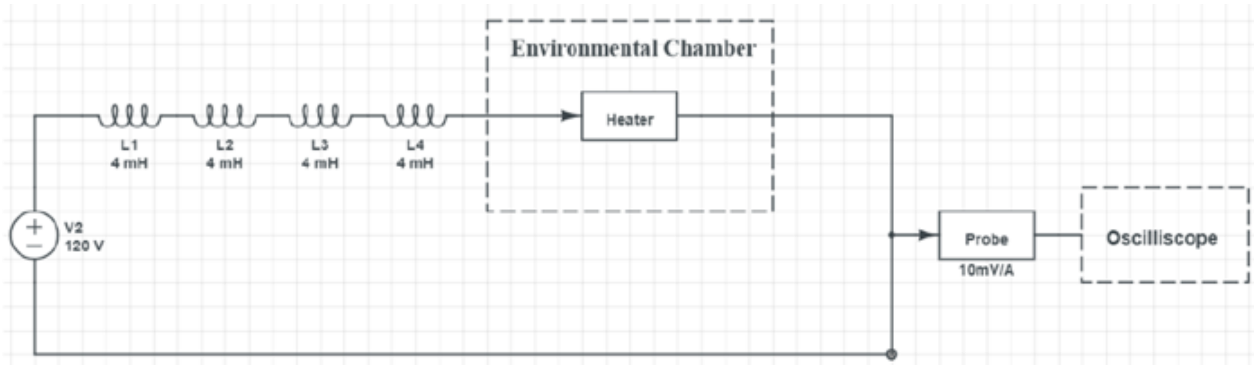
Figure 2: Three HK6902 Heaters in series. Inrush current is 1.0 Amps

Results: Success! The etched foil heaters worked as a fixed resistor in series to reduce the inrush current to just **1 Amp**.

Why choose this solution: A hybrid SmartHeat and etched foil design provides a more elegant, fully integrated solution. It does not include the same need for additional design considerations present in the first, NTC thermistor, solution. It also delivers the most dramatic inrush current results. Additionally, due to the specific placement and design of the solution, power (and heat) is only applied where absolutely necessary—which minimizes power loss and prevents overheating or delamination of the componentry.

EXPERIMENT #3: INDUCTORS

This final scenario sought to reduce the inrush current by “choking” the 400Hz current with added inline induction.



Results: **Failed.** Four different configurations were used, including one and four inductor configurations. The four-inductor solution only provided marginal inrush current protection, as 15.5 Amps were still present during power on.

Ready to Innovate with SmartHeat?

When it comes to truly game-changing design, engineering teams need technology that allows them to build smaller, build lighter and build better. Minco's SmartHeat solutions can help deliver precise temperature control that checks all three boxes—and provides the quiet confidence your end users seek with every big investment.

If you and your team are ready to take the next step and build high-reliability SmartHeat solutions with additional inrush current protections, contact our heater and sensor experts to begin identifying the right solution that promotes system safety, operational efficiency and optimal performance. Or visit Minco.com to learn more about SmartHeat technology and explore our selection of SmartHeat components.

UNLOCK HIGH-RELIABILITY SOLUTIONS FOR MISSION-CRITICAL APPLICATIONS.

Call Minco at 763.571.3121 or send us an email at CustServ@minco.com to get started.