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**WATLOW**®

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# Tackling Thermal System Complexity: The Promise of **ATS**™

Adaptive  
Thermal  
Systems



## Summary:

- The benefits of precise thermal control also come with an engineering challenge: Keeping the complexity of the system in check while addressing issues of thermal uniformity and system responsiveness.
- **Adaptive Thermal Systems**® (**ATS**™) is a suite of technologies designed to combine heating, sensing and control technologies to meet this challenge.
- **ATS** technologies can reduce the wiring and space requirements of diverse systems while improving real-time sensing, diagnostics and control.
- Getting started with **ATS** technology is a matter of partnering with Watlow's engineers to discover which technologies can improve current systems and provide ROI.



Any device or process with a heater also needs some degree of thermal control; some devices or processes need more precise control than others. That precision is traditionally done by adding sensors and controllers to heaters. The more precision needed, the more complex the control apparatus (and the wiring needed for it) becomes.

Adding that kind of complexity is not always an option, however. For example, the size of the system might not easily allow for the parts and wiring required. Or, it could be that having the average temperature of a surface, in real time, is more important than having multiple readings that have to be further processed and averaged, creating a lag in responsiveness.

**Adaptive Thermal Systems (ATS)** represent a different and more innovative approach to controlling thermal performance for such systems. **ATS** combines sensing, heating and control technologies to meet the unique challenges of these applications.

## The Challenges That Give Rise to **ATS** Technologies

Thermal solutions are a part of almost every modern industry, from chip manufacturing to medical devices to oil and gas operations. What these diverse industries have in common is a need to design simple, yet responsive, systems that can monitor and maintain the precise application of heat.

Historically, this need has meant engineers have had to contend with:

### Complex Systems in Small Spaces

Suppose a surface needs to be heated to within a certain temperature range. This requires not only several heating elements, but also sensors that can detect the temperature of the surface at various points. Those sensors then deliver that feedback to a controller that then responds by adjusting the power sent to the heater(s). If the temperature of the surface fluctuates, the sensors and controller should be able to respond in tandem to maintain the desirable temperature range (i.e., they need to be tunable).

Traditionally, the approach to getting such fine control of the heating surface has been to increase the zone count, which entails the addition of more independent sensors—and hence more wires and more controllers. As the system scales, the complexity of the system grows exponentially; but the overall space in which this needs to happen does not. In many manufacturing scenarios, precise control is needed in a confined space, and additional wiring and equipment is not a feasible option.

### Disconnected Control Systems

Different banks of sensors at different points in a process are often connected to separate controllers, and those controllers might not be networked in such a way that their activity can be coordinated easily. This results in unresponsive systems, with engineers having little insight into what is going on—especially when something goes wrong.

### Unpredictability and Poor Thermal Uniformity

The above challenges often result in adding an element of unpredictability to the system. The added complexity of additional sensors and controllers will, for some applications, either compromise adaptability or prevent the system from achieving desired thermal uniformity (or both). These, in turn, lead to excess waste and variable material quality.



## The Key to Meeting These Challenges

Precision and tunability of a thermal system is traditionally achieved by adding elements to the system— i.e. more sensors and more controllers. But there are plenty of applications where this is not a viable option: Semiconductor manufacturing, analytical devices, home medical devices and more. **ATS** makes possible a greater degree of control in systems where piling on more components is simply not an option.

## What is Watlow's *Adaptive Thermal Systems (ATS)*?

**Adaptive Thermal Systems (ATS)** is a suite of technologies that combines sensing, heating and controlling in innovative ways to improve thermal performance. The technologies at the forefront for achieving this goal include:

- Power conversion
- High temperature coefficient of resistance (TCR) materials-based temperature control
- Integrated thermocouple heater (TCH) junction temperature control
- Multi-loop control and sensing

A particular thermal application might use one, some or all of these technologies, depending on the system and demand characteristics.

## STREAMLINE™



Figure 1: Watlow's STREAMLINE™ thermal system with ATS technologies



## Power Conversion

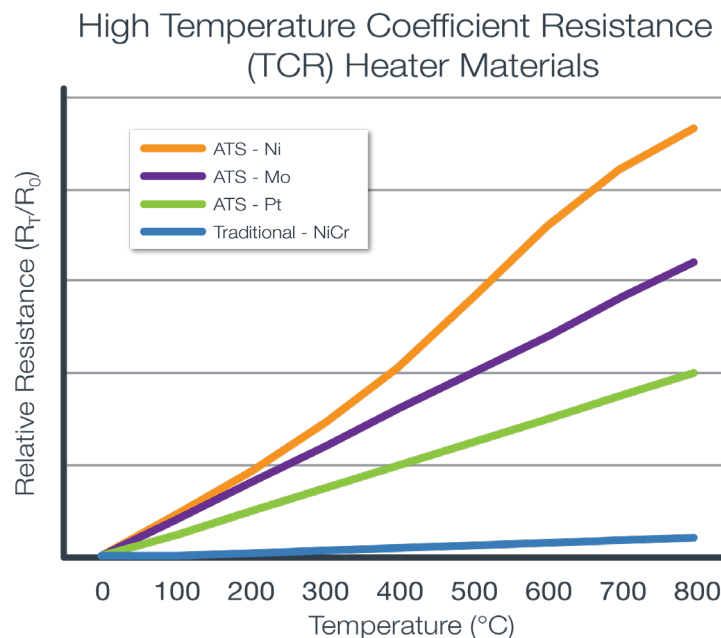
Traditional control of power to heating elements has relied on what amounts to simple on/off switches. But there are many circumstances where one might want the ability to “ramp up” and “power down” the power smoothly and in a much more controlled manner. For example:

- Systems with more fragile heaters (with silicon or ceramic parts, for example)
- Systems that would be sensitive to pulsing
- Systems where wire size needs to remain small

This is where power conversion technologies come into play. They help control the power coming into heating elements, allowing designers to choose heaters that are particularly suited to an application without worrying about the power being fed into them. It is also less noisy and less limiting than other options, such as phase-angle converters.

## High TCR Materials Based Temperature Control

High TCR materials undergo a measurable change in resistance as temperature changes. Integrating these types of materials into heaters can, in essence, make them into sensors as well.



**Figure 2:** The relative resistance of different materials changes with temperature

Combining the heater and sensor into a single component helps meet a number of challenges. Because the sensor is the heater itself, the signal produced is a much more accurate reading of the average temperature over the entire heater region, with virtually no time delay. This, in turn, improves sensor reliability and overall thermal response.

High TCR materials also mean much more integrated and streamlined designs. For example, sensors can now exist in places where it was previously impossible to fit a sensor, or where there are already too many sensors. Or a single heated surface can have several independently heated and controlled zones for better temperature uniformity.

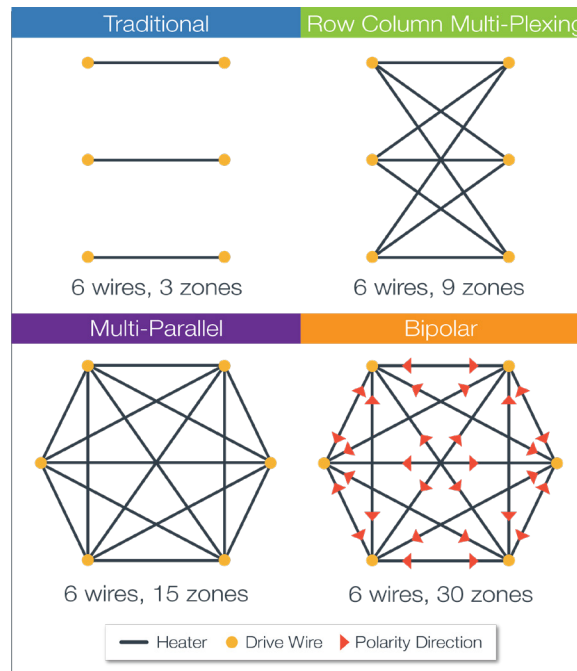
## Integrated TCH Junction Temperature Control

Just as high TCR materials can turn a heater into a sensor, integrated TCH can turn heater power leads into a thermocouple junction, again allowing for the precise measurement of temperature without a separate sensor. This reduces the number of wires required and saves space, lowering both sensor and integration costs.

And, unlike TCR, TCH control is a point measurement at a precise location. This is ideal for circumstances where a precise reading is needed, as opposed to an average over the entire heating area.

## Multi-Loop Control and Sensing

Multi-loop control and sensing integrates a unique power switching approach with high TCR sensors, in a multiplex wiring scheme, to create a high zone count while reducing the overall wire count. A high zone count allows for high-fidelity control of surface temperature, while the low wire count makes it possible to fit everything into a small space.



**Figure 3:** Traditional vs. Multi-Parallel Circuits for Multi-Loop Sensing and Control

## ATS at Work: Benefits of ATS Technologies and Their Integration

Every application is unique, and some can take advantage of many ATS technologies at once while others might use just one. That said, the true value of ATS shows when multiple technologies work in tandem.

For example, consider a process where traditional power pins with a low TCR are replaced with high TCR power pins, allowing the heaters thus powered to become sensors as well. Every heater on the line can now be its own zone of control when combined with the appropriate controller. This allows for more uniform temperatures, in real time, while also reducing wire count and system complexity.

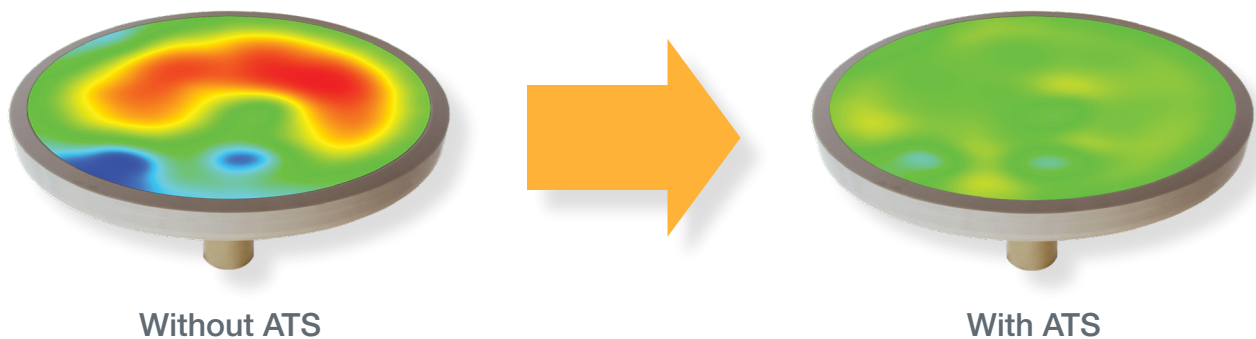
This can further open up the space of designs, too. For example, if wiring count is no longer a limiting factor, it is possible to increase the number of heating zones for a surface to achieve better thermal uniformity and control. Real-time feedback from the system can make diagnostics easier, and so on.

## Three Brief Examples of Industry Use

Thus far, **ATS** technologies have been described at a very general level. Here we provide some real-world examples where this technology is making a difference. Of course, the following represents just a small sample of what is possible.

### Semiconductor Manufacturing

Deposition pedestal heaters must reach certain temperatures during the chipmaking process, and temperature uniformity is critical to quality control. The pedestal itself allows little room for extra wires, however. With high TCR materials and multi-loop control and sensing, individual heaters can be made into sensors, and the number of heating zones can be more than doubled. These zones can be independently controlled, in real time, adjusting heater output to achieve a more uniform surface temperature.



### Analytical and Medical Equipment

Existing medical and analytical equipment often have to meet new agency requirements, like safety specifications for allowed temperatures. Having heaters that can sense their own temperature can send appropriate signals to a controller that then adjusts power levels via power conversion, keeping temperatures within safe limits.

### At-Home Medical Devices

Many medical procedures traditionally performed in a hospital setting are now being done, partially or fully, at home—mostly due to the development of small, simpler devices. Manufacture of such devices for a global market is difficult, however, due to the varying power requirements in different countries. With an appropriate power conversion tool built into devices, the same device can be sold in the U.S., Europe and Japan without the need to switch parts, add adaptors or otherwise worry about the longevity of components. Appropriate control of heating elements also helps devices to meet government agency safety specs.

## Partnering on **ATS**

The beauty of **ATS** is that it is not one solution, but a suite of solutions that can be tailored to specific engineering challenges. Unlocking the benefits of this technology requires a deep understanding of the product or process in question, including the thermal and power requirements of the system.

Watlow's engineers have decades of experience with thermal systems, and can work with your engineers and designers to incorporate **ATS** technology into your process or product. If this is something your organization would like to pursue, please contact your local Watlow representative.

*Further information is available at: [www.watlow.com](http://www.watlow.com)*

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