



Temperature Control System

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Introduction

The common industry temperature control system allows an oven zone to add/subtract heating capacity in order to prevent significant temperature under- and over-rides. However, due to its temperature-only control basis, true precision is not achieved. In reality, situations can frequently arise in which this scheme actually works against itself, causing increased loss of precision and, in some situations, reducing oven lateral heat effectiveness.

In contrast, the Banner-Day temperature/pressure based temperature control system provides not only exceptional control over oven zone heating capacity, but does so while providing precision temperature control and maintaining lateral heat definition.

Oven Zone Temperature Control Overview

Oven zone temperature control schemes are designed to maintain the temperature within a given zone as close to the desired setpoint as possible. Historically, this was accomplished strictly by control of the firing rate, through modulation of the air header pressure via the modulation motor/valve. The downside of this scheme was that even at the minimum firing rate, there was often too much heating capacity in a given oven zone. This caused temperature override when there was reduced or no product in the zone. A common fix for this was to run empty or water filled pans, commonly referred to as flash pans, to absorb the excess heat.

With the advent of DSI and the application of automated control systems, it became possible to turn off or "Stage" individual burners. This further reduced the heating capacity of a given zone to acceptable levels, negating the need for flash pans. Prior to DSI, the typical turndown ratio was in the neighborhood of 3:1. Since DSI and the application of staging, a ratio of 12:1 is obtainable.

While nearly all oven control system manufacturers have implemented some form of burner staging in new, rebuilt and retrofitted ovens, making the overall heating capacity of a given zone adjustable, the majority fall short in providing precision temperature control. Banner-Day, however, has taken the next step to provide a reliable, stable and precise zone temperature control scheme.

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Common Industry Temperature Control Schemes

The common industry temperature control scheme is one based solely on temperature. The process temperature is used in combination with the temperature setpoint by a PID control to command the modulation motor to drive the firing rate.

Burner staging is also strictly a temperature function. At specific temperature deviations from setpoint, burners are staged off in an attempt to reduce the heating capacity of a given zone. For instance, stage 1 may occur at 5 degrees below setpoint, stage 2 may occur at setpoint, stage 3 may occur at 5 degrees above setpoint, and stage 4 may occur at 10 degrees above setpoint.

This scheme has several inherent problems. First, the staging is based on temperature deviation, which means temperature deviation **MUST** occur. If one assumes that the desired optimum temperature deviation is **ZERO**, this scheme is not optimal.

Second, this scheme makes no allowance for true load demand. For example, if a product, such as a lidded product, with a very high heat demand is running, nearing the maximum heating capacity of the oven, this control scheme can exacerbate the problem. As the oven struggles to reach the zone setpoint at maximum firing rate, it can suddenly find 25% of heating capacity drop-off because it came within the 5 degree staging window. As a result, setpoint is never reached.

The converse situation can also exist. If the oven were to run empty, the modulation motor/valve will drive the burners to the lowest firing rate and all burners will be staged off. As product is re-introduced to the oven and the heat load increases, the burners will begin staging on faster than the modulation motor/valve can drive back up. As a result, when the setpoint is reached, the modulation motor will tend to maintain the **LOWEST** possible firing rate, with the burners staging on and off providing control instead of the modulation motor/valve. This can have a serious impact on the lateral heat definition of the associated burners. If the firing rate is too low, overall zone temperature may be maintained, but the lateral heat definition may not be acceptable. This could easily result in product having uneven color across the width of the oven.

Lastly, minor misadjustment in the PID control tuning values, or mechanical misadjustment of the modulation motor/valve linkage can cause what should be continually varying control of the oven zone heating capacity to suddenly become strictly a four stage on/off scheme. In this situation, the modulating motor typically maintains its last position and the burners are continually staged on and off. This further reduces the precision of the temperature control.

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Banner-Day Temperature Control Scheme

While the Banner-Day temperature control scheme has some similarities with the common industry practice, the Banner-Day scheme has a significant difference that enables continuous precision zone temperature control. This difference is that a process value is added to the control scheme: air header pressure.

The Banner-Day system allows the PID control to command a firing rate based on the zone process temperature and temperature setpoint, just as the common industry control scheme does. The difference between the industry standard and Banner-Day is in the staging scheme. Instead of a staging scheme based on temperature deviation, the Banner-Day system stages based on the air header pressure that is managed by the PID control.

As the air header pressure falls, the Banner-Day system stages groups of burners off. If the air header pressure increases, burners are turned back on. Since this system is effectively based on load demand, precise temperatures can be maintained. A Banner-Day system running at steady state typically maintains temperature within 2 degrees of setpoint. A sudden change in load demand caused by introducing product to an empty oven, or, conversely, a full oven running empty typically results in no more than a 10 degree deviation that is quickly corrected.

Since temperature deviation is no longer a requirement for staging, deviations are kept to an absolute minimum. Temperature deviation as an estimate of required heating capacity is eliminated. If maximum heating capacity is required at or near setpoint, maximum capacity is maintained. The effects of minor misadjustments are minimized. Since air header pressure modulation MUST occur first, continuously variable control is always maintained. As a result of the burner firing rate being optimized prior to staging, the lateral heat definition is maintained at all times.

Conclusions

While sharing some similarities, the Banner-Day temperature control system is far superior to standard industry practices for the following reasons:

- **Precision Temperature Control** – Steady state temperatures are within 2 degrees of setpoint. This means only using the BTU content required to bake the product which translates to energy savings. It also means that the baker can tighten the quality window with confidence to ensure a better and more consistent product for the consumer.
- **Optimal Lateral Heat Definition** – Banner-Day system burners begin staging off BEFORE reaching the lowest firing rate thus allowing the remaining burners to operate at a higher firing rate. This, in turn, helps maintain the lateral heat definition set by baker to prevent dark/light product in the oven.

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Terminology

Oven Zone – Group of oven burners having a common air supply header and natural gas header. Each zone is completely independent of the others. All burners within a given zone operate at the same firing rate controlled by the air pressure header modulation motor/valve.

Modulation Motor/Valve – Motorized butterfly valve that controls the air header pressure for the associated oven zone. Each motor has its own PID control, allowing for constant variable control over the firing rate for the zone.

Direct Spark Ignition (DSI) - Each burner has a dedicated ignition source combined with a flame safety monitor.

Proportional Integral Derivative Control (PID Control) – Method of controlling an infinitely variable (i.e. analog) process value (temperature, flow, etc.) based on the current process value and the desired set-point. This control method allows for very tight control, minimizing over- and under-ride when tuned properly.

Staging (also known as Cutback) – Practice of turning off a percentage of oven burners (typically 25%), in an oven zone in **STAGES** to reduce the heating capacity of that zone.

Turndown Ratio – Ratio between the maximum and minimum heating capacity of a given burner or zone. For example, if the maximum heating capacity of a zone is 600,000 BTU, and the minimum is 200,000 BTU, the turndown ratio is 600,000:200,000 or 3:1.

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