Applications of Model Based Control in Float and Fiberglass

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Abstract

Significant quality and throughput improvement to the glass float and fiber manufacturing process has been demonstrated by a new control method. The new temperature control method utilizes ACSI's predictive-adaptive Model Based Control system. The Model Based Control system continuously adjusts the upstream process to ensure that the flow temperature is at the setpoint regardless of environmental conditions. The system has been field tested in a multitude of installations and has demonstrated the ability to improve temperature stability substantially as compared to conventional PID control. Results of implementing the new control method include improved manufacturing efficiency, product quality, and reduced mass flow temperature recovery time following a temperature setpoint change.

Introduction

ACSI has successfully combined our glass process knowledge with new innovative technology in our model based control. The combination of ACSI's process expertise and Brainwave® software capability enables our systems to greatly outperform standard PID in all Fiber and Float glass applications. Traditional methods use PID (feed back only) to control variables such as furnace temperature, working end temperature, forehearth temperature or glass level. Our advanced control uses a model to control the process. Once the optimum model is created the controller:

- Predicts control actions required to quickly drive the variable to setpoint without overshoot
- Adapts to process and production changes for continuous improvement without manual intervention
- Models both feed forward and feedback inputs to provide maximum stability

Model Based Control (*Model Based Control versus PID)*

Model Based Controllers (MBC) are outperforming PID control in glass applications and therefore have become a preferred installation by manufacturers. The MBC quickly responds to process disturbances and reacts swiftly to stabilize temperature variations. A Model Based Controller creates models for each control/process variable and feed forward input. The ideal model then anticipates changes needed to maintain consistent glass temperature. Once the optimum process is modeled, Model Based Control

• Predicts control actions required to drive the glass temperature to setpoint quickly without overshoot.

•Continuously adapts to process and production changes automatically for better control without loop tuning. (wear and tear of furnace, seasonal changes, etc.)

• Models feed forward inputs and updates control actions to quickly stabilize temperature variation.

Another benefit of Model Based Control is it's consideration of dead time. PID does not understand dead time, which results in oscillation. MBC understands & accounts for it when making adjustments. The MBC understands what the typical dead time is and waits before continuing with adjustments.

Figure 1: With PID, oscillation occurs before settling at Setpoint

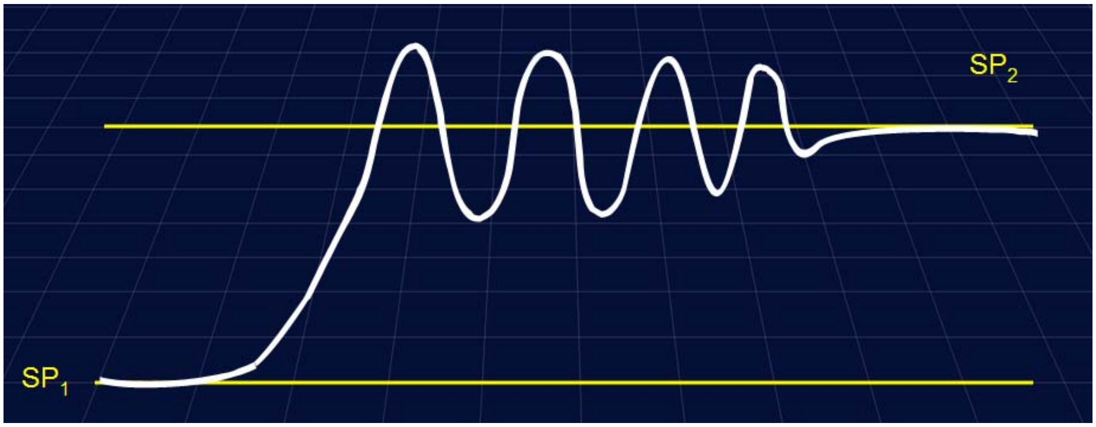
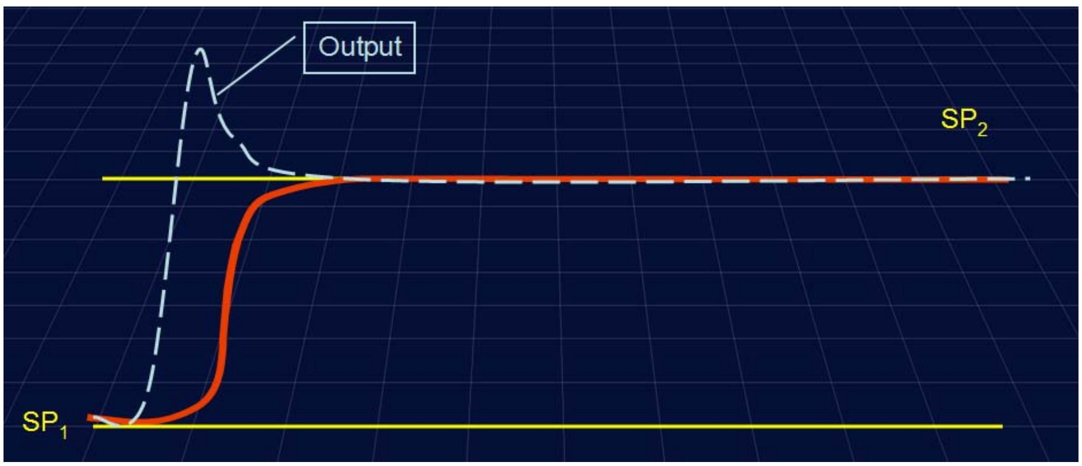


Figure 2: With MBC, the PV reaches SP faster without overshoot.



Model Based Control should be applied selectively to avoid high costs and ineffective use.

MBC should be implemented the following areas:

- Loops that are dead time intensive
- Places where it is essential for the control system to understand the relationships between/among loops
- Areas where feed forward signals would increase productivity, decrease process variation
- Anywhere delay time, changing loop dynamics or non-linear responses make for a tough control problem

Overall benefits of Model Based Control:

- Energy Savings
- Greater Overall Stability
- Increased Quality
- Decreased Defects

Float Glass Control

The ACSI MBC is applied to the following loops to determine the effectiveness versus traditional methods:

Melter Temperature control
Canal temperature control
Refiner temperature control
Glass Level control
Block Cooling
Lehr Temperature
Tin Bath Bottom Temperature

The model based control runs in a separate computer that is attached to the control system via Ethernet or Profibus. (Ethernet is preferred) The control system is programmed to allow the model controller to change the outputs to directly control the process. If the model fails the system automatically reverts back to the prior control (normally PID). The only change to the operator interface is an additional mode of control shown (model). The communication interface can be via OPC.

Creating the model requires that the loop is "bumped" through step changes to learn how they response. The Setpoint "bumps" are within limits that do not disturb the running process.

Temperature Control Example

Traditional glass design places a sensor at the exit outlet of each temperature zone to measure glass temperature as it exits the zone. The sensor relays data to the PID controller which adjusts the heat to bring the glass temperature back to set point. As the molten glass travels through each chamber, respective controllers continue to "play catch up".

Also PID controllers do not understand dead time. Dead time is the delay in response to a valve adjustment. Thus PID controllers must be tuned to respond slowly in glass applications.

The ACSI model-based controller is effective in controlling zone temperatures by modeling the existing process. The controller creates models for each control/process variable and feed forward input. These ideal models allow the system to anticipate changes needed to maintain consistent glass temperature.

Figure 3: Temperature and Gas Flow before and after Model Based Control

Working End, Canal Temperature and Glass Level Examples

The following trend displays show the affect of model based control when applied to the Working End temperature control.

The first is Working End temperature prior to the application of model based control. The second is using ACSI MBC.

Figure 4: Working End Temperature before MBC

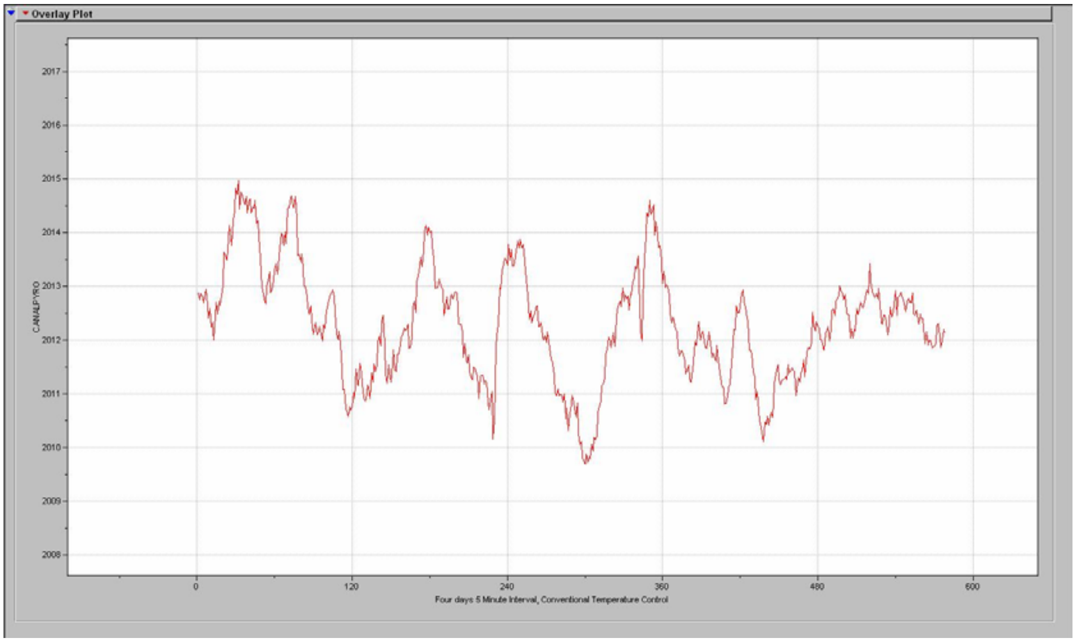


Figure 5: Working End Temperature after MBC

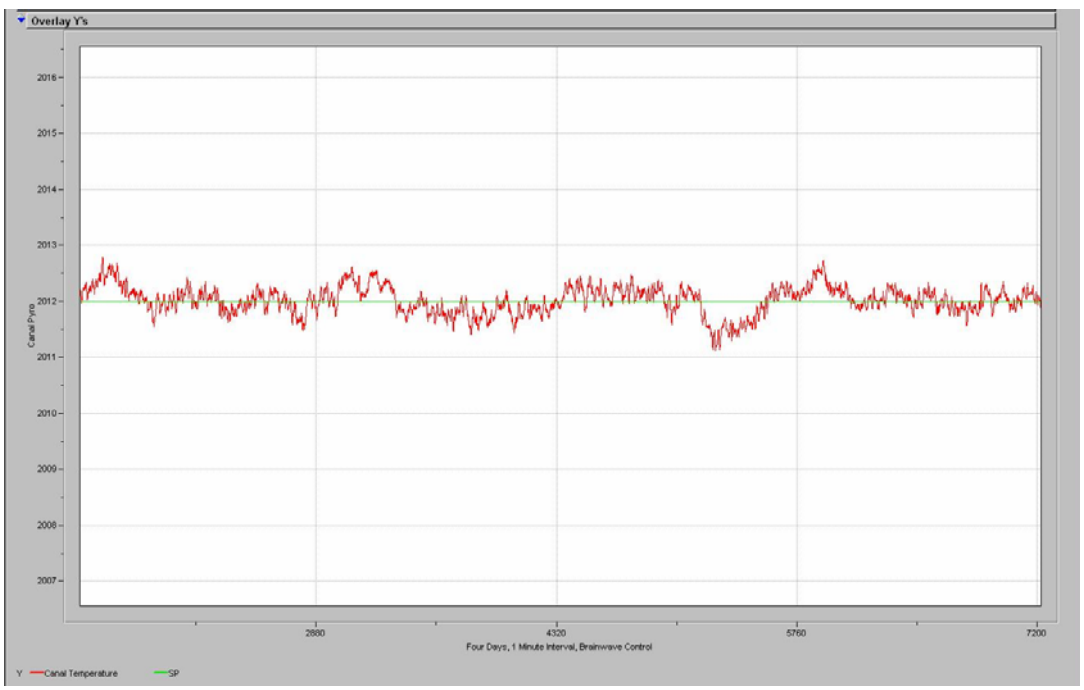


Figure 6: Canal Temperature before MBC

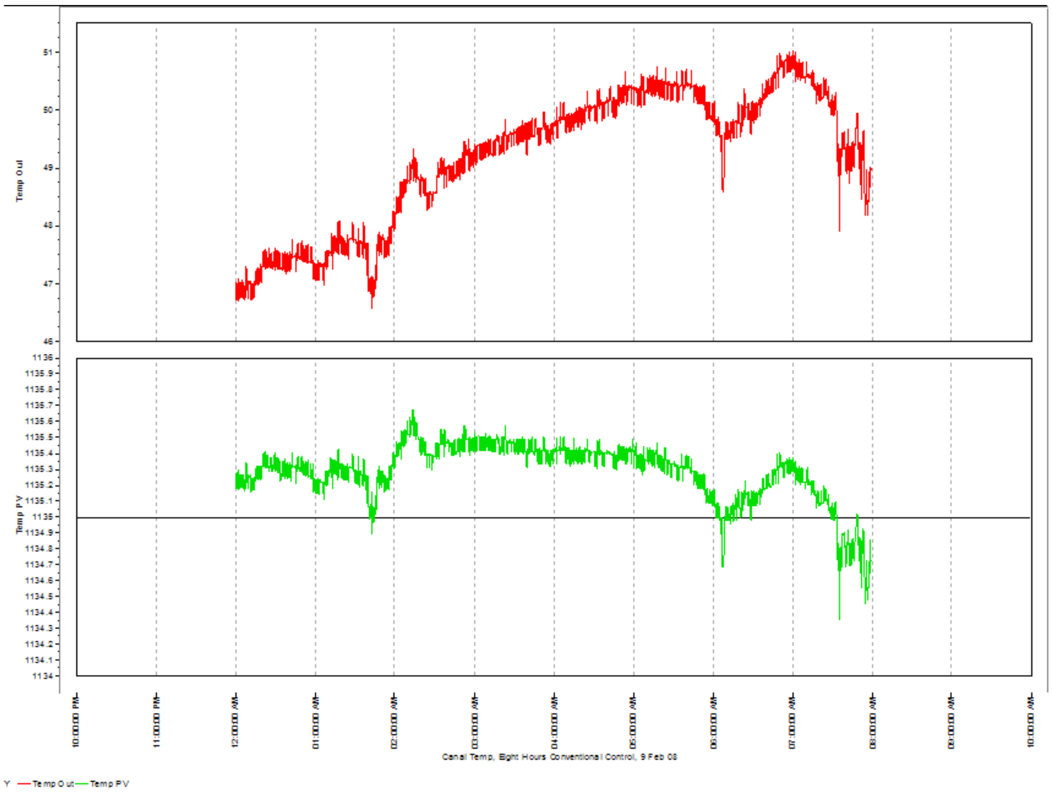
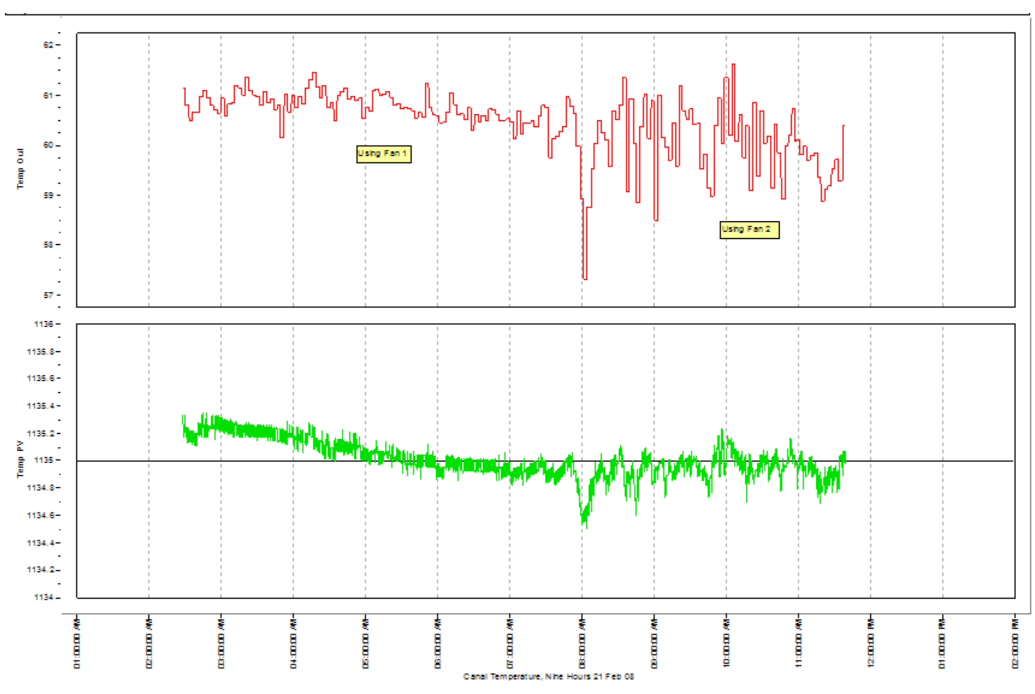


Figure 7: Canal Temperature after MBC



The following images display the affect of model based control when applied to the Glass Level control.

The first is Glass Level prior to the application of model based control. The second is using ACSI MBC.

Figure 8: Glass Level before Optimization

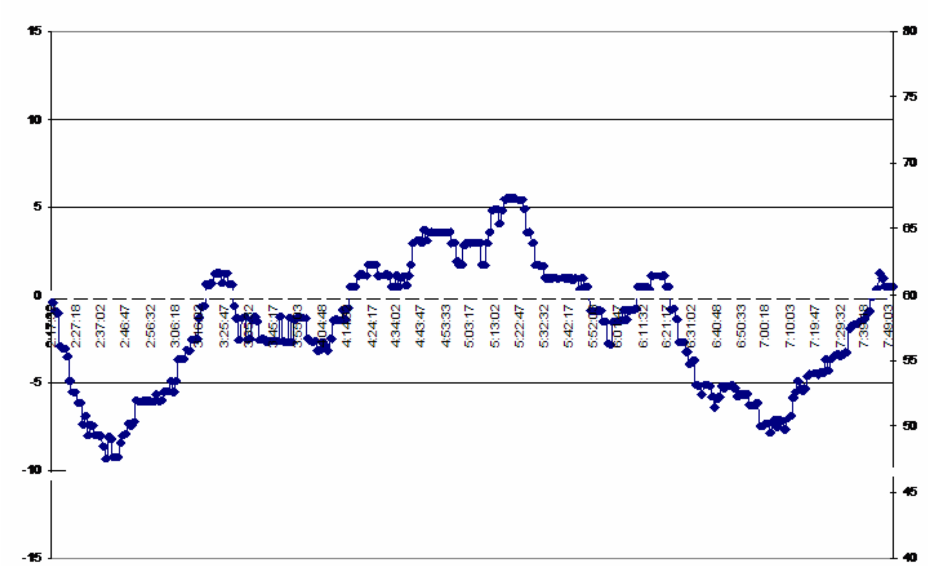
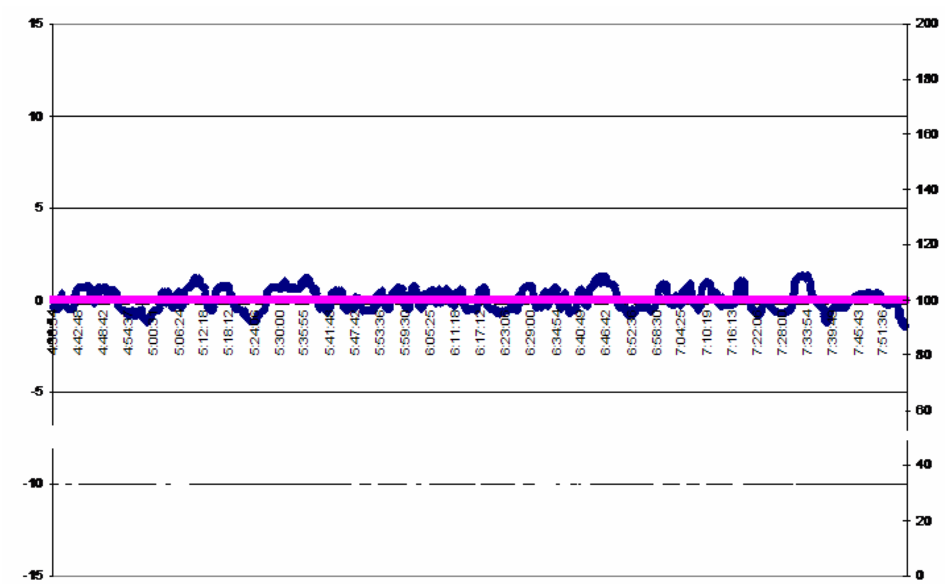


Figure 9: Glass Level after Optimization



Note: Range shown in "before and after" graphs for both Working End temperature and Glass level are the same parameters

A recent float installation demonstrated our ability to improve the quality of control using a model based controller. The details of the application of this control were as follows:

Leading float glass manufacturers had been using standard PID loops to control glass level and canal temperature. By incorporating BrainWave® model based control into the existing Melter system, ACSI was able to provide the customer with optimal results that exceeded expectations. BrainWave® technology combines adaptive modeling and predictive control to obtain the best possible results in the least amount of time.

Problems with current solution:
The customer's glass level control, a simple PID loop, was being compromised due to oversized batch logs not melting properly and disturbed convection from the oversized logs cooling the glass beneath the batch blanket. These problems were causing process performance to deteriorate in the forms of poor fuel efficiency and off-quality glass.

The cascaded closed control loop, controlling the Canal temperature, required frequent tuning, produced sluggish response time, and caused an unacceptable variability of the canal temperature.

Results:
A Model Based Control solution provided the customer with measurable advantages both economically and operational.

Benefits

- Increased production
- Energy reduction
- Large reduction in temperature variation
- Noticeable reduction in recovery times
- Improved level control
- Quality and repeatability
- Operator intervention eliminated

Customer Results

- 2.7% reduction of fuel consumption without compromising quality
- 30% reduction of defect density
- Added an additional 10 tons per day without compromising quality
- 50% reduction on error from setpoint in glass level
- Canal temperature variability was reduced by 72%
- Melter Temperature variability was reduced by 67%

Temperature Control for Fiberglass Forehearths

Previous forehearth control systems have relied solely on PID feedback control for glass conditioning to the bushing. ACSI has optimized this control by using advanced model based control to achieve exceptional stability and control right at the point of entry to the bushing. The models use both feedback and feed forward strategies. Customers who have applied the MBC solution have realized significant benefits including improved production efficiency and excellent temperature stability. The solution has been applied to both new and older forehearths using existing control systems with excellent results.

Figure 10: Eight days of forehearth zone control before applying ACSI optimization

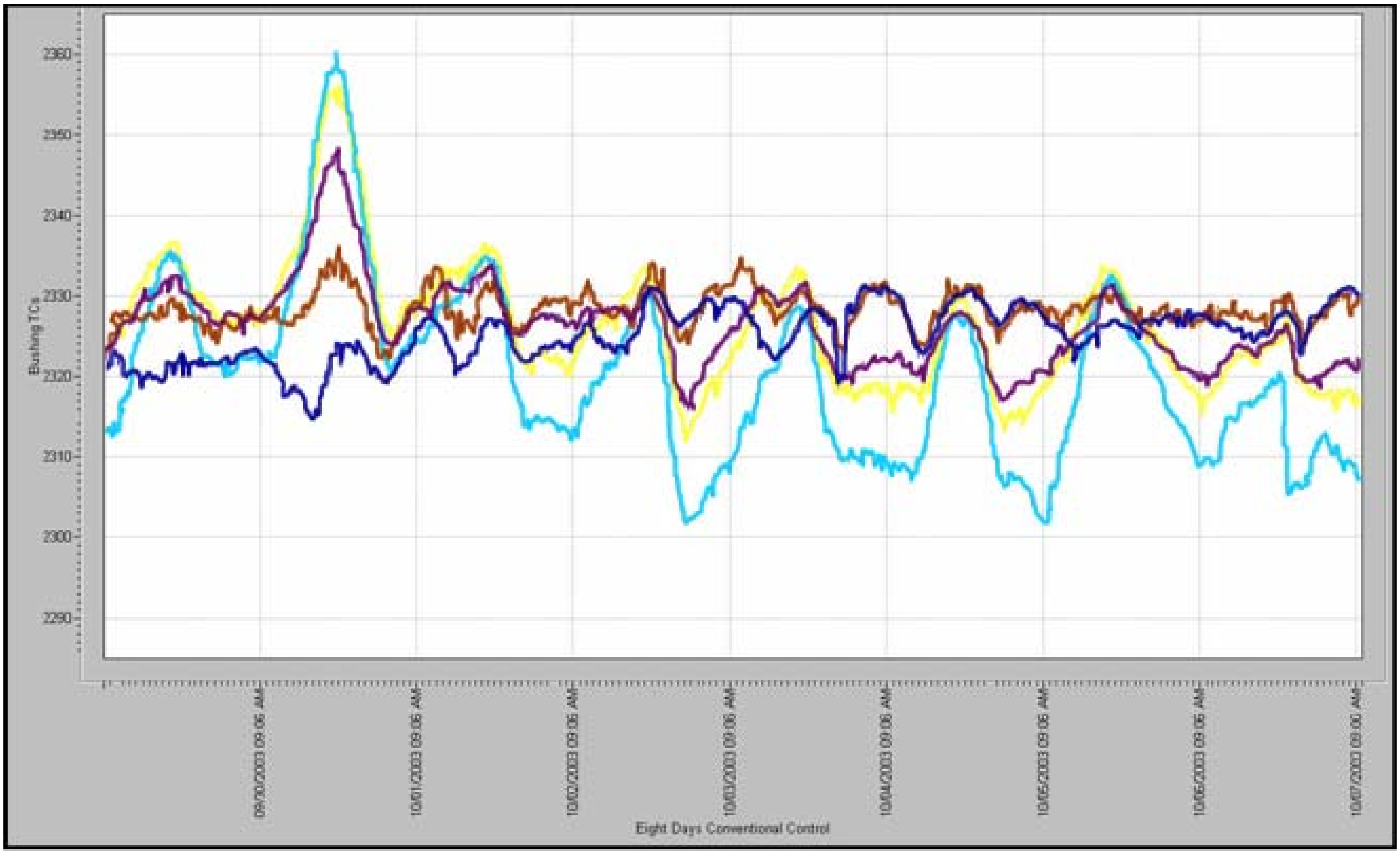
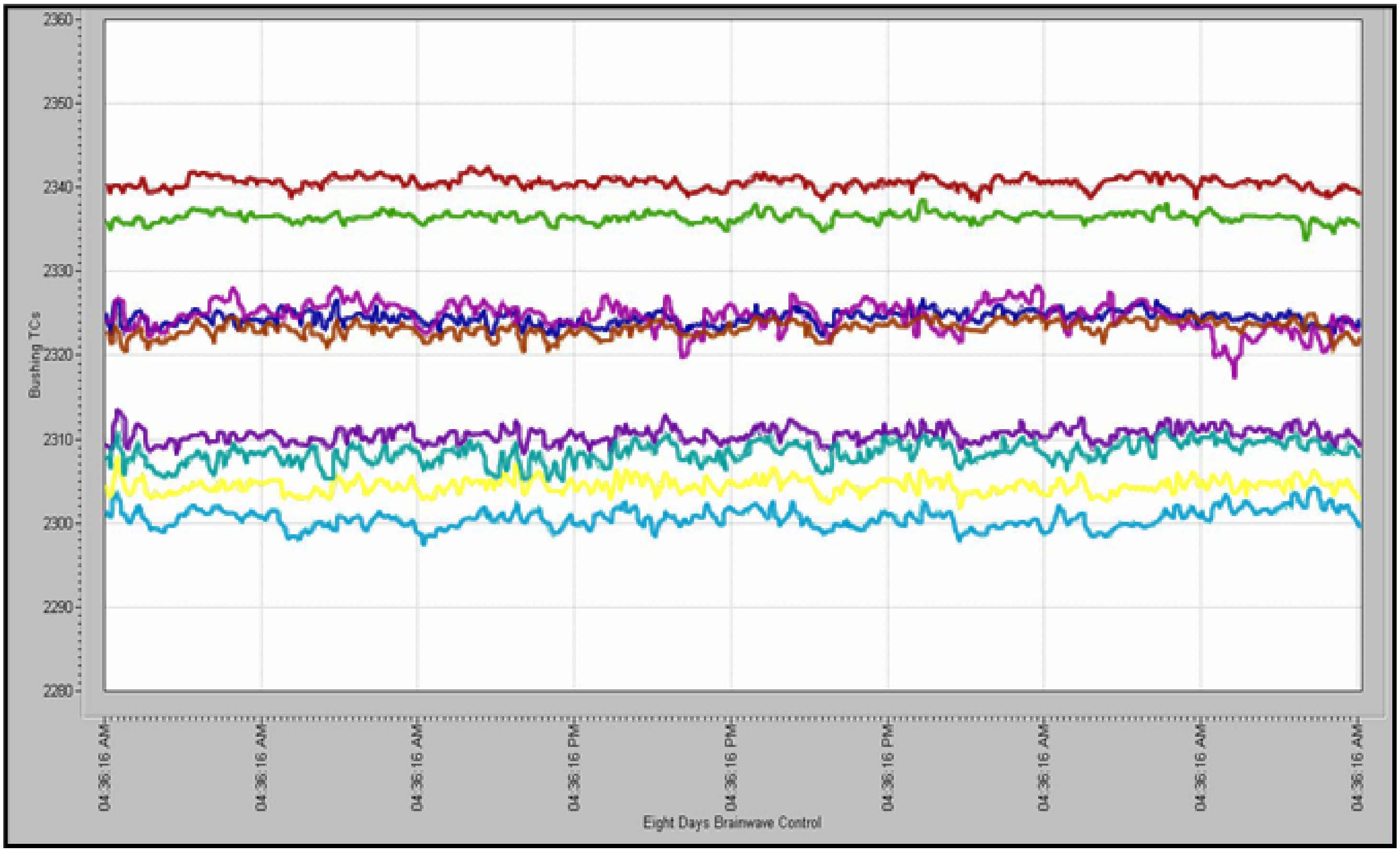


Figure 11: Eight days of forehearth zone control after applying MBC optimization



BENEFITS

- Improved Temperature Stability
- Disturbance Rejection
- Reduced Breakage
- Increased Production
- Reduced Energy Usage

CUSTOMER RESULTS

- 65-100% reduction in temperature variation
- 50% less time to achieve stability over PID
- 2% improvement in Pack
- 20% reduction of Bushing breaks per hour
- 2-5% reduction of fuel consumption