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FIVES NORTH AMERICAN COMBUSTION, INC.

North American CertiFire™ Automatic Combustion System Tuning for Furnace Uniformity Surveys

AISTech 2022

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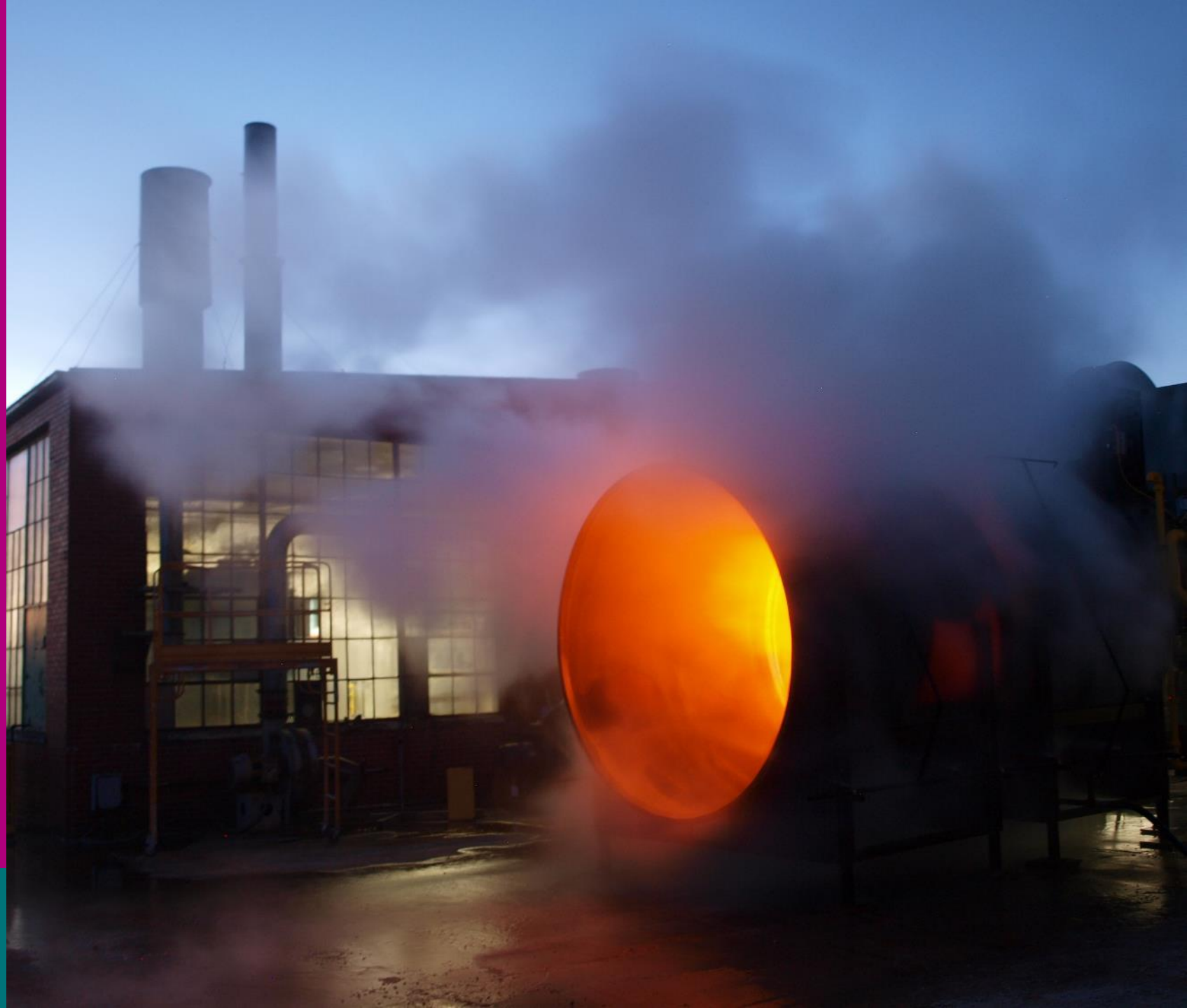
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FIVES NORTH AMERICAN COMBUSTION

Company Overview



PROCESS
TECHNOLOGIES



North American Combustion, Inc.

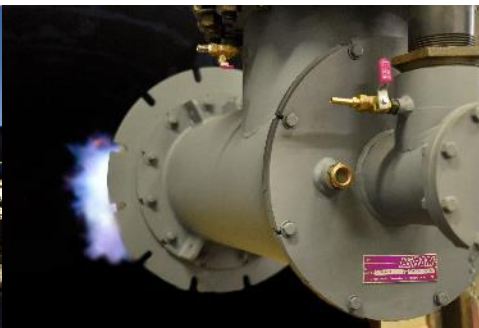
— Company Overview



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- ✓ Largest Combustion Catalog in the world
- ✓ Strong Technical Knowledge
 - R&D Team and Facility
 - Engineering team consisting of Combustion Physicists, Mechanical Engineers, Chemical Engineers
 - Service Team with on average over 15 years of experience in Thermal Processes
- ✓ 400,000 sqft facility
- ✓ National and International Sales offices
- ✓ Largest Combustion Lab in the industry



North American Construction, Inc.

— Company Overview



- ✓ Integrated Single Source Provider
- ✓ Life Cycle Support
 - Complete furnace rebuilds including demolition and replacement
 - Refractory, structural and mechanical maintenance
 - Combustion tuning
 - Preventative Maintenance Schedules
 - Thermal Imagine
- ✓ Large In House Manufacturing and Equipment Assembly
- ✓ Construction and Field Erection
- ✓ Offices in IN and NC to be close to customers
- ✓ In house Engineering and Design for furnaces
- ✓ Turn Key Solutions for new and brown field plants



Forging & Heat Treat

Forging & Heat Treat

- Proven track record of providing engineered solutions to the industry
- Wide range of burner and control technologies
 - Tempest® DMC Ultra Low NOx High Velocity
 - TwinBed™ II Regenerative System
- Industry best temperature uniformity
 - Systems capable of Class I (+/-5°F) uniformity

Car Bottom and Moveable Hood Furnaces

- Fully engineered Design & Build Solutions
- Wide variety of offerings for heat treat and forging solutions
- Furnace can be fully assembled and tested at NACS facility, limiting on site assembly, installation and testing period

Tempest Fired Carbottom Tip Up Furnace



TwinBed II Regenerative Box Forge Furnace



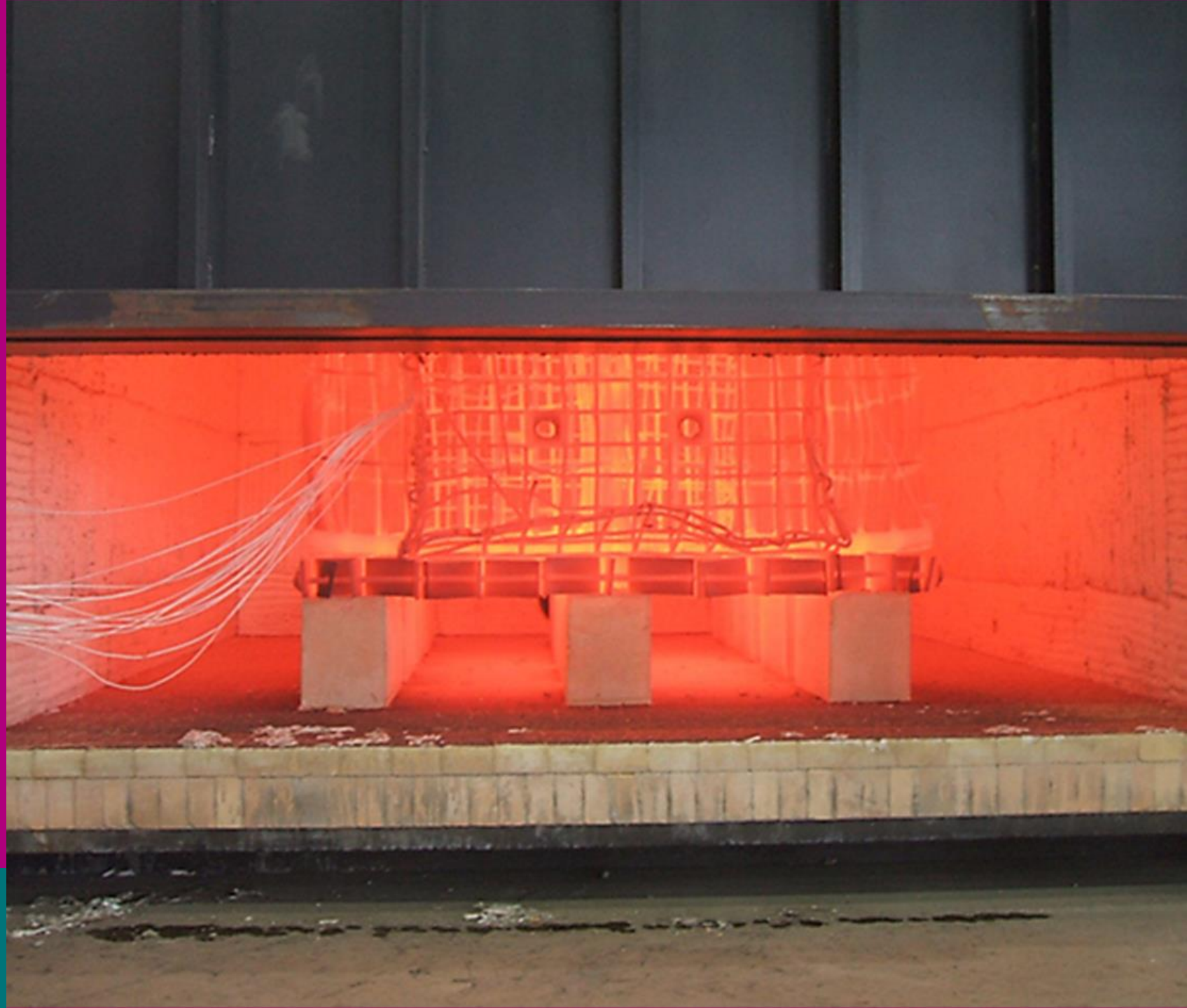
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TUS

Combustion system tuning and
temperature uniformity surveys

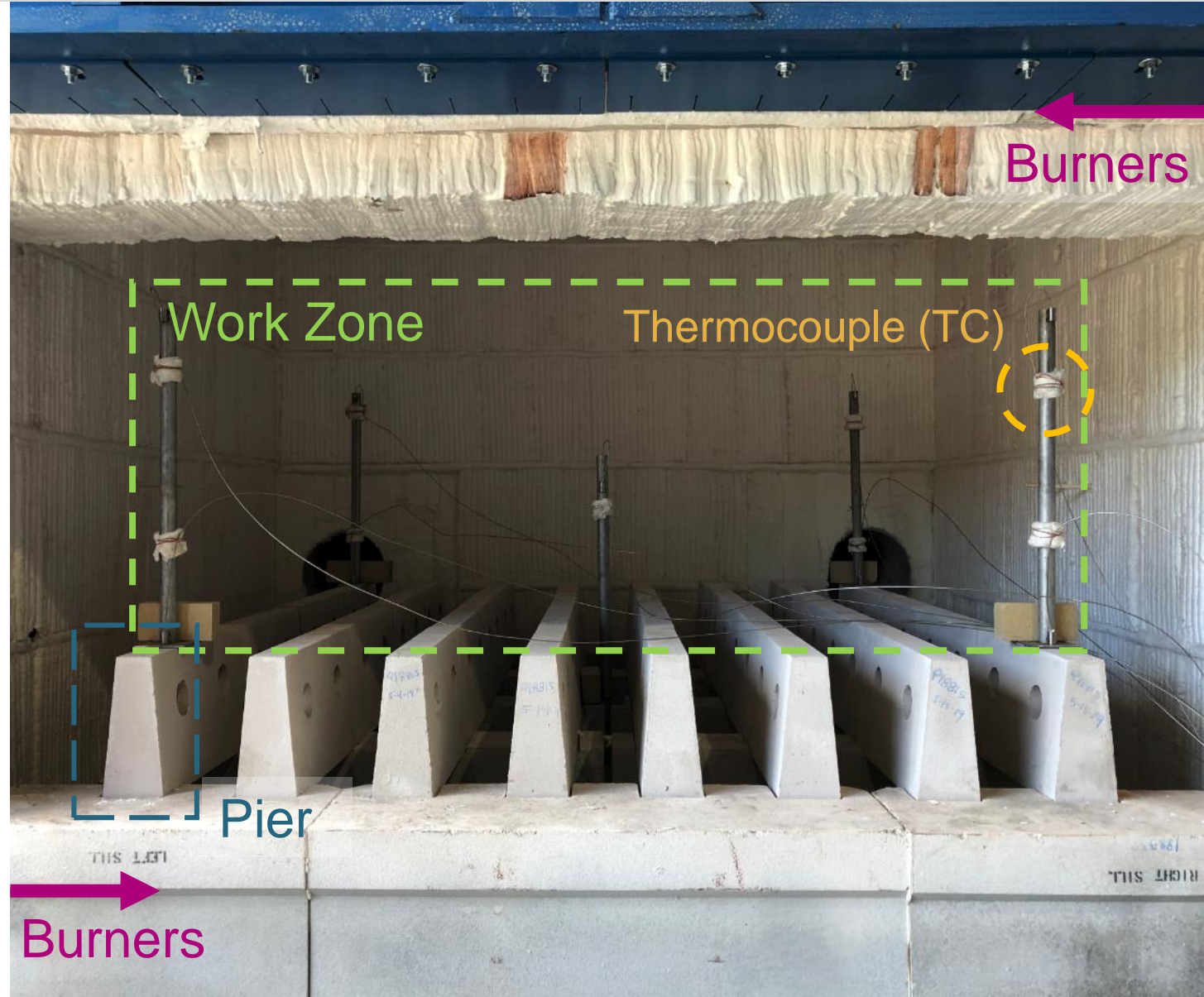


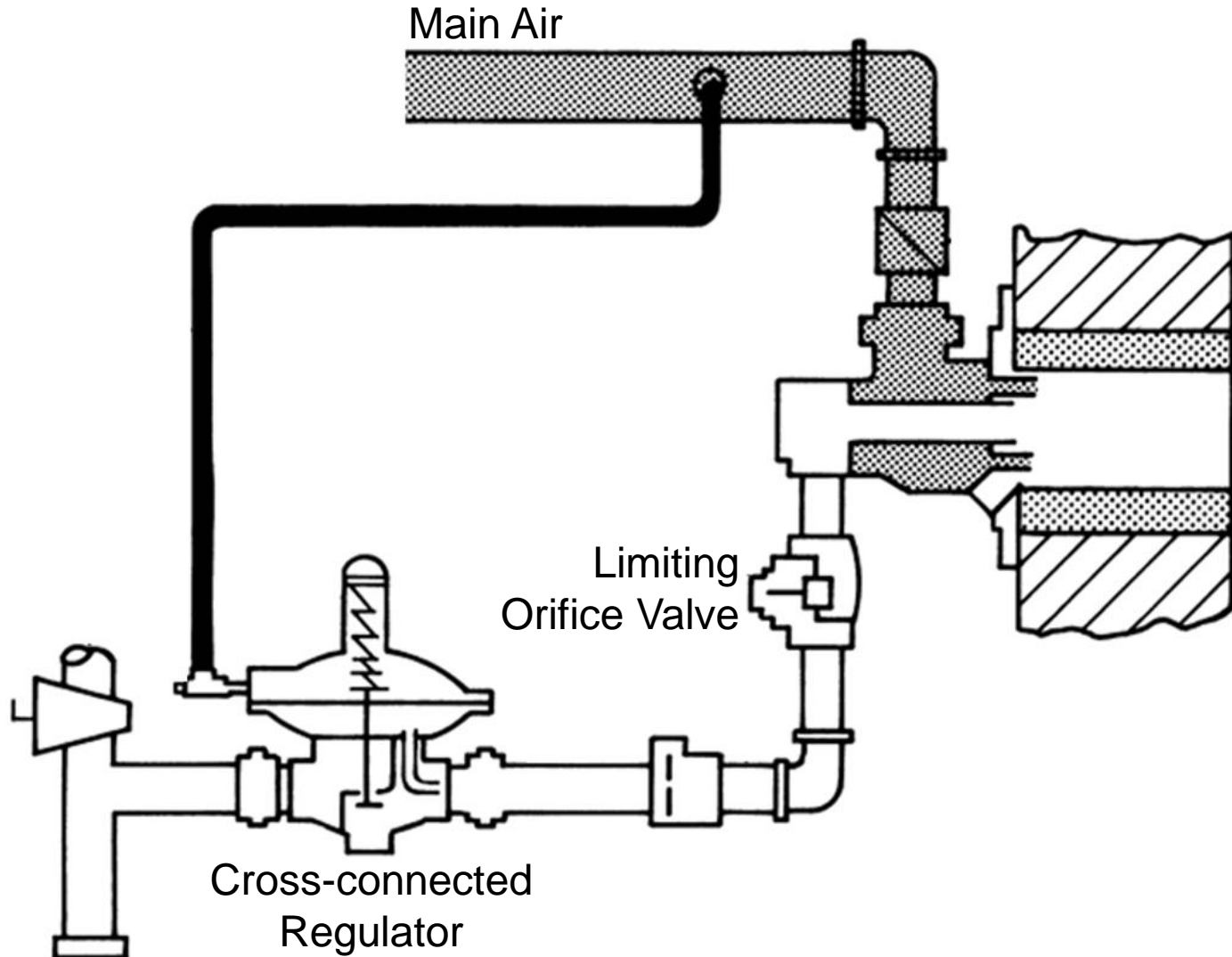
PROCESS
TECHNOLOGIES



Basic Furnace Geometry

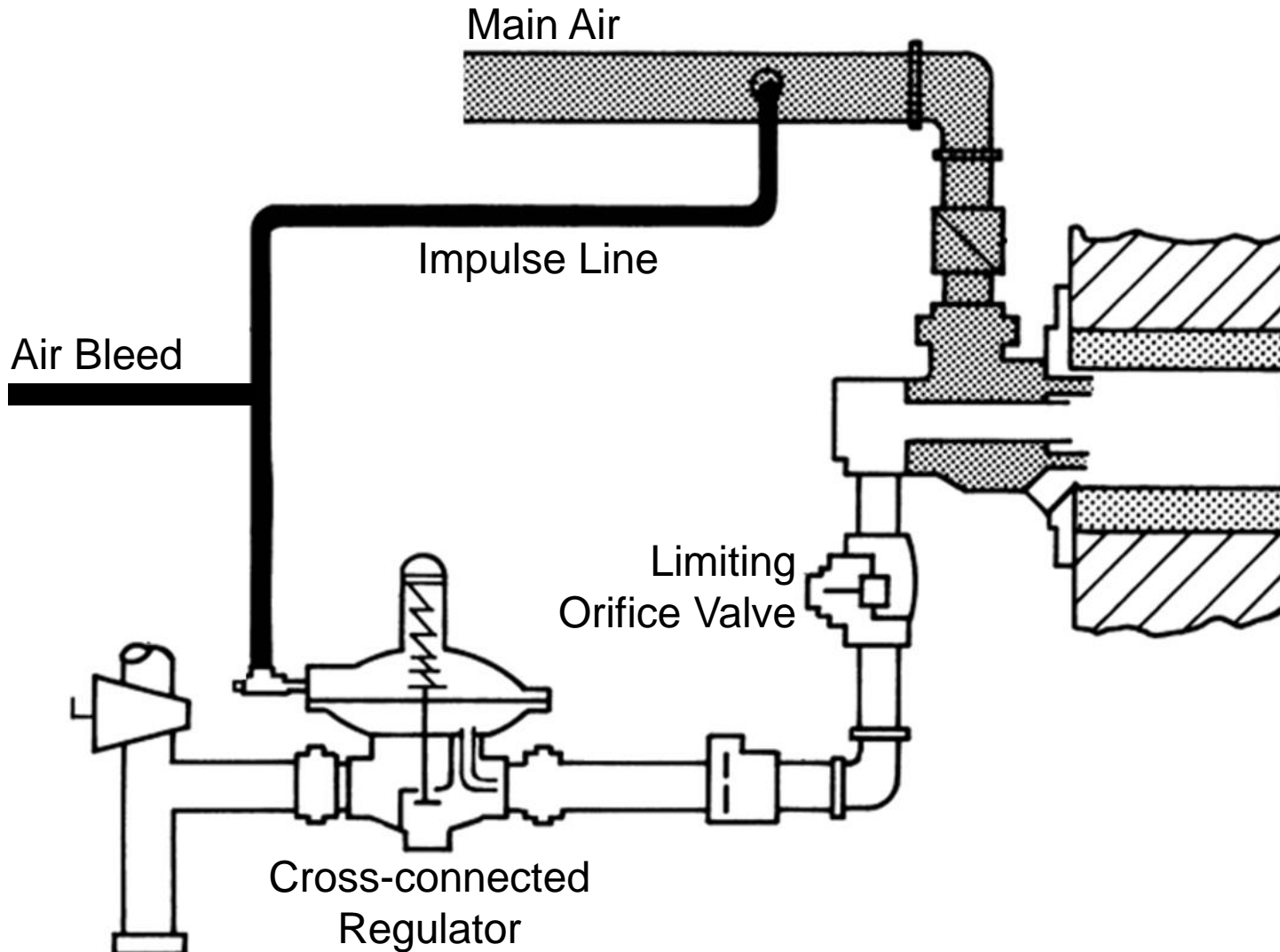
- Center the work zone away from the walls and off the hearth with piers
- Burners fired high and low in opposite directions to circulate products of combustion
- Gap between piers allow gases to circulate
- Thermocouples placed in the corners and center of the work zone





Simple Burner Control

- High velocity nozzle-mix Tempest[®] burners
- Air/gas ratio regulator with vent cross-connected to main air line
- Coarse (zone) control with main air valve
- Fine (individual) control by manually adjusting the regulator's spring bias

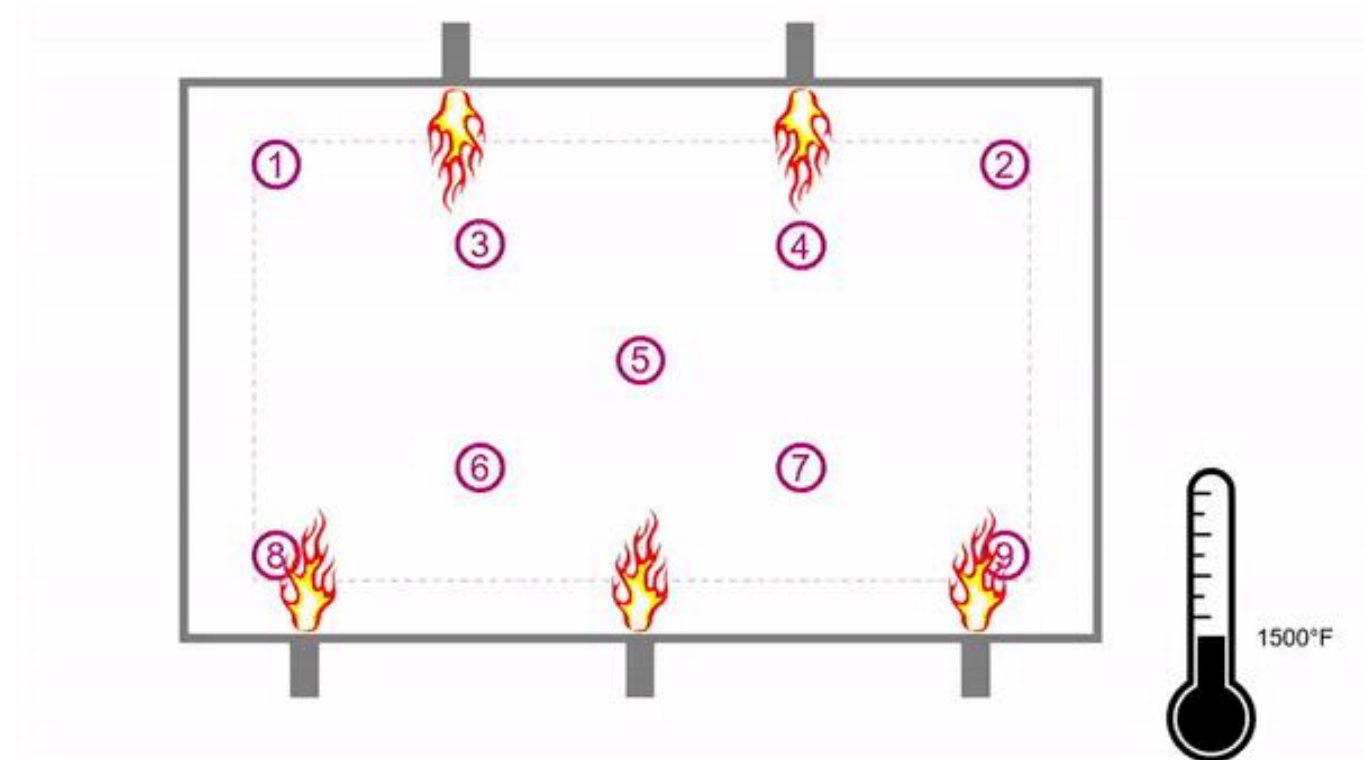


Advanced Burner Control

- Pressure bleed line installed in regulator bias piping
- Adjustable port valve with PLC controlled actuator
- Coarse and fine control can now be automated with PLC

The Problem with Manual Tuning

- Coarse (main air valve) and fine (per-burner bleed valve) tuning is now in the PLC
- Technician tuning is still done manually
- Furnaces are multi-variable, nonlinear systems
- Tuning is a brute-force, recursive process





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NORTH AMERICAN CERTIFIRE™

Automatic Combustion System
Tuning for Furnace Uniformity
Surveys



PROCESS
TECHNOLOGIES

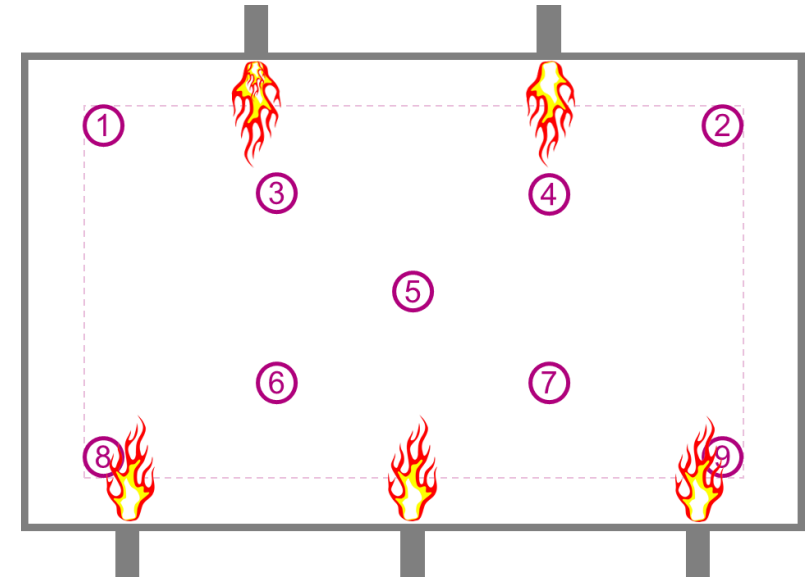


Patented Solution Algorithm

- Training the Furnace to Create the Model
 - The CertiFire™ communicates with the PLC and modulates each burner in a controlled way, depending on the survey temperature and certification class.
 - The temperature response from each modulation is coded into a **response matrix**

- Using the Model to Tune to Convergence
 - Use the **response matrix** created during the training phase
 - Tune the furnace by continuously solving a system of linear equations
 - Dampen the solution to slow the convergence approach to account for errors

$$\begin{bmatrix} \Delta t_1 \\ \vdots \\ \Delta t_q \end{bmatrix} = \begin{bmatrix} k_{11} & \cdots & k_{1r} \\ \vdots & \ddots & \vdots \\ k_{q1} & \cdots & k_{qr} \end{bmatrix} \begin{bmatrix} \Delta u_1 \\ \vdots \\ \Delta u_r \end{bmatrix}$$

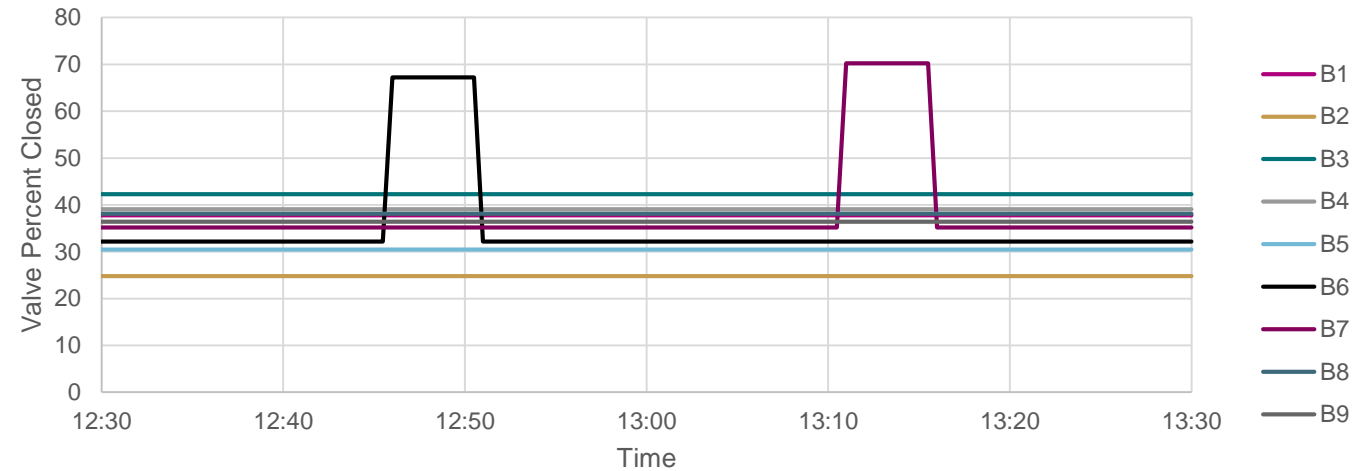


Burner	TC-1	TC-2	TC-3	TC-4	TC-5	TC-6	TC-7	TC-8	TC-9
1	0.55	0.21	1.00	0.24	0.81	0.92	0.25	0.61	0.18
2	0.20	0.56	0.25	1.00	0.80	0.26	0.91	0.17	0.60
3	0.75	0.10	0.68	0.35	0.61	0.74	0.49	1.00	0.11
4	0.43	0.35	0.82	0.82	1.00	0.95	0.96	0.39	0.41
5	0.10	0.74	0.34	0.69	0.62	0.49	0.73	0.12	1.00

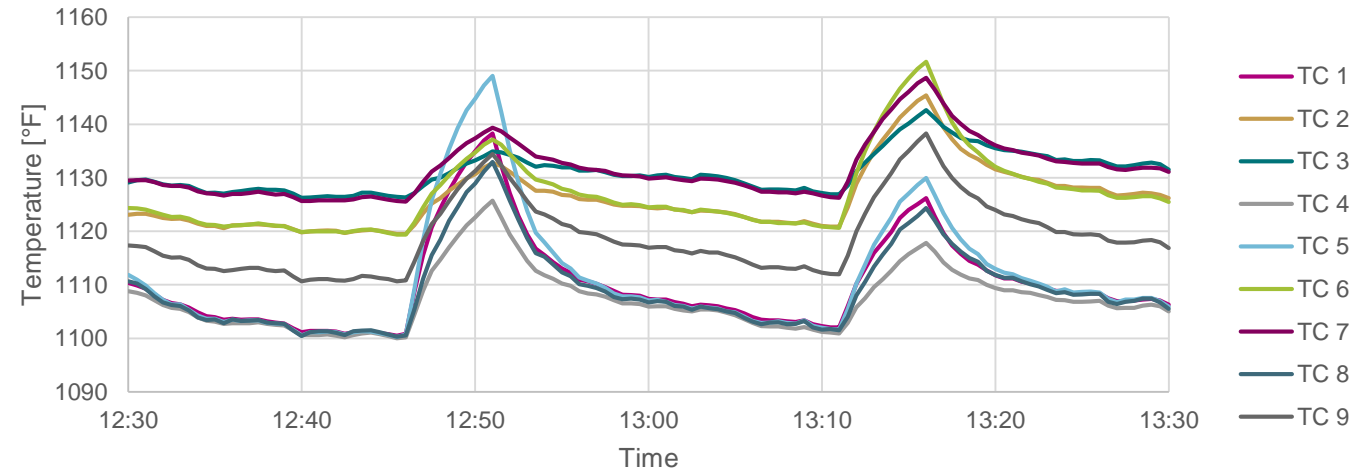
Training Modulation

- Each burner modulation produces a unique temperature response
- Burners B6 and B7 shown on the right created measurably different thermocouple responses
- Thermocouple TC5 reacts significantly stronger to B6 than to B7
- Response matrix created on nine (9) burner furnace in under four (4) hours

Burner Bleed Valve Modulations



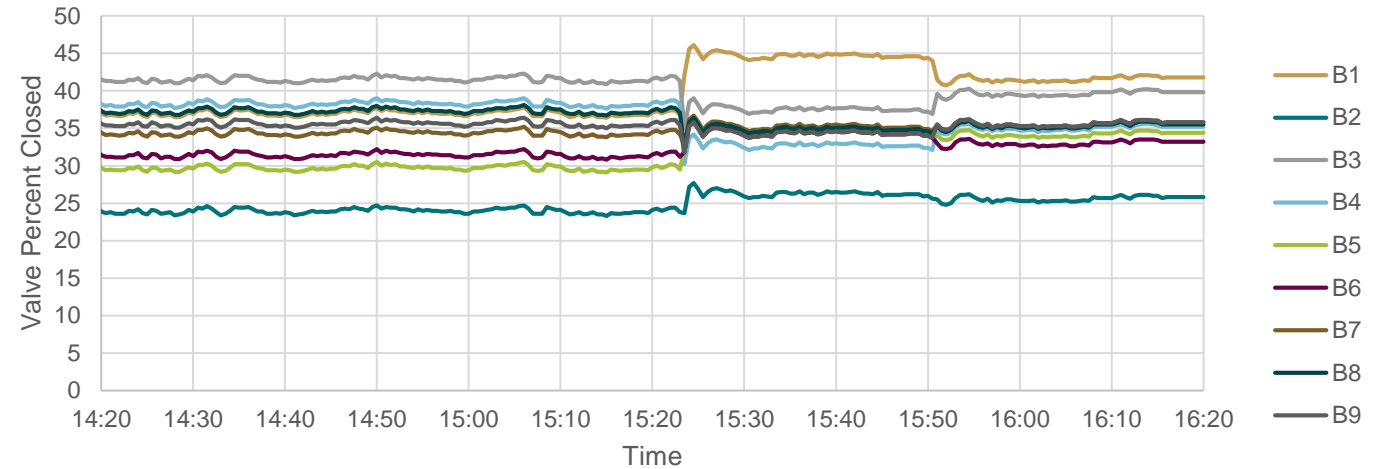
TC Temperature Response to Burner Modulations



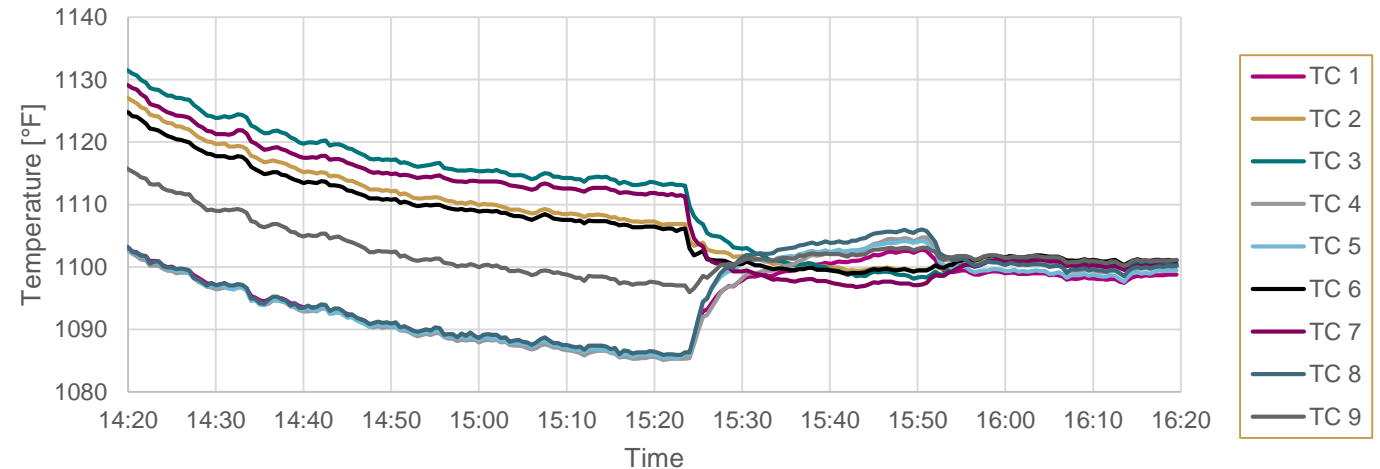
Tuning Results

- Tuning modulations started halfway through the graphs shown on the right
- Initial furnace temperature span of 28 °F
- Temperature disparity reduced to a span of 9°F in first thirty minutes
- Temperature disparity reduced to a span of 3 °F in a total of forty minutes
- Furnace was trained and tuned in under six (6) hours
- Furnace certification class improved from AMS2750 Class 4 to Class 1

Burner Bleed Valve Positions During Tuning



Tuning - TC Temperatures

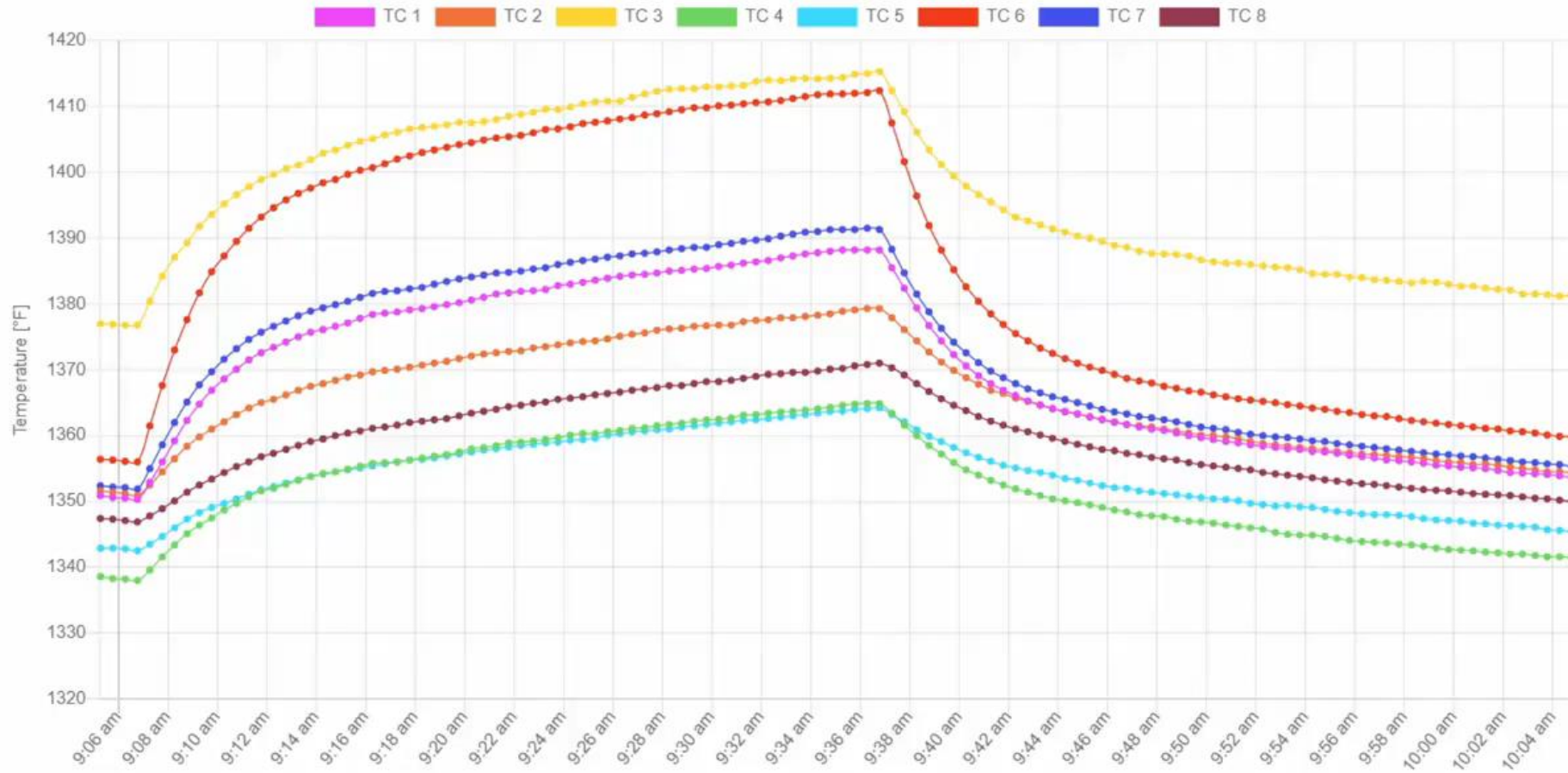


North American CertiFire™ - Furnace Test Data



TC Temperature Chart

Span: 39.9 °F, Avg: 1355.2 °F Last Updated: 7/31/20 10:04:47am (2w)





CertiFire™ TUS Solution

- Plug-and-play automation
 - Shipped with your furnace pre-configured
- Independent of furnace geometry, combustion system, burner size, and burner type
- Potential to reduce survey time 10x
- Certify to tighter temperature tolerances
 - Upgrade older hardware
 - Upgrade your certification class
- “Smart” component provides tuning insights
 - Predict failures, plot degradation, avoid outages

Evolution of Industry 4.0

- Data is becoming invaluable
- Push for greater insights into our technology
- Remote monitoring is now a necessity
- Certification standards will follow the technology innovations



**North American CertiFire™ - Automatic Combustion
System Tuning for Furnace Uniformity Surveys**
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Industry can do it