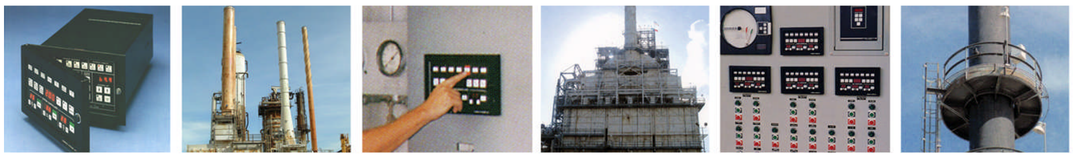
Texas Technology Showcase 12-7-06



Craig Rahn – Bambeck Systems Inc.
Gerald Holmes – Valero Energy Corp.

NOx Reduction from Implementing CO Based Combustion Control

A Case Study

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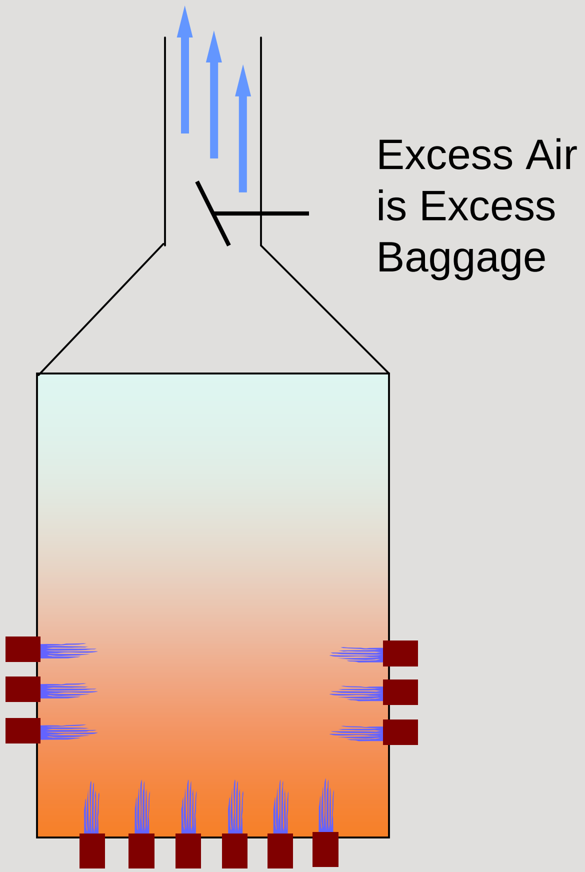
The Technology Concept

A. The technology minimizes the excess air that is not required for combustion.

   Btu's used to heat the excess air are eliminated, thus increasing heater efficiency.

B. System monitors and controls unburned fuel (CO) in a fast & safe way.



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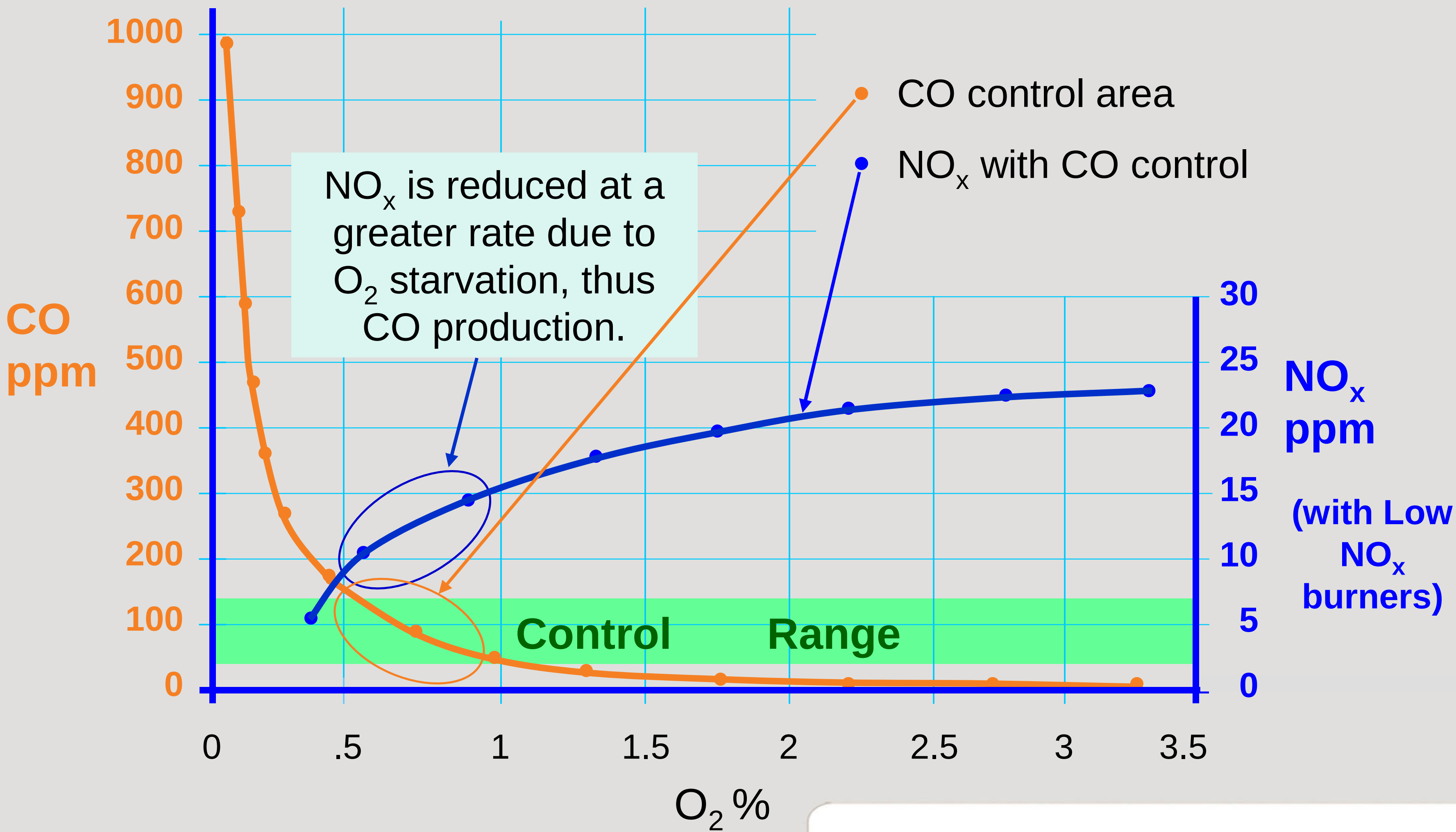
CO vs. O_2 vs. NO_x Relationship



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Why CO vs. O_2 Control

1. CO controls directly on process variable of concern.

   Since CO is the precursor to combustibles, controlling with CO insures none.

2. Across-the-stack measurement of CO.

   CO catches the worst burner in the heater. O_2 measures a single point thus the burner below the sample point.

3. High sensitivity to combustion: 0 to 0.1% (1000 ppm).

   CO is more sensitive than combustibles measurements. Controls far below any LEL.

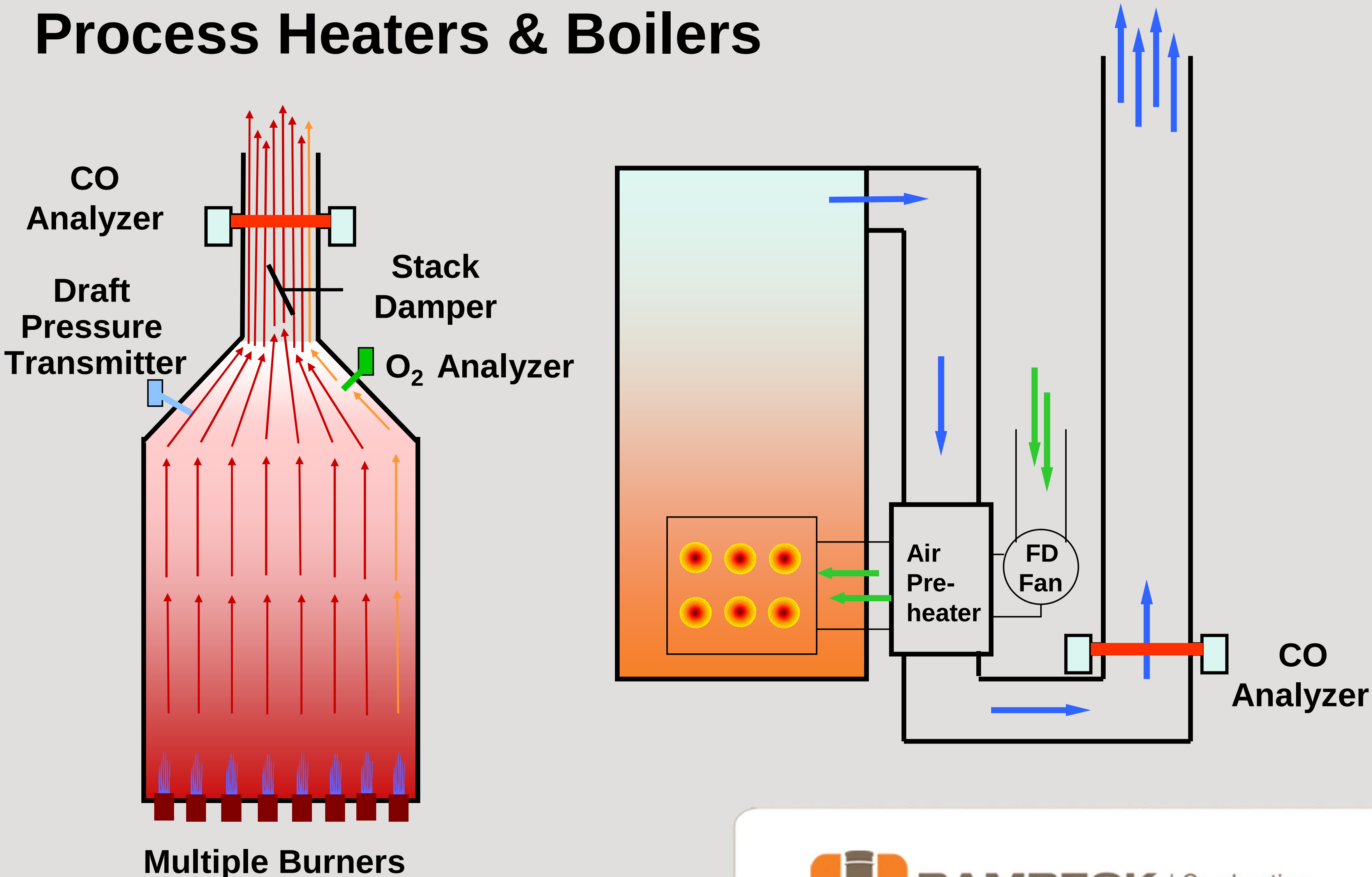
4. Fast, control type analyzer & control strategy:

   The fast CO analyzer detects $^1/_7$ of a second and the heater specific algorithm controls CO before problems occur. It catches fuel BTU swings, and adjusts appropriately.

5. Air leakage is not a significant factor with CO control.

   Furnace tramp air leaks are a major problem with O_2 measurement and thus O_2 control.

Low Excess Air Control of Process Heaters & Boilers



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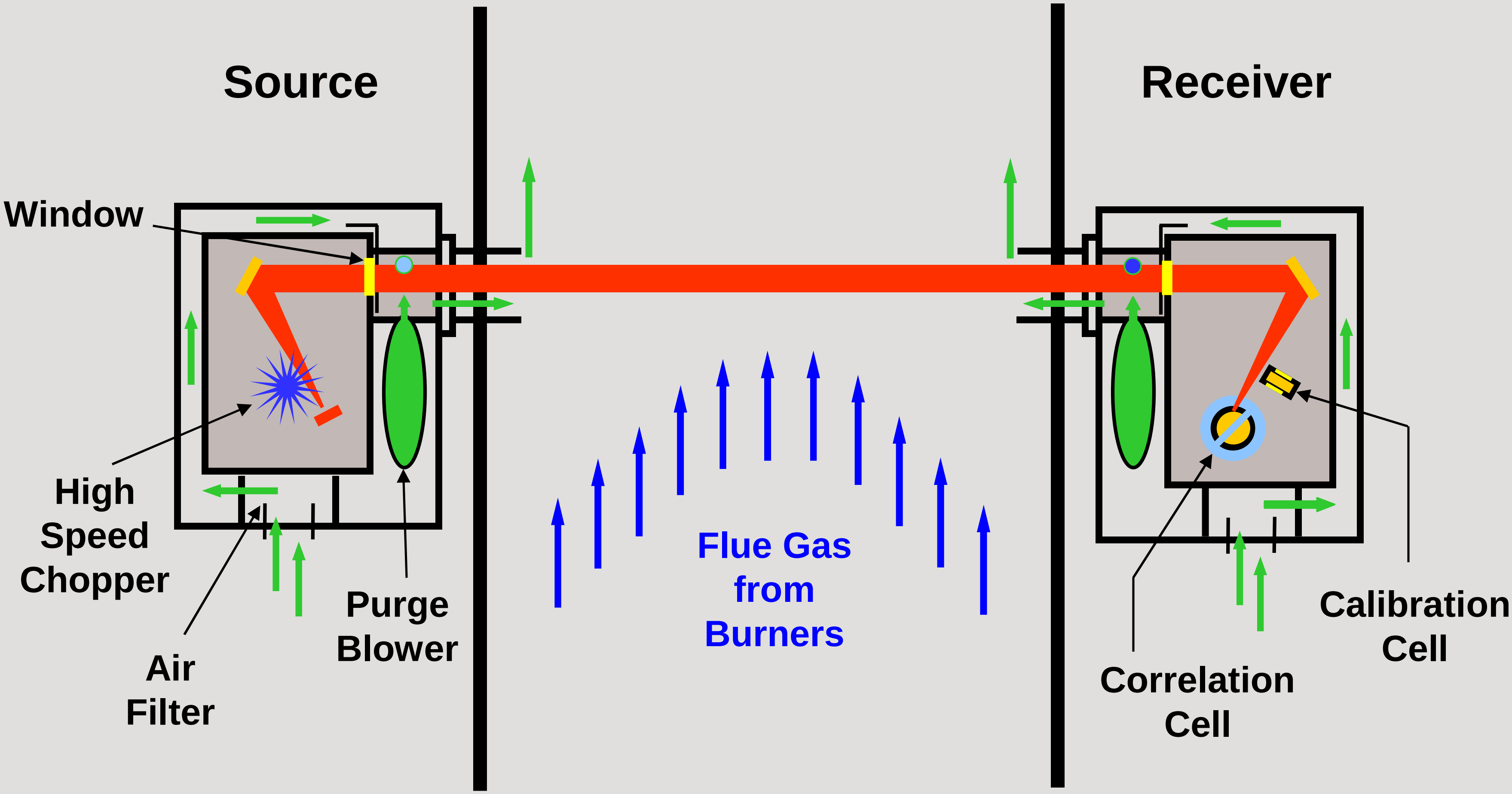
Across the Stack CO Analyzer



Stoichiometric Combustion

The Combustion Equation for Methane:

$$CH_4 + 2\ O_2 = CO_2 + 2\ H_2O$$

The Combustion Equation in General:

$$C_mH_n + (m+n/4)\ O_2 = m\ CO_2 + n/2\ H_2O$$

CO control begins with complete stoichiometric combustion.

As combustion air is reduced, the second Oxygen molecule becomes less available to complete CO_2 and CO remains.

A trace amount of CO is carried in the flue gas, exits the stack and is used for control.

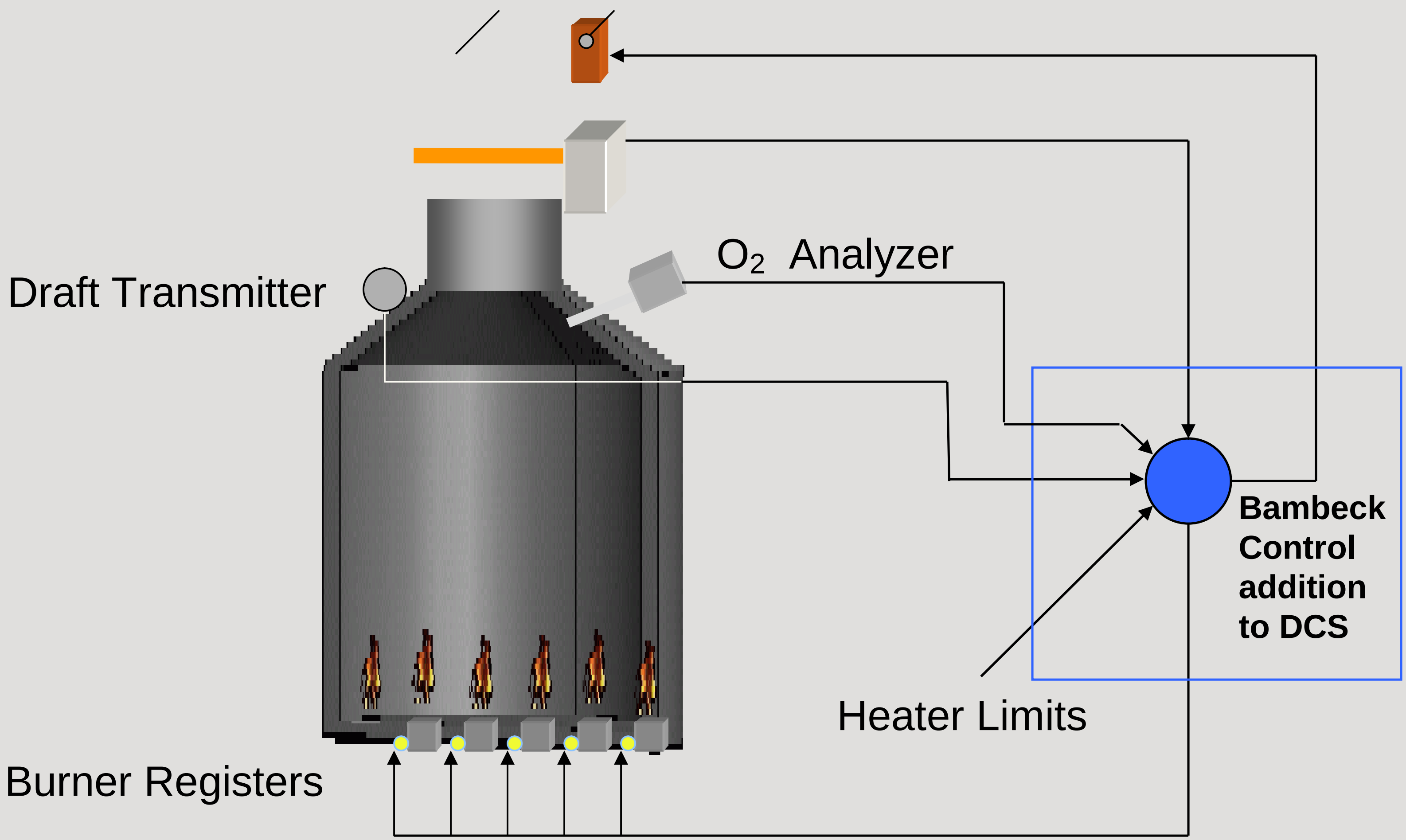
Air for Stoichiometric Combustion

	scf of air per scf of Fuel:	Btu/scf:
Methane	**9.55**	**909**
Propane	**23.87**	**2,315**
Hydrogen	**2.39**	**274**

Plant fuel gas varies greatly in BTU value.

CO control is fast enough to catch fuel composition changes, even in upset conditions, and make required air adjustments.

Using CO & Draft to Control Dampers



Implementing CO Control Technology

A. Must start with complete combustion. CO control system is not a start up or shut down device.

B. Excess air is reduced by closing stack damper (FD damper as applicable) under controlled conditions.

C. Control trims dampers while checking furnace draft & CO for proximity to their set-points. (Draft Limit: ~ 0.05) (CO: ~ 150ppm)

D. Burner air registers are adjusted either manually or through automatic control to balance combustion and flame pattern.

E. Operator interface is from DCS screen currently used for control.

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Safeguard Issues

CO control system must be designed to be fail-safe

1. **Power Loss -** CO output goes to zero; fail safe pneumatic control opens damper.
2. **CO analyzer fault -** Control reverts to previous control (O2 or Manual), slightly opens damper and not allow CO control. Diagnostics identifies problem.
3. **Actuator fault -** CO and/or Draft alarm Operations that no action can be taken.
4. **Break in pneumatic line -** Actuator can be set up to fail in place or open 100%.
5. **BTU fuel swings -** CO analyzer will immediately see CO increase. Control is responsive enough to catch changes and react. CO may spike.
6. **Damper wide open and CO higher than 800ppm -** Alarms Operations that no automatic action can be taken. Typical instructions are to open burner registers.
7. **Damper wide open and draft closer to zero than limit -** Alarms that no automatic action can be taken. Typical instructions are to cut fuel.

Above items are specific to natural draft fired heaters on plant DCS.
Additional items may apply to FD, balanced draft heaters and boilers.

Results

1. Reasonable expectation of 0.2 - 0.8% furnace O_2
   CO is the control set-point, O_2 goes where it needs to be for the CO to be at set-point.
2. Safer operation
   Correction occurs immediately upon an upset condition before combustibles occur.
3. NO_x emissions reduced
   Minimum of a 20% reduction. (may reduce capital avoidance) Typical reductions are 25-30%.
4. Combustion efficiency is improved
   Typical improvement ranges from 1 to 5%.
5. Greenhouse gas CO_2 emissions reduced
   Reduction is directly related to efficiency improvements.
6. Increased unit capacity
   If heater draft limited, Bambeck allows furnace debottleneck.

Technology Summary

A. Improves **Heater Efficiency**.

B. Reduces **Fuel** Usage.

C. Reduces **NOx** Formation.

D. Reduces **CO_2** Emissions.

E. Typical Payback from **½ to 2** Years.

F. **Safer** Operation.

G. Potential Unit **Debottleneck**.

Case Study Heater

Heater H-60 CDHDS, Valero Energy, Texas City Refinery

Manufactured by OPF, Chanute, KS

Cylindrical, bottom fired, with 8 Callidus low NOx “CUB” burners

75 MMBtu/hr firing rate using refinery gas with Btu fluctuations

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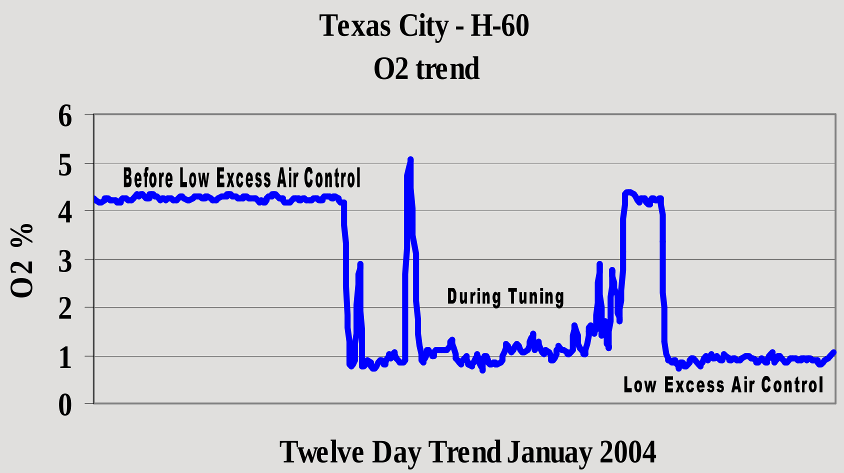
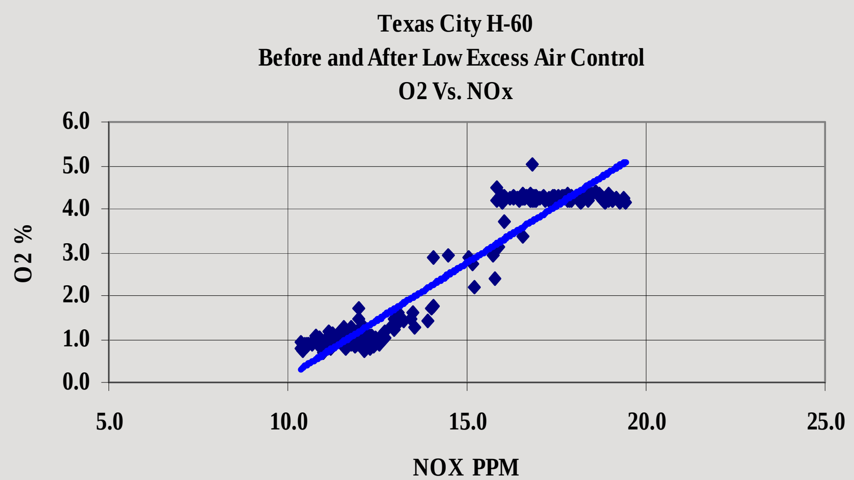
Lower O_2s Show Reduced NOx





- NOx Emissions Reduced
- CO Controlled Below Permitted Levels
- Burner/Heater Operating With Stability
- Efficiency Improved
- Combined With Burners, NOx Limits of 0.02 lb/MMBtu (HHV) Achievable
- CO_2 Emissions Reduced
- Safer Operation

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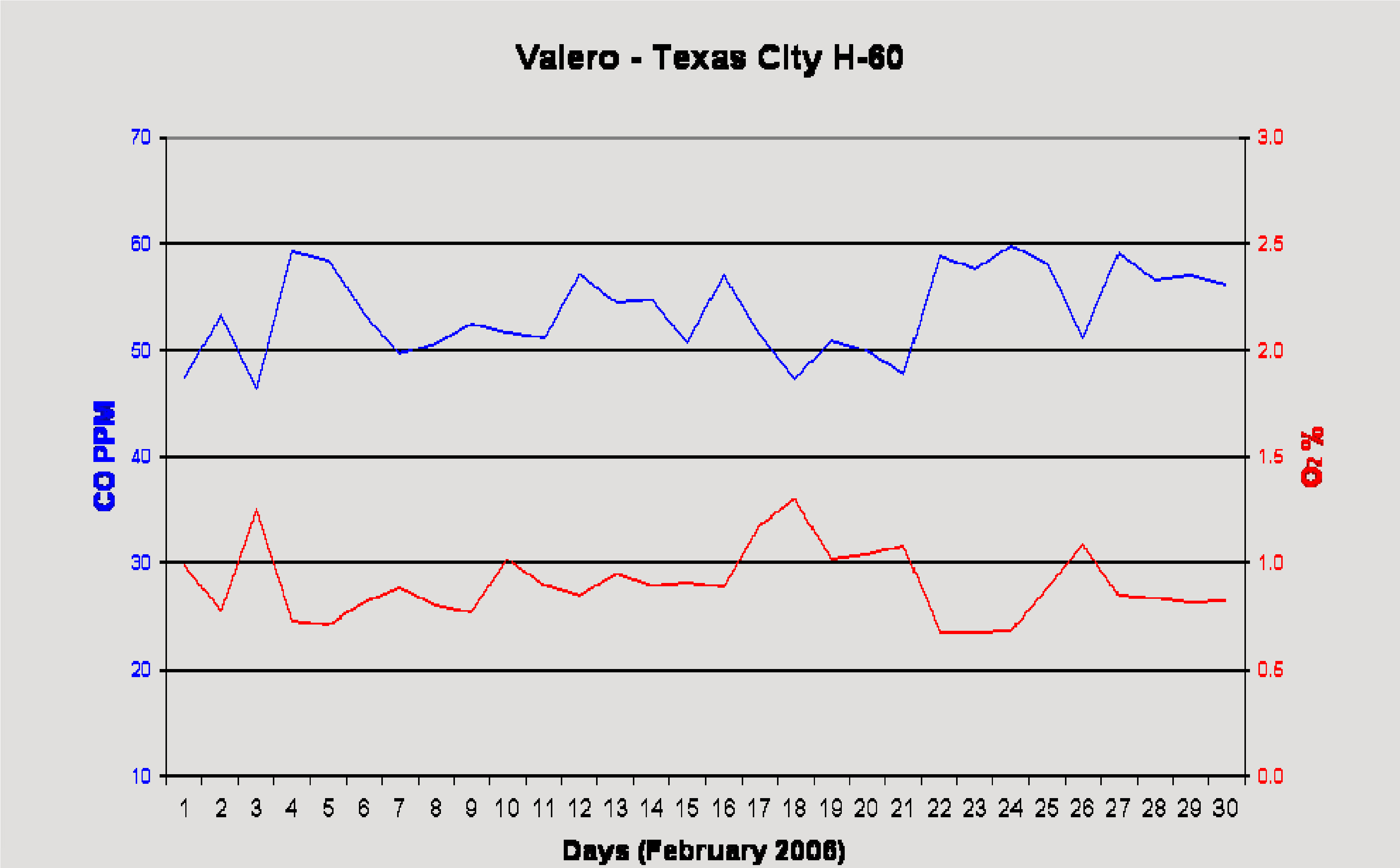

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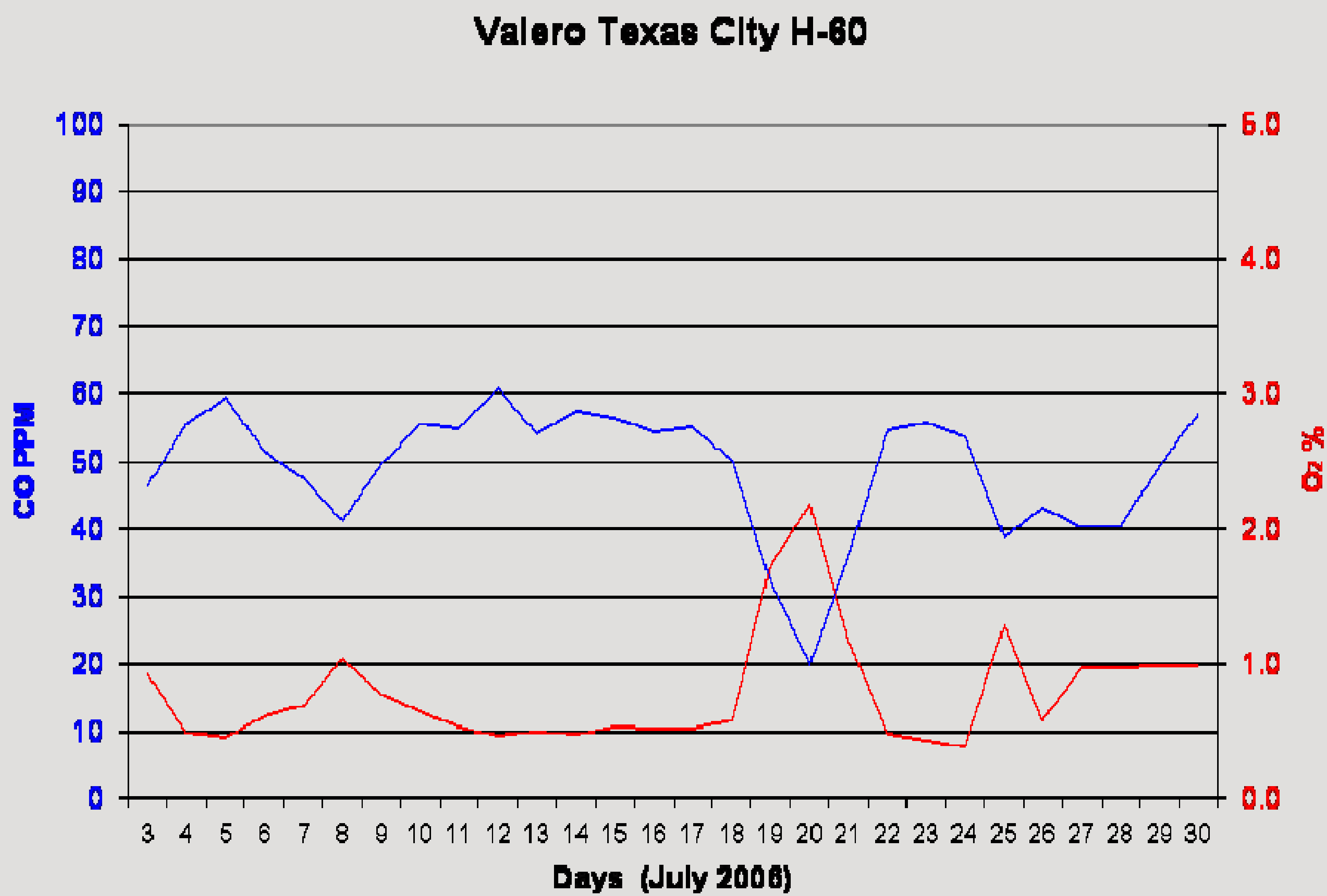

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Requirements for Successful Implementation

1. Required a change of culture from traditional O_2 based furnace combustion control to CO based.

2. Plant management from the top down endorsed this change of furnace control technology.

3. All departments were brought on-board from the introduction of the project. All questions, issues and concerns were addressed.

4. Requires diligence in keeping the controls on-line providing continuous savings, reduced emissions and improved furnace safety. Continuous training and education made available.

5. A committed maintenance department with factory trained technicians and on-site spares.

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