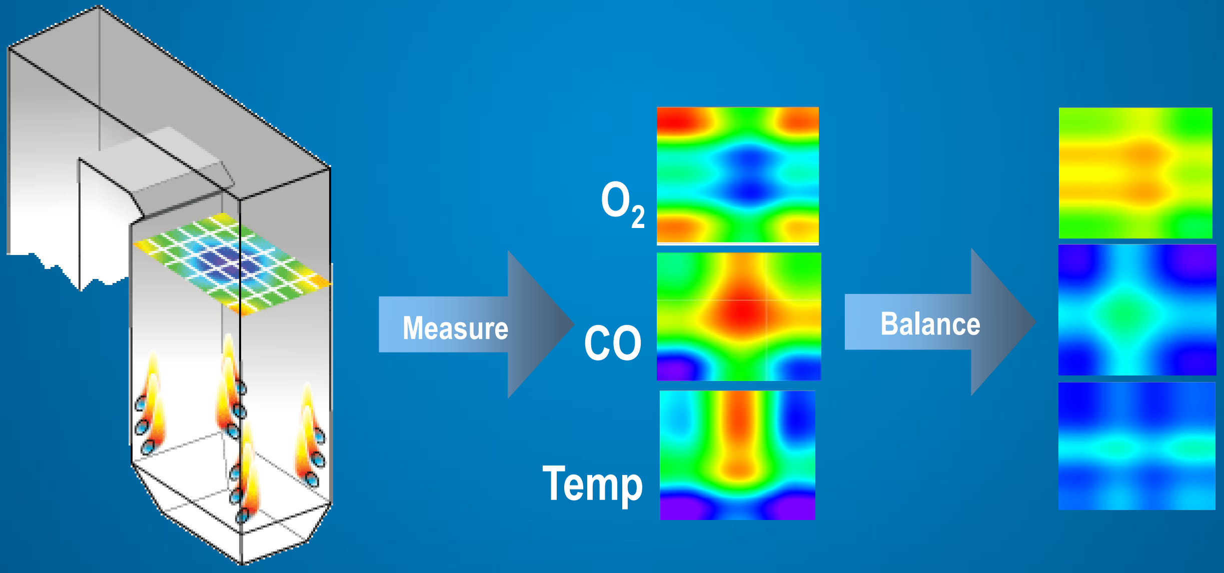
Zolo*BOSS*:
Laser-based Sensor for Real-time Combustion Optimization



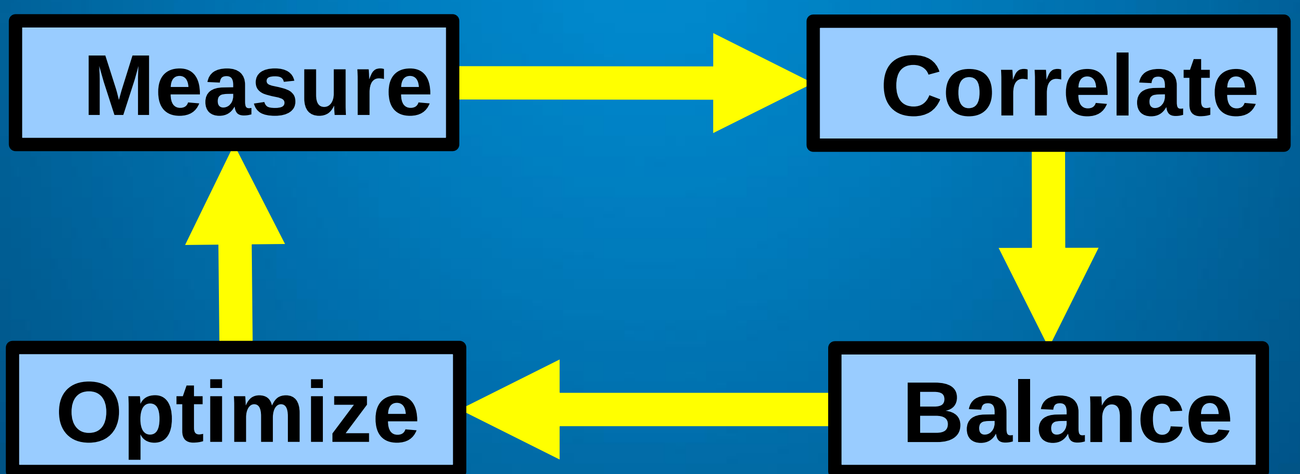
Better Measurements, Better Results

ZOLO TECHNOLOGIES

August 7, 2013

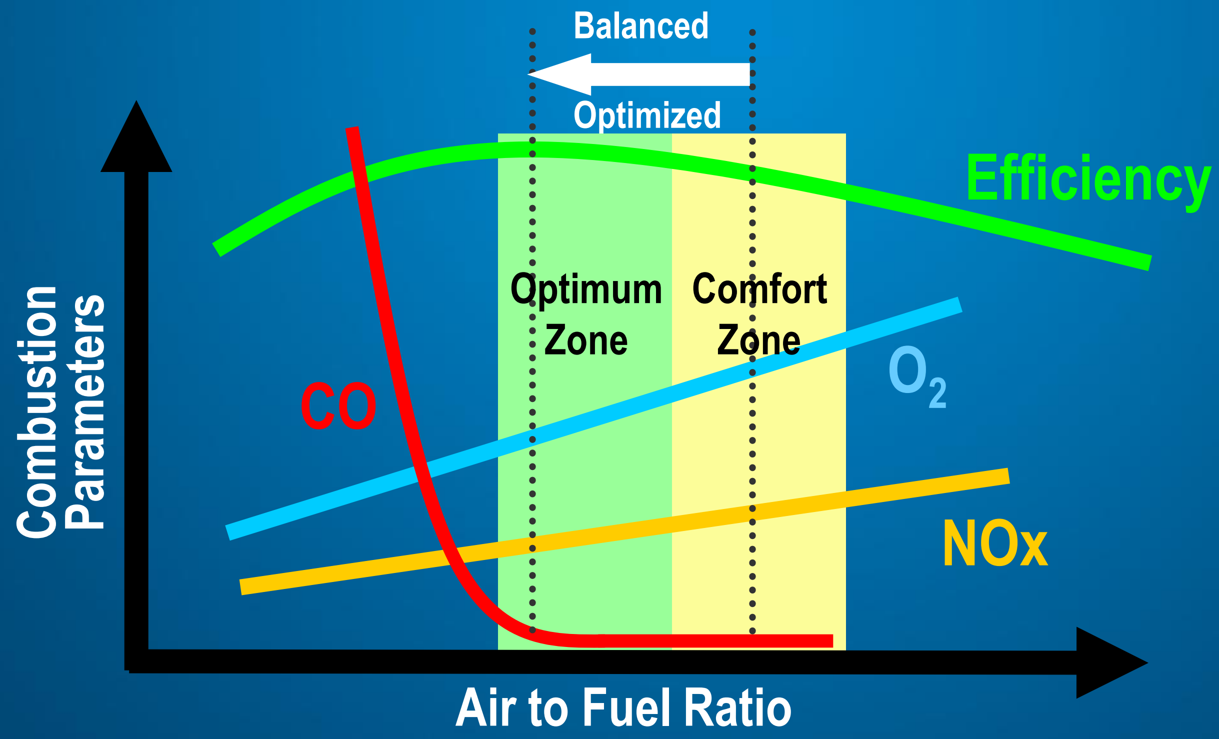
Combustion Optimization Principles

1. ***Measure*** the right constituents, at the right place
2. ***Correlate*** constituent profiles to manipulated variables
3. ***Balance:*** manipulate variables to balance combustion
4. ***Optimize***: safely lower excess O_2 to optimize combustion



Balanced Combustion → Optimized Combustion

- Balanced combustion (Temp, O_2 & CO) is better combustion
- Balanced combustion permits safe operation at lower excess O_2
- Lower excess O_2 → increases efficiency (heat rate)
- Lower excess O_2 → lowers NOx rates
- Subject to constraints on CO and slagging



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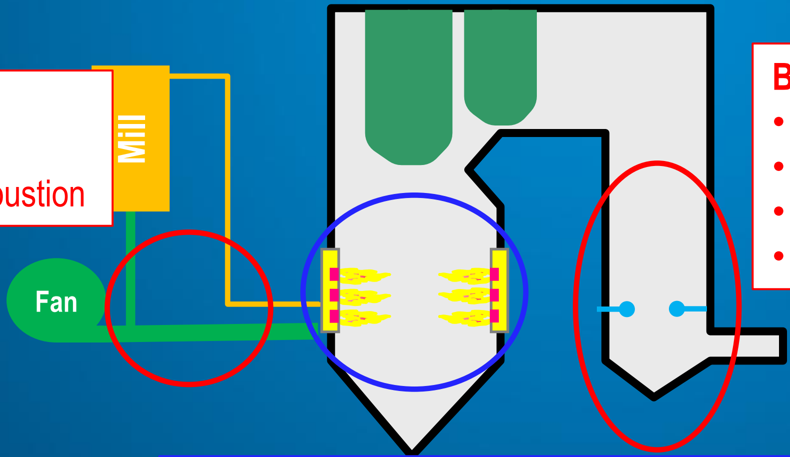
Maintaining Furnace Balance Is Difficult

- Traditional measurement sensors/locations are not adequate
  - "The right amount of ingredients don't make a good cake"
  - Proper air/fuel at each burner is important but may not mean optimized combustion
- Natural process variations will lead to local imbalances in furnace
  - 80% of combustion problems occur in 20% of furnace – but where??
  - CO increases exponentially, Slag/fouling hot spots, NOx with high O_2
- Permanent measurement is needed to maintain performance
  - One-time tuning is only good for a short period
  - Conditions change over time: loads, fuels, operators



Air/Fuel Measurements
- Good for burner performance
- Not indicative of overall combustion

Back Pass Measurements
- Limited info on local furnace conditions
- Typically point measurement only
- Good for overall O_2 control
- Good for overall CO monitoring

In-furnace Measurements
- Critical for in-furnace balancing
- Identifies localized combustion issues
- Permanent measurement maintains optimal combustion

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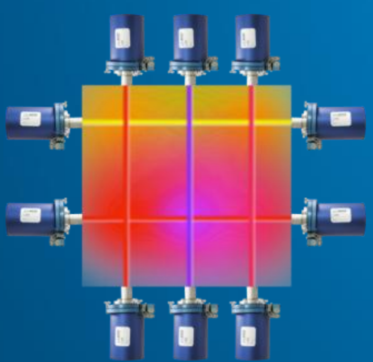
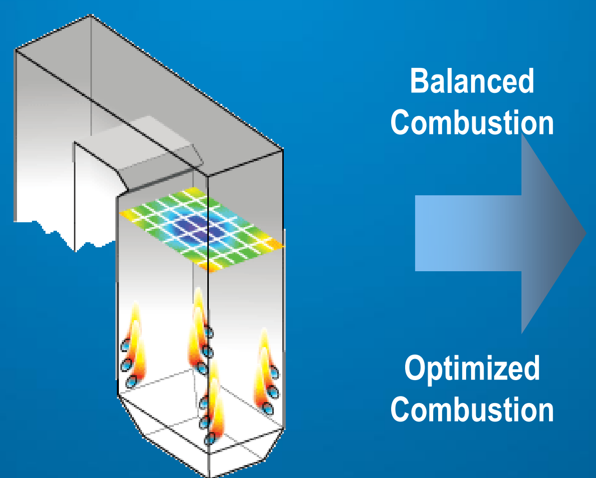
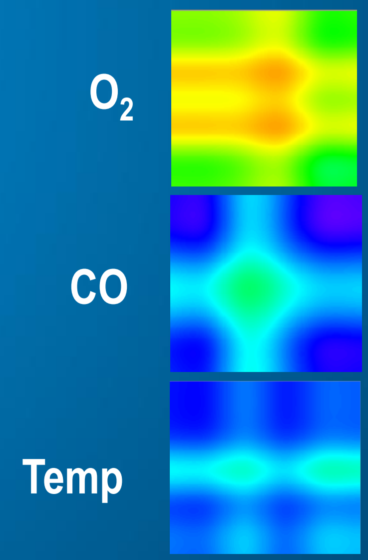
The Solution: The Zolo*BOSS* System

- **Measure the Right Things**
  - Uses TDLAS to simultaneously measure Temperature, O_2, CO & H_2O
- **Measure in the Right Place**
  - Real-time measurement directly in the furnace
- **Measure all the time**
- **Multiple measurement paths**
  - Generate two-dimensional images or profiles







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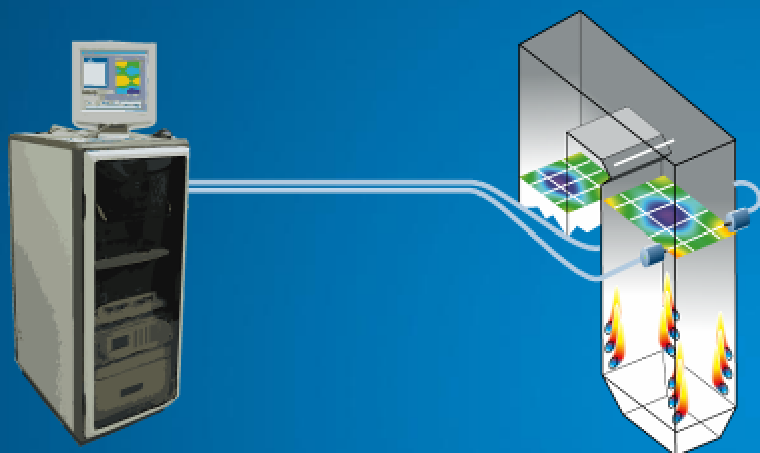
Typical Zolo*BOSS* Layout



SensAlign Heads installed on front wall

3/8 " x 3 "
(9.5 x 76mm)
Slot

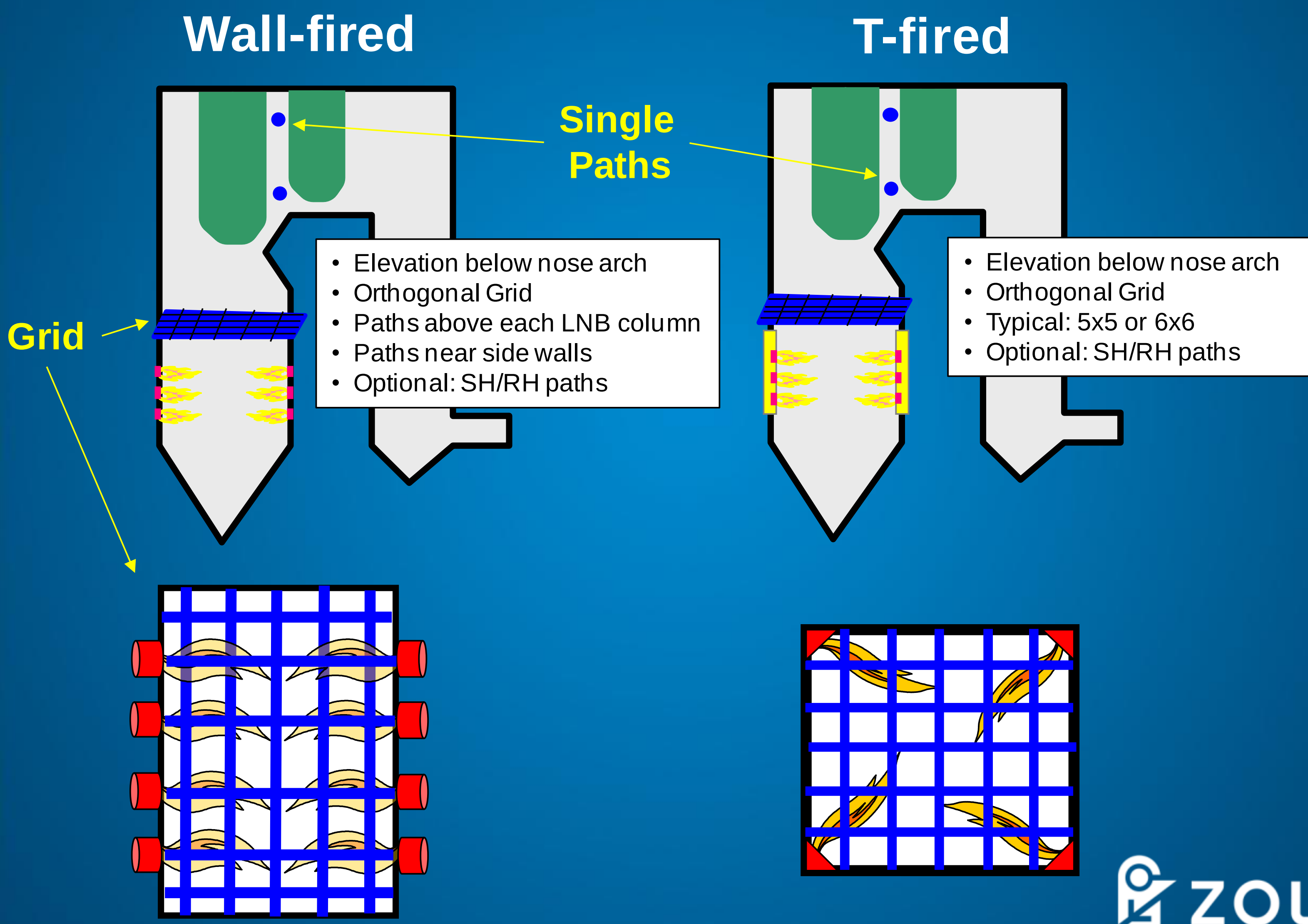
Slotted Opening in Membrane

Port Rodder

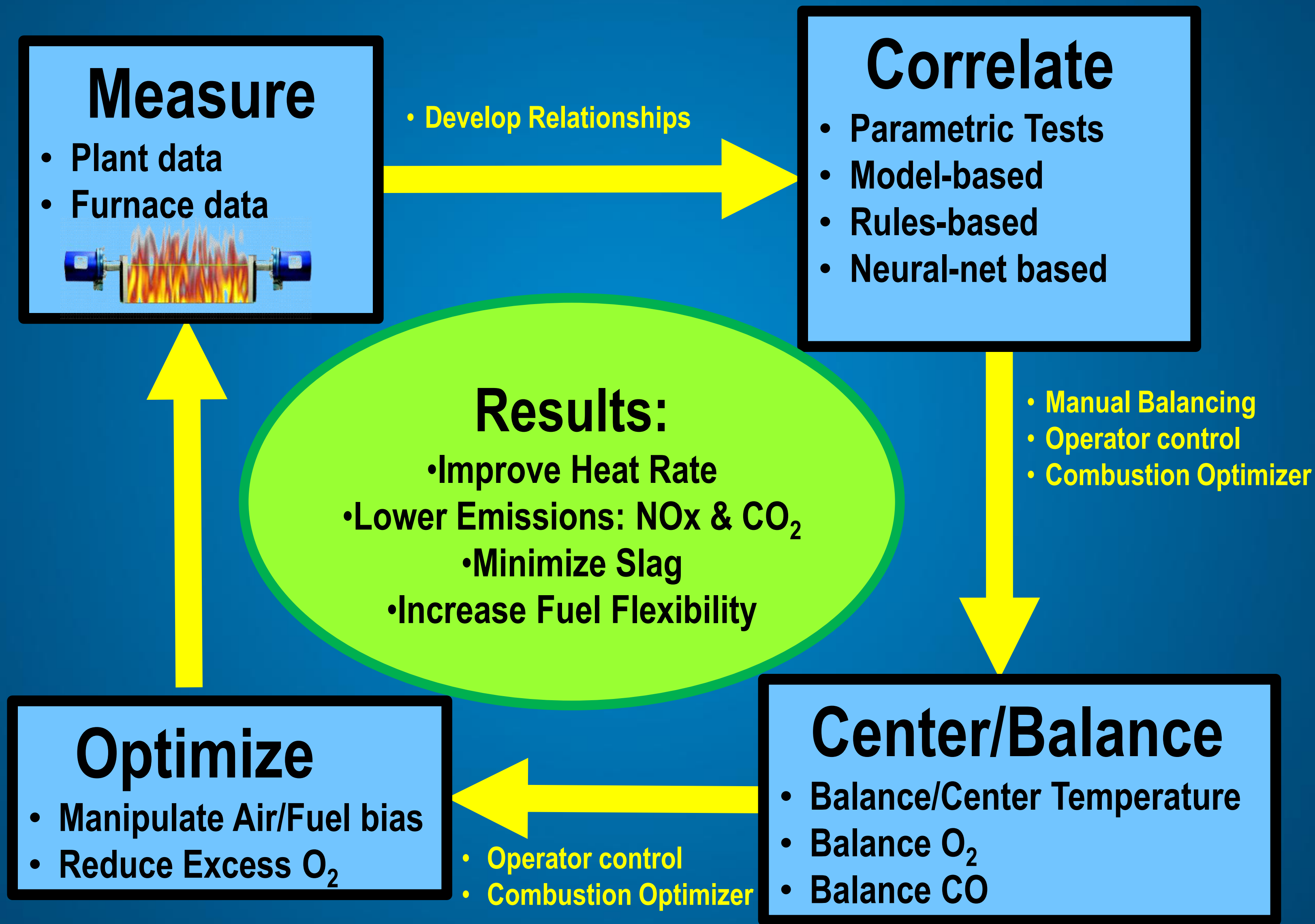
SensAlign Head w/ Port Rodder

SensAlign™ Head

Typical Zolo*BOSS* Layouts

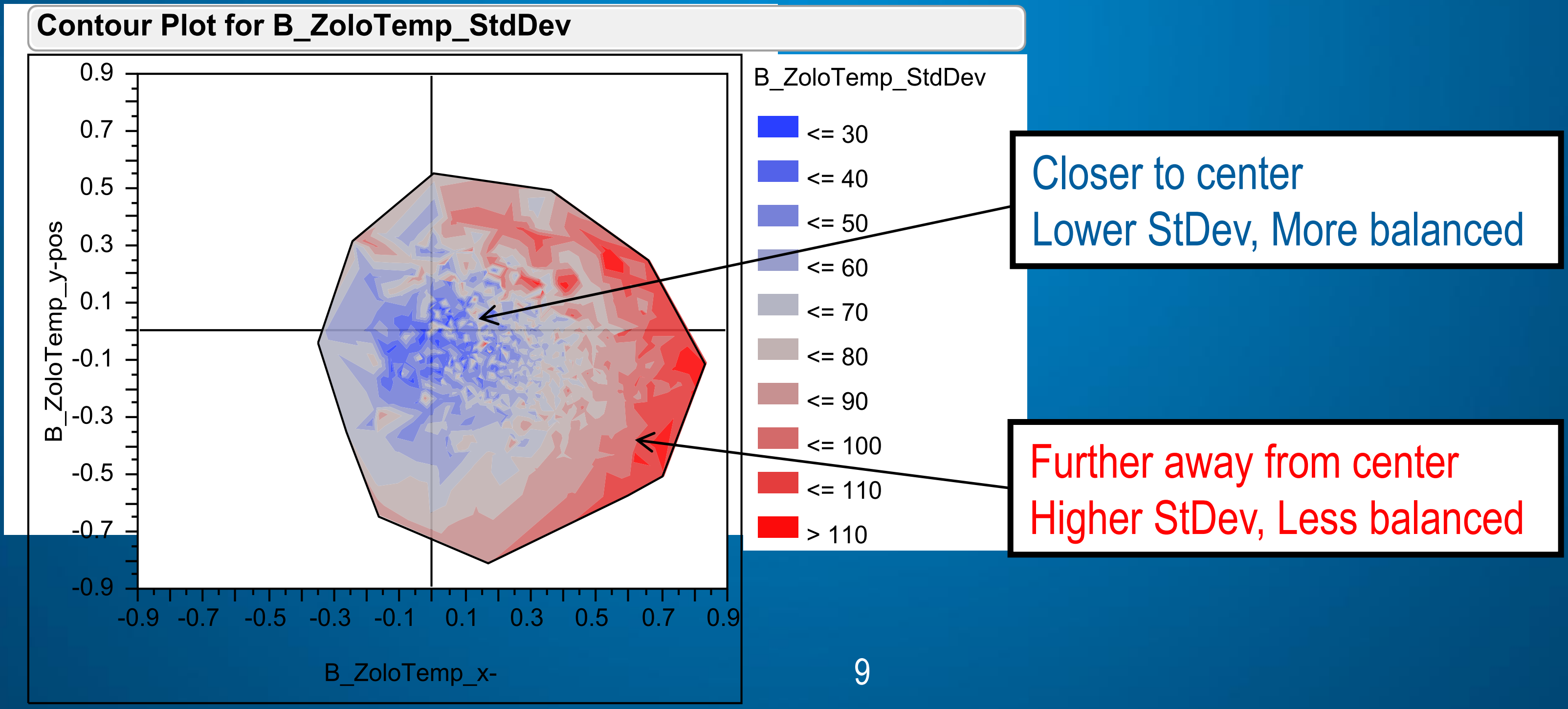


Combustion Optimization



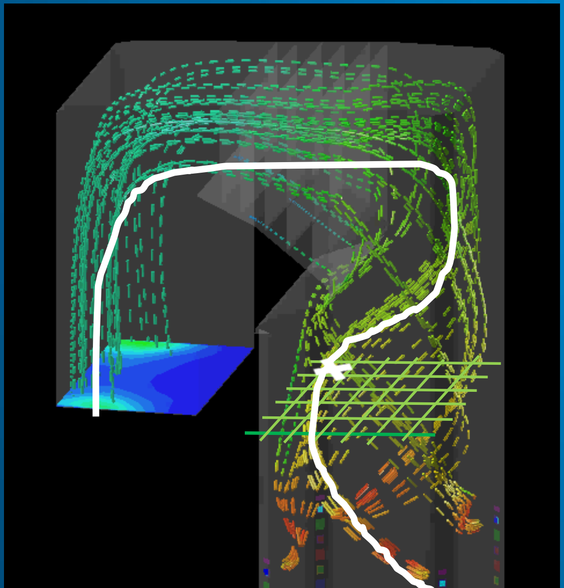
Center Combustion: Why?

- Centered Combustion = Balanced combustion
- Goal = Centered Combustion (fireball)
  - Fireball center is a compass to direct combustion manipulations

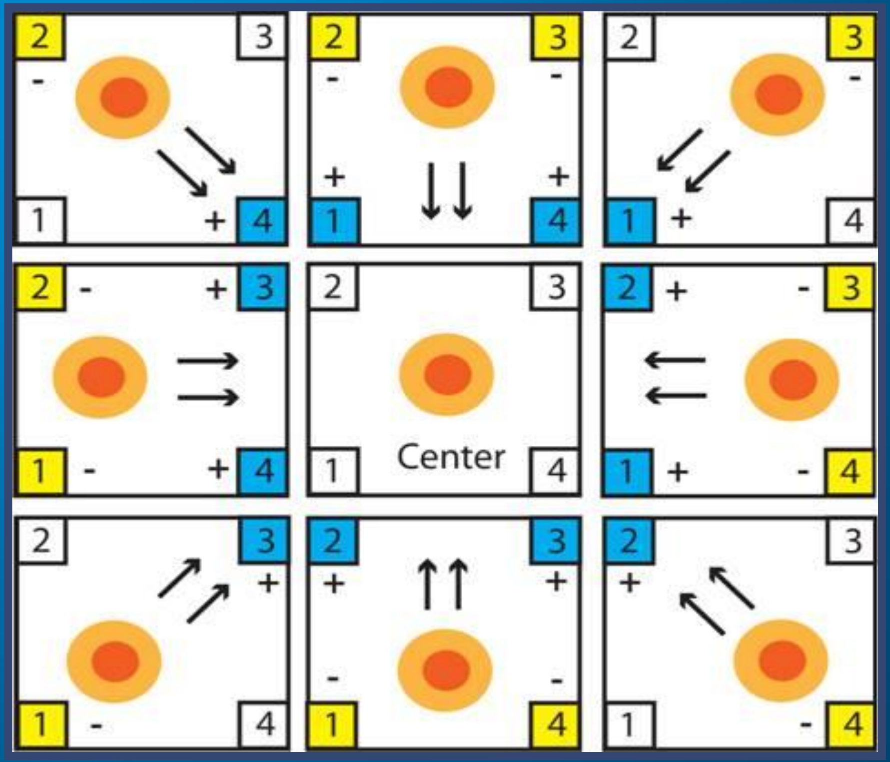


Fireball Centering for T-Fired Furnace (1)

- 660 MW T-fired Furnace
- Supercritical conditions
- 6 x 6 ZoloBOSS Grid
- Parametric testing produced “rules” for centering fireball
- Zolo*BOSS* readings 180° out of phase of burner locations due to flame swirl.



Zolo*BOSS* readings 180°out of phase of burner location due to spiral flow of flue gas

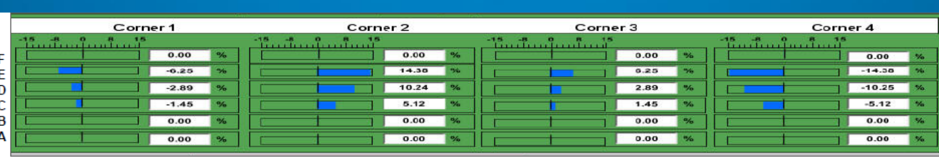


Closed-loop Combustion Optimization (2)

Optimization Objective	Operational Adjustments	Performance Improvement
Fireball Centering	Secondary Auxiliary Air • Corner & levels (A-F)	• Improved heat transfer • Reduced slagging • Improved boiler efficiency
O_2 Balancing	SOFA • Corner & layers (I-IV)	• Improved boiler efficiency • O_2 too high = efficiency loss • O_2 too low = efficiency loss
Combustion Balancing (Temp, O_2 and CO)	Secondary Boundary Air • Corner & levels (A-F)	• Improved heat transfer
O_2 Reduction	O_2 Set Point	• Lower flue gas flow ➔ Lower dry gas losses ➔ Improved boiler efficiency

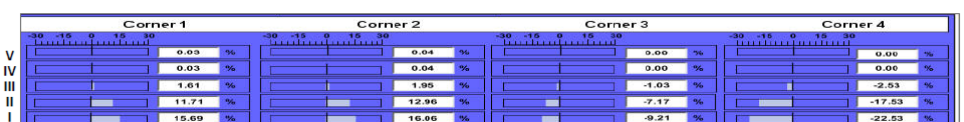
Fireball Centering

By modifying
Secondary Auxilary Air



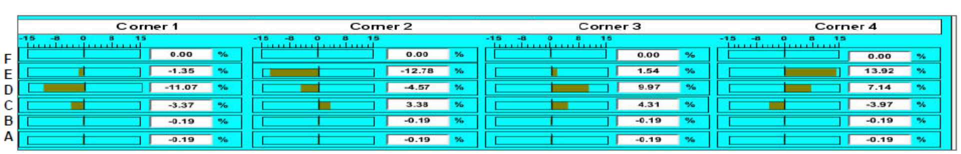
O_2 Balancing

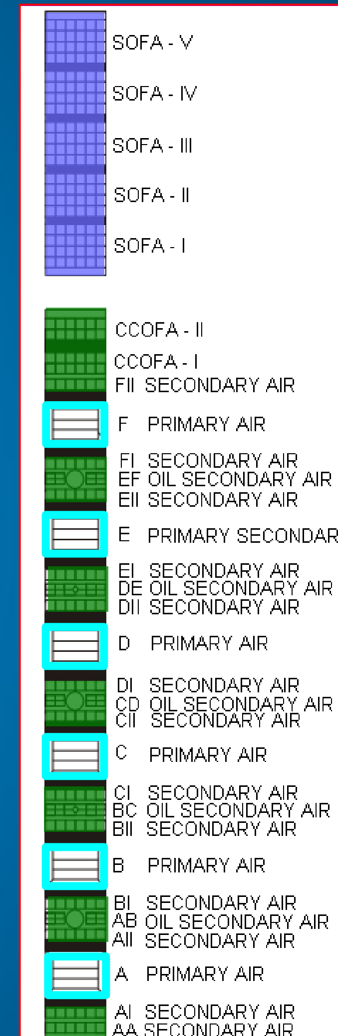
By modifying
SOFA



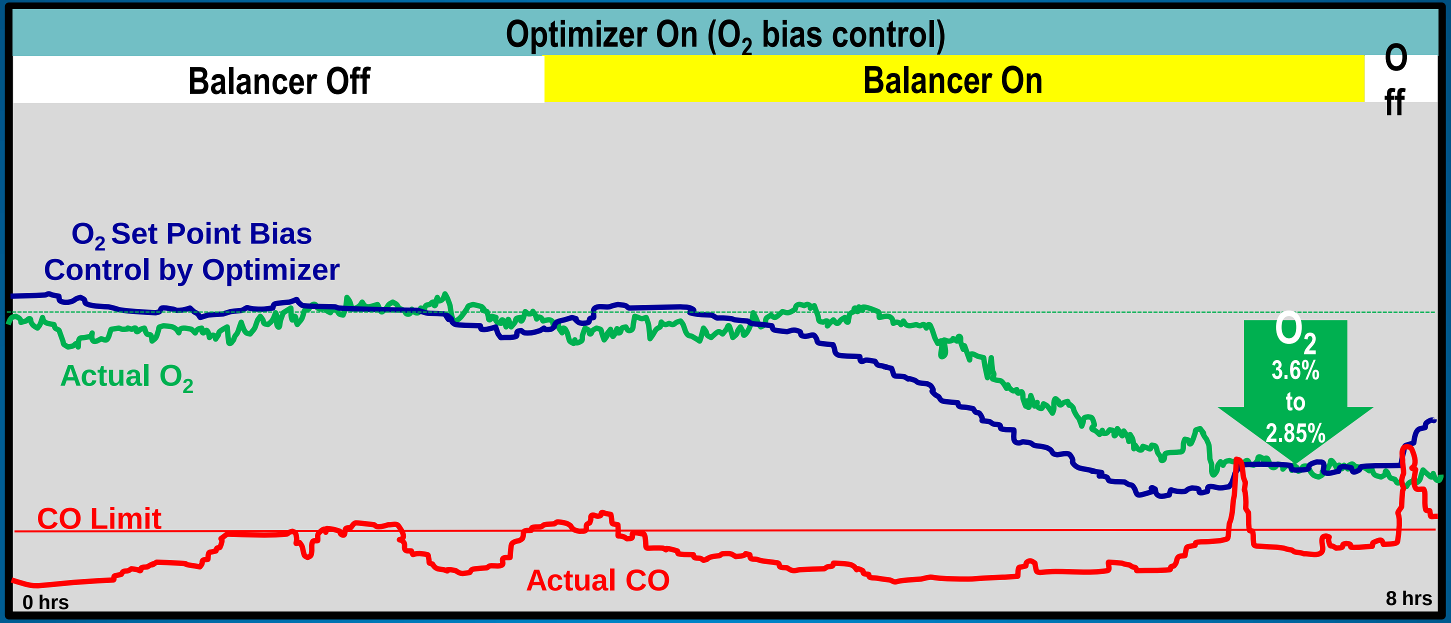
Combustion Balancing

By modifying
Secondary Boundary Air





Optimizer Control w/ Balancer



- Balancer Off
  - Optimizer can not lower O_2 ➔ CO increases and hits limit
- Balancer On
  - Optimizer lowers O_2 from 3.6% to 2.85%
  - CO stays within limits
  - NOx Reduced by 14%
  - Efficiency Improvement = 0.49%

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700MW Twin Tangential-fired Boiler

Plant Objectives:

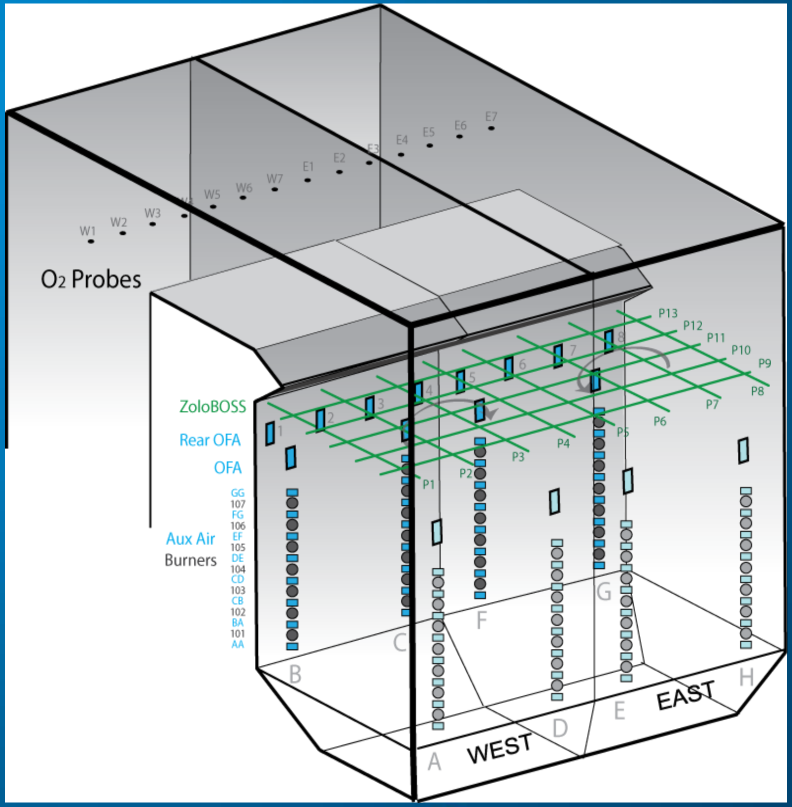
- Maintain NOx at <100ppm
- Maintain CO at <200ppm
- Maintain SH and RH temperatures at >1000 F

Problem:

- CO & NOx targets met with optimizer
- Steam temps generally below 1000F

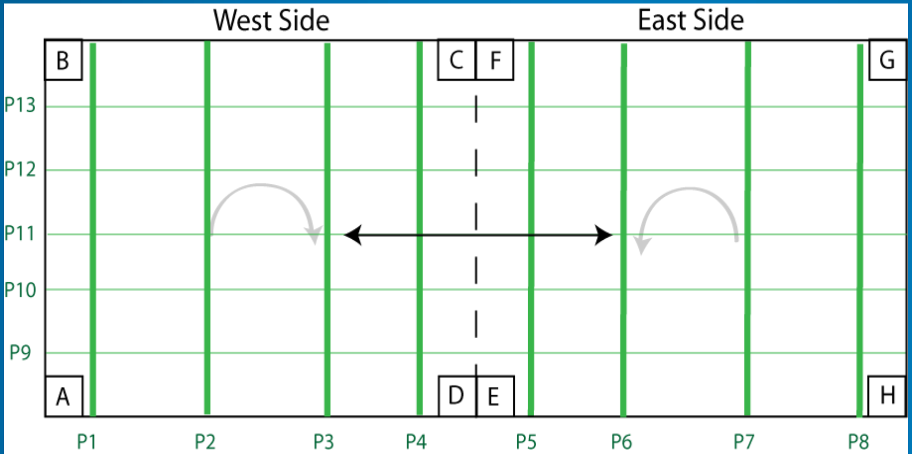
Solution:

- In-furnace measurement with ZoloBOSS
- Balance furnace combustion

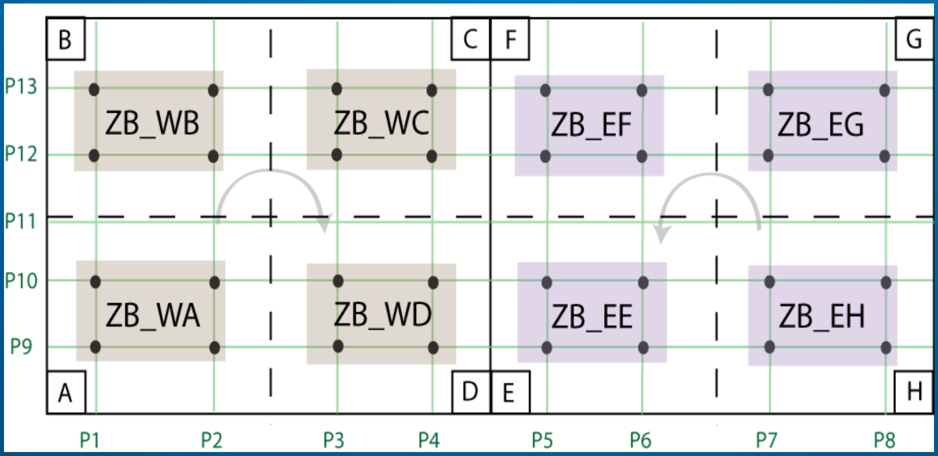


Basic Balancing Strategy

1. Equilibrate East and West Furnace.



2. Balance Combustion Within Each Furnace.



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Overall Results

	Stack NOx (ppm)	CO (ppm)	Excess O2 (%)	Power (MW)	Superheat Temp (F)	SH Split W-E (F)	Reheat Temp (F)	RH Split W-E (F)
Baseline - Optimizer Control	78.2	72	3.00	40.4	997.7	10.1	983.0	32.7
Move air from East to West Furnace	73.0	630	2.24	37.4	997.3	14.2	995.0	14.7
Balance CO within each Furance	74.3	175	2.24	38.0	1004.1	-0.1	1001.0	6.6
Heat Rate Impact (Btu/kWh) *			**24.2**	**34.4**	**11.6**	-	**22.7**	-
Total Heat Rate Reduction (Btu/kWh)								**92.8**

- Emissions:
  - NO_x ↓ by 5% (78 to 74ppm); Maintained CO limits < 200ppm
- Steam Temps:
  - Superheat ↑ 6.4F; Reheat ↑ 18.0F; (SH split - 0.1F, RH Split of 6.6F)
- Auxiliary Power:
  - ↓ 2.4 MW
- Heat Rate:
  - Total Heat Rate Reduction **~0.9%**

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Summary

Optimized combustion requires:

- Real-time, in-furnace measurement data
- Combustion must be balanced before optimization

Balanced / Optimized combustion leads to:

- Improved heat rate (efficiency)
- Enhanced availability
- Greater fuel flexibility
- Decreased emissions
- Minimize slagging

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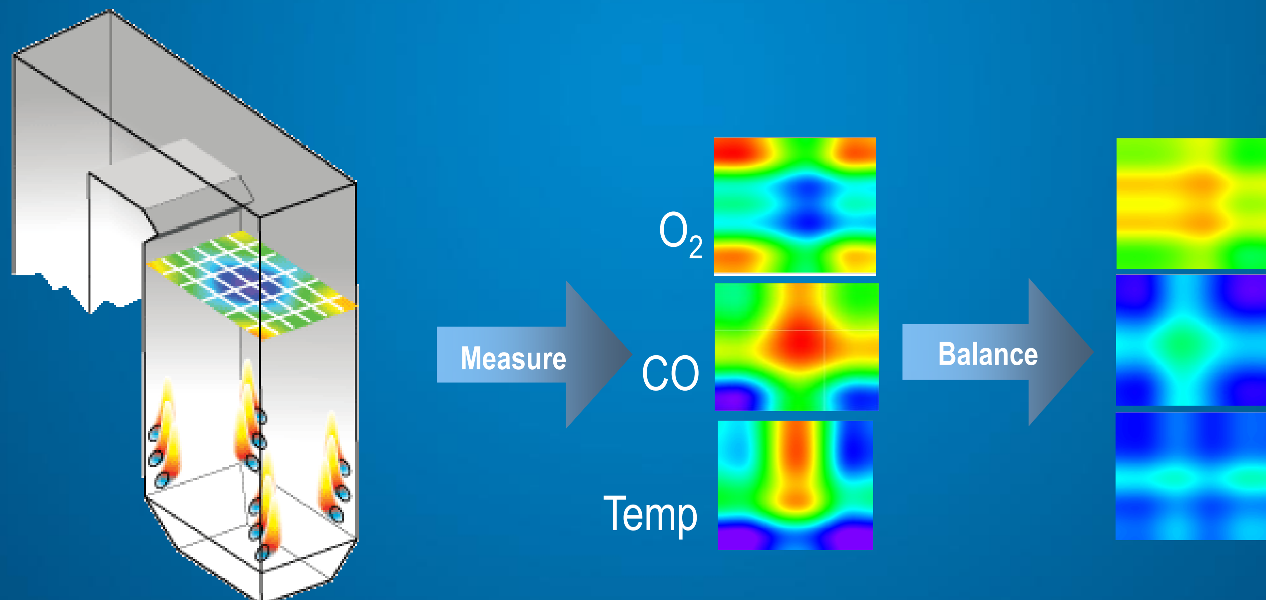
Questions?

- Please visit our website at www.zolotech.com
- Thank you for your time and your interest!



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