REINHOLD ENVIRONMENTAL Ltd.

2016 NOx-Combustion-CCR Round Table Presentation

February 1 & 2, 2016, in Orlando, FL / Hosted by OUC

Orlando, FL
February 2, 2016

Broaden the Operating Range of Coal Fired Units by Lowering the Minimum Operating Temperature

Reinhold Environmental 2016 NO_x-Combustion-CCR Round Table

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Technologies to enable clean efficient energy

Volker Rummenhohl

Agenda

- Introduction
- Basics of SCR Minimum Operating Temperature (MOT)
- Variety of solutions to reduce MOT
- Conclusions

Introduction

- Improving unit dispatch in an ever changing coal electricity generation market place requires the lowest possible unit load.
- The boiler is often limited by the Minimum Operating Temperature of the SCR system.

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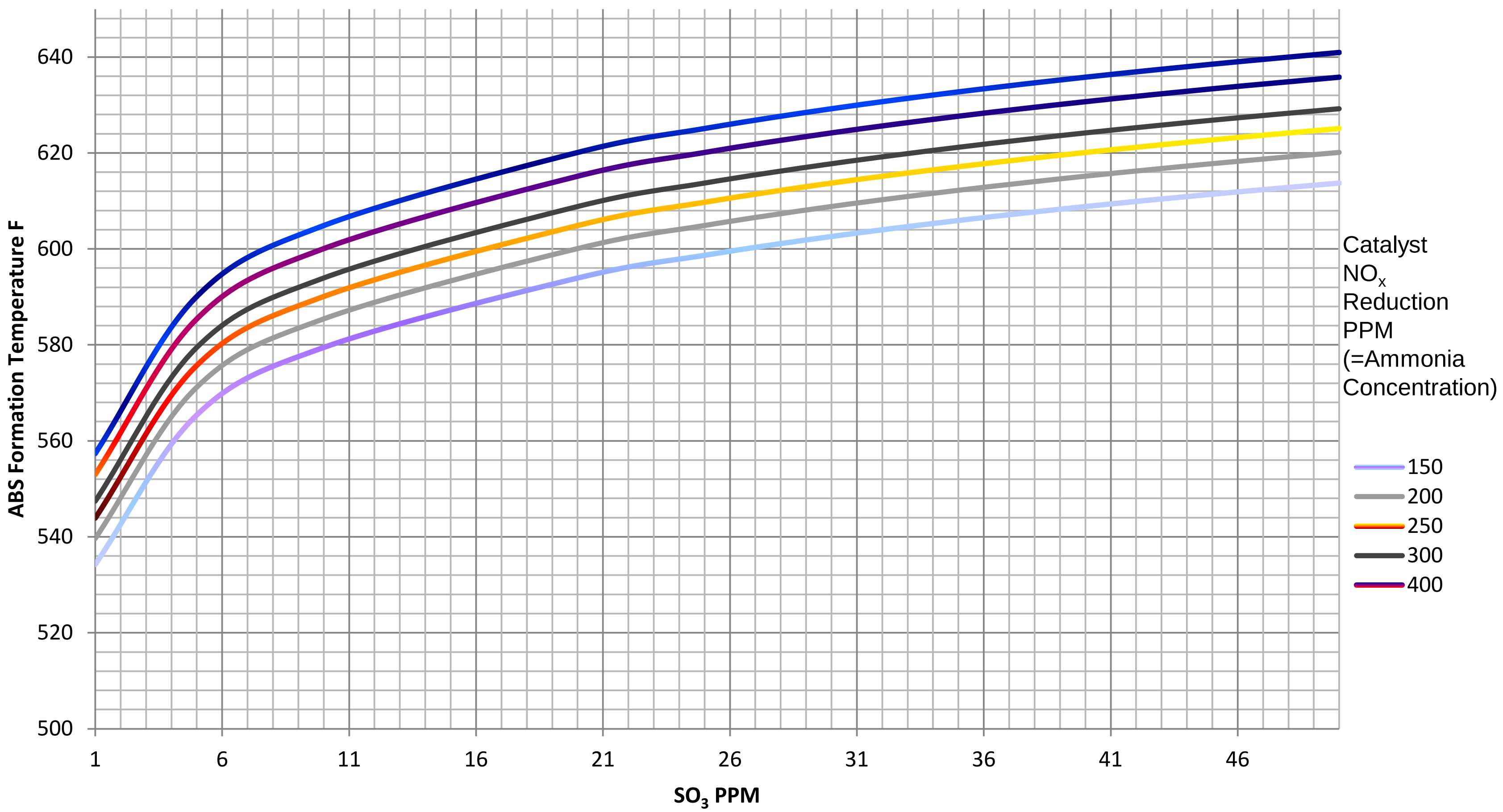
MOT

- The Minimum Operating Temperature is the temperature below which ammonia and sulfur trioxide combine to form ammonium bisulfate (ABS).
- $NH_3 + SO_3 + H_2O \rightarrow NH_4HSO_4$
- ABS deposits in the micro pores and reduces the catalyst activity.
- The ABS deposits can be removed at higher temperatures.
- The MOT depends on the NH_3 and SO_3 concentration in the flue gas.

Example



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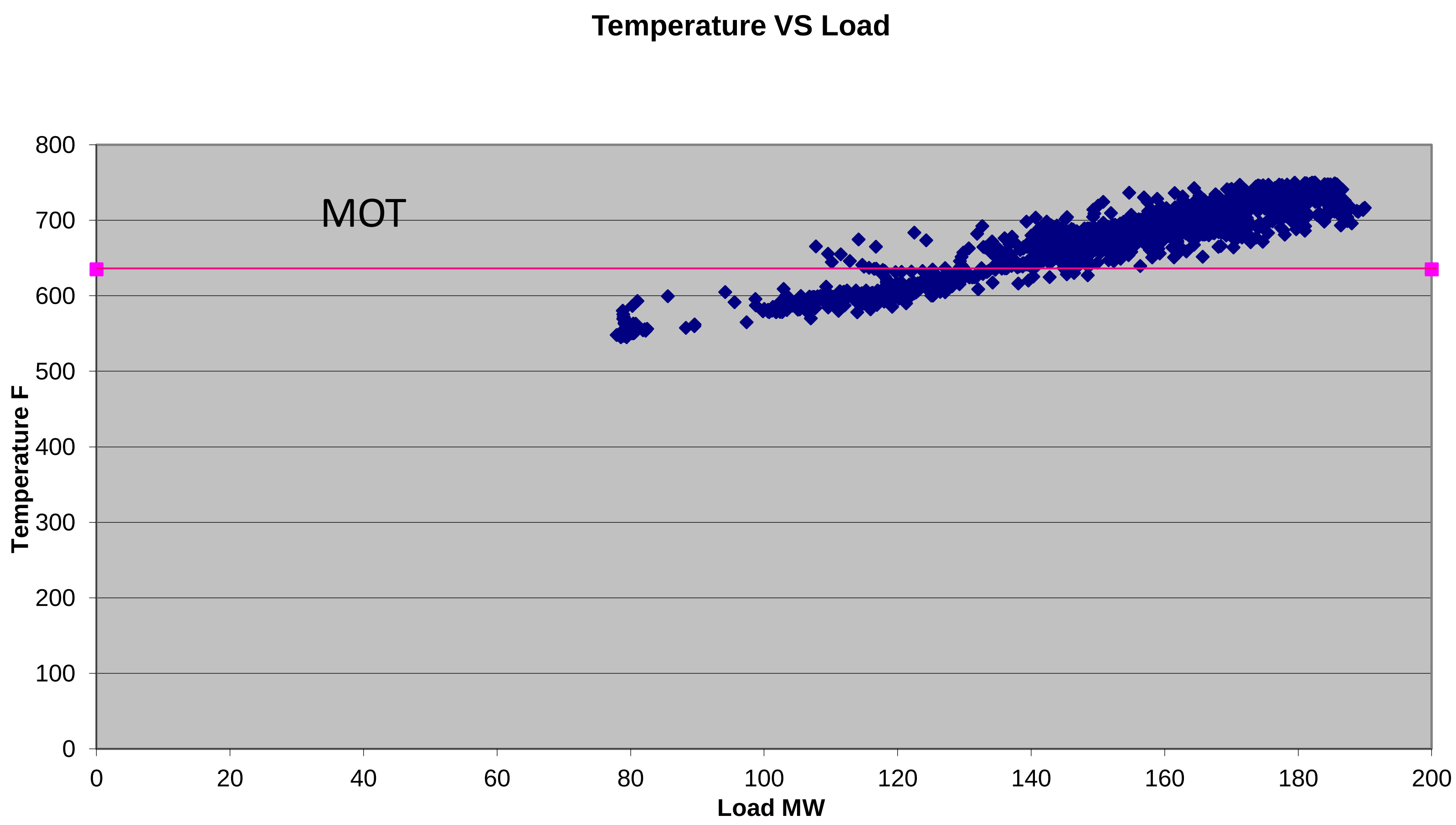
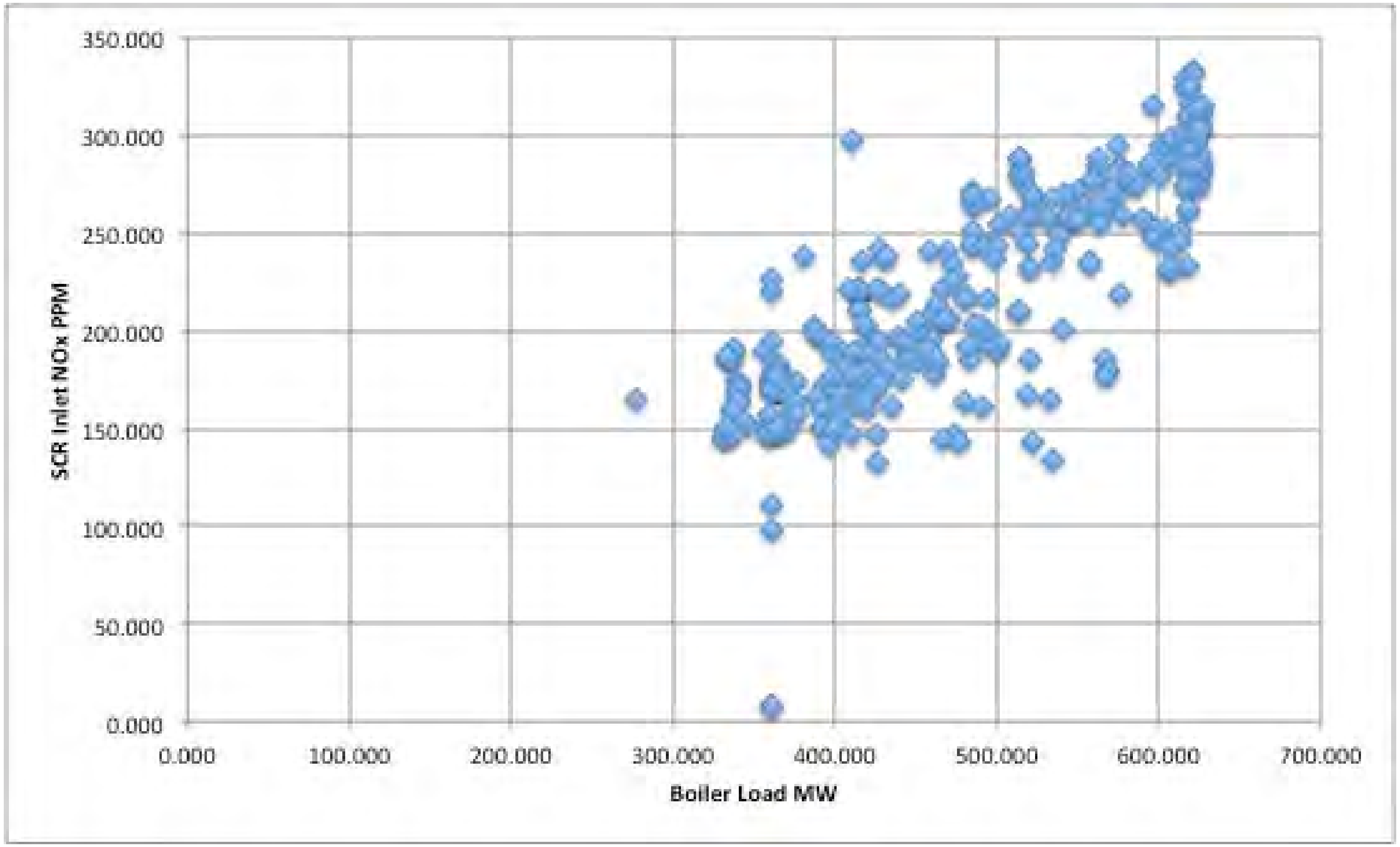
Economizer Temperature Characteristic



Solutions

- Verify operating data at low loads
- Operate below MOT
- Increase economizer outlet temperature
- Reduce ammonia concentration in the flue gas
- Reduce sulfur trioxide concentration in the flue gas
- Combination of the above

NO_x VS Load



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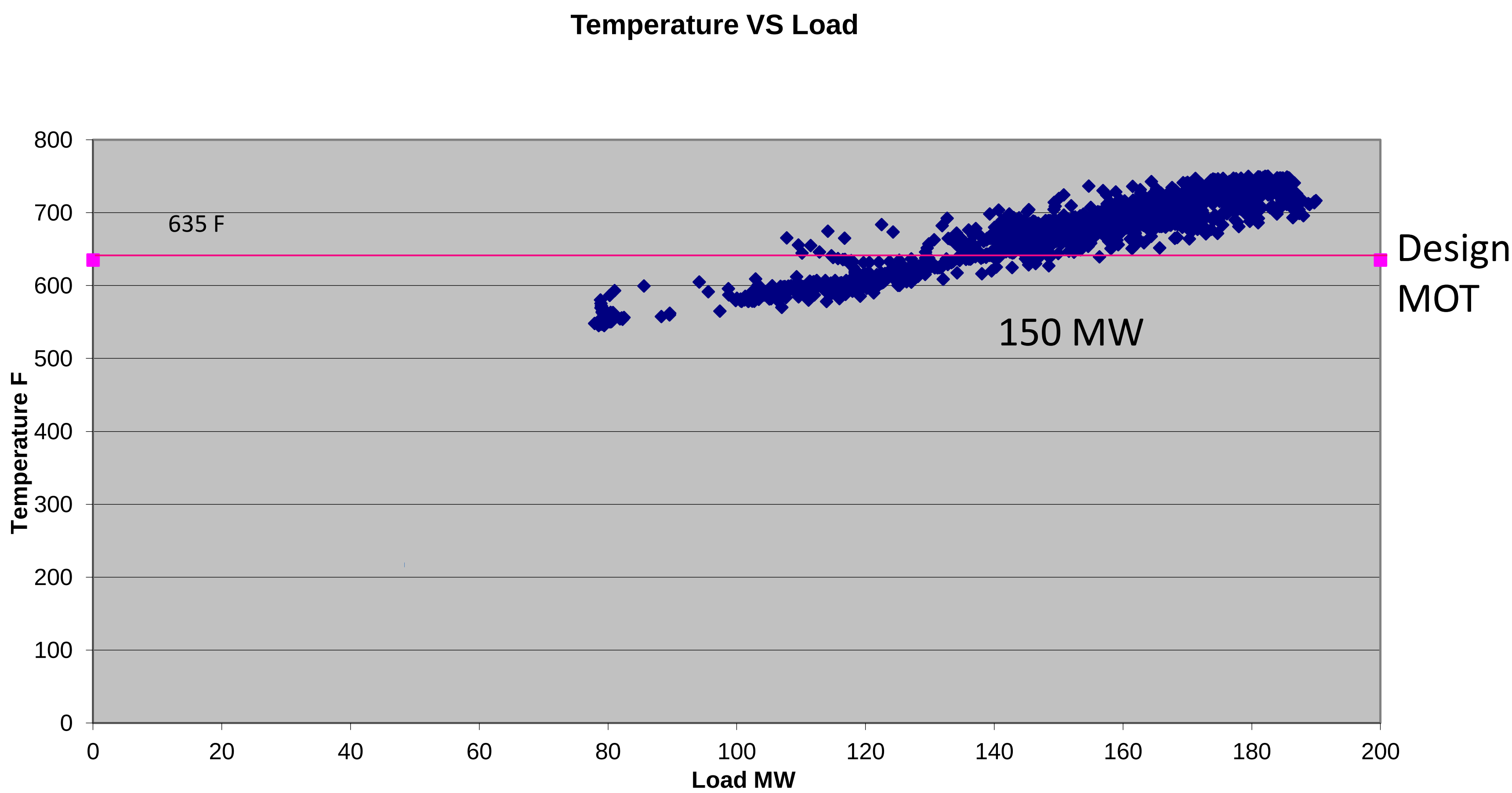

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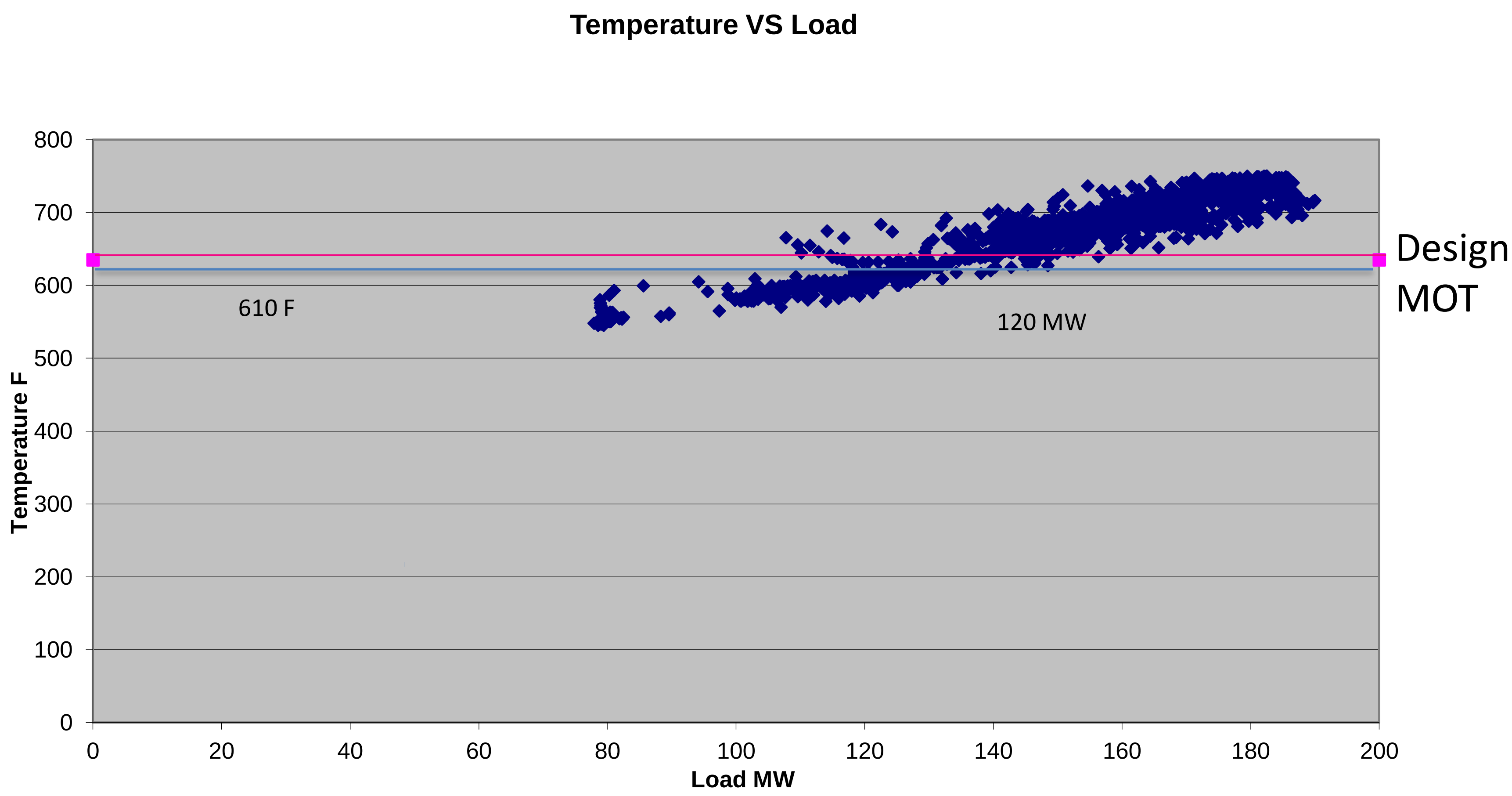
Verification of Low Load Operating Data

- NO_x inlet
- NO_x distribution
- SO_2 inlet
- SO_2 distribution
- SO_3 inlet
- SO_3 distribution
- Temperature inlet
- Temperature distribution
- Ammonia slip

Verification of Low Load Operating Data



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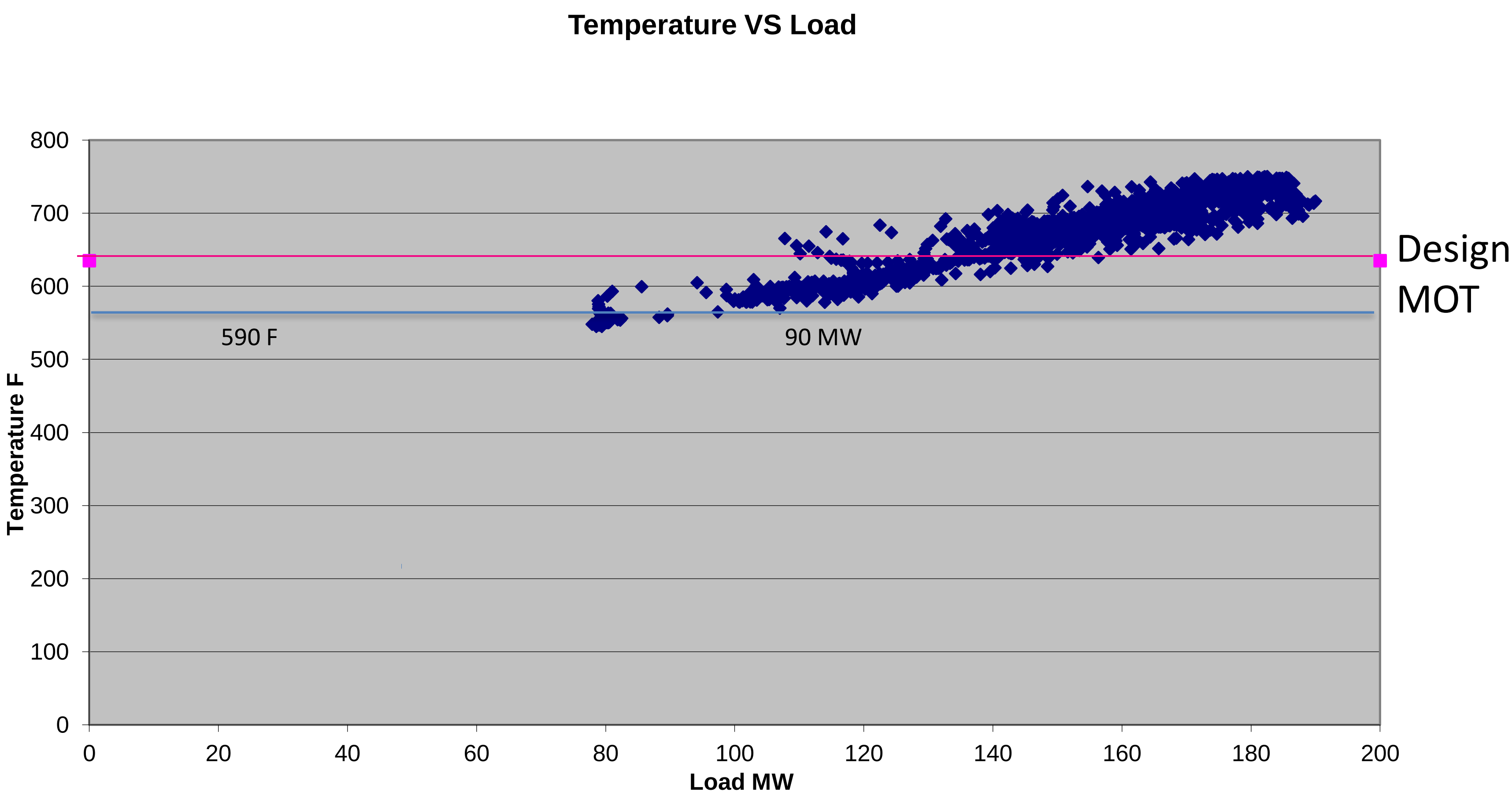
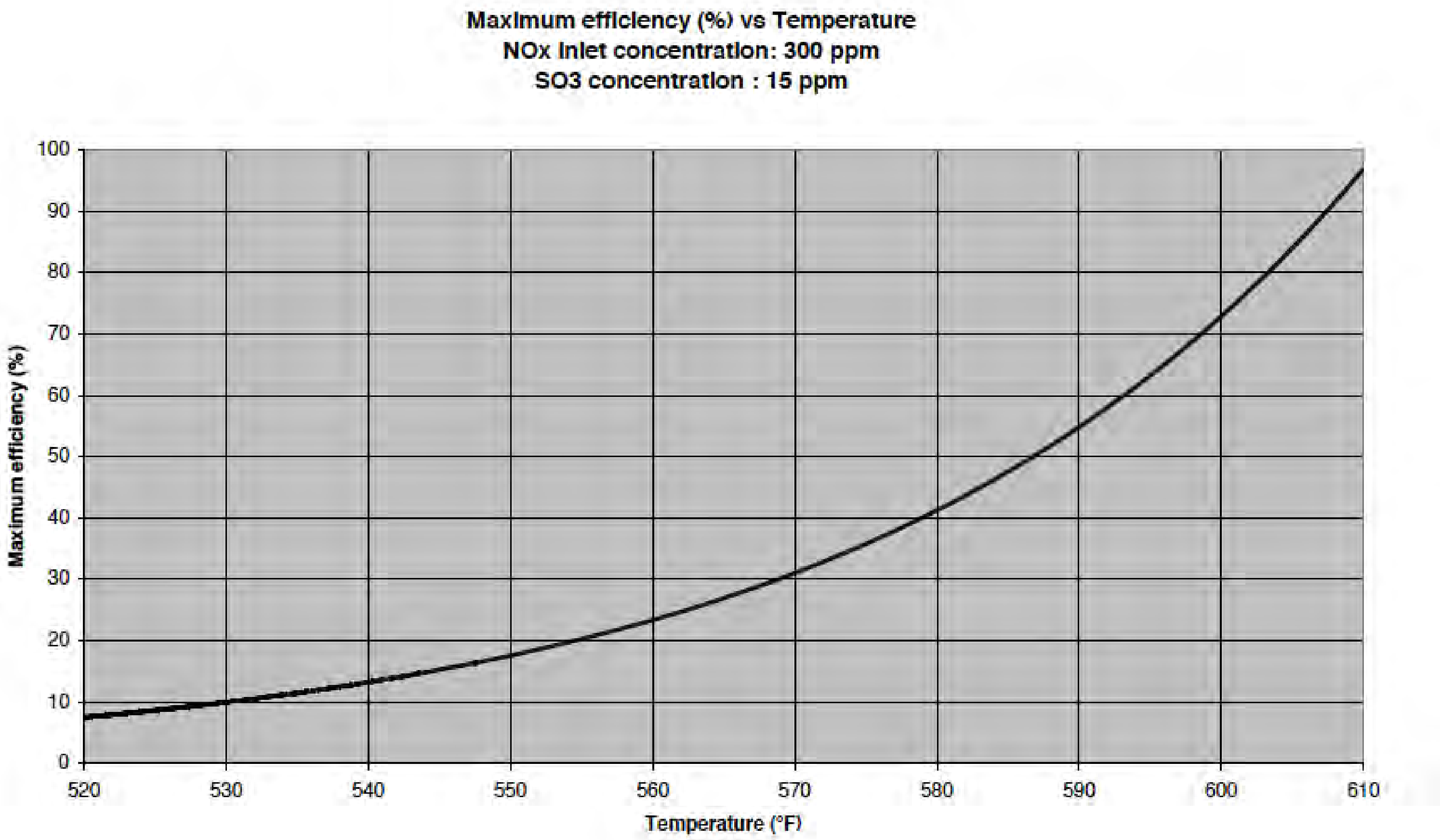
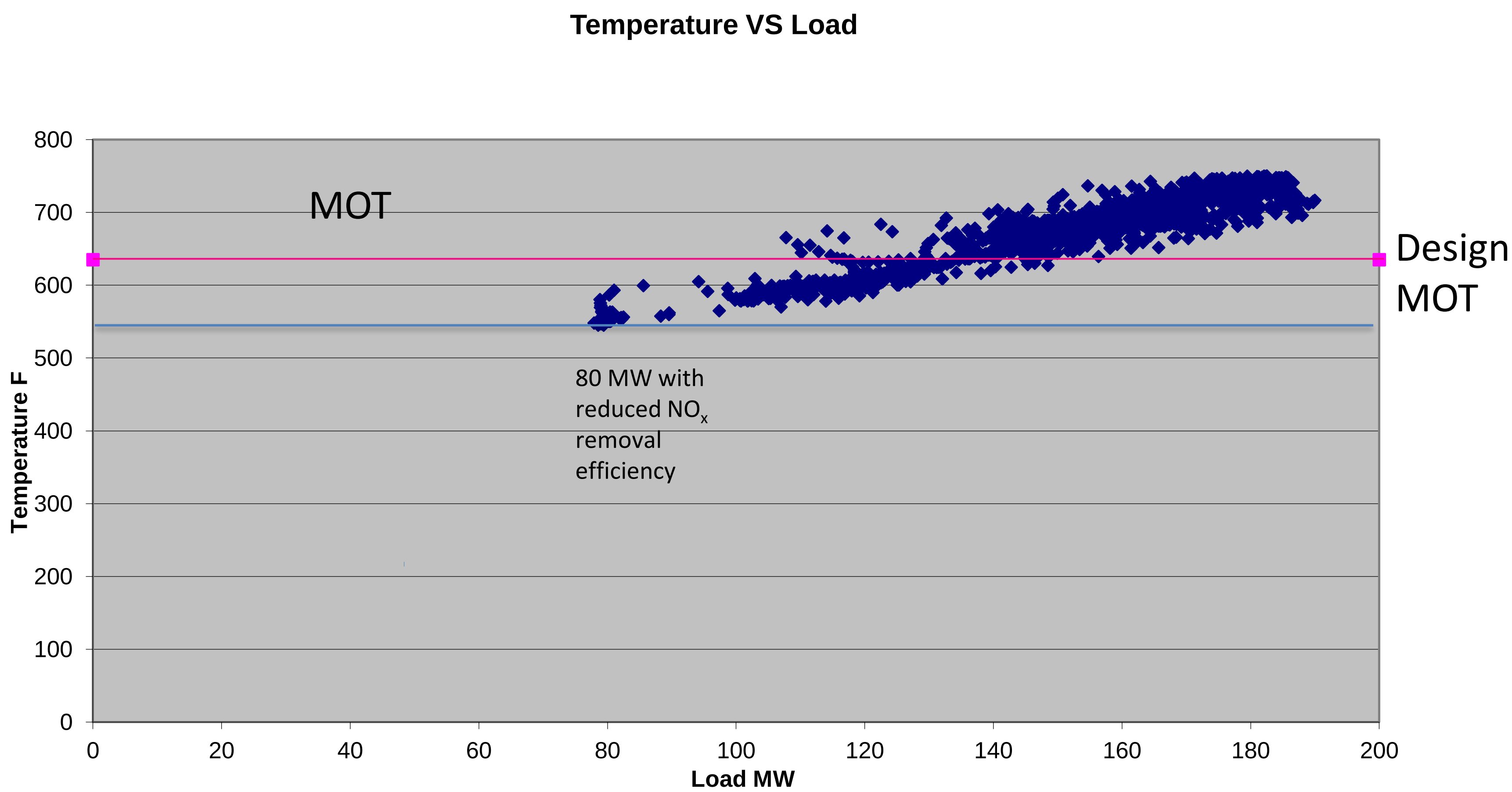


Reduce Ammonia concentration



Economizer Temperature Characteristic



Operation Below MOT

- Deterioration of Ammonia/NO_x profile inside the catalyst mostly on high sulfur units
- Time dependent
- Other sulfite formation

Operating Below MOT on High Sulfur Unit

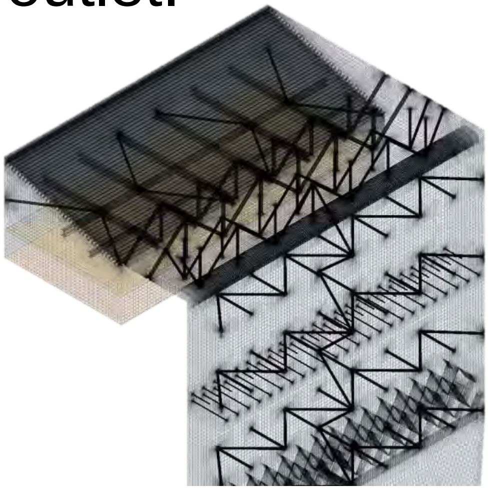
- 500 MW unit wall fired
- Bituminous coal with 3% sulfur
- Full load performance test
  - Guaranteed NO_x removal exceeded
  - Ammonia slip not detectable
  - NO_x outlet distribution +/- 10 PPM
- Low load Second performance test
  - Guaranteed NO_x removal exceeded
  - Ammonia slip 2 PPM
  - NO_x outlet distribution +/- 20 PPM

Operating Below MOT on High Sulfur Unit

- Low load first performance test
  - As full load test
- Low load second performance test
  - Guaranteed NO_x removal exceeded
  - Ammonia slip 2 PPM
  - NO_x outlet distribution +/- 20 PPM
- Low load third performance test
  - Guaranteed NO_x removal exceeded
  - Ammonia slip 10 PPM
  - NO_x outlet distribution +/- 50 PPM

Bio Mass Unit

- SCR clean side arrangement (444˚F) - downstream of baghouse and DSI.
- Most catalyst poisons have condensed on ash and removed in bag house.
- DSI removes 70-90% of SO_x
- Minimum operating temperature of 423˚F based on design SO_2 / SO_3 values at baghouse outlet.
- Additional design constraints:
  - Ammonia Slip <5ppmvd @ 7% O_2
  - 2 year initial lifetime guarantee
  - Catalyst pressure drop <1.2" wg



Bio Mass Unit

- Boiler first fire July 7, 2013
- SCR Baseline testing began on November 19, 2013.
- NO_x removal set point target set at 0.078 lb/MMBTU and met.
- Ammonia slip testing done at a set point of 0.045 lb/MMBTU. Set point was met and no ammonia slip excursions found.
- Initial compliance emissions testing results, November 2013:
  - NO_x: 0.052 lb/MMBtu
  - Ammonia slip: 0.7 ppmvd @ 7% O_2

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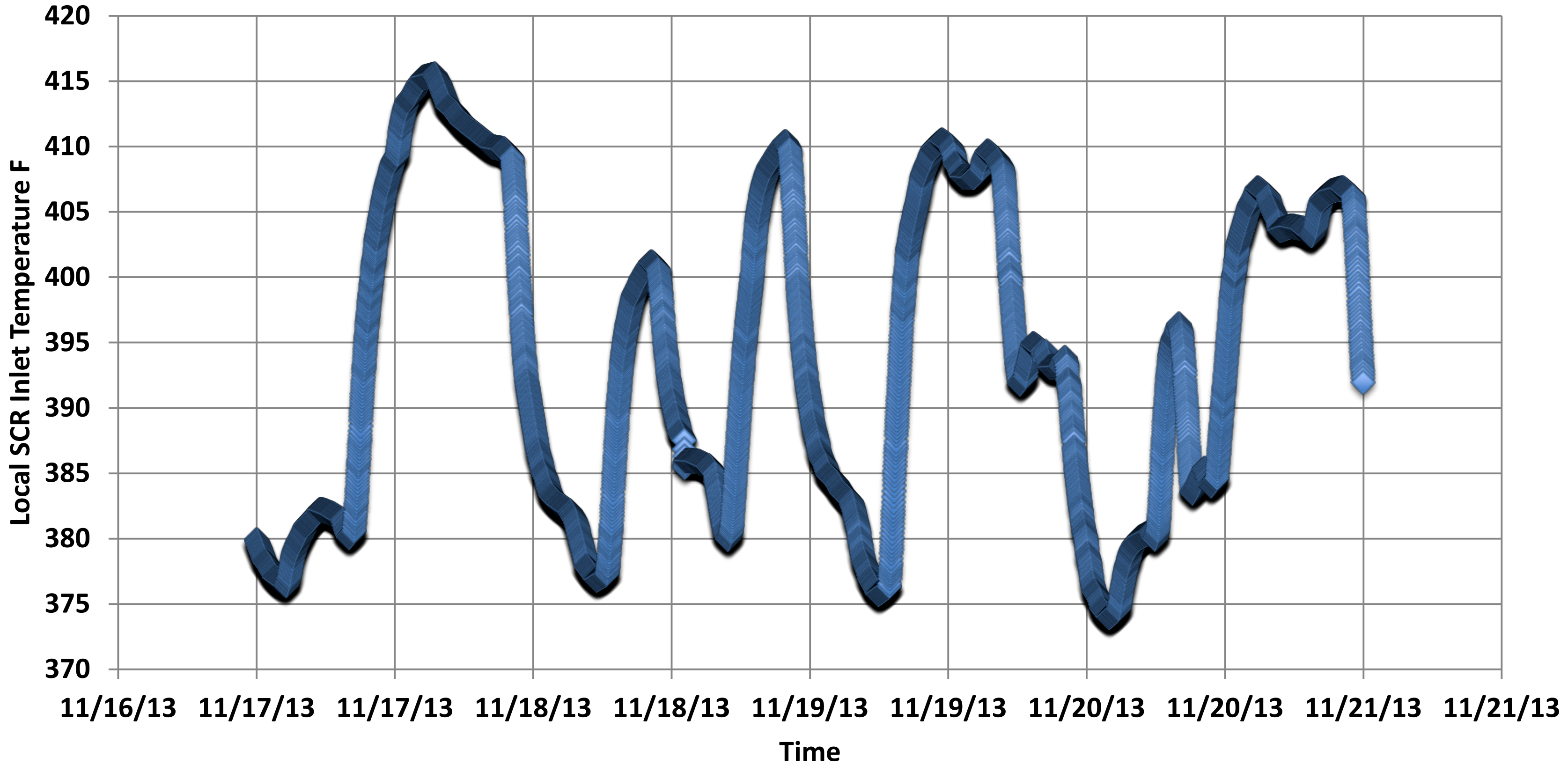
Bio Mass Unit

Current Operation

- NO_x Inlet 0.138 - 0.155 lb/MMBTU
- NO_x Outlet 0.032 - 0.075 lb/MMBTU
- Temperature 375˚F - 423˚F
- Pressure Drop (SCR) less than 2” Wg

Operation Below MOT



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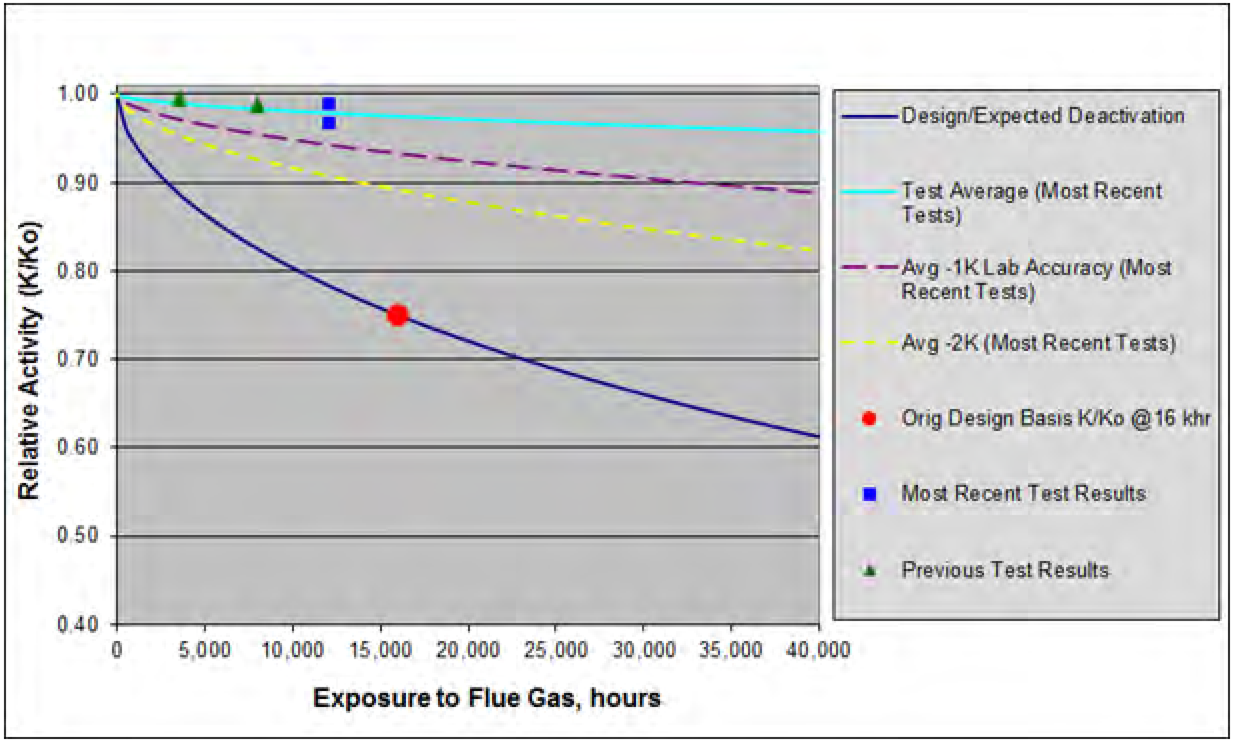
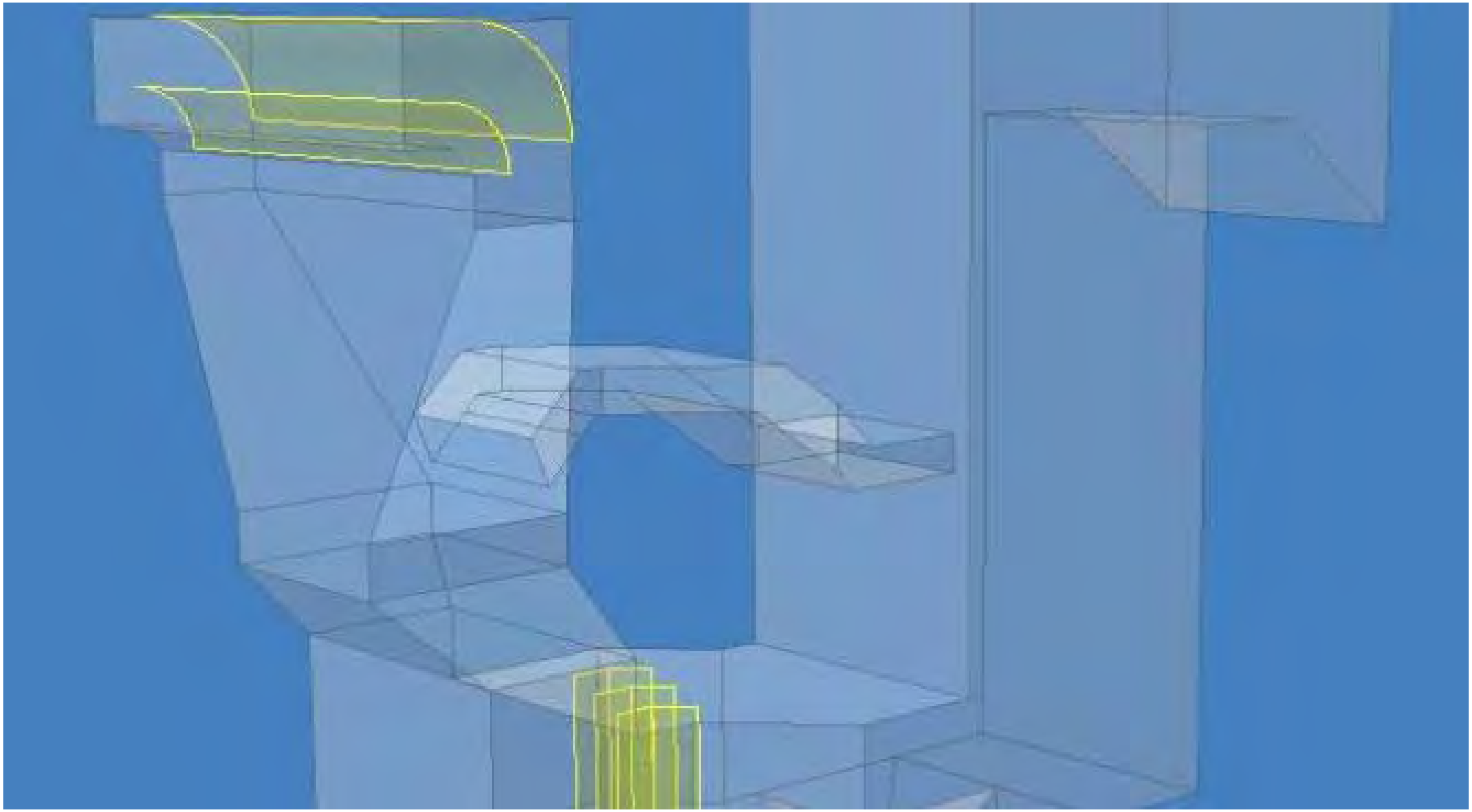
Bio Mass Unit

- Testing done at 4,000 and 8,000 hours



Economizer Gas Side Bypass



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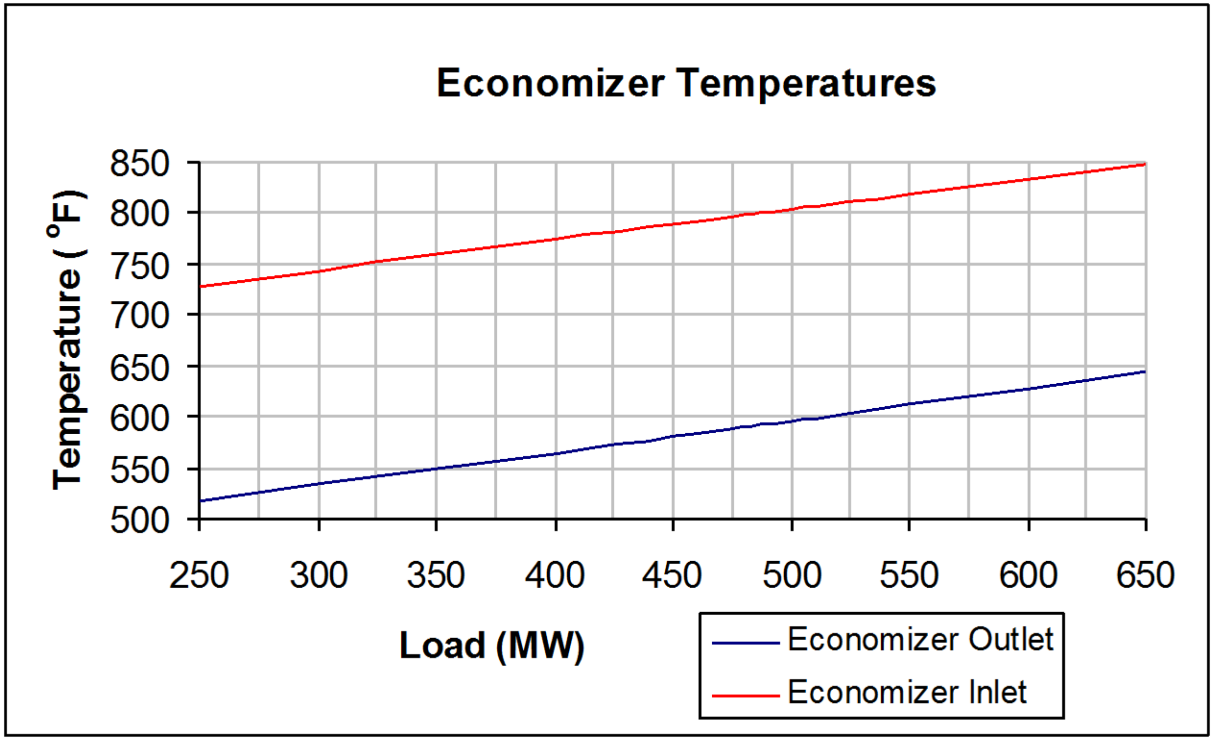

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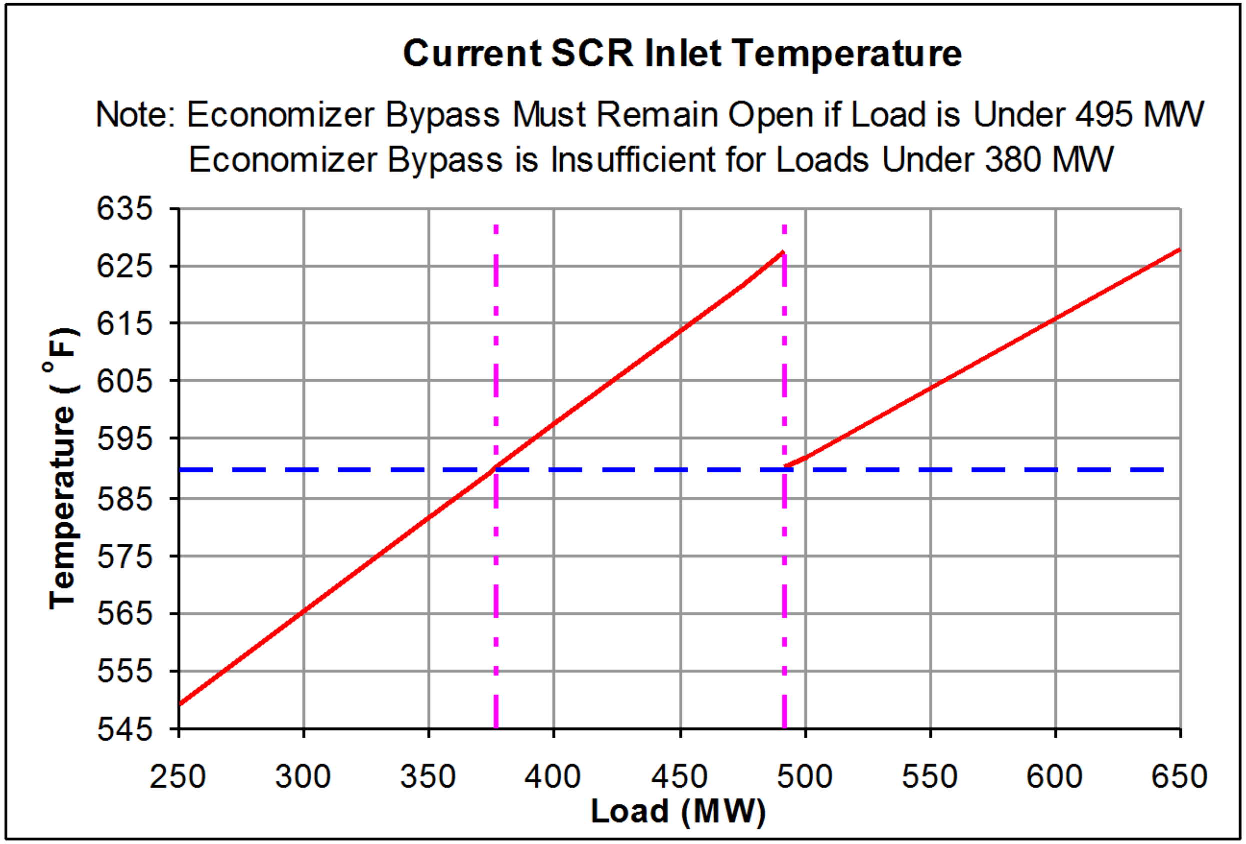

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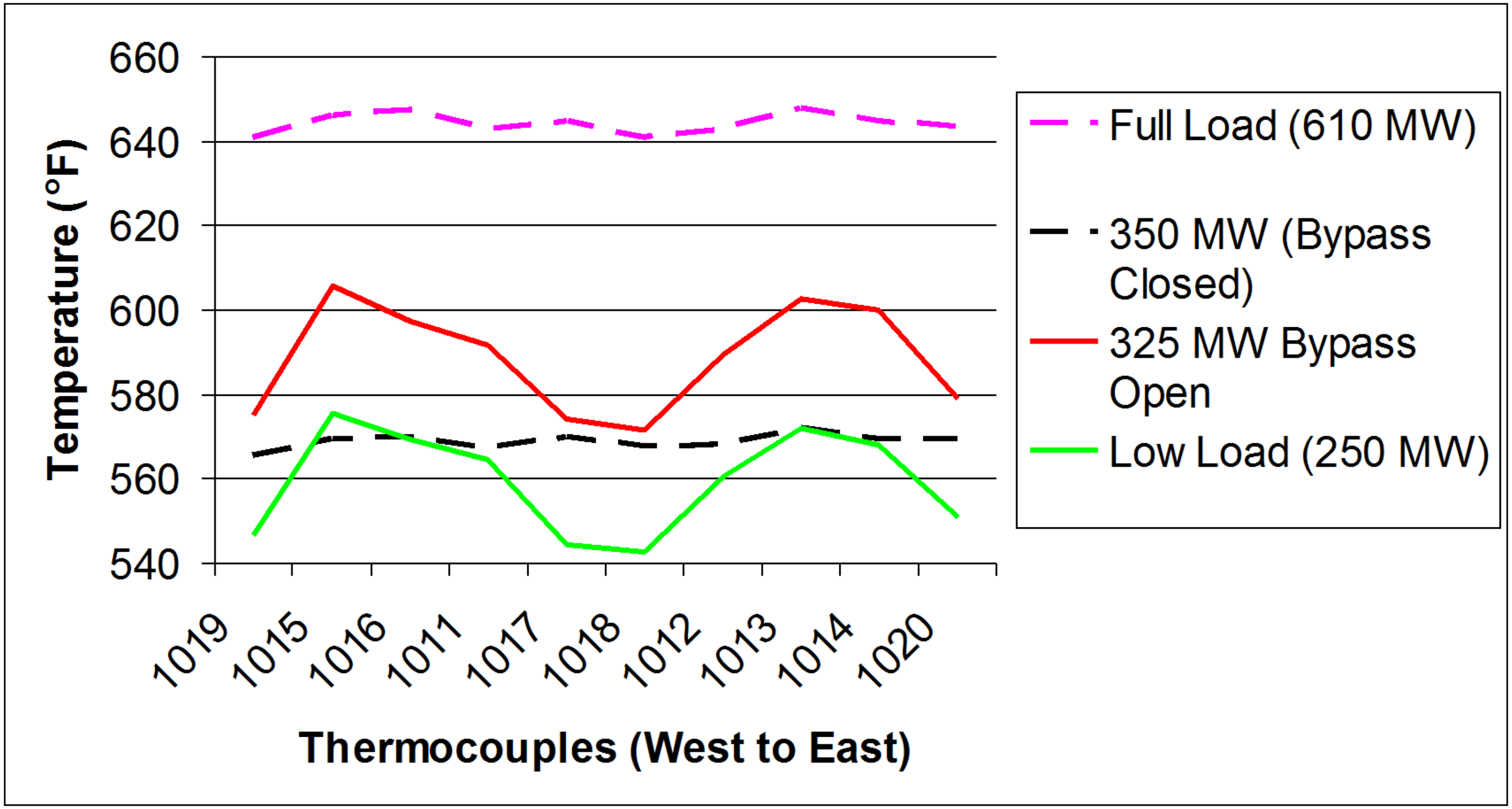

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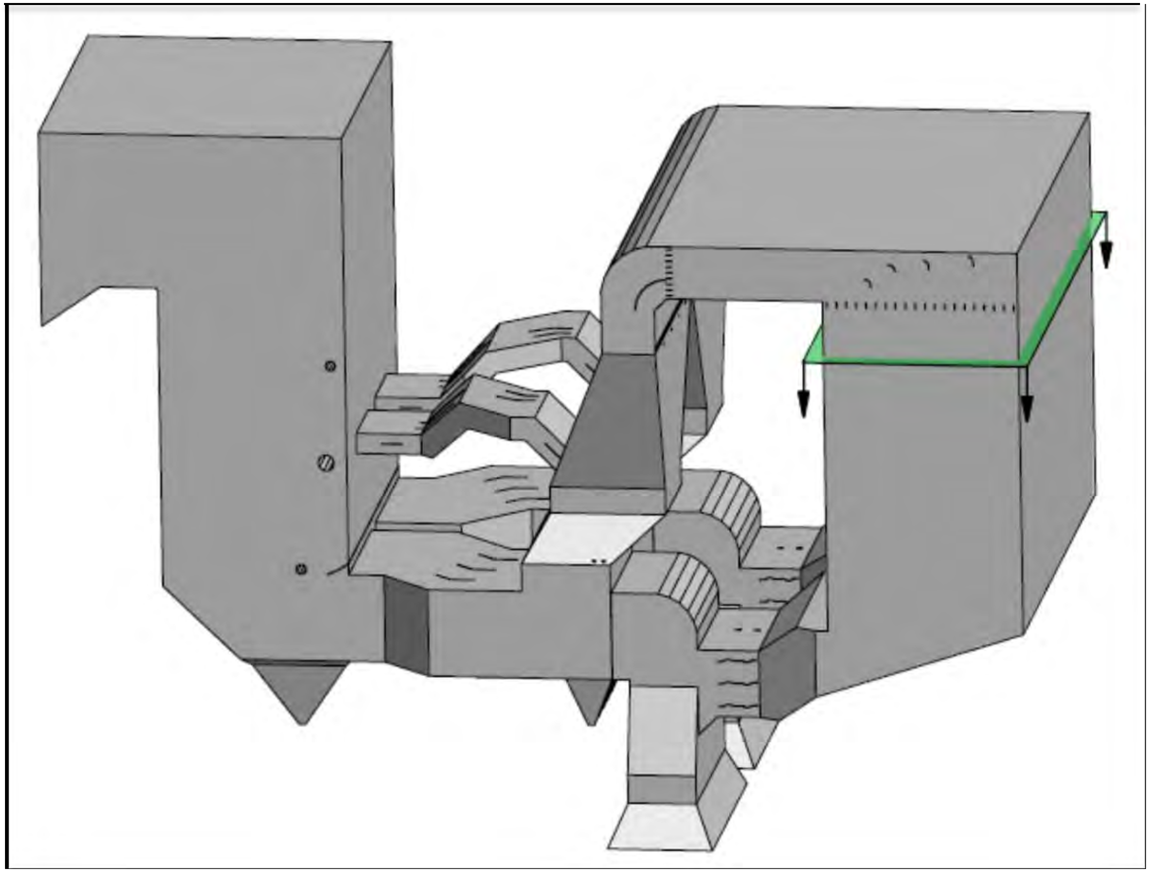

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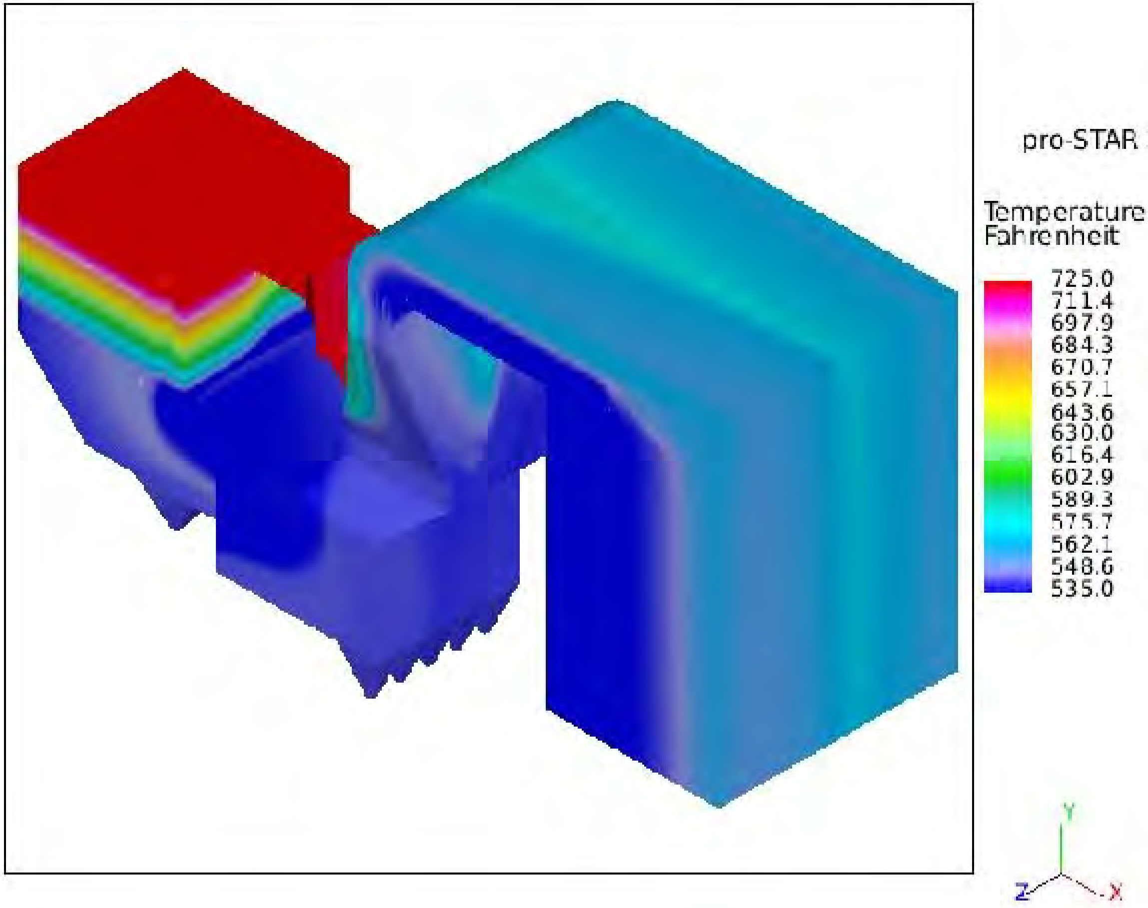

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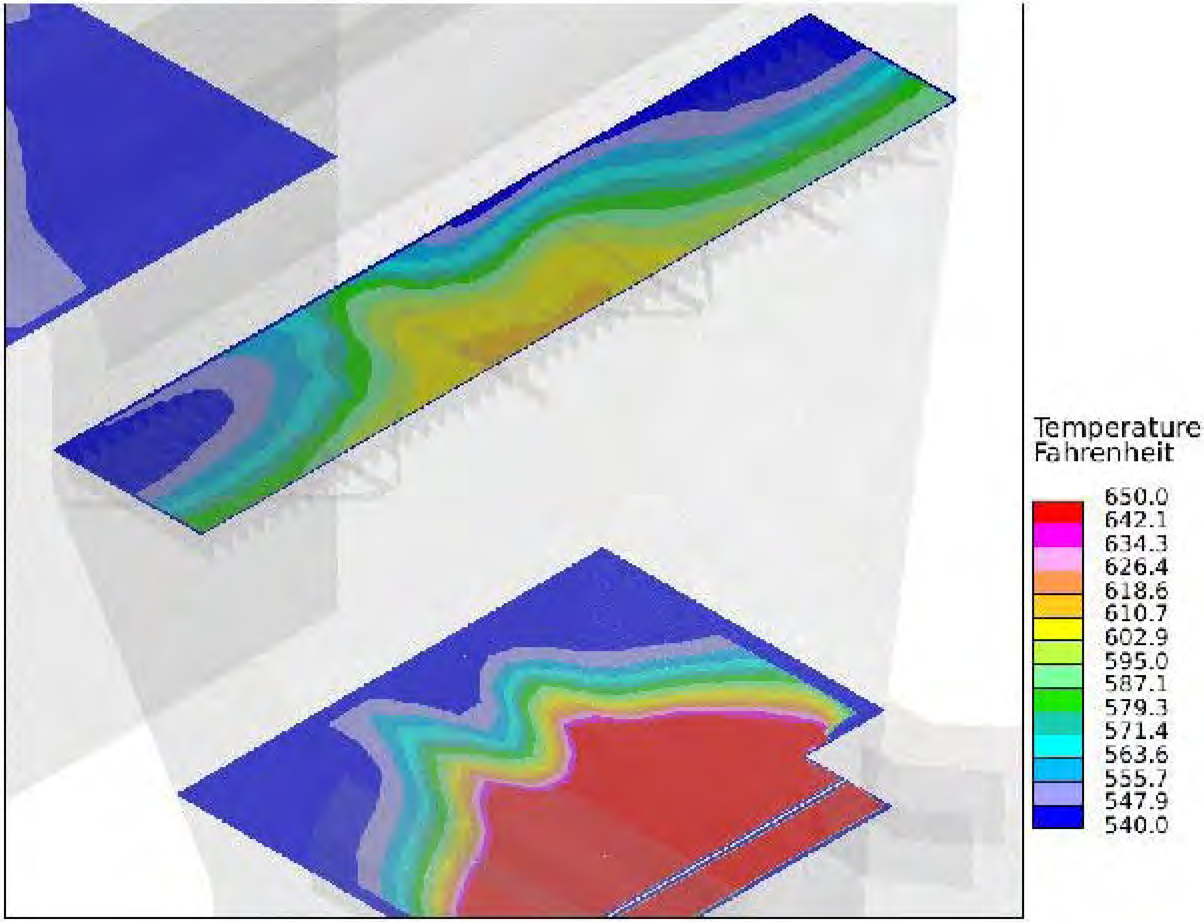
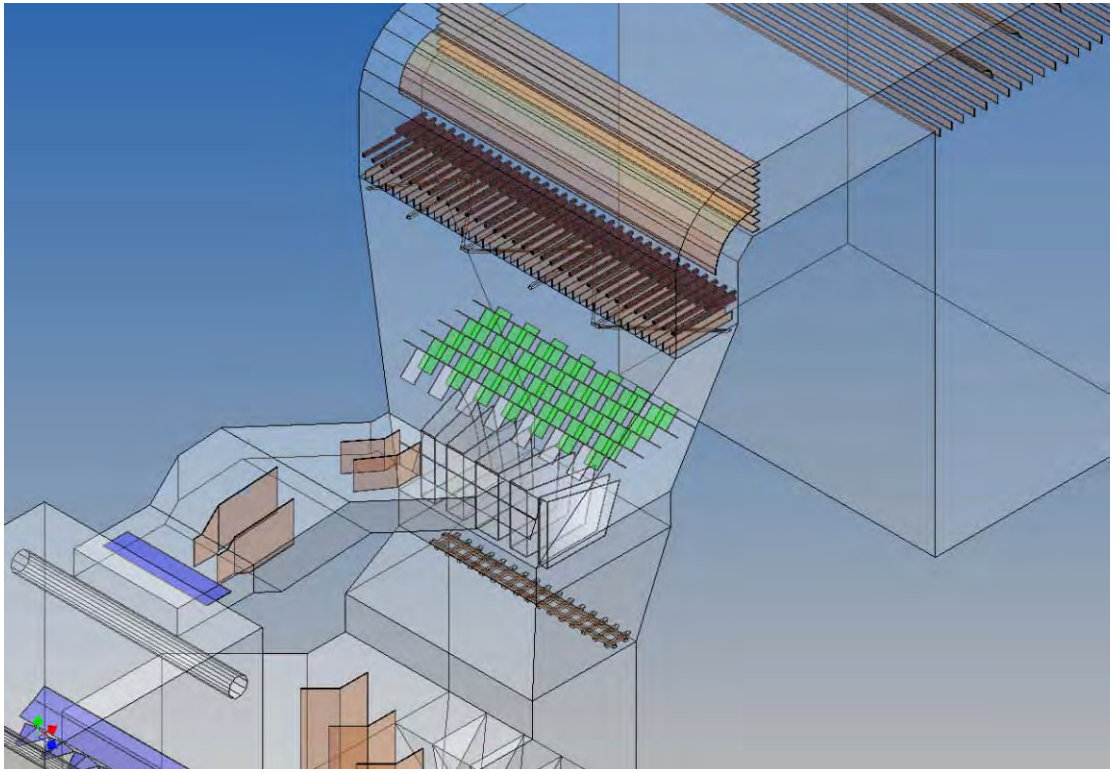


Economizer Gas Side Bypass

Possible Solution



Economizer Water Side Bypass

- Pro: No flue gas mixing issues
- Con: Many times difficult to retrofit
- No flow water flow through part of the economizer

SO_3 Reduction With Targeted In-Furnace Injection TIFI

- $Mg(OH)_2$ calcines to high surface area MgO
- Direct Reaction with MgO
  - $MgO + SO_3 \Rightarrow MgSO_4$
  - $MgO + NH_4HSO_4 \Rightarrow MgSO_4 + NH_3 + H_2O$
- Lower Furnace Temperature
  - Decreased Oxidation Rate
- More Balanced Furnace
  - Reduced Excess Oxygen
- Reduced Slag and Iron Deposits
  - Less Catalytic SO_2 Oxidation

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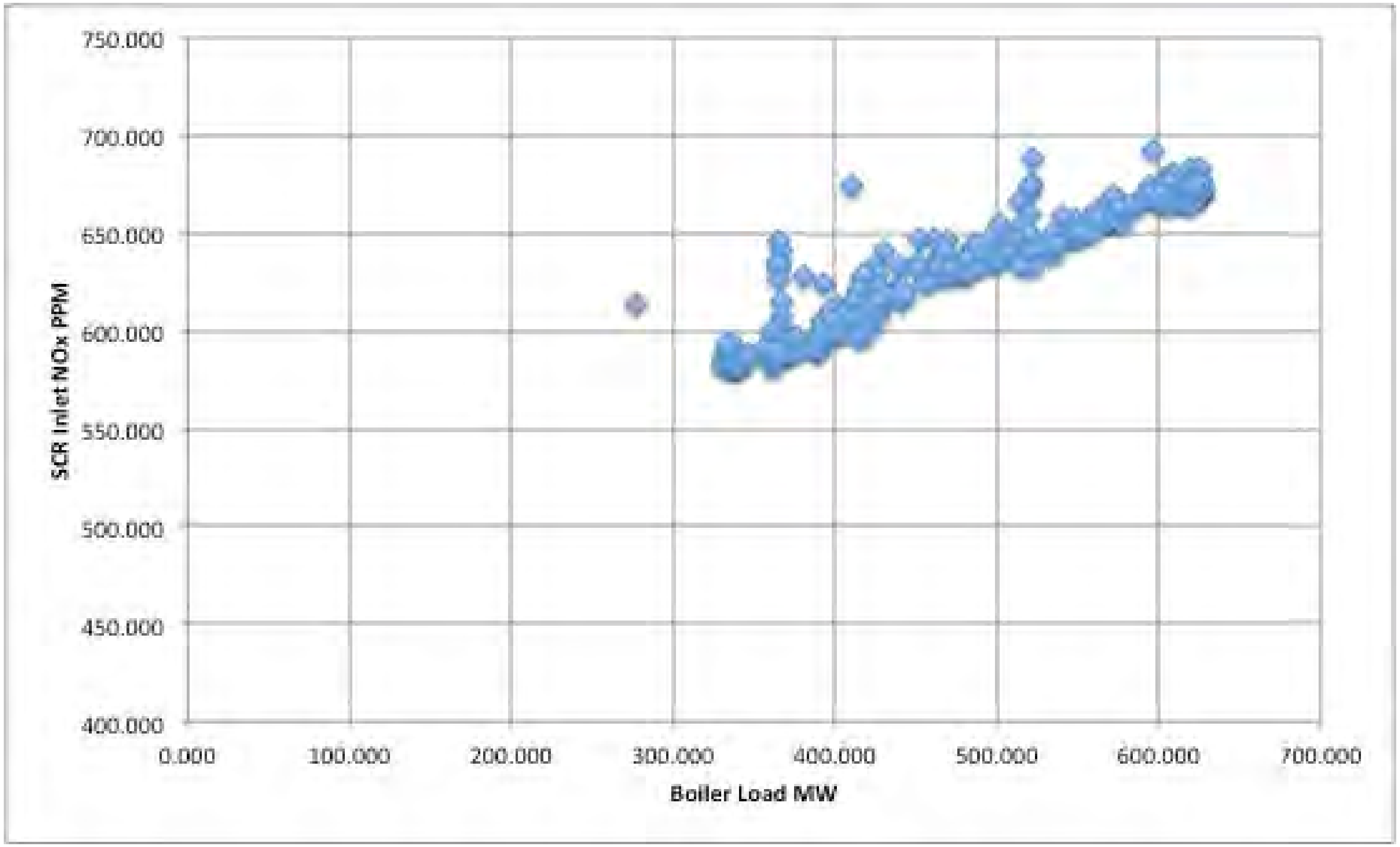
MOT Reduction With Targeted In-Furnace Injection TIFI

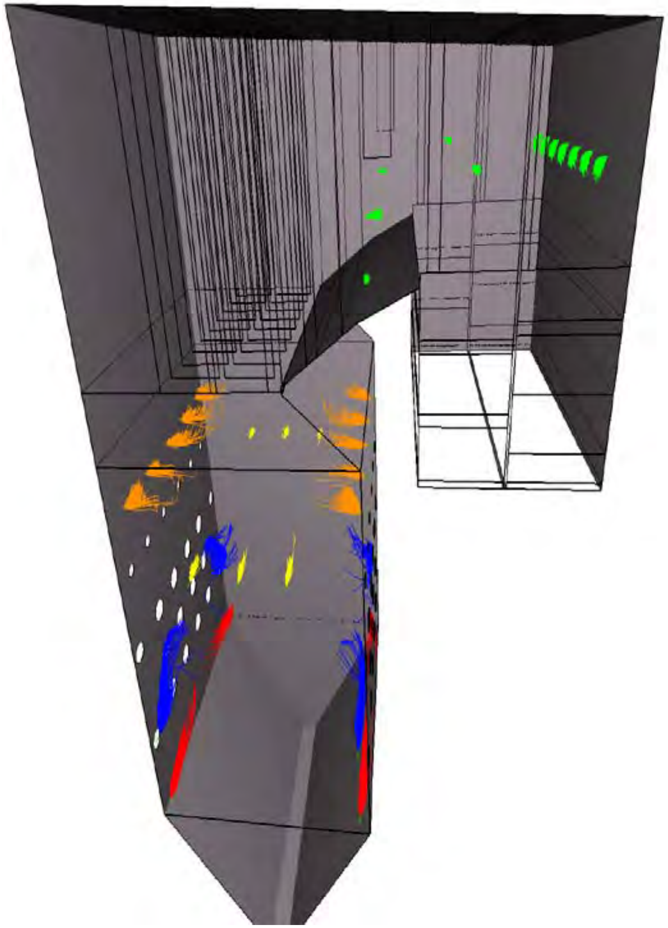
- 600 MW Wall Fired.
- Illinois Basin Coal.
- Need for Greater Low Load Flexibility.
- New Low Load Operations began Aug 2013 and continues through present.
- Original Low Load 430 MW – reduced to 275 MW

SO_3 Reduction With Targeted In-Furnace Injection TIFI



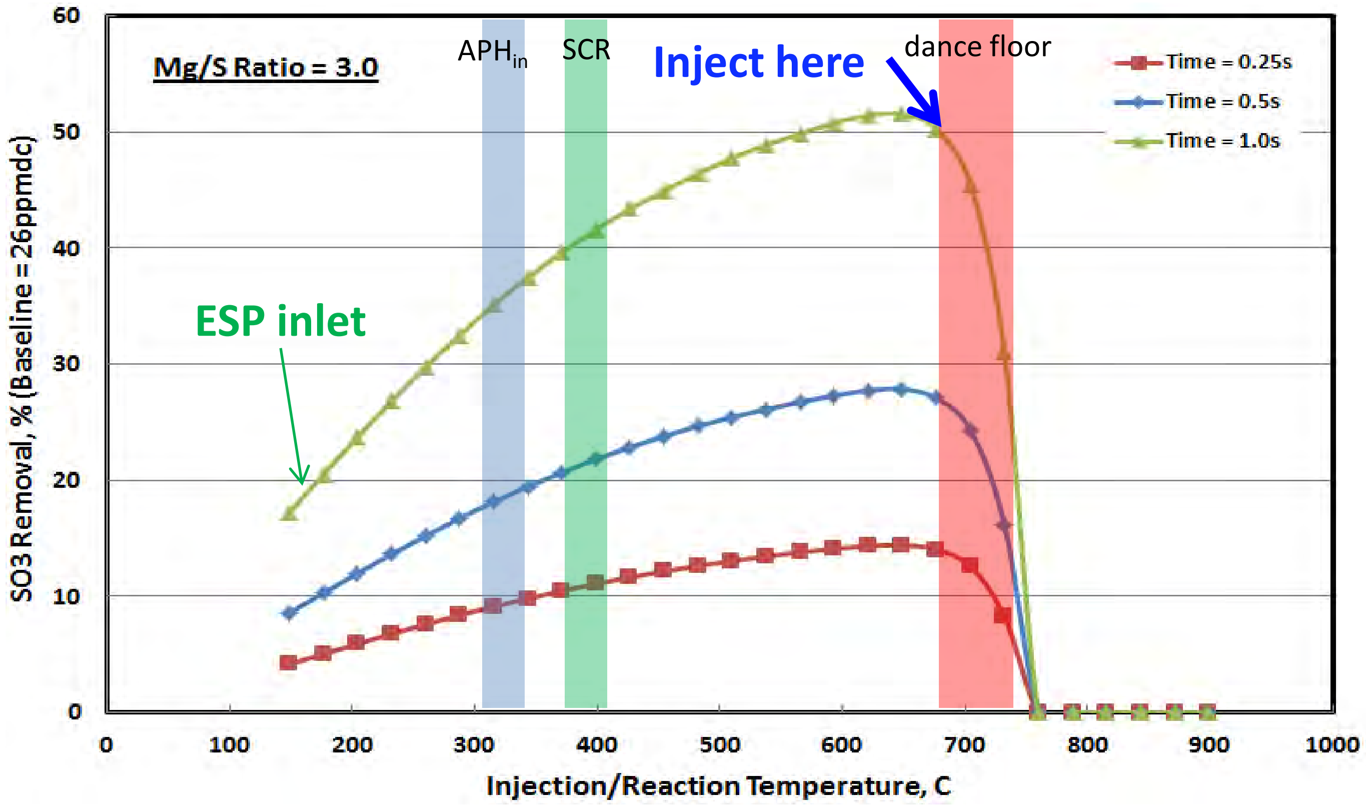
SO_3 Reduction With Targeted In-Furnace Injection TIFI

- Lower furnace injection (zones 1 – 4) is optimal for slag/fouling control
  - MgO reacts with ash to modify ash fusion temperature
  - MgO captures SO_3
- Zone 5 injection is more efficient for SO_3 control and still provides slag & fouling control at the horizontal superheats, reheats, economizer, SCR & air heater
  - MgO does not readily react with fly ash at T < 2000ºF
  - Less sintering of MgO = more available surface area for SO_3

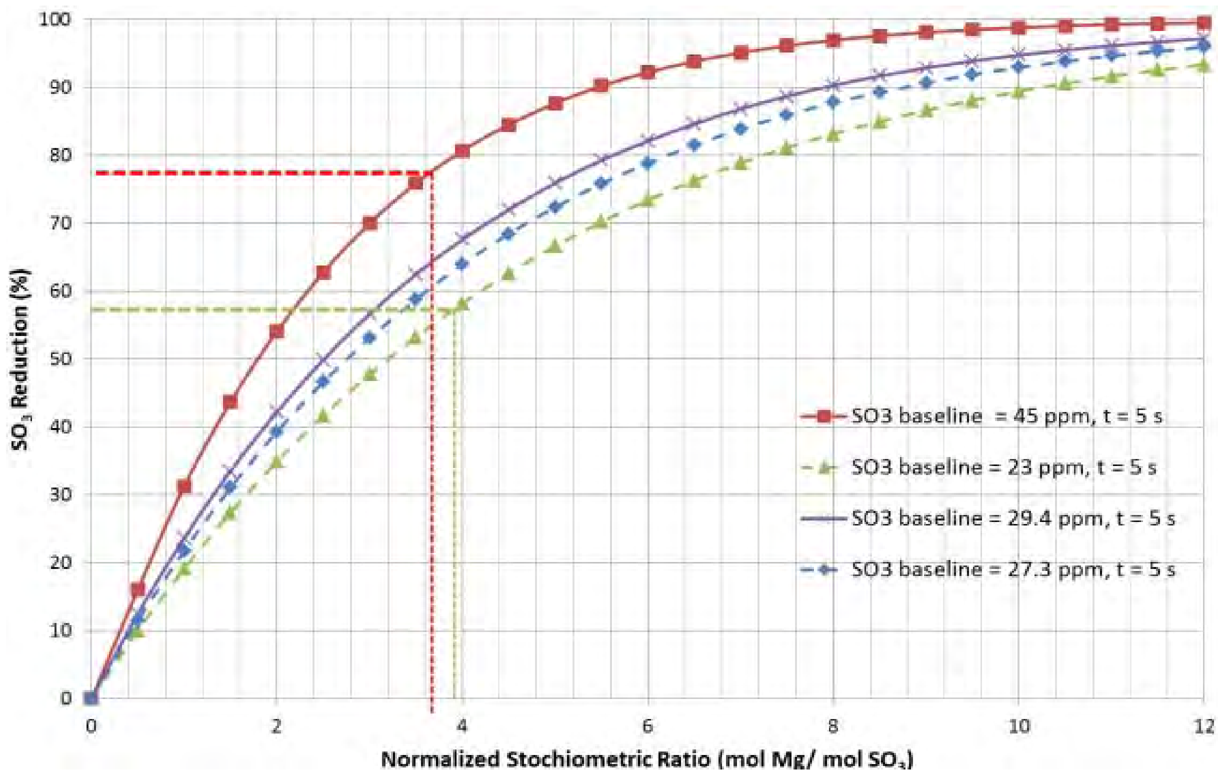


Zones 1 – 4, 5

Optimized $Mg(OH)_2$ Injection for SO_3 Control



Predictive Performance Model for SO_3 Control



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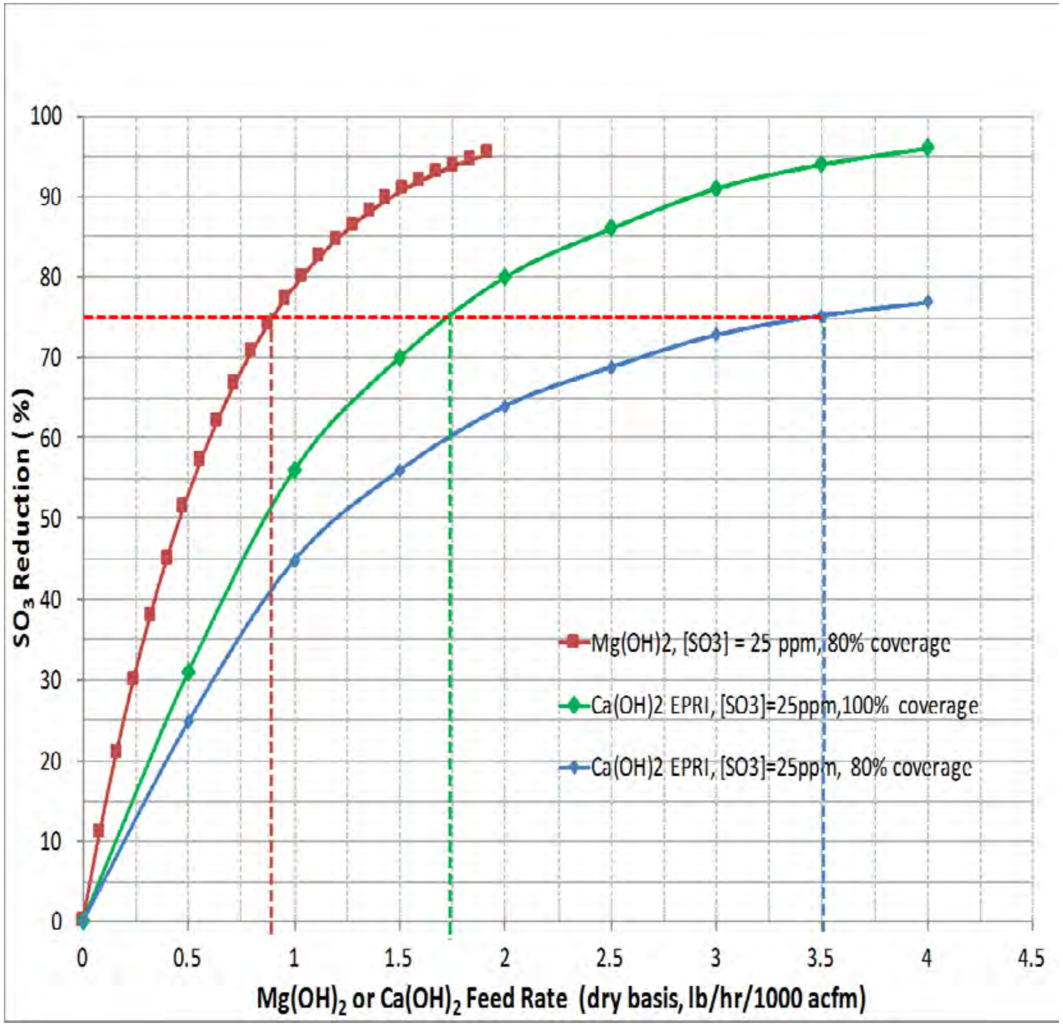

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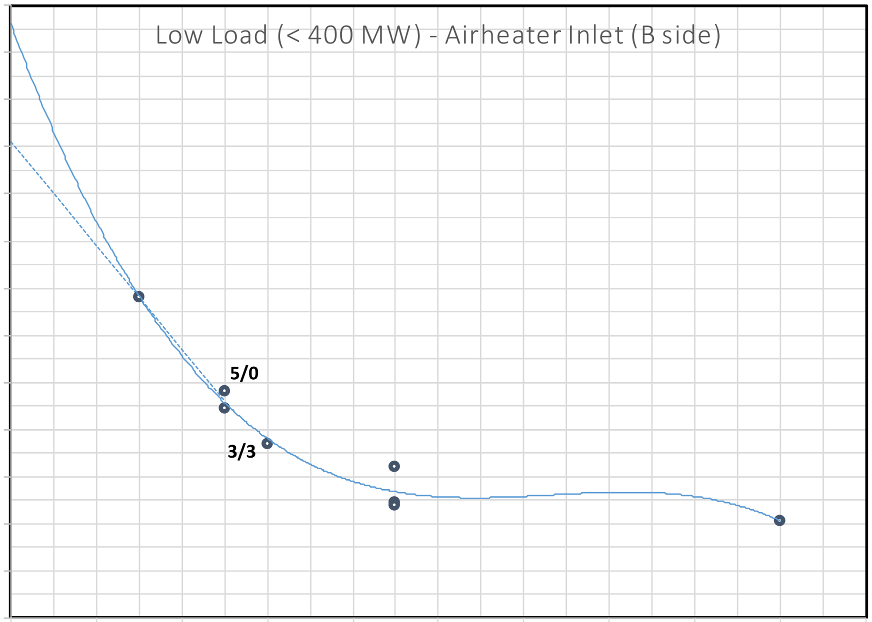
SO_3 Tests

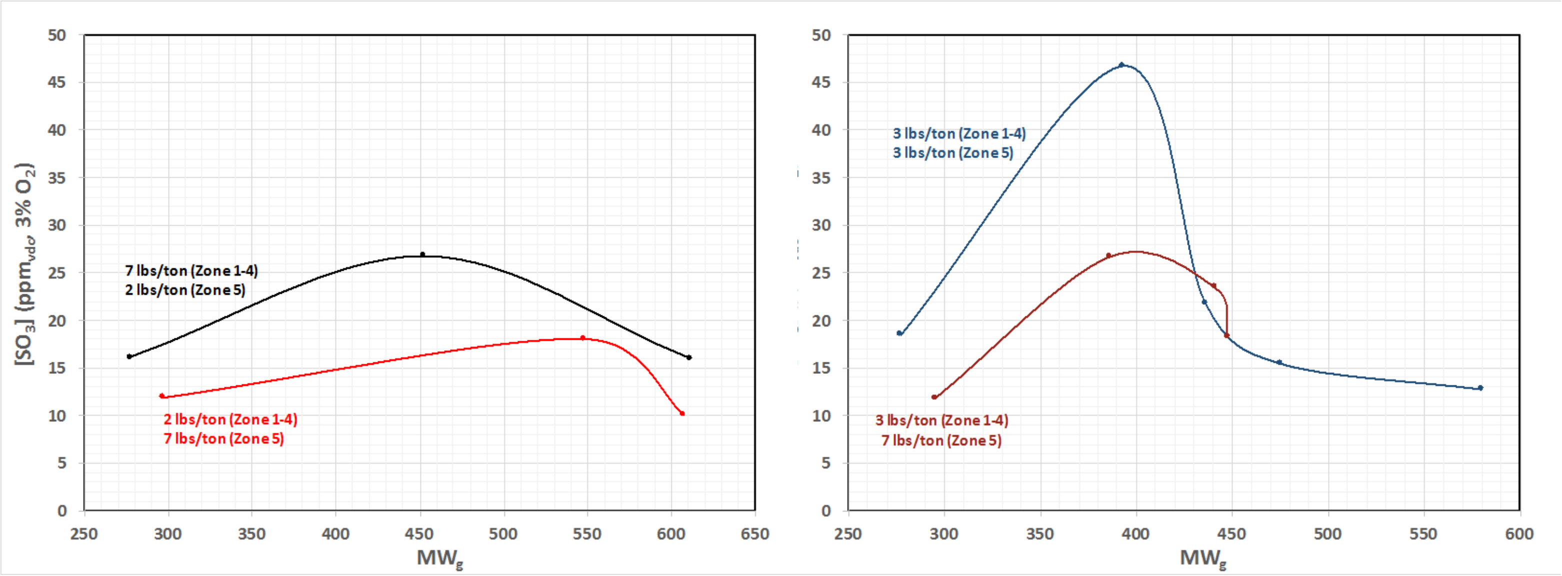
- Modified EPA Method 8A Controlled Condensate
- Single train sampling
  - Preliminary tests conducted to understand cause (dose) and effect (reduction) relationship
  - One SO_3 train measured AH inlet at low load, ramp period and full load
- Six train full test protocol July 13 -- 17
  - SO_3 measurement locations (both sides):
    - -- Economizer outlet
    - -- SCR outlet
    - -- APH outlet
- Unit configuration during measurements:
  - -- Low load
  - -- Ramp
  - -- High load
- Determined critical data on SO_2/SO_3 conversion rates, sorbent performance as a function of temperature during each unit configuration

Results at Low Load (< 400 MWg)



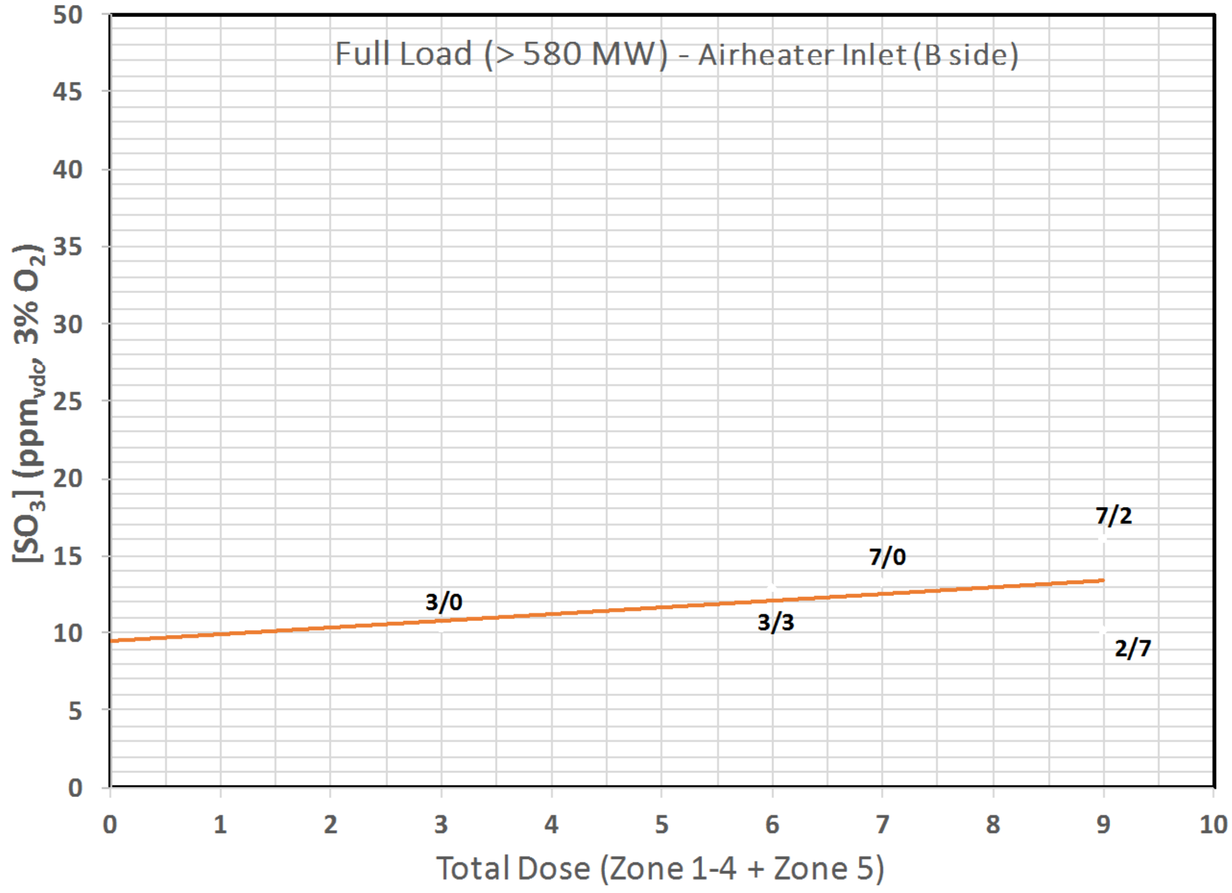
- Uncontrolled SO_3 concentration is 51 – 63 ppm_{vdc} (at 3.0% O_2)
- SO_2 concentration during this period averaged 3.66 ± 0.24 lbs/MMBtu
  - Corresponds to SO_2 = 1926 ± 125 ppm_{vdc} at 3.0% O_2
- Side B total conversion rate 2.6% -- 3.5%
  - Side B O_2's are approximately 1 -- 2% lower than Side A
  - Therefore Side A conversion is expected to be greater than Side B

Results During Ramp

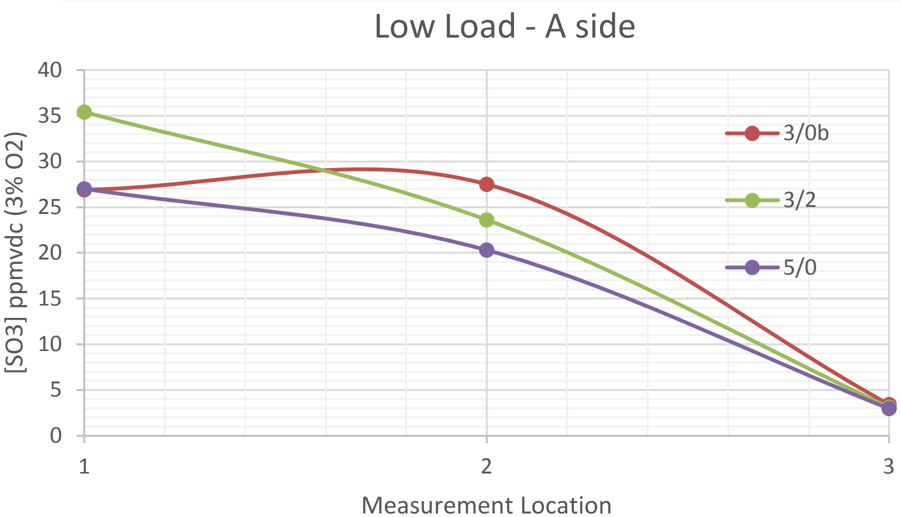


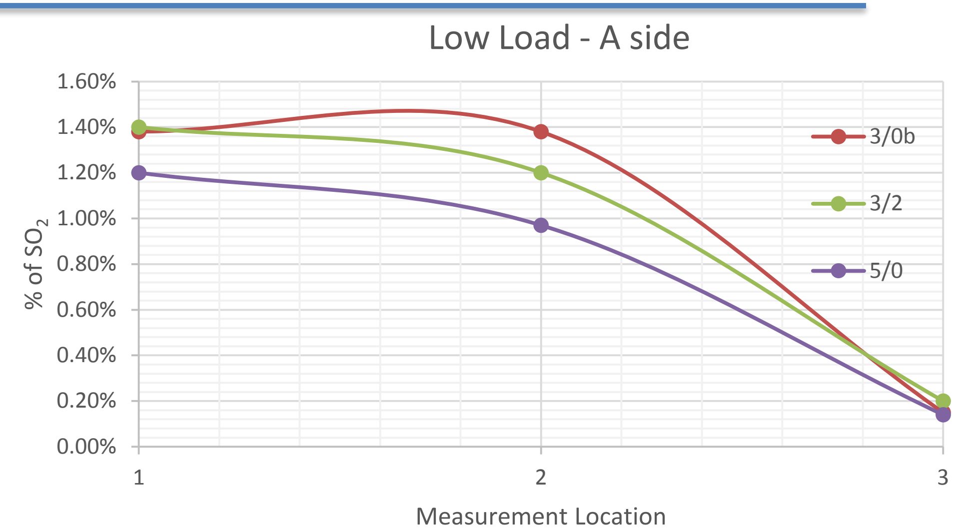
- As unit ramps, the catalyst releases stored SO_3.
- Increasing $Mg(OH)_2$ feed rate in zone 5 during ramp decreases severity of "burn off".
- Dance floor injection (zones 5) is 20% -- 30% more efficient than furnace injection for SO_3 control.

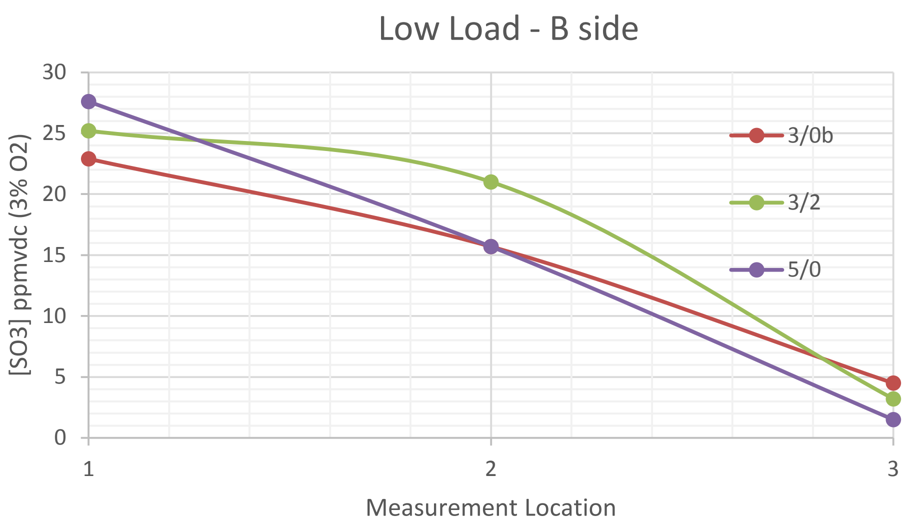
Results at Full Load

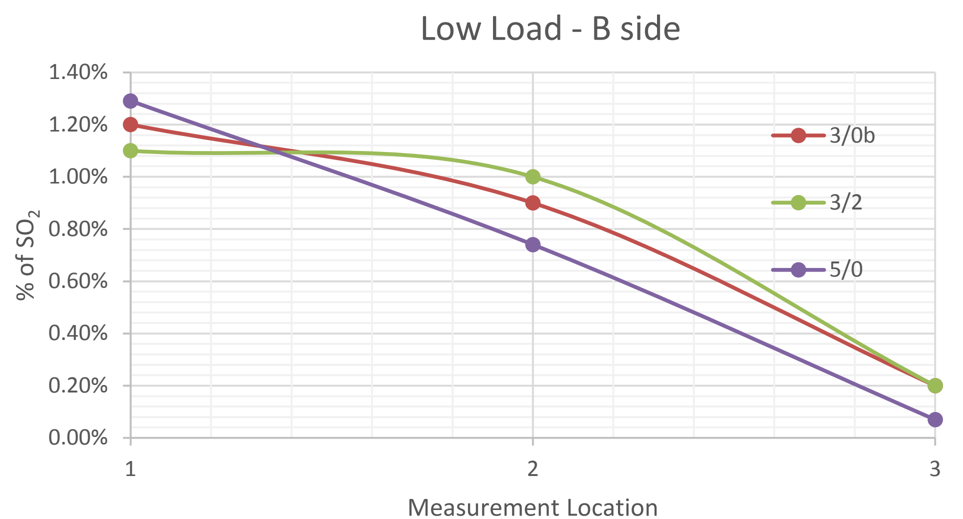


Low Load Results









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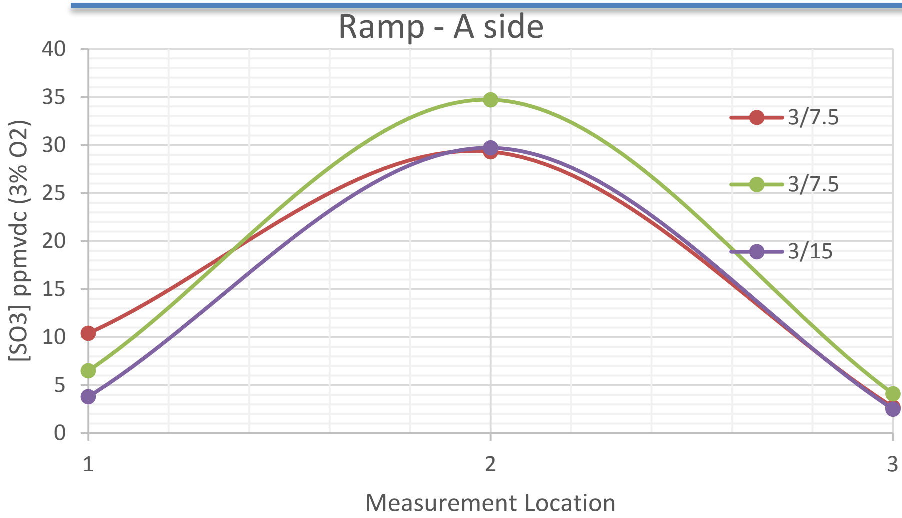
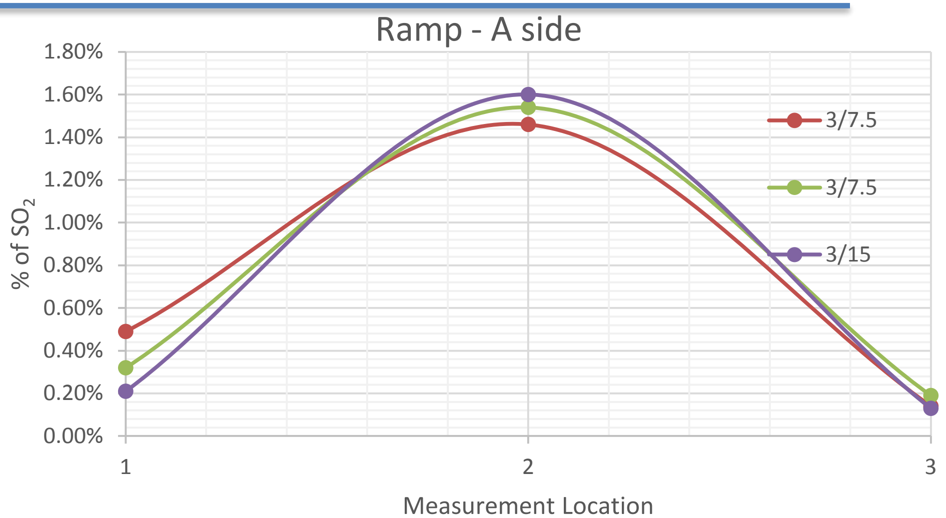
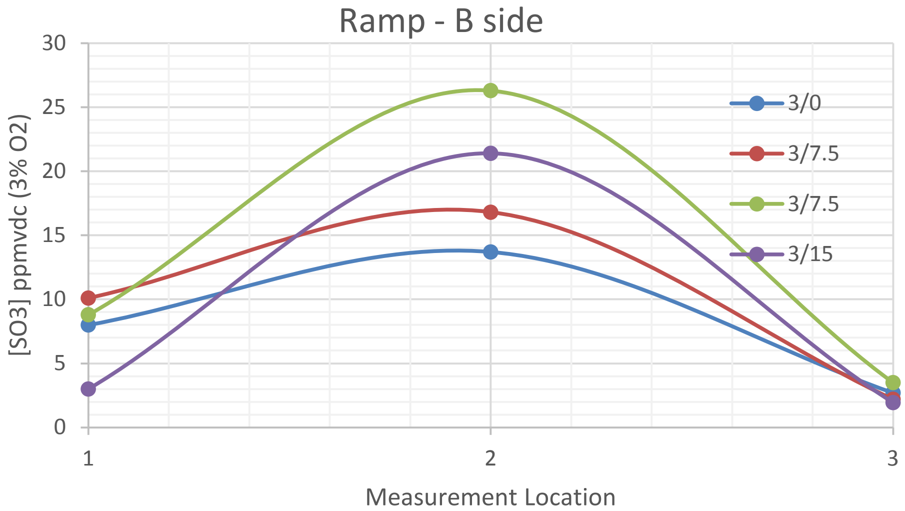
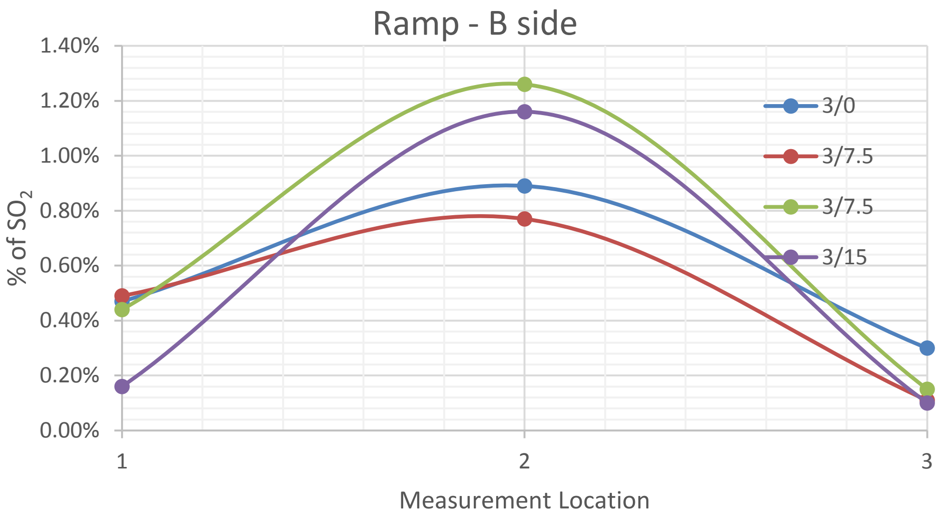
Ramp Results

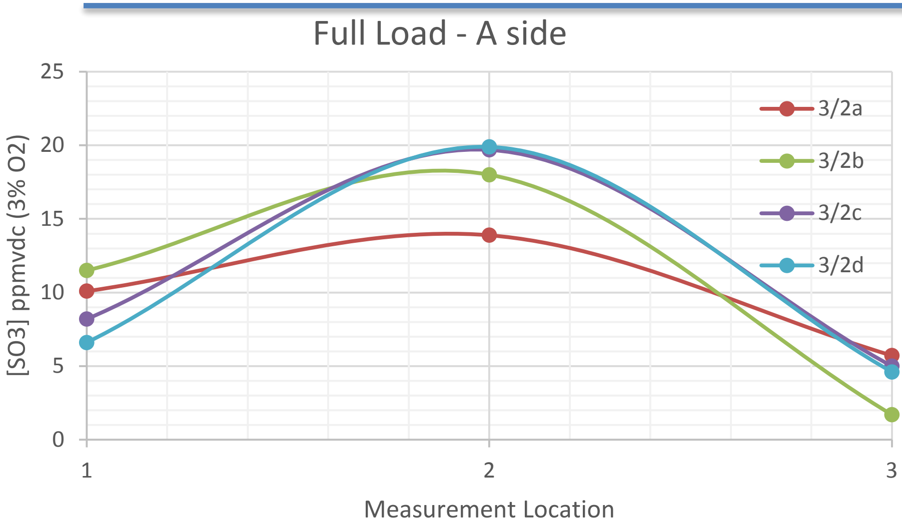


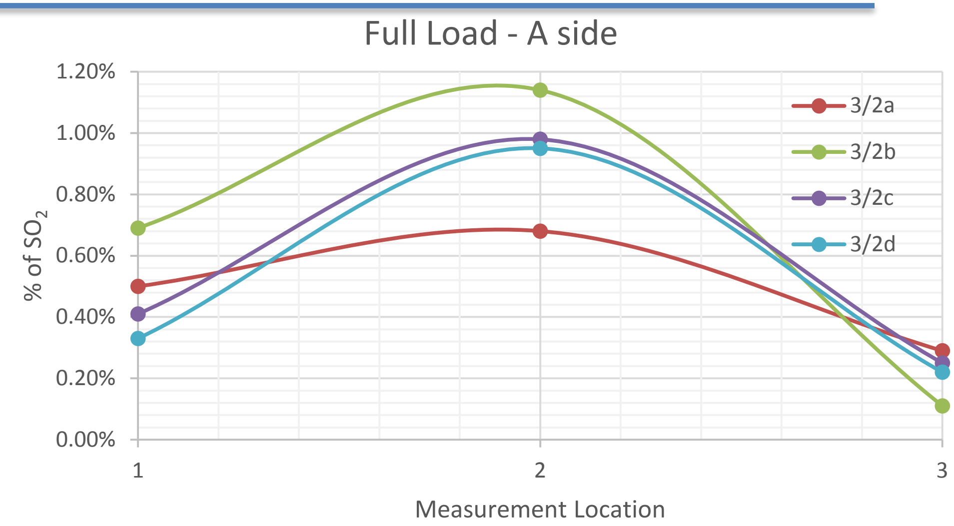


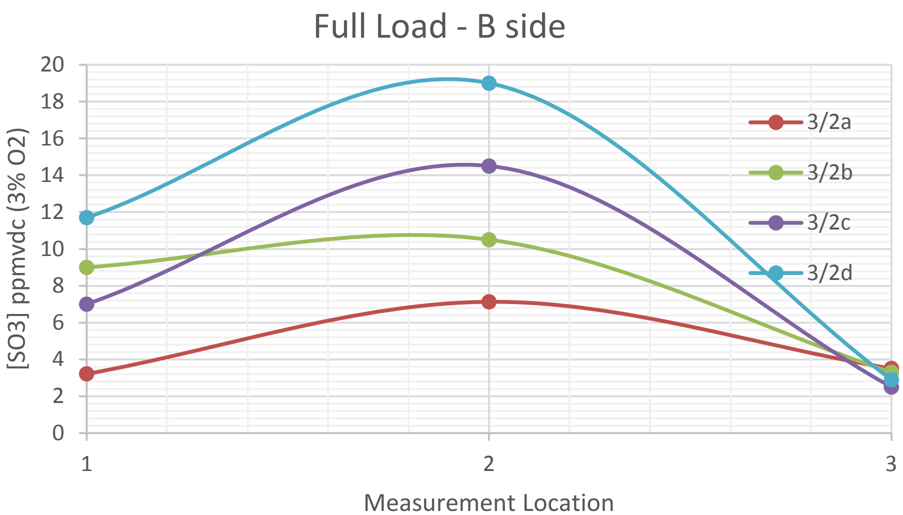


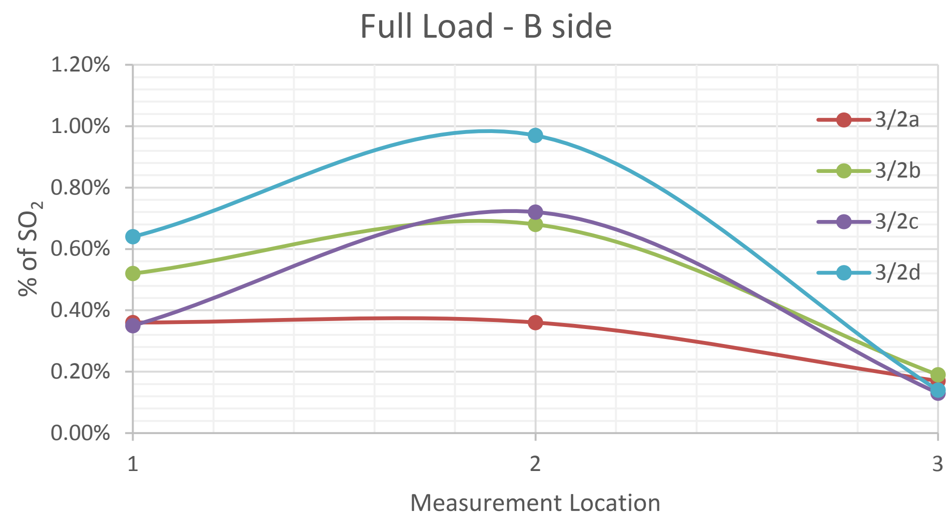


Full Load Results

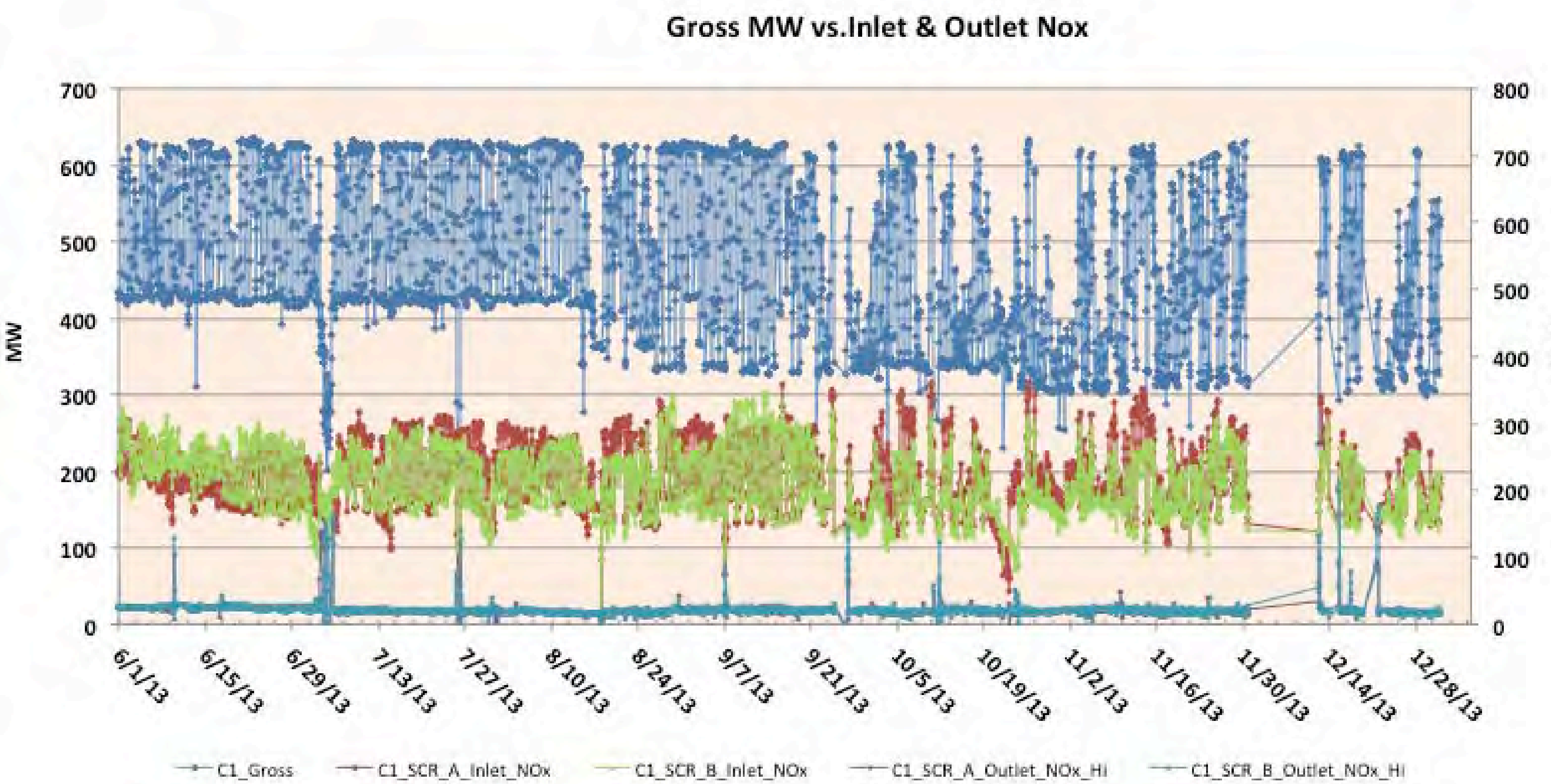








New Minimum Loads



- New limiting load factor – combustion stability
- Wider operating range may pay for all day chemical consumption

Additional Solutions

- Duct burner to raise the temperature
  - Pro: Provides the entire load range
  - Con: Economics
- Gas co-firing
  - Reduces SO_3 and NO_x concentration in the flue gas
- Burner improvements to reduce the NO_x concentration
- SNCR to reduce the NO_x concentration
- Waterside economizer bypass

Conclusions

- Several options are available to broaden the SCR operating range.
- Precise definition of low load operating conditions is mandatory.
- Operation below MOT can be detrimental if there is no mechanism to preclude ABS formation in the air pre heater.
- Economic evaluation important for optimized solution.
- TIFI is a solution especially for high sulfur applications to reducce SO_3 and broaden the operating range.

Thank You

Questions?