REINHOLD ENVIRONMENTAL Ltd.

2015 NOx-Combustion Round Table & Expo Presentations

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"Operations of SCRs with EPA's new Startup Rule"

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EPA New Rules Startup-Shutdown 4/15/2015 Nov. 7 2014 Provides for 2 options to startup

- **Option 1**
- Startup begins first firing of fuel into a boiler (startup or aux. fuel)
- • Must operate CEMS during startup
- • Must use "clean" fuel throughout startup and shutdown.
- Startup ends when first power is generated.
- When start burning Primary fuel
- • Engage PM equipment, WFGD, DSI and ACI.
- • Do not have to engage DFDG or SCR
- • Engage DFDG and SCR when you reach emission limits
- • Must comply with all applicable emissions limits at all times except for periods that meet the applicable definitions of startup and shutdown.
- • Record keeping and reporting

EPA New Rules Startup-Shutdown

- **Option 2**
- Startup begins with either the firing of any fuel in an EGU for the purpose of producing electricity or useful thermal energy
- All CEMS must operate during startup. Clean fuels to the maximum extent possible throughout the startup period.
- PM equipment must be engaged 1 hour after firing Primary fuel.
- Must meet the startup period work practice requirements as identified in §§63.10020(e).
- Startup ends 4 hours after any power is generated

EPA New Rules Startup-Shutdown

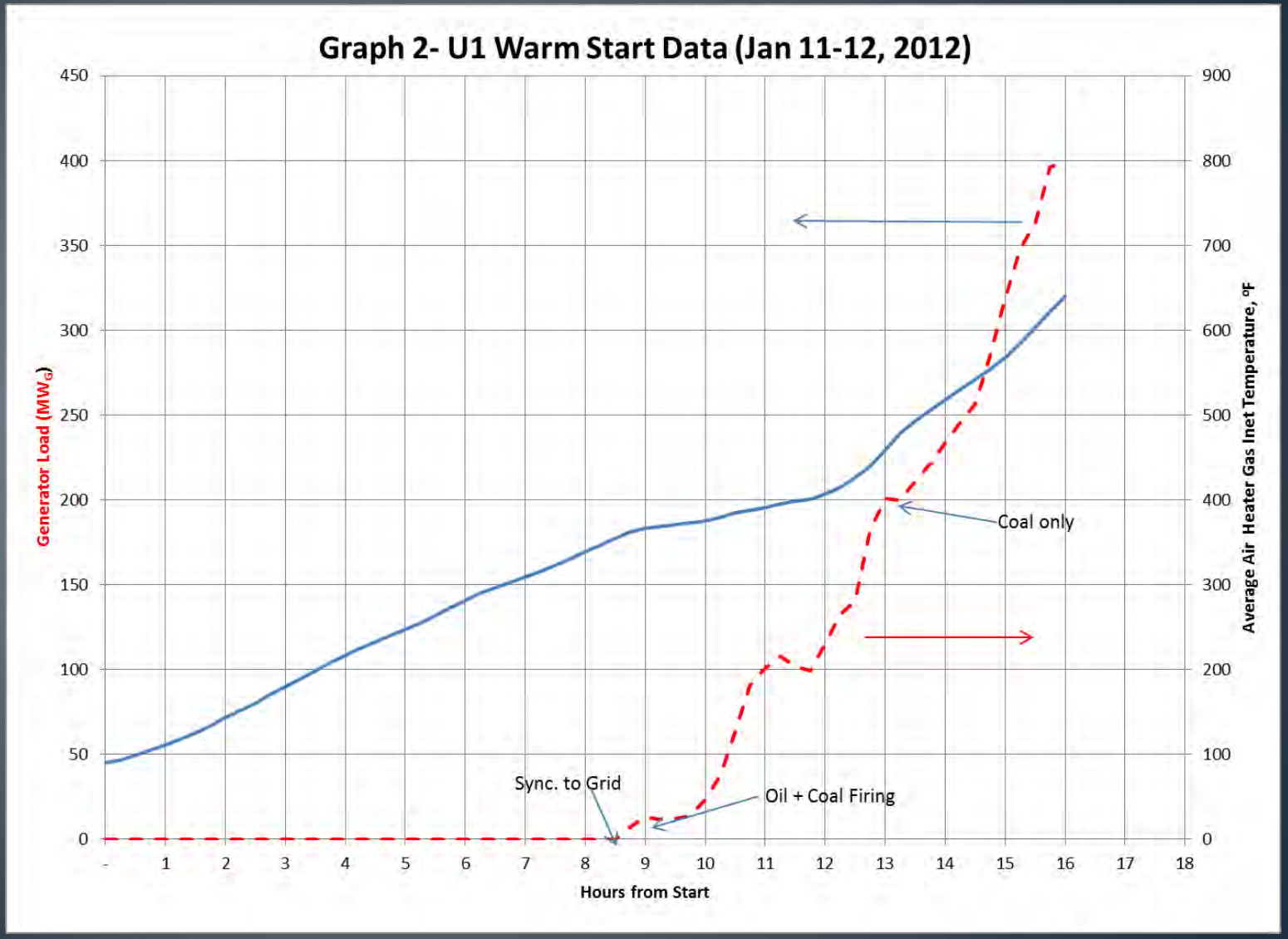
Option 2 Continued

- Once any power is generated, you must be in compliance with emission limits within 4 hours.
- Must start all other applicable control devices as expeditiously as possible, considering safety and OEM recommendations, but, in any case, when necessary to comply with other standards made applicable to the EGU by a permit limit or a rule other than this Subpart that require operation of the control devices
- You must keep records during startup periods

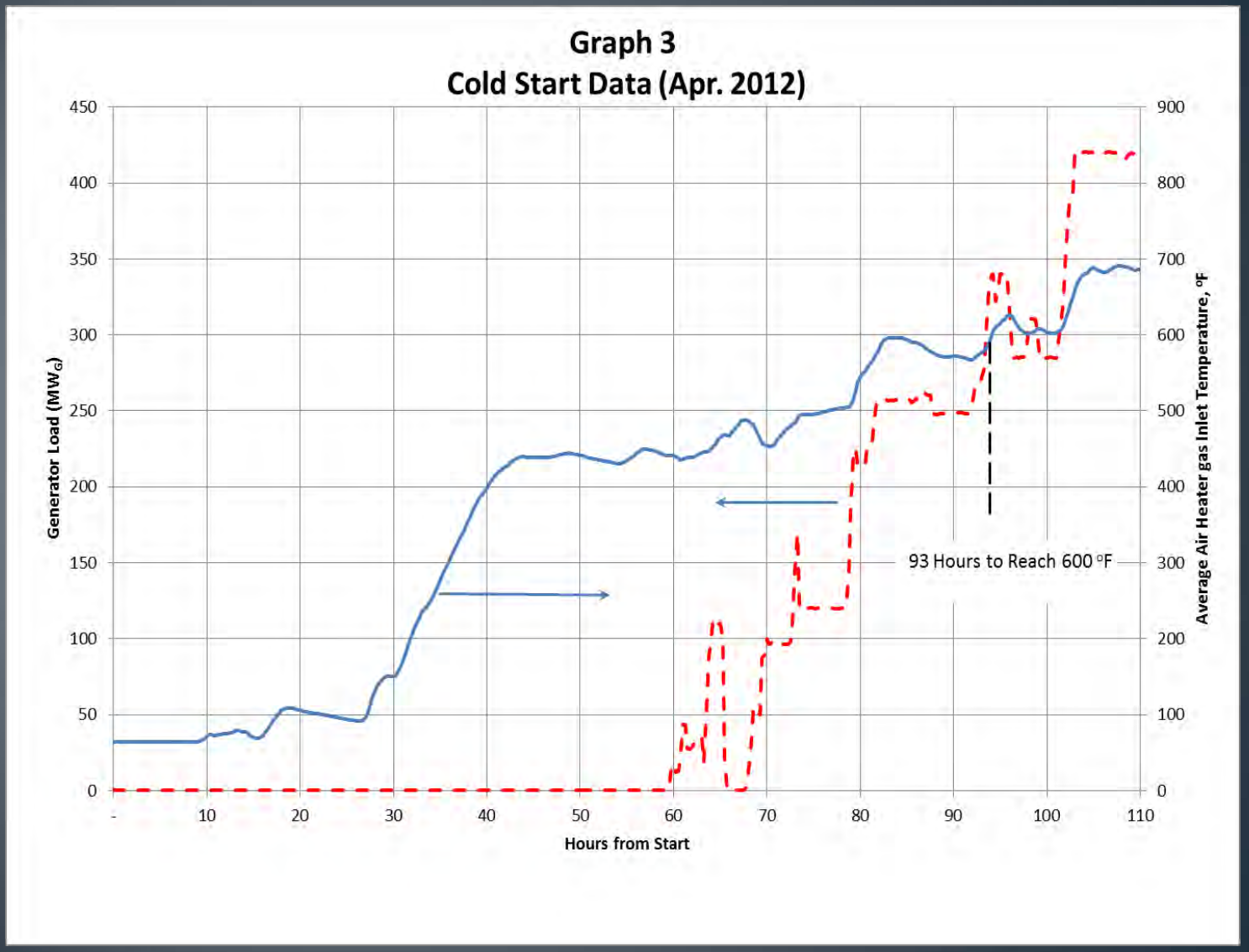
O&M Issues Coal Fired Plants

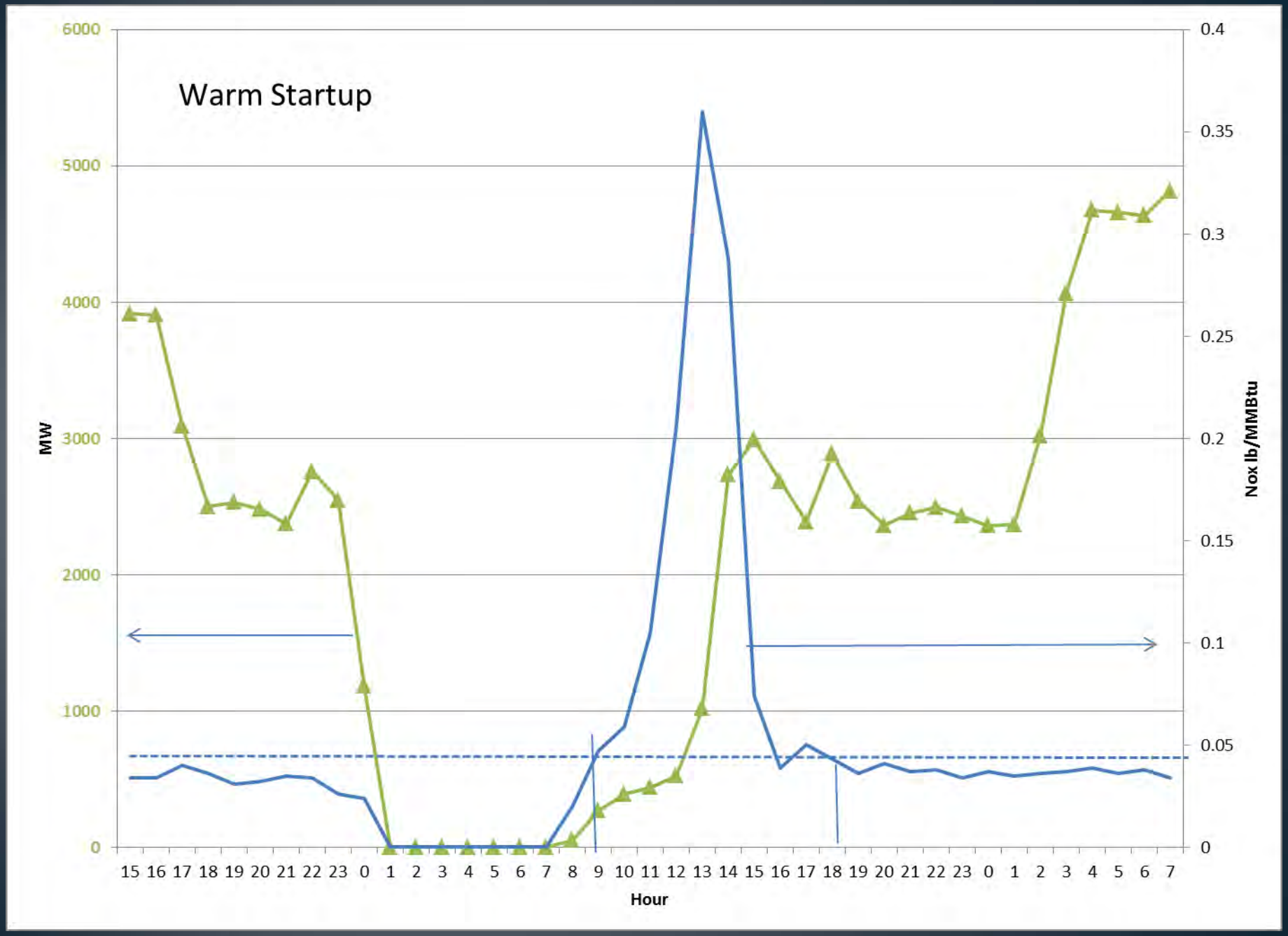
- Other Industry Challenges Cycling Loads
- "Green" Energy and gas price: coal plant cycling
  - Shutdowns: hours to a few days
- Low load operations
- Improved heat rate for CO_2 Rule
- Burn more startup fuel !!!!!!
- Economizer Bypass
- DSI applications
- Low NOx Burners
- Change operating procedures

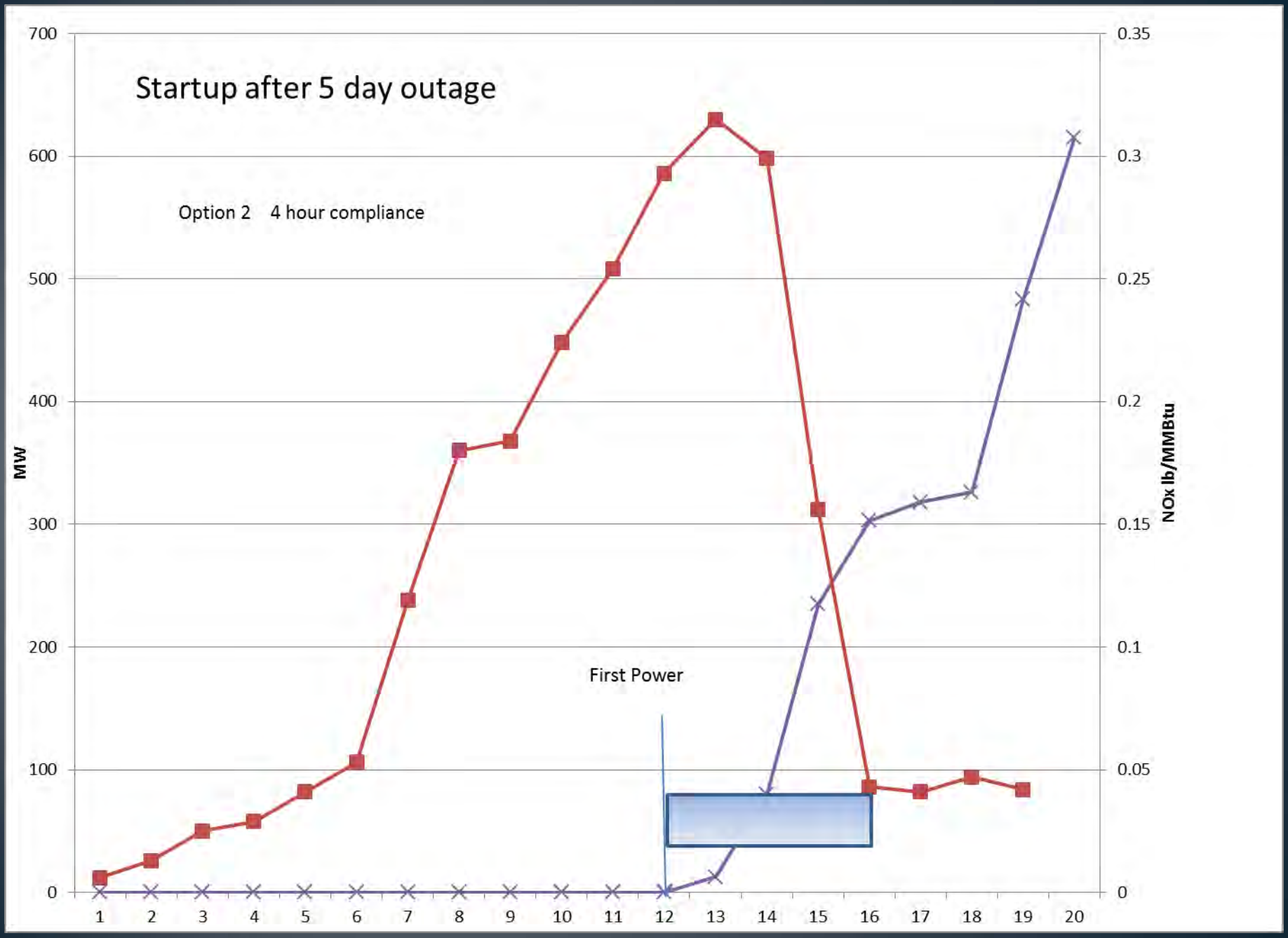
Warm Startup



Cold Startup




Warm Startup
MW
Nox lb/MMBtu
Hour
6000
5000
4000
3000
2000
1000
0
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
15 16 17 18 19 20 21 22 23 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 0 1 2 3 4 5 6 7


Startup after 5 day outage
Option 2 4 hour compliance
First Power
MW
NOx lb/MMBtu
700
600
500
400
300
200
100
0
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20

Can DSI Help????

- How soon can we turn on or turn off on DSI & carbon systems.
- Prevent deposits forming in ductwork.
- Sorbent contact with acid gases/Hg at low flow conditions -**mass transfer**
- Does the chemistry work at lower temperatures seen during startup/shutdown?
- Contact time
- Impacts on balance of plant

SO_3 Acid Dew Point Curve

Ken Fast - AEP

Basics of Mercury Oxidation

As halide content in the flue gas increases, the oxidized mercury content from the SCR outlet INCREASES.

As the NH_3 content in the flue gas increases, the oxidized mercury content from the SCR outlet DECREASES.

As the O_2 content in the flue gas increases, the oxidized mercury content from the SCR outlet can either INCREASE or DECREASE.

As the V_2O_5 content of the catalyst increases, the oxidized mercury content from the SCR outlet INCREASES.

As the space velocity through the SCR increases, the oxidized mercury content from the SCR outlet DECREASES.

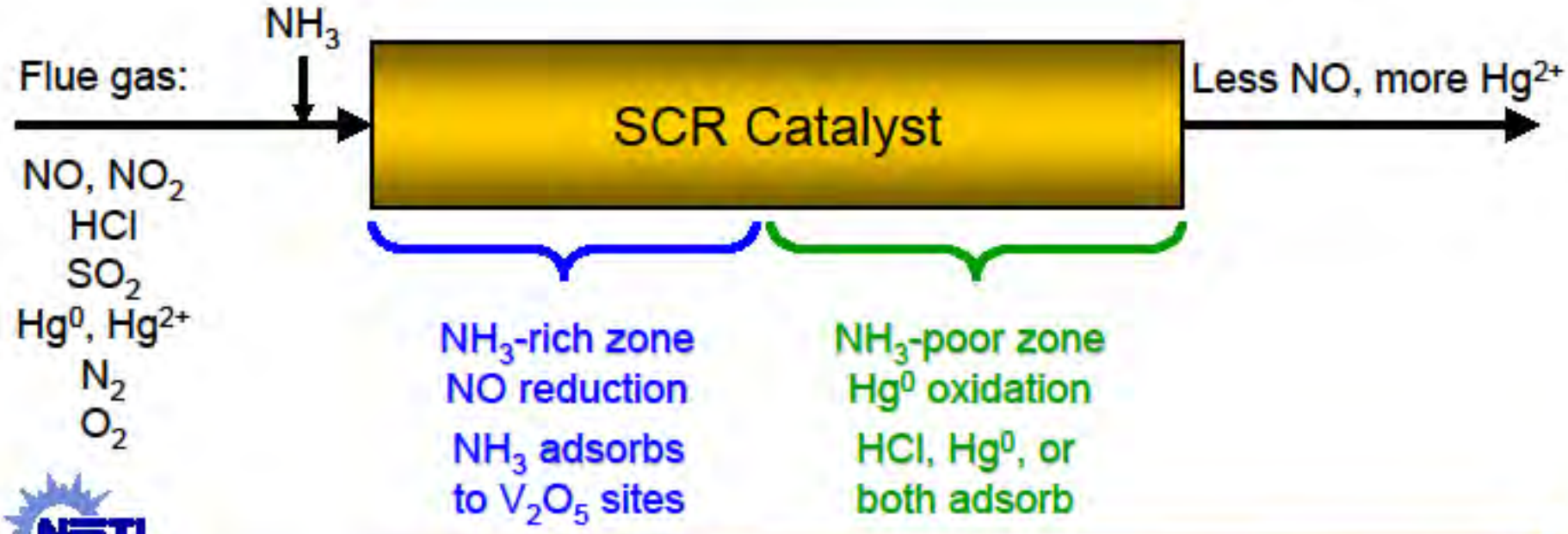
- Space Velocity is a measure of volumetric flow passed through a volume in a specific time frame. Ex: 1000 m^3/hr passed through a 1000 m^3 volume gives us a space velocity of 1 hr^{-1}.

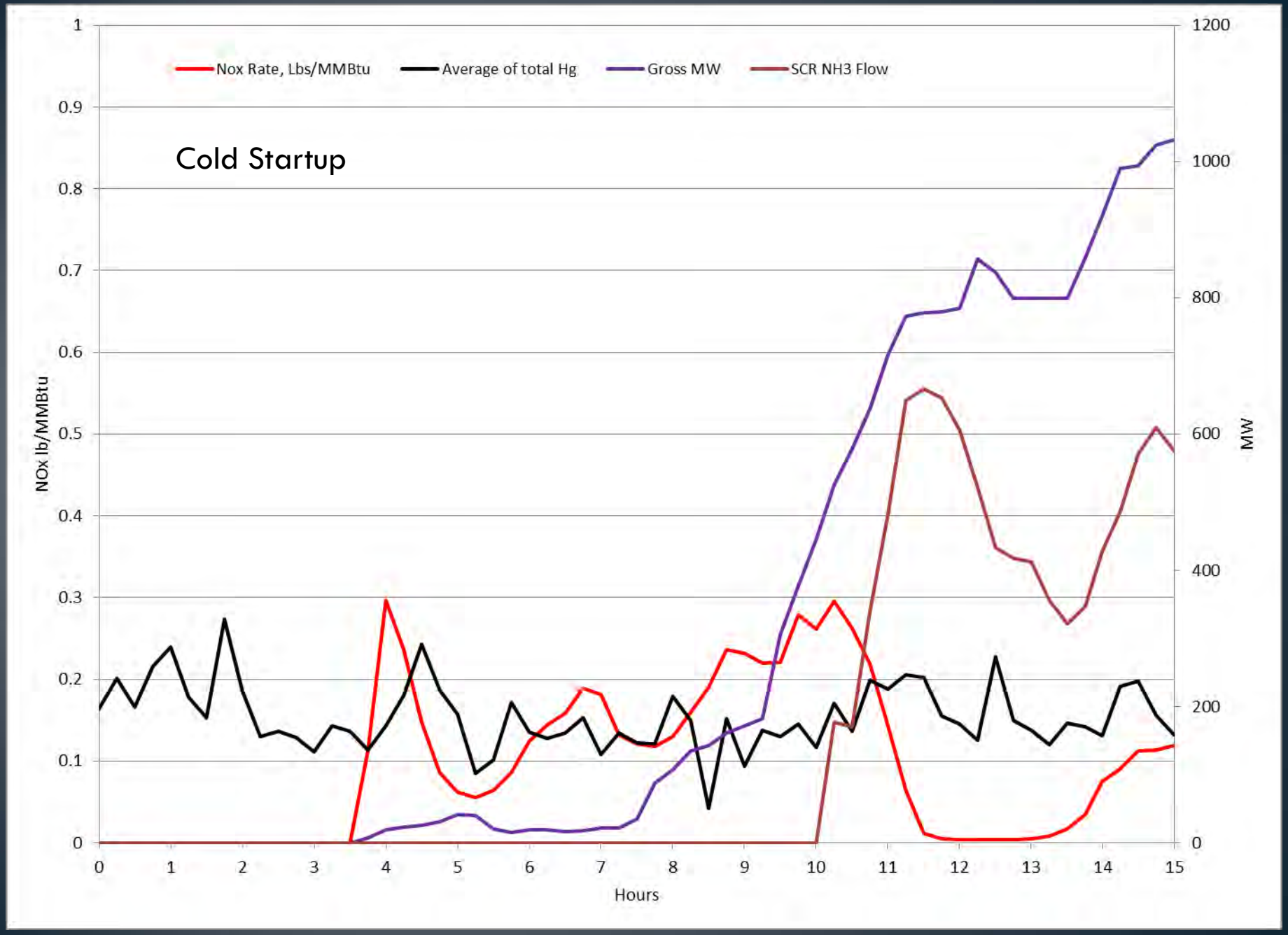
As temperature increases, the oxidized mercury content DECREASES.

- Highest oxidation at 600 deg. F with NH_3 (simulated flue gas)
- Highest oxidation at 700 deg. F without NH_3 (simulated flue gas)

SCR Catalysts

- **Used for reduction of NO to N_2**
  - V_2O_5/WO_3 on TiO_2 support
  - T > 300° C



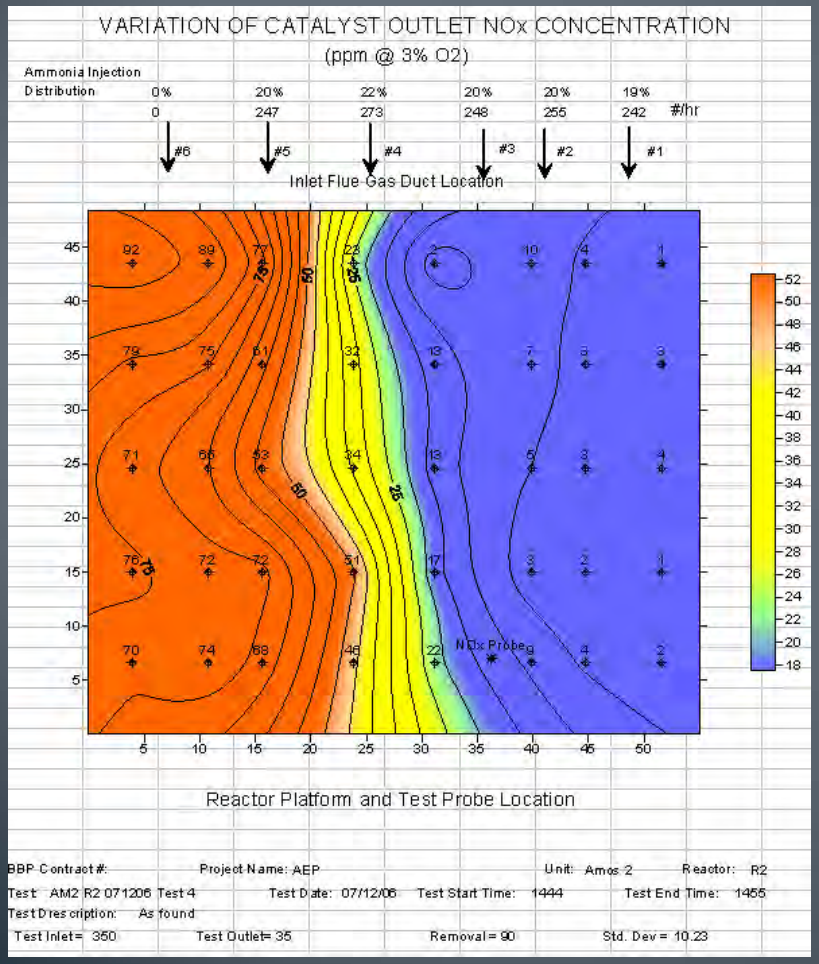

Nox Rate, Lbs/MMBtu
Average of total Hg
Gross MW
SCR NH3 Flow
Cold Startup
NOx lb/MMBtu
MW
Hours
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
0
200
400
600
800
1000
1200
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15

SCR Operation

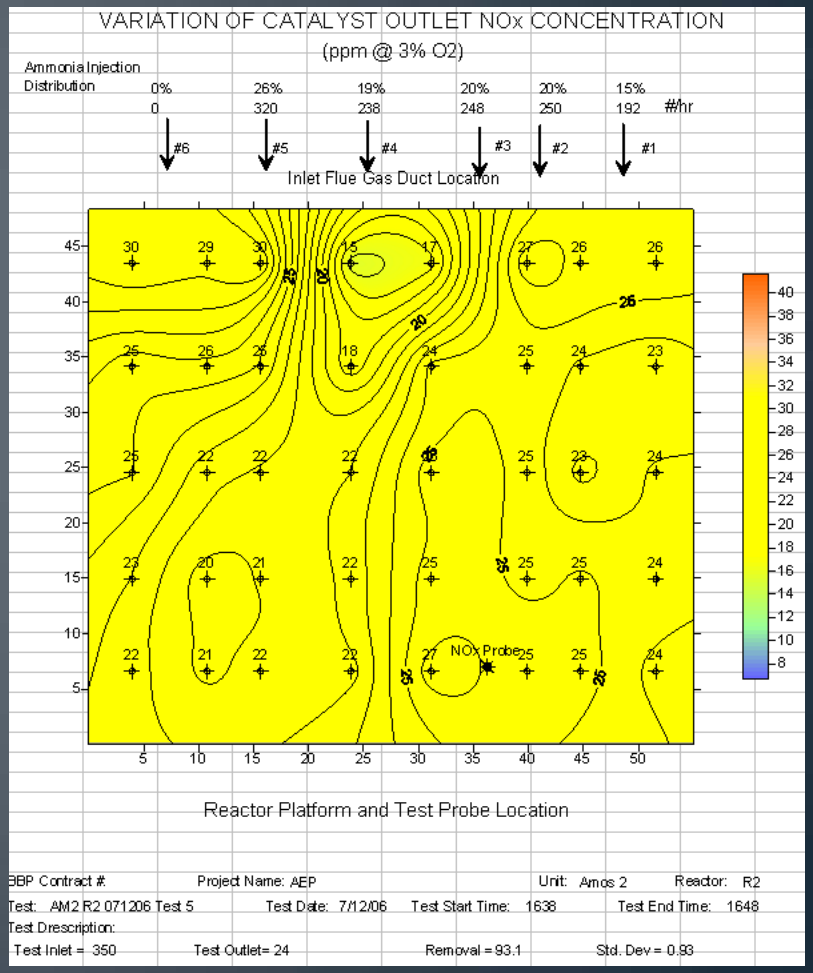
- SCR Bypass
  - Recommend that bypass be eliminated for mercury oxidation during startup phase
- Adhere to OEM temperature ramp rates
  - Implement/improve oil lighter maintenance program
- Burner maintenance program
- NH_3 injection controls tuning
  - Reduce NH_3 over injection and slip on load ramps
- Elevated focus on NH_3 distribution balancing

The Goal of Tuning NH_3 Systems

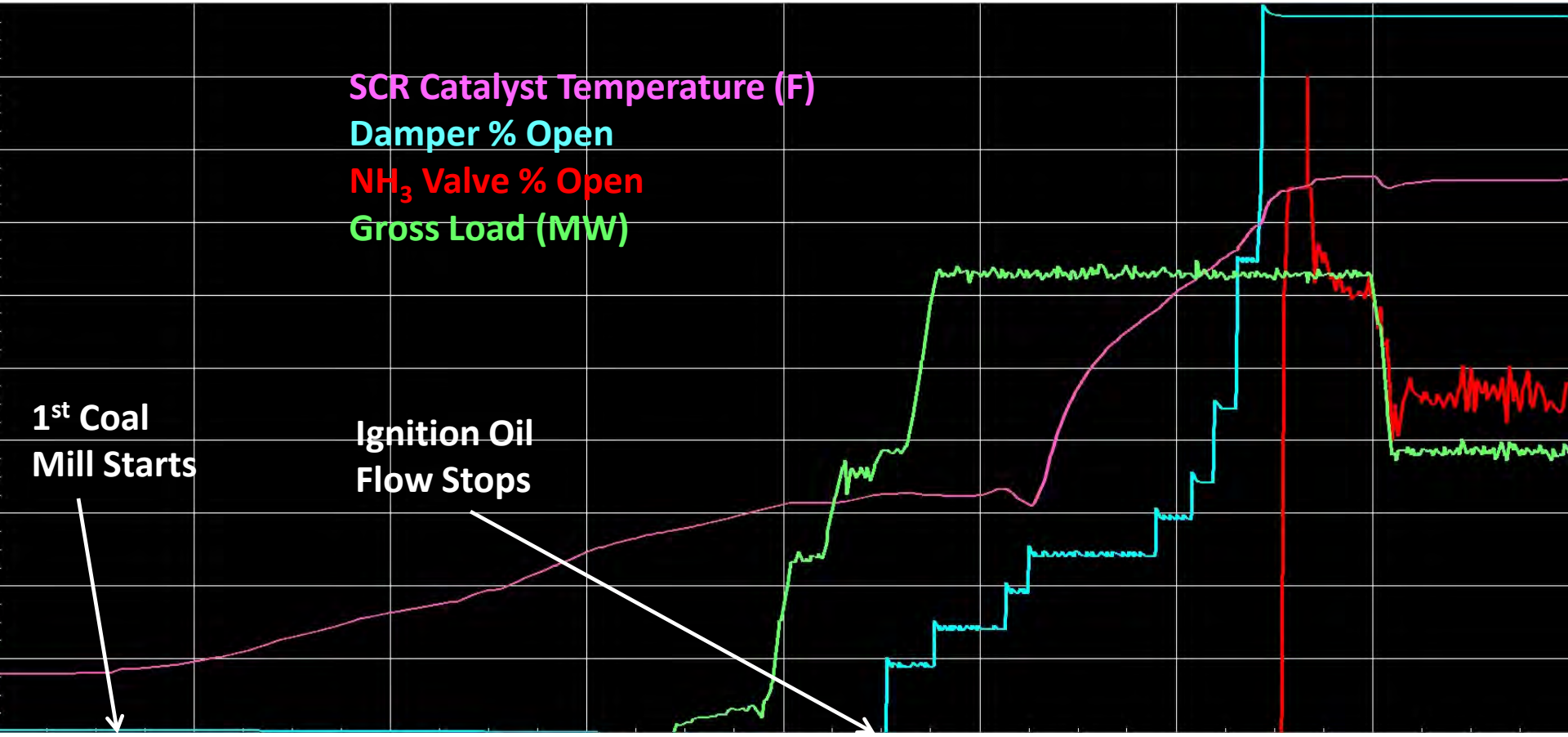
Make This



Look Like This



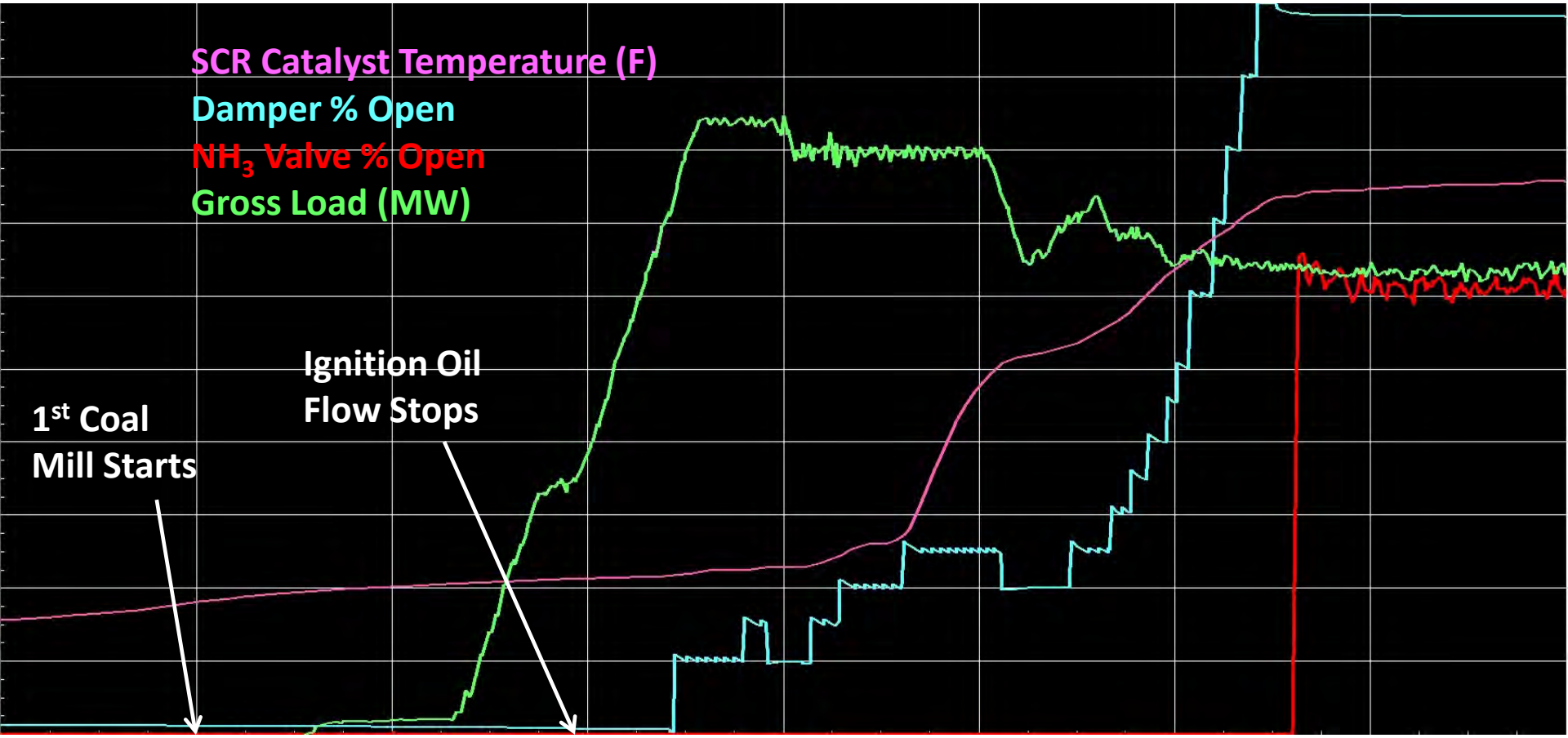
Ned West – Southern Company



SCR Cold Startup

1 day, 18 hours elapsed time

SOUTHERN COMPANY



SCR Hot Startup

1 day elapsed time

SOUTHERN COMPANY

Southern Company

- At present we plan to use start-up Option 1.
- We currently begin to open the SCR dampers after all oil ignitors are out of service. If necessary, we could open SCR dampers several hours earlier when the first coal mill is in stable operation.
- We currently have a fixed MIT of about 600 F as an ammonia injection permissive for each SCR. We plan to begin calculating the MIT and MOT dynamically based on SO3 and NH3 concentrations which are inferred from SO2 and NOx measurements.

Discussion of DSI Applications for SCR Startups

What Can We Do?

- Modeling - most modeling for flow distribution and deposition done at full load conditions.
- Need to model at low flow conditions
- Inspections of ductwork after cycling operations
- Use CEMS when possible to optimize sorbent injection.
- Other
  - Better distribution
  - More frequent tuning
  - Frequent cleaning of catalyst & airheater
  - DSI injection ahead of airheater

Benefits of DSI Injection During Start/Shutdown and Cycling Operations

- With increased cycling operations we expect to see increased corrosion along the flue gas path. DSI could mitigate corrosion that will develop with these operating conditions
- Allow SCRs to startup earlier (lower operating temp.)
  - Startup - Shutdown Conditions
  - Turn on ammonia ≈ 600 °F
    - Actual depends on fuel primarily sulfur
  - SCRs are temperature driven – no relationship to MW generation

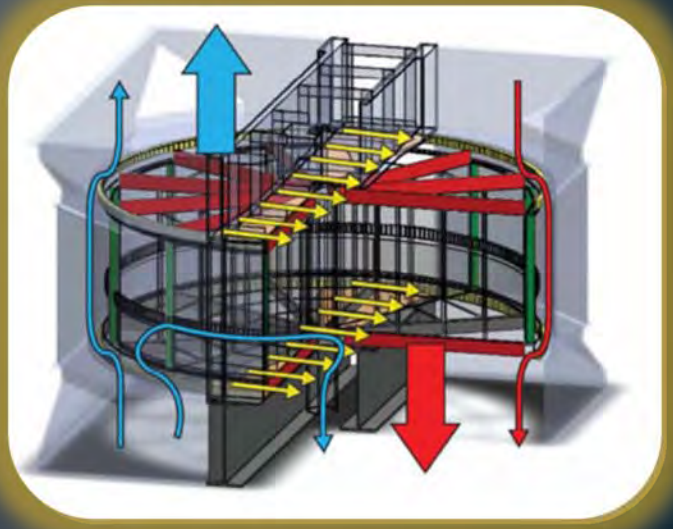
Typical SCR Startup & Shutdown

- Startup - Shutdown Conditions
  - Temperature limited by ABS formation that fouls airheater
  - ABS needs SO_3 and NH_3
  - Take SO_3 out and you can start injecting NH_3 sooner which will result in reducing NOx and being in compliance sooner
  - DSI before catalyst or airheater
    - May be able to lower startup temperature from 600 $\longrightarrow$ 540 °F

Benefits of SO_3 Removal prior to the APH

APH operations

- Eliminate ABS buildup from ammonia slip
- Reduce dP growth over time
- Eliminate outages for cleaning



Benefits of Pre-APH Removal of SO_3

<u>Improve Heat Rate/Reduce CO_2 Emissions</u>

- Reduce SO_3 Dew Point prior to APH
- Reduce operating temperature of APH

40°F reduction → 1% heat rate improvement → 1% savings on fuel budget

- Reduction in CO_2 emissions
  - 1 lb coal → 2.5 lb CO_2

DSI Challenges

- Emissions Control
- Operate over wide range of load conditions
- Can it play a role in heat rate improvement
- "Net" low cost sorbents that minimize impact on other APC equipment performance and ash management

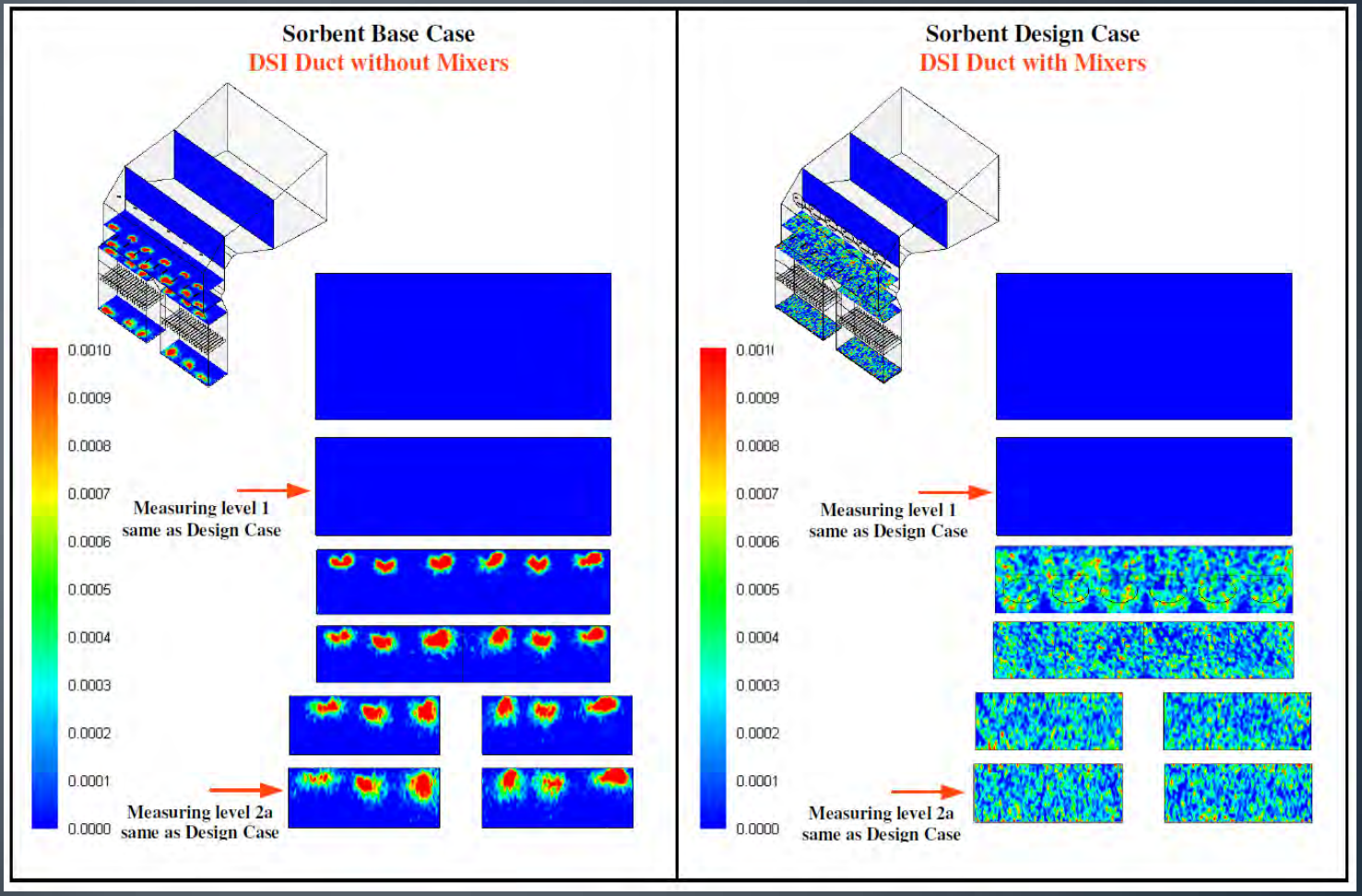
DSI Design

- Periods of operation, especially for boiler startup, characterized by rapid transient changes in flue gas composition, quantity, temperature, and moisture conditions.
- The problems are aggravated with installation of multiple APC equipment and processes, especially those required to achieve MATs compliance.
- Minimize Sorbent usage
  - Cost
  - Ash
  - Other APC equipment

Key To DSI Design

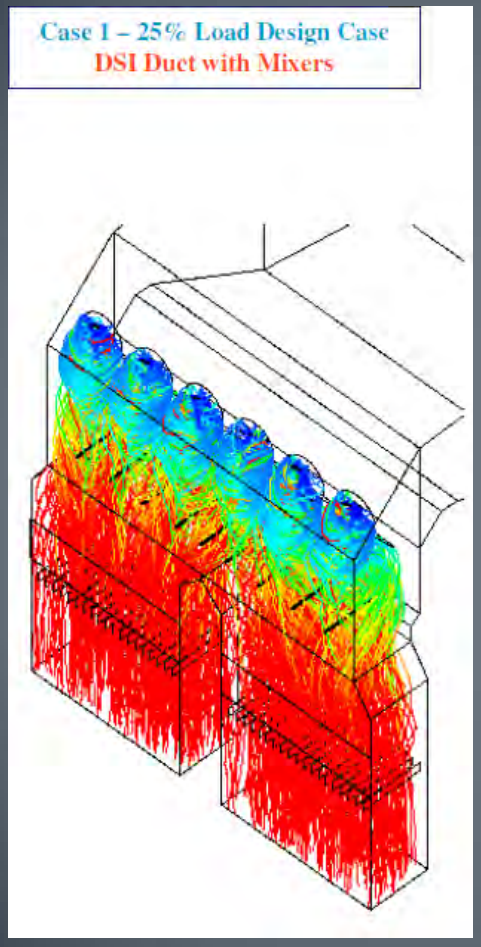
- Distribution of sorbent
- Get the sorbent to the pollutant in the flue gas
- Adjustable feed rate – don't overfeed or underfeed
- Modeling
- Mixing
- Maintain Calcium/air ratio in transport pipe and injectors (>0.4 lbs hydrate: lb air)
  - High air (low ratio) -> tendency toward scale
  - Low air (high ratio) -> stay above saltation velocity

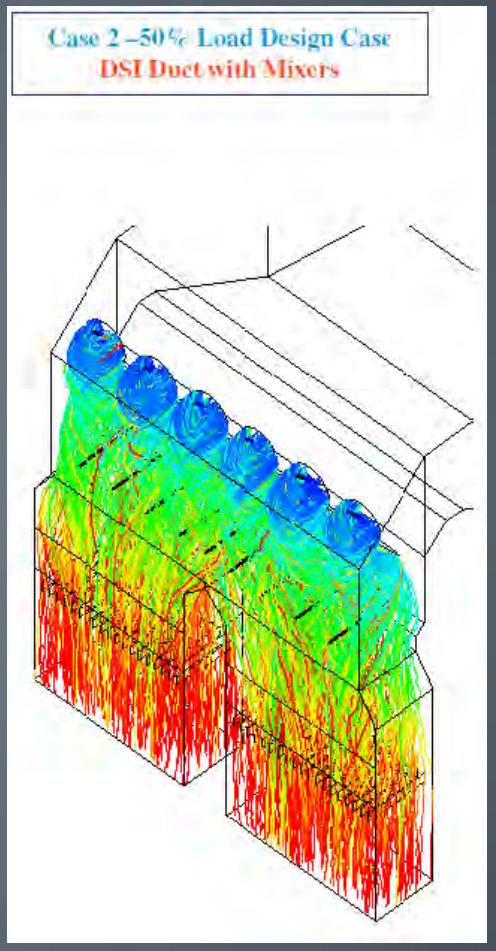
Use of Mixers for Uniform Distribution

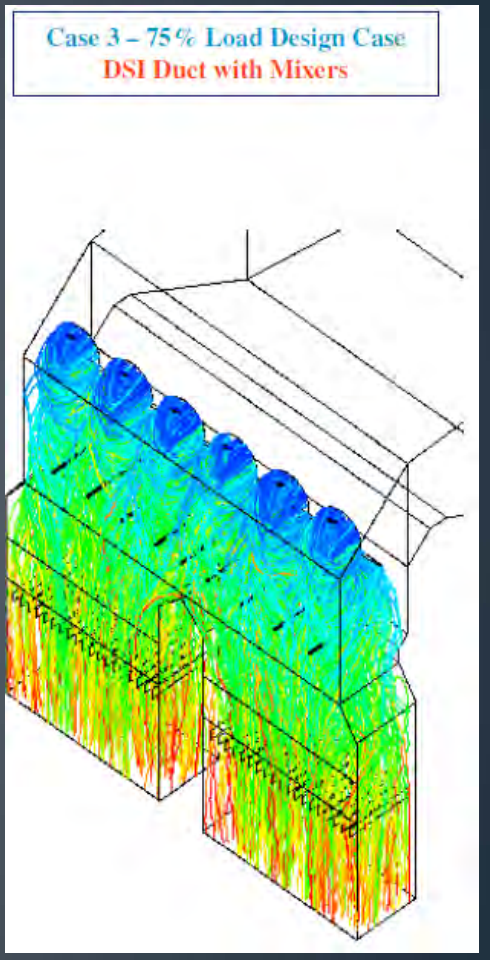


Provided by Babcock Power

Mixing at Various Loads





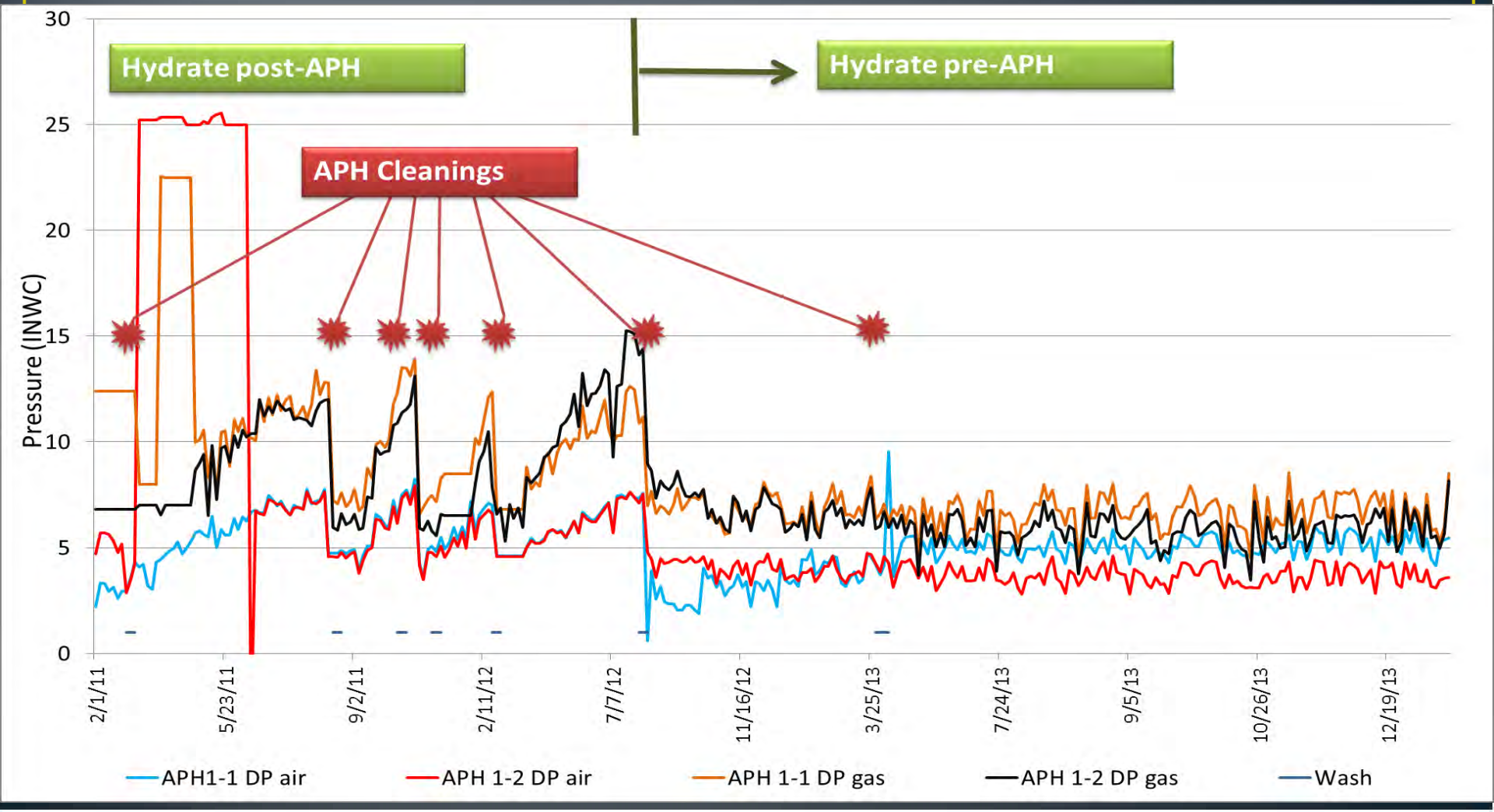


Provided by Babcock Power

Pre-APH with DSI
Where are We Now?

- Significant testing, retro-fits, and installations in past 3 years
  - Over 35 units (~23 GW)
- Many units have operated with Pre-APH injection of hydrate for over 12 months and multiple outage cycles
- SO_3 is being controlled
- Air preheaters are staying clean

Hydrated Lime Injection Upstream of APH
Example of Recognized Improvement



TVA – Paradise Units 1 & 2
Benefits from Pre-APH Injection of Hydrate

Post-APH Injection of Hydrated Lime (Jan '11 – Mar '13)

- Over **570,000 MWh** were lost as a result of air heater fouling from both units

Pre-APH Injection of Hydrated Lime (Mar '13 – Current)

- **0 MWh** have been lost as a result of air heater fouling
- Have not experienced any APH pluggage attributed to hydrate injection
- Contributing Factors:
  - Air Heater maintenance
  - Combustion Tuning
  - SCR catalyst replacement/ Tuning

Injection of DSI Pre-SCR

Benefits

- Earlier control of SO_3
- Longer contact time
- Enhanced mixing

Concerns

- Fouling of catalyst
  - No signs of deactivation on test conducted to date
- Likely need secondary hydrate injection point downstream of SCR
- Implications of HCl removal on Hg

Questions & Answers

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