REINHOLD ENVIRONMENTAL Ltd.

2015 APC Round Table
& Expo Presentation

July 13 & 14, 2015, in Atlanta, GA / Hosted by Southern Company

Plant Efficiency Improvement via SO_3 Control and APH Upgrade

Sterling Gray, AECOM
Louis Bondurant, ARVOS

Reinhold Environmental APC Conference
July 14th 2015, Atlanta, GA

LJUNGSTRÖM | ARVOS GROUP
AECOM

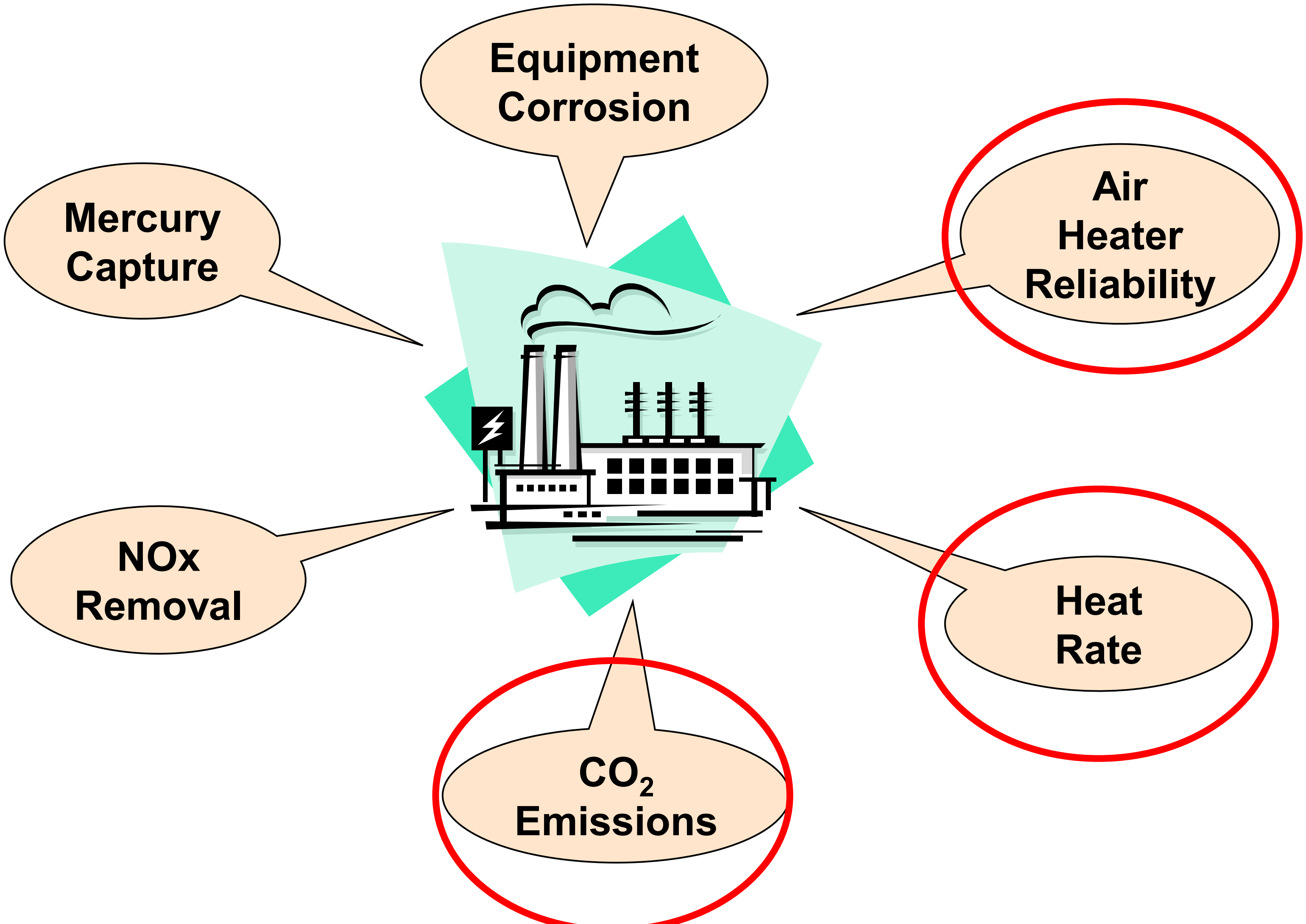
I. SO_3 Impacts and Removal

II. APH R&D and Efficiency Upgrades

III. Long-Term APH Efficiency Demo

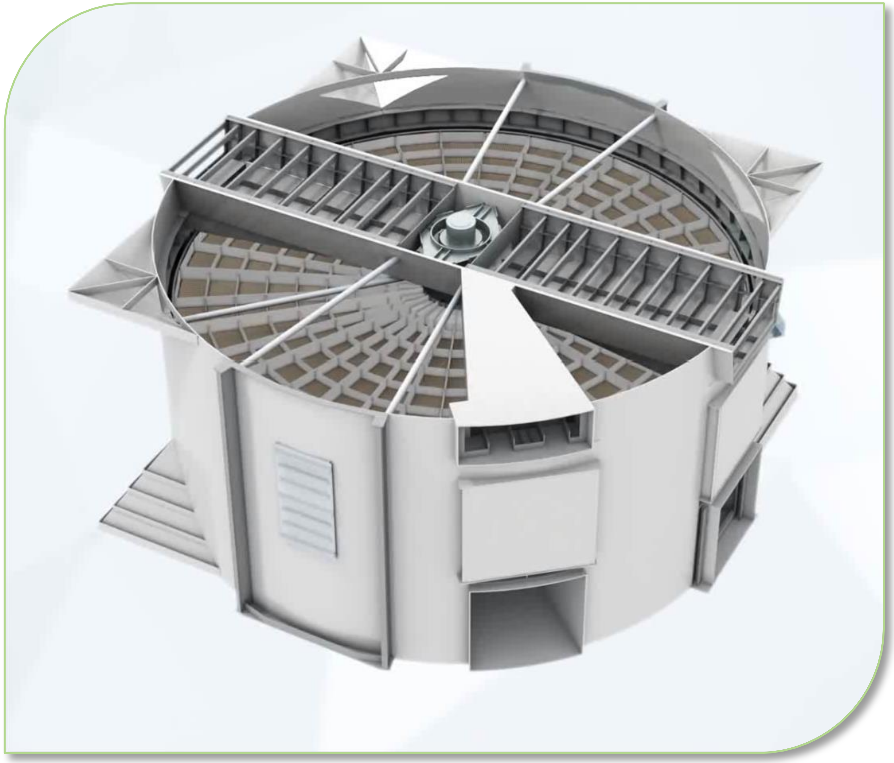
IV. Summary and Conclusions

SO_3 Adversely Impacts …



AECOM

Air Heater Fouling Agents



Ash

Sulfuric Acid

Ammonium Bisulfate

AECOM

Strategy: APH Performance Improvement

1) Inject Sorbent to Remove SO_3 Prior to Air Heater

$$SO_3 + H_2O \rightarrow H_2SO_4$$

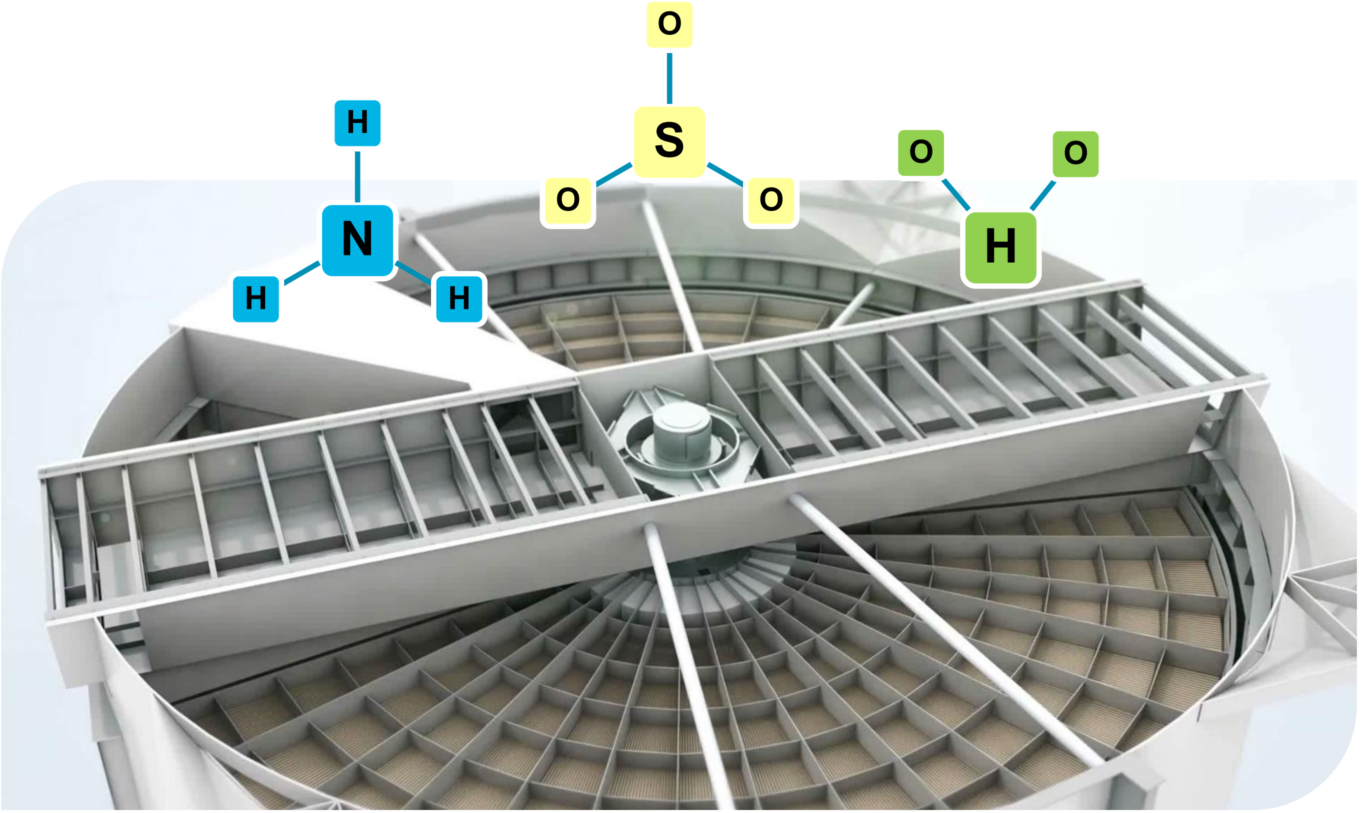
$$NH_3 + SO_3 + H_2O \rightarrow (NH_4)HSO_4$$

2) Change Air Heater to Reduce Exit Gas Temp

- *Reduce or eliminate air pre-heat*
- *Modify air heater internals*

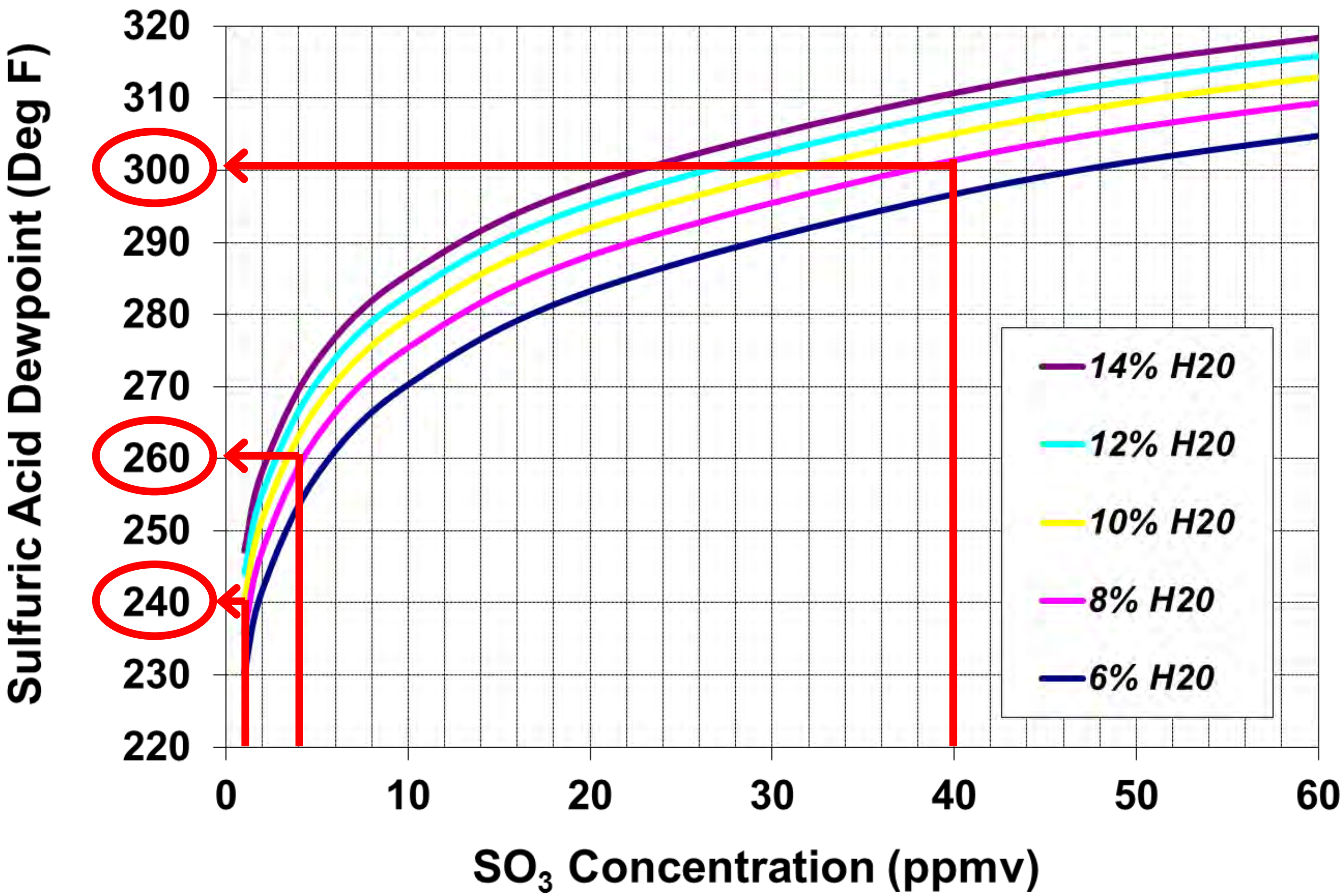
AECOM

Strategy: Step 1



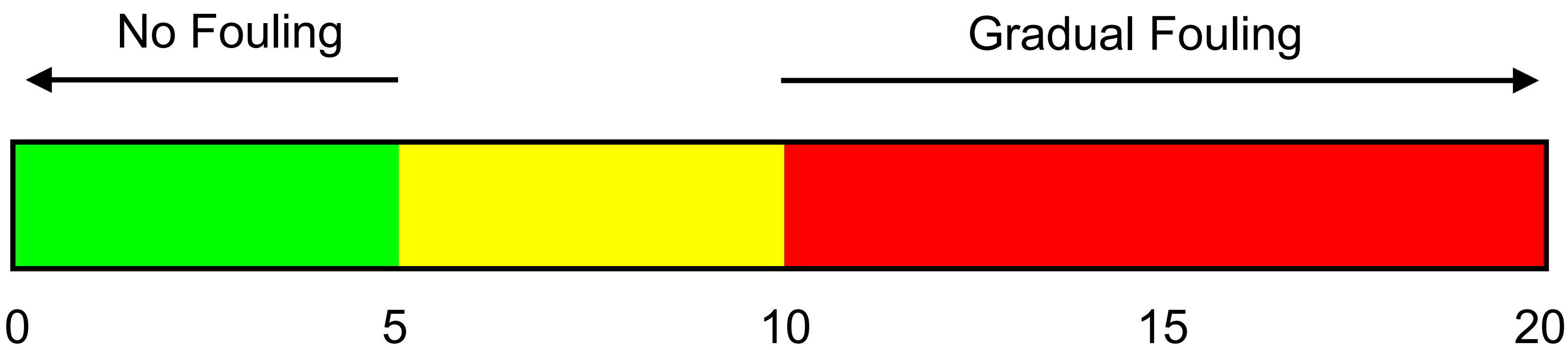
Result: No Fouling of Air Heater

Strategy: Step 2



AECOM

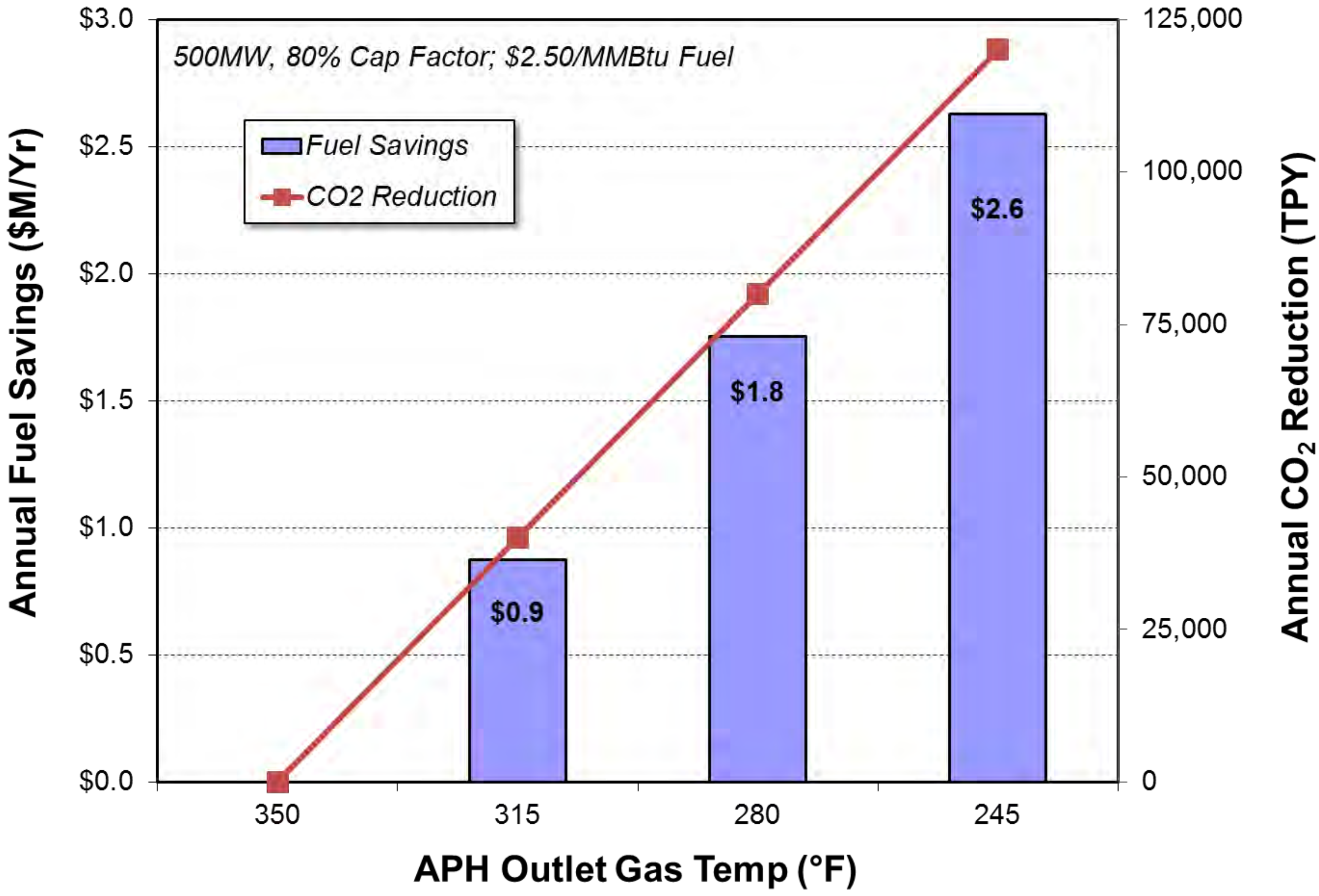
Air Heater Fouling Impact



AH Inlet SO_3 Concentration

Goal: Control SO_3 to 5 ppm or less at AH inlet

Strategy: Heat Rate Benefit



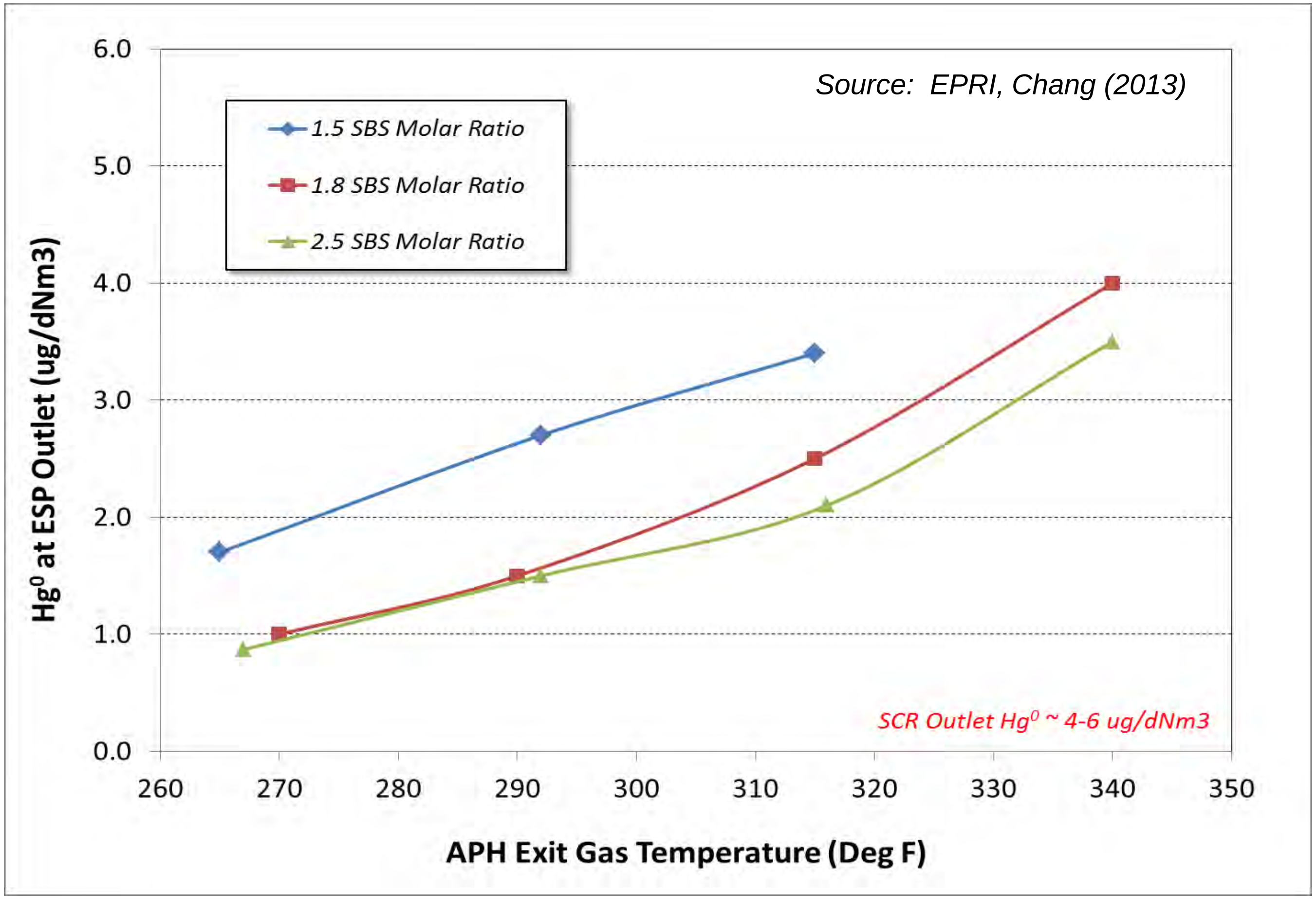
AECOM

Strategy: Other Co-Benefits

- Reduced CO_2 Emissions
  - higher unit energy efficiency
- Enhanced Mercury Capture
  - greater carbon absorption capacity
  - less SO_3 interference
- Enhanced ESP Performance
  - lower gas volumetric flow (higher SCA)
  - lower ash resistivity (temp and SO_3 effect)
- Reduced Fan Aux Power Consumption
  - reduced gas flow and gas path pressure drop
- Reduced WFGD Water Consumption
  - cooler inlet flue gas temp
- Reduced Unit Derates
  - higher PA temp and greater fan margin

AECOM

Mercury Co-Removal Benefit



Lower APH Exit Temp = Lower Mercury Emissions

AECOM

I. SO_3 Impacts and Removal

II. APH R&D and Efficiency Upgrades

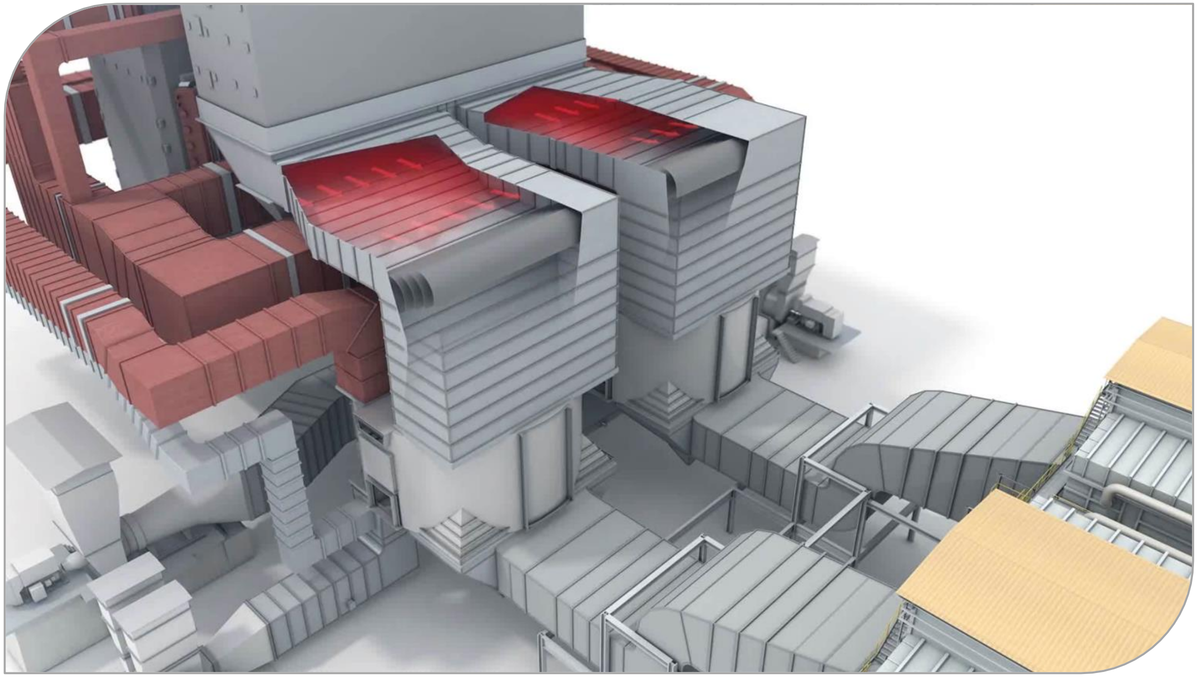
III. Long-Term APH Efficiency Demo

IV. Summary and Conclusions

LOW GAS OUTLET TEMPERATURE

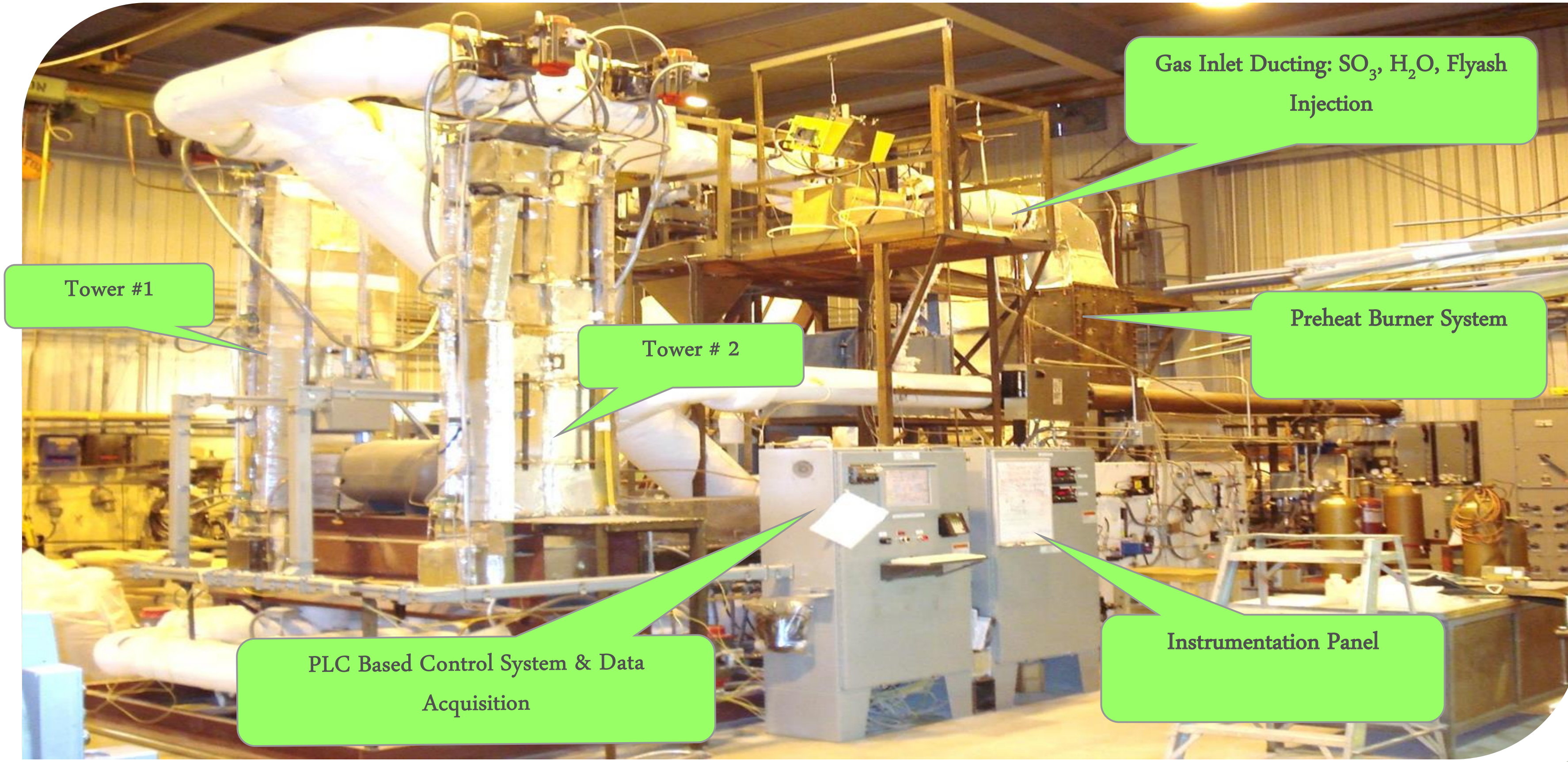
LJUNGSTRÖM | ARVOS GROUP

- Our R&D program objective is to approach 220°F gas out with stable operation and no loss in availability
  - Significant reduction in "Dry Gas Loss" and increase in boiler efficiency
  - Reduced CO_2 emissions
  - ESP benefits from reductions in both volumetric flow and increased fly ash resistivity
  - Reduced volumetric flow rates for downstream FGD, CO_2 capture, etc.



BENCH-SCALE AND PILOT SCALE TEST APPARATUS

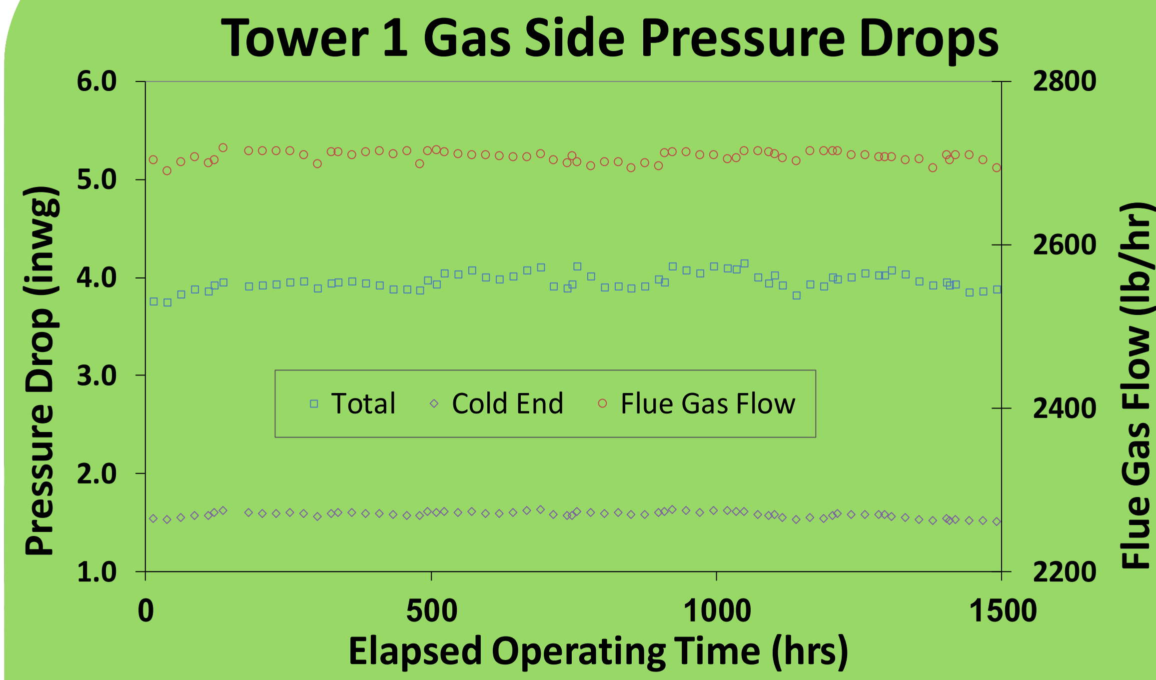
- Bench scale testing started in 2006
- Significant investment initiated in 2007 with advanced system capabilities
- Long-term tests (typically 1500 to 2000 hrs)
- Online, cold end soot blowing (3 cycles/day typical)



PILOT SCALE TEST
SIMULATED SBS INJECTION™

LJUNGSTRÖM | ARVOS GROUP

- We added the capability to model URS SBS Injection™ system
  - Full mitigation
  - 5ppmv SO_3
  - Na_2SO_4 by-product
  - 220°F outlet
- The SO_3 mitigation by-product sodium sulfate was added in powder form to the injected eastern bituminous fly ash
- Not SO_3 mitigation performance test but an APH fouling test
- Results from long term testing indicate that fouling can be mitigated based on the anticipated results from the URS SBS Injection™ Technology.



Stable Pressure Drop Response for ~ 2 Months

CONCLUSIONS

LJUNGSTRÖM | ARVOS GROUP

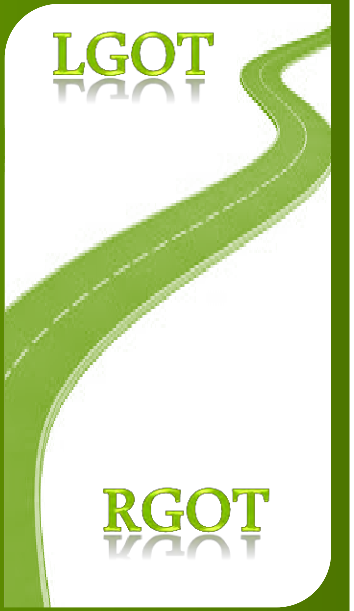
- The predicted allowable SO_3 concentrations for long term air preheater fouling mitigation at 220°F flue gas outlet temperature are low
  - Mitigation must reduce SO_3 concentrations to <=5 ppmv entering APH
- The particle size distribution effects deposition rates on air preheater surfaces with temperatures below the acid dew point
- We have a greater understanding of interaction between APH flue gas constituents, fouling mechanisms, and to some extents fouling rates
- Broad understanding of possibilities when SO_3 is mitigated, and proprietary data to allow modelling of APH with SO_3 removed

	SO_3	*Pressure Drop*	*Deposit*
	<=5 ppmv	Cold layer pressure drop did not increase	No significant deposit thickness was found
@220°F	>5<10 ppmv	Cold layer exhibits some fouling increase	Some deposits found
	>10 ppmv	Rapid increases in cold layer pressure drop occurred	Significant sodium bi-sulfate deposit was found

REDUCED GAS OUTLET TEMPERATURE PATH FROM LGOT TO RGOT

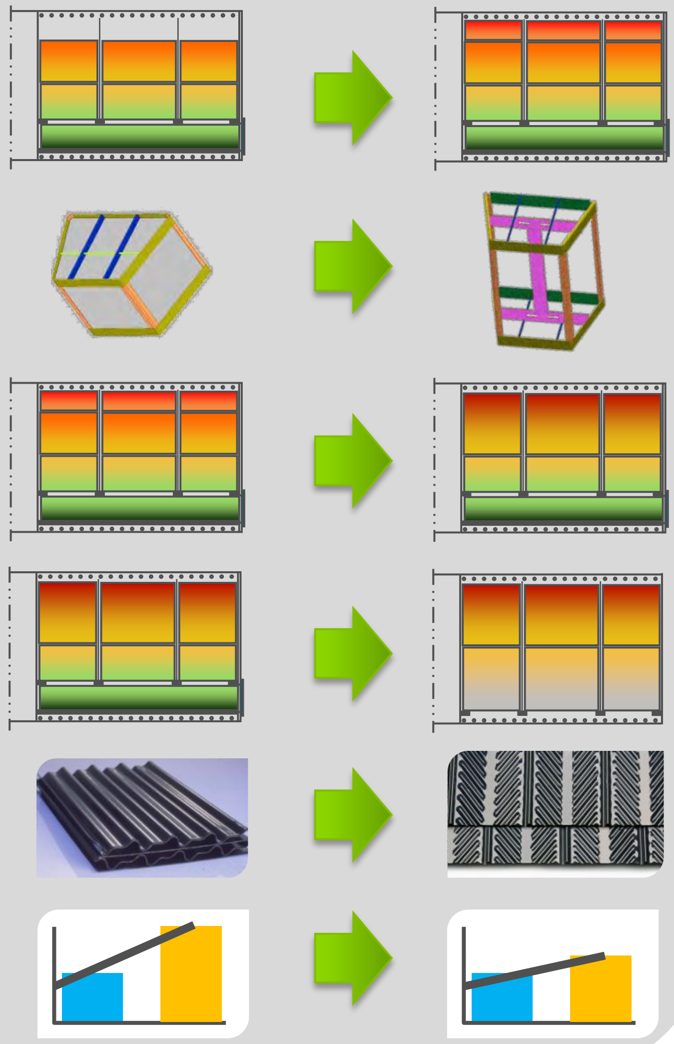
LJUNGSTRÖM | ARVOS GROUP

- **Simple modifications to an existing air heater typically cannot achieve gas outlet temperature <220˚F**
  - An increase in airflow can provide a significant reduction in gas temperature.
  - Co-benefit, if this this incremental hot air can be used elsewhere in the plant.
- **Reduced gas outlet temperature (~250°F) can be pursued in lieu of LGOT**
  - Basic benefits retained, implementation cost lowered significantly.
  - Reduced potential for corrosion, but need to stay above H_2O dewpoint

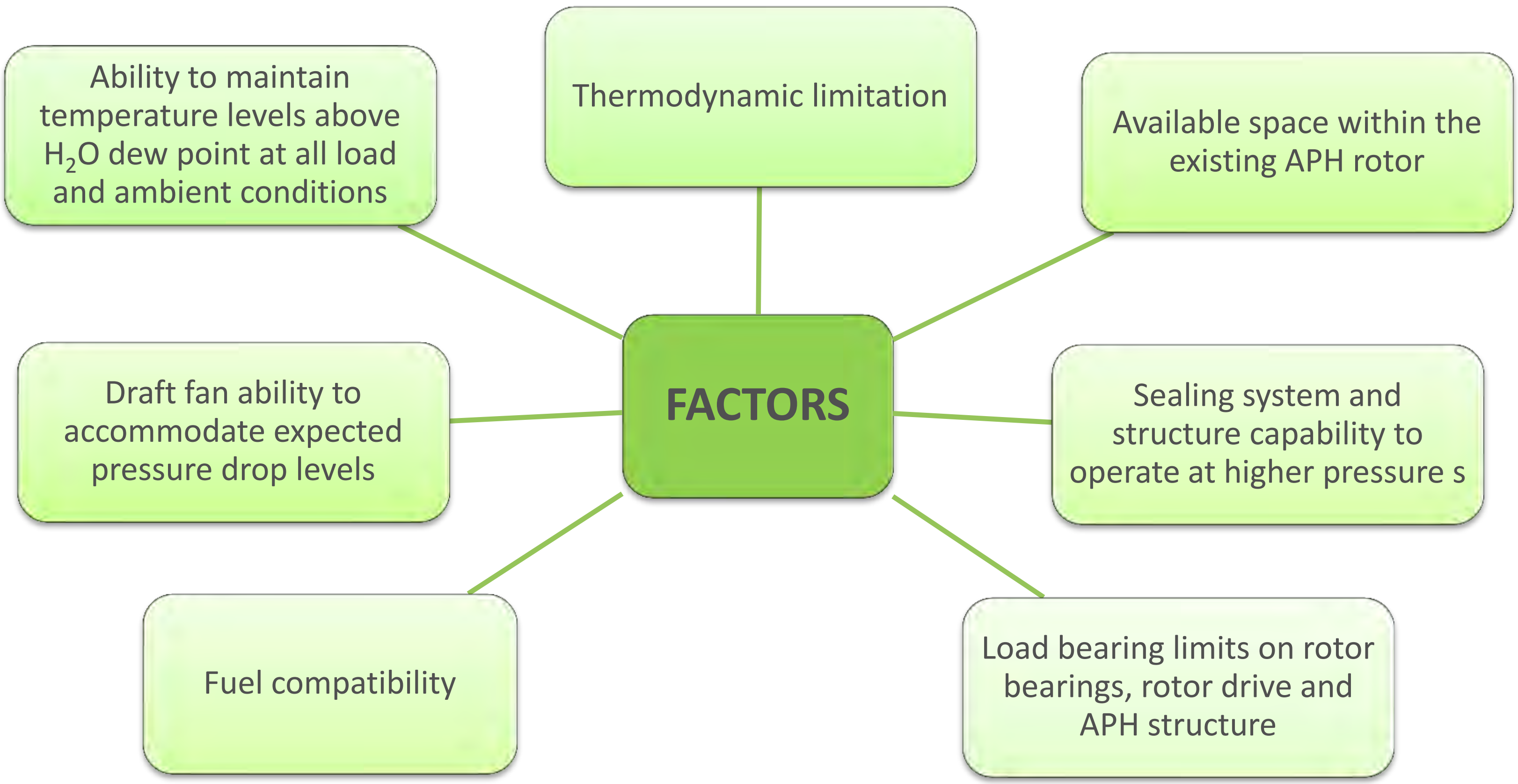


RGOT OPERATION
MEANS TO ACCOMPLISH

1. Fill empty voids in APH rotor with additional basket layers
2. Utilize special basket designs to maximize useable space for heat transfer surface
3. Consolidate shallow basket layers into single deeper layers
4. Modify APH rotor to more efficiently support basket layers
5. Switch to more efficient types of heat transfer surface
6. Reduce air preheater to air inlet of APH



RGOT OPERATION
CONSIDERATIONS



EXAMPLES

LJUNGSTRÖM | ARVOS GROUP

Basket & Element Replacement

- Replace existing baskets with new, advanced surfaces
- up to 20°F reduction in flue gas temperature

Deeper Layers & Low Profile Basket

- New advanced surfaces in a basket design that allow additional depth within existing rotor
- up to 35°F reduction in flue gas temperature

New Configured Rotor

- Replace rotor with new modules pre-loaded with advanced surfaces to maximize available depth
- Maximum reduction in flue gas temperature

I. SO_3 Impacts and Removal

II. APH R&D and Efficiency Upgrades

III. Long-Term APH Efficiency Demo

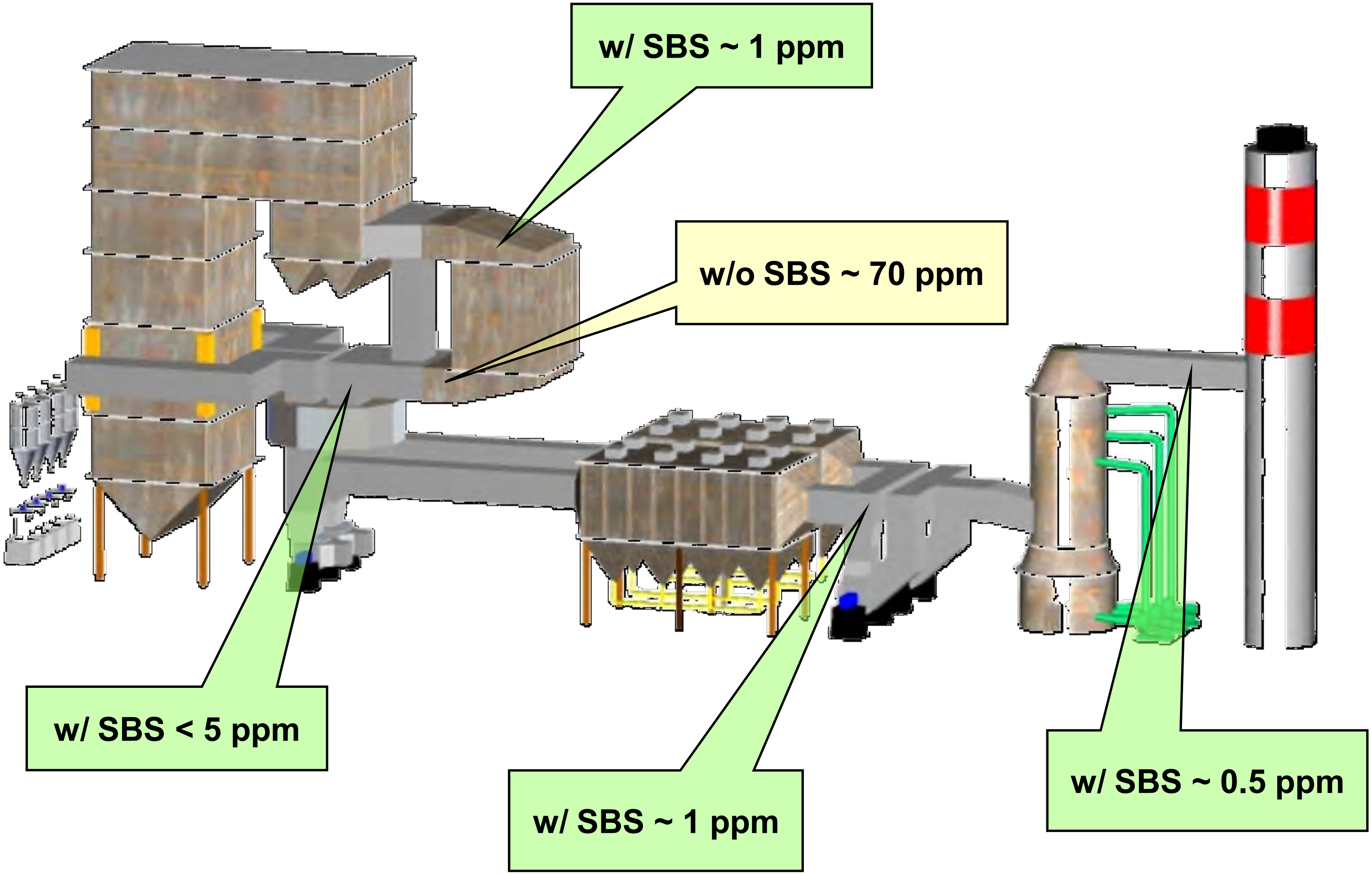
IV. Summary and Conclusions

Midwestern Power Plant

- 500 MW
- SCR-APH-ESP-WFGD
- Illinois Basin Fuel
- 5 lb SO_2 Fuel
- 40-70 ppm SO_3
- SBS Injection (2012)
- APH Upgrade (2014)

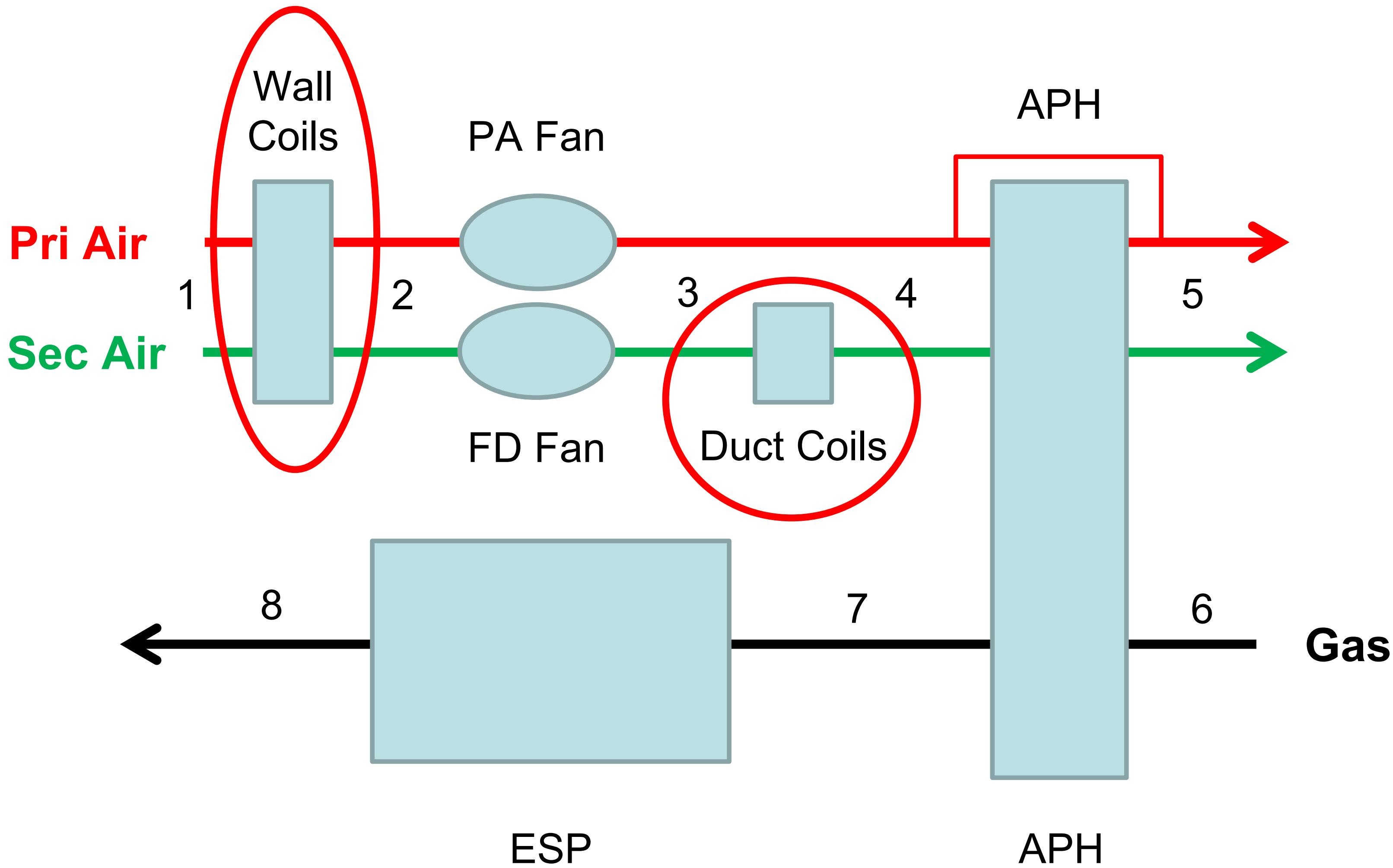
AECOM

Relative SO_3 Levels Thru Gas Path



AECOM

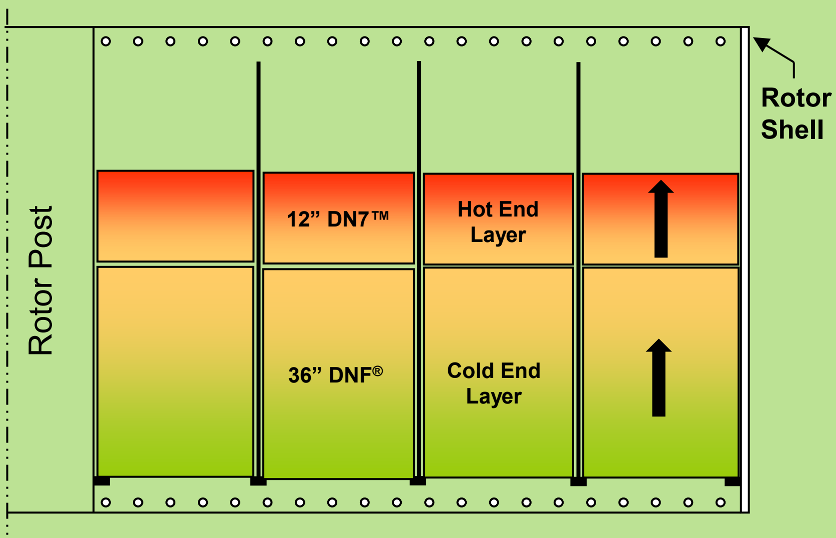
APH Configuration and Operation



AECOM

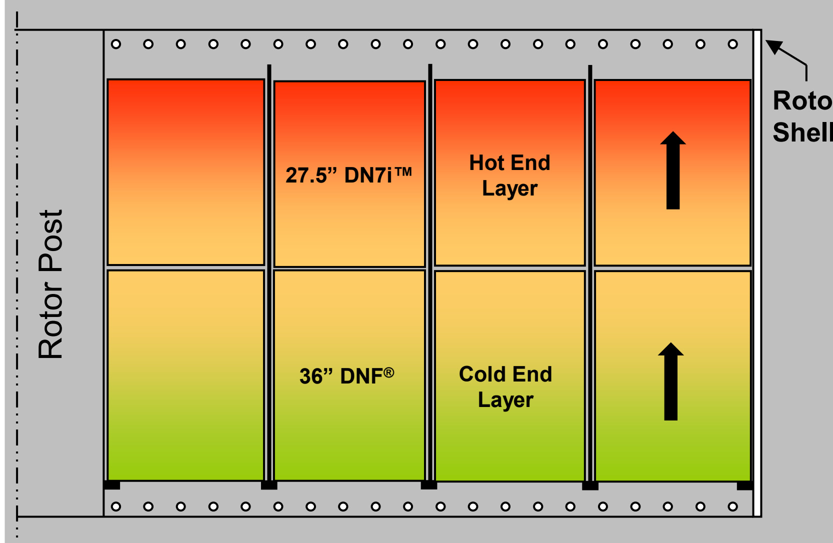
APH Upgrade Modifications

Old Configuration



Total heat transfer surface depth 48"

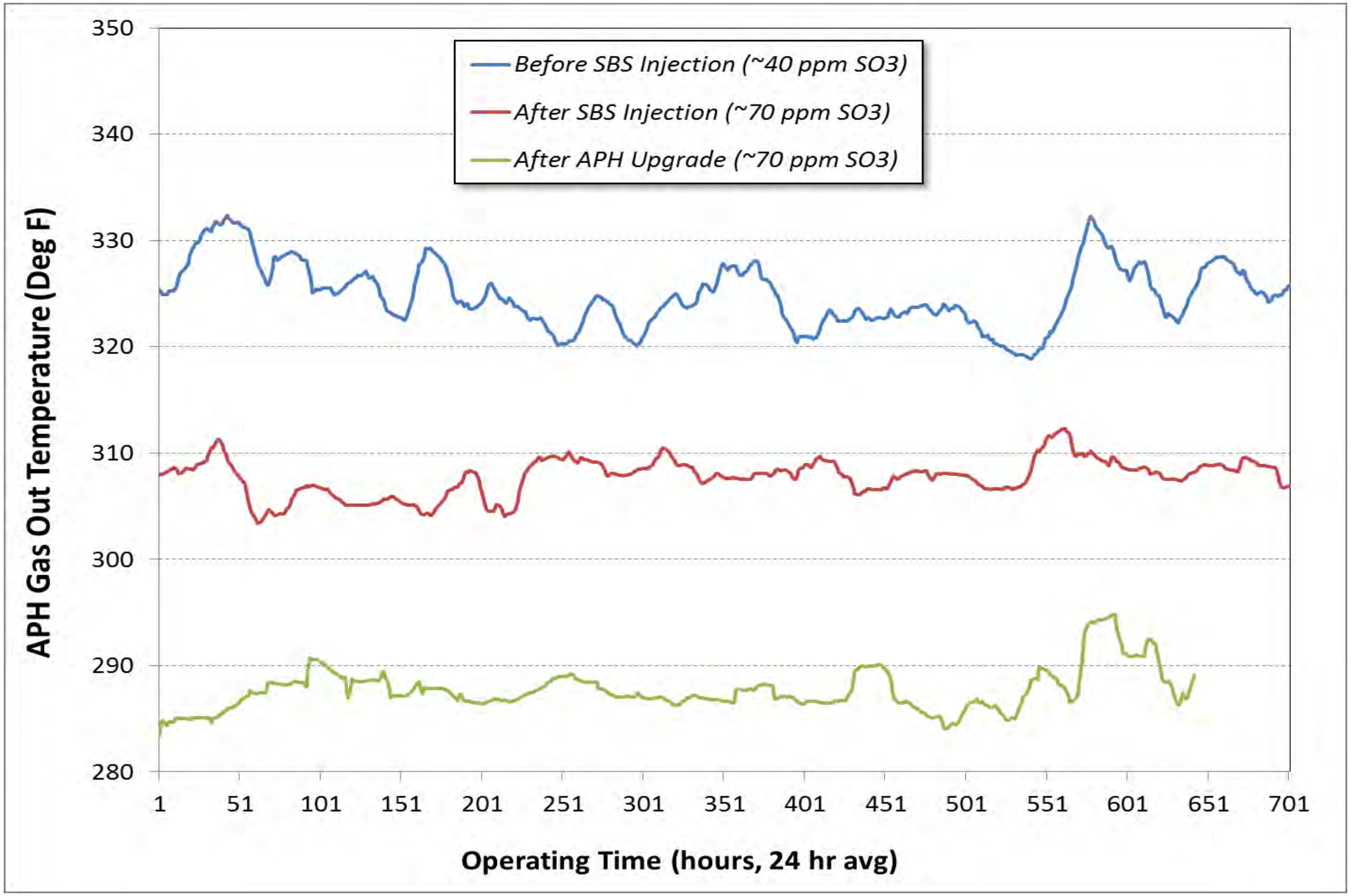
New Configuration



Total heat transfer surface depth 63.5"

AECOM

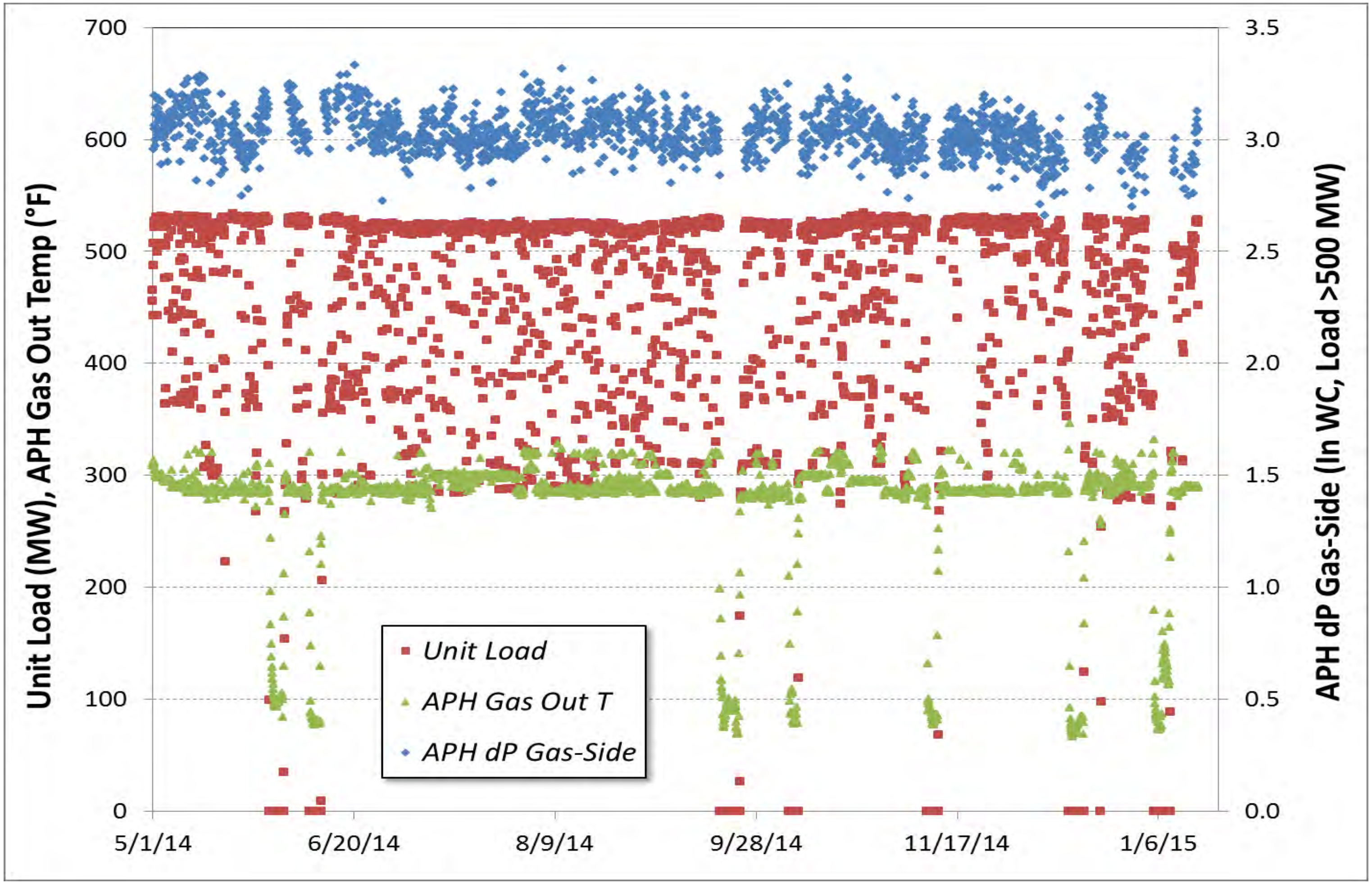
APH Temperature Changes



SO_3 Mitigation Allows Lower APH Op Temps

AECOM

APH Operating History (2014)



No APH dP Increase Over 8 Months Operation

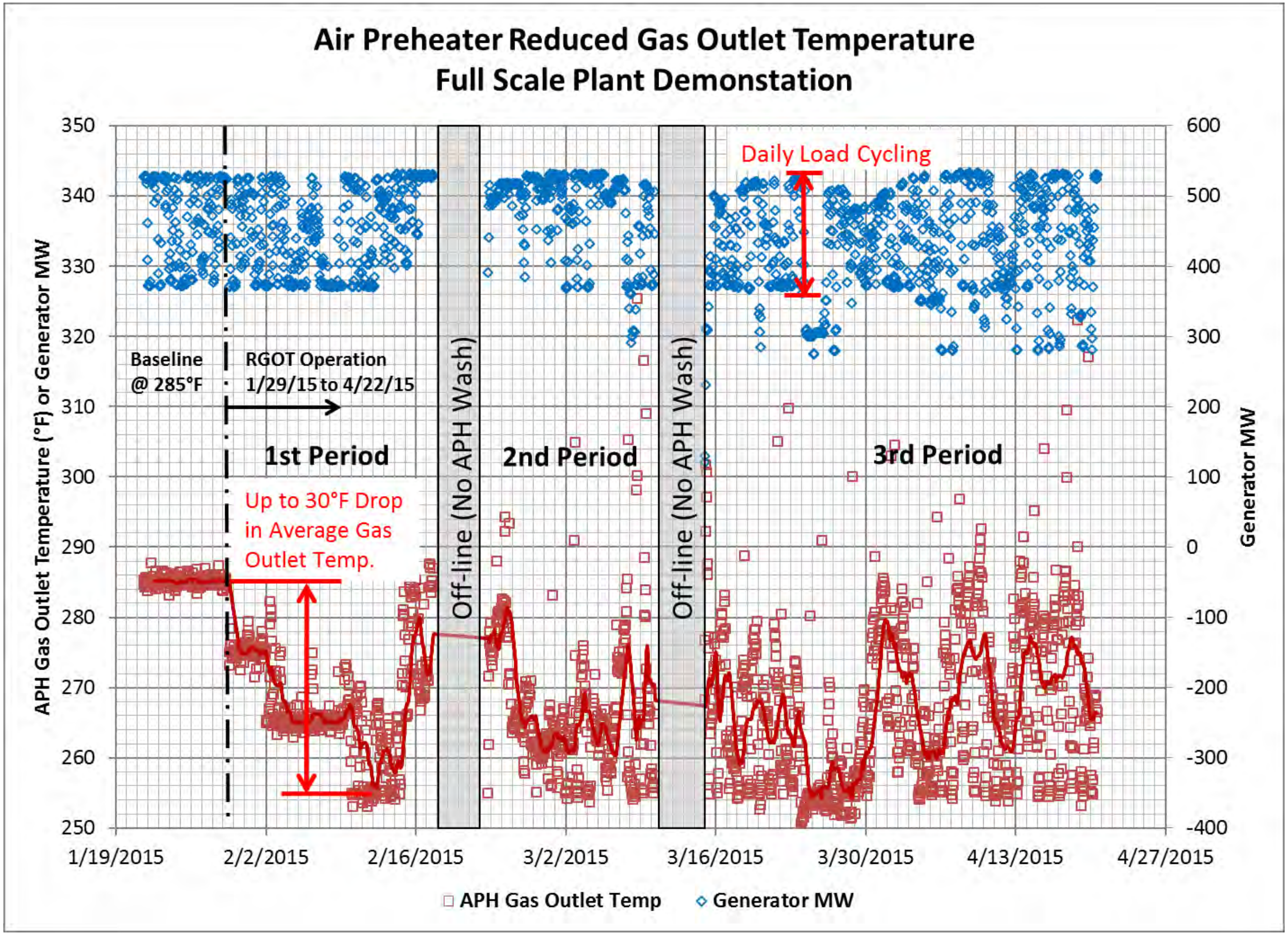
AECOM

LONG-TERM APH DEMONSTRATION
REDUCED GAS OUTLET TEMPERATURE (RGOT)

- **For the air preheater, the critical purpose was to *"demonstrate successful operation at reduced gas outlet temperatures without fouling and pressure drop increases"*.**
- **The air preheater gas outlet temperature was reduced by reducing the temperature of one or both of the air inlet flow streams.**
  - Made possible by conducting the demo during the winter and reducing inlet air preheat
  - The reduction was carried out in 10°F increments
    - Baseline gas outlet temperature at the start of demo was **285°F**
    - On January 29th the gas outlet temperature set-point was reduced to **275°F** and held for ~ 4 days
    - On February 2nd the gas outlet temperature set-point was reduced to **265°F** and held for ~ 8 days
    - On February 10th the set-point was reduced to **255°F**
- **For the purposes of analysis and discussion the demo period has been divided into 3 periods separated by two different outages**
  - Period 1: January 29 through February 17
  - Period 2: February 22 through March 10
  - Period 3: March 15 through April 22

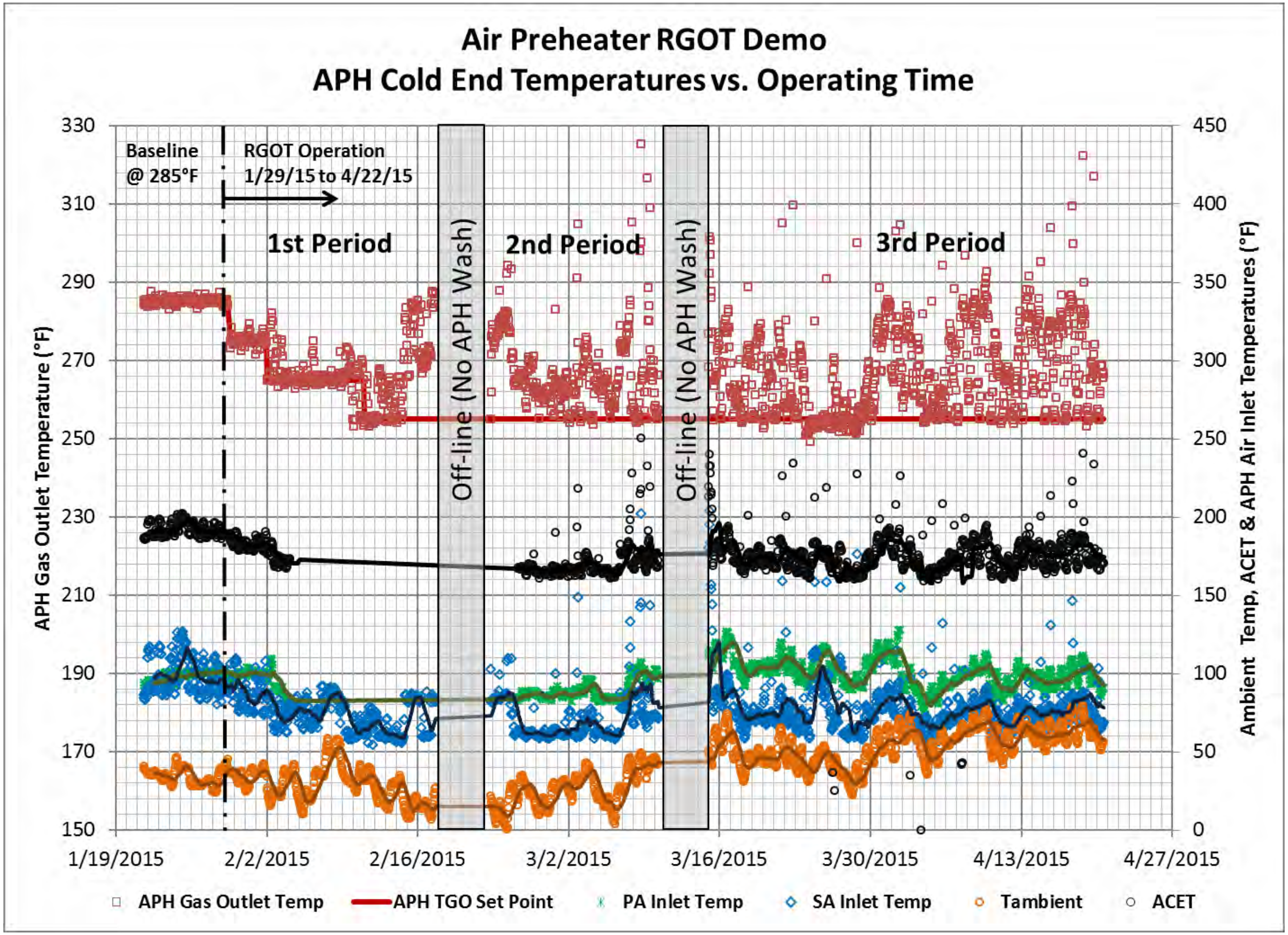
UNIT LOAD AND APH TEMPERATURE

LJUNGSTRÖM | ARVOS GROUP



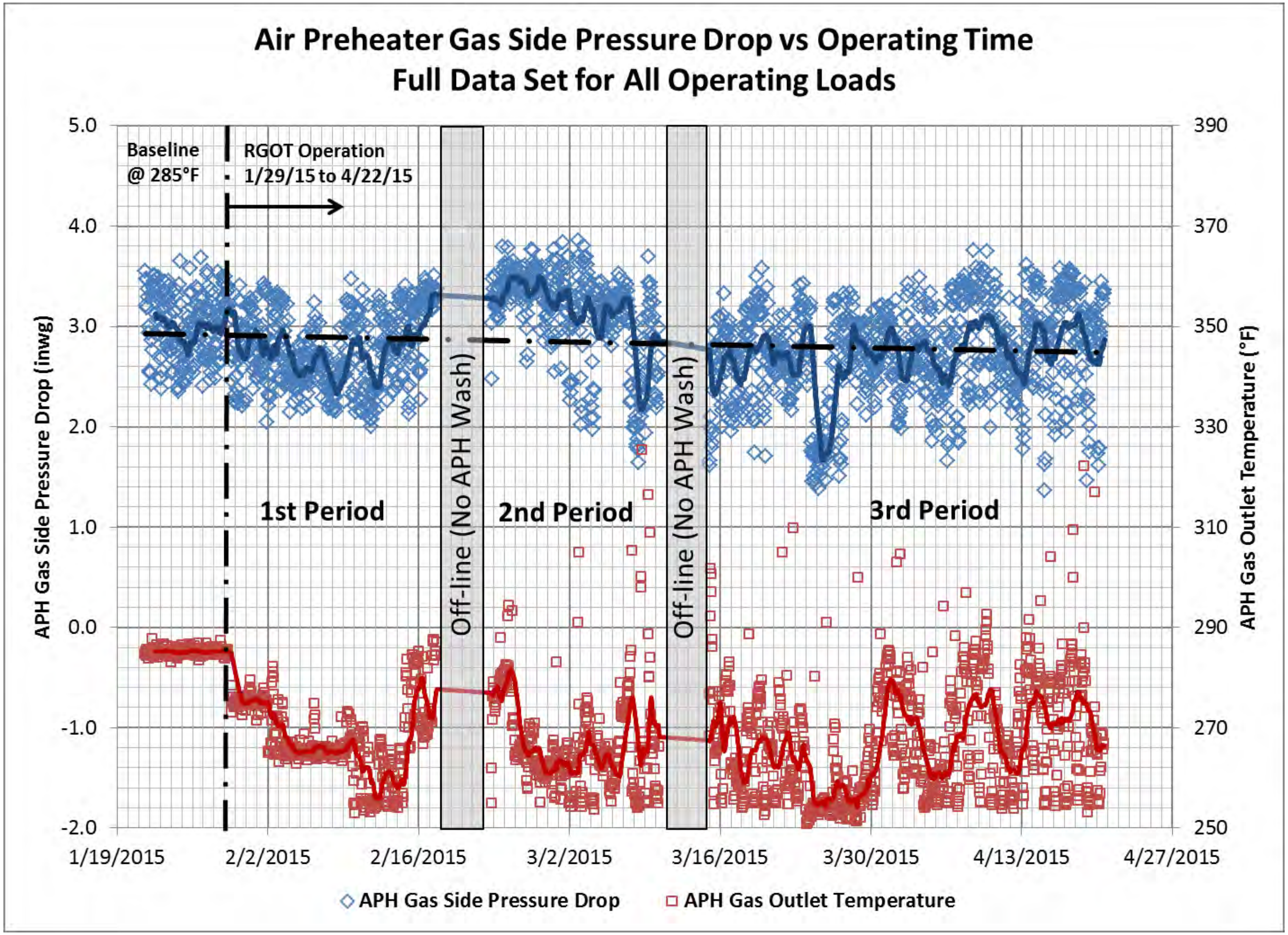
COLD END TEMPERATURES VS. TIME

LJUNGSTRÖM | ARVOS GROUP



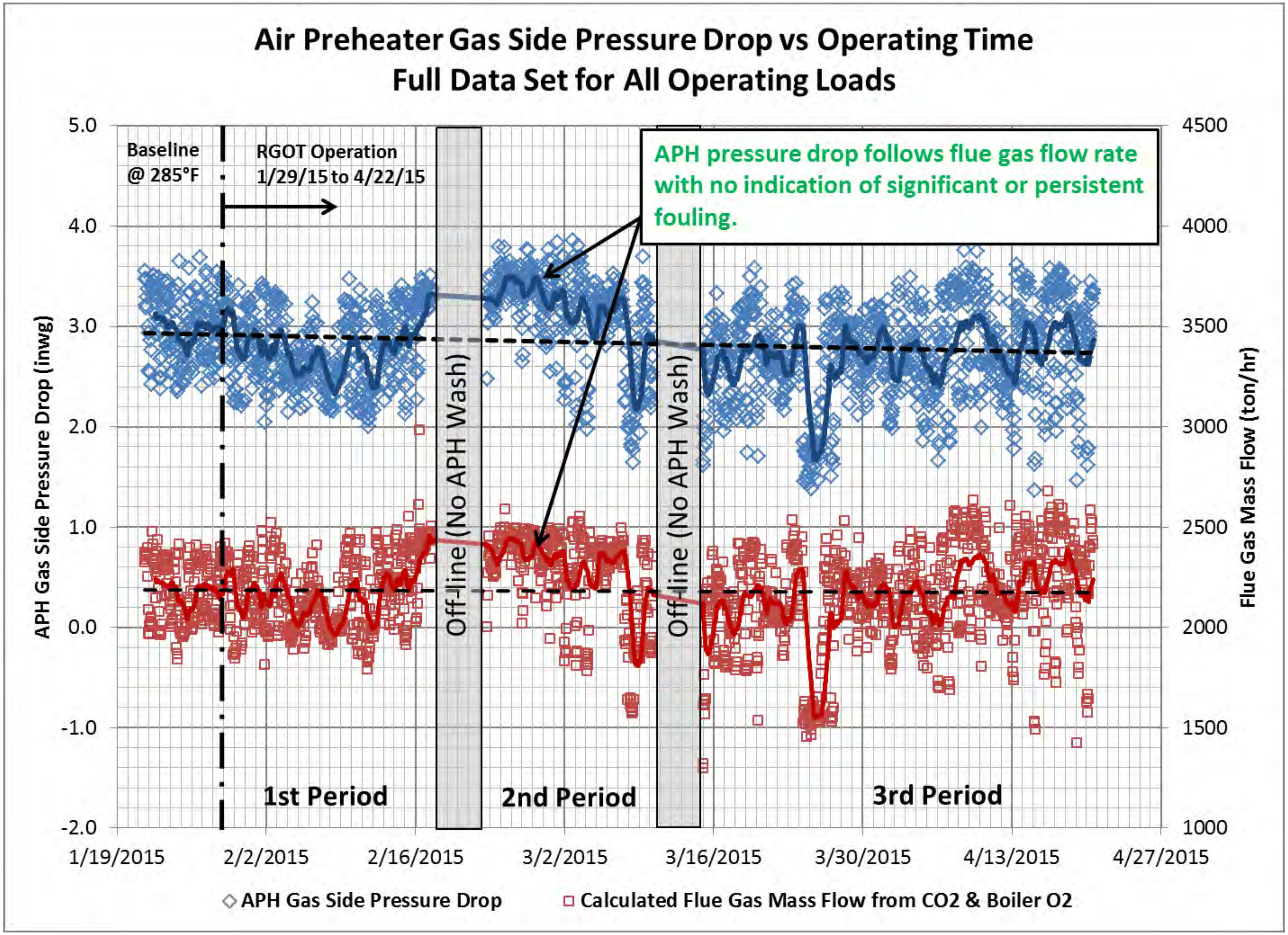
APH PRESSURE DROP VS. TIME

LJUNGSTRÖM | ARVOS GROUP



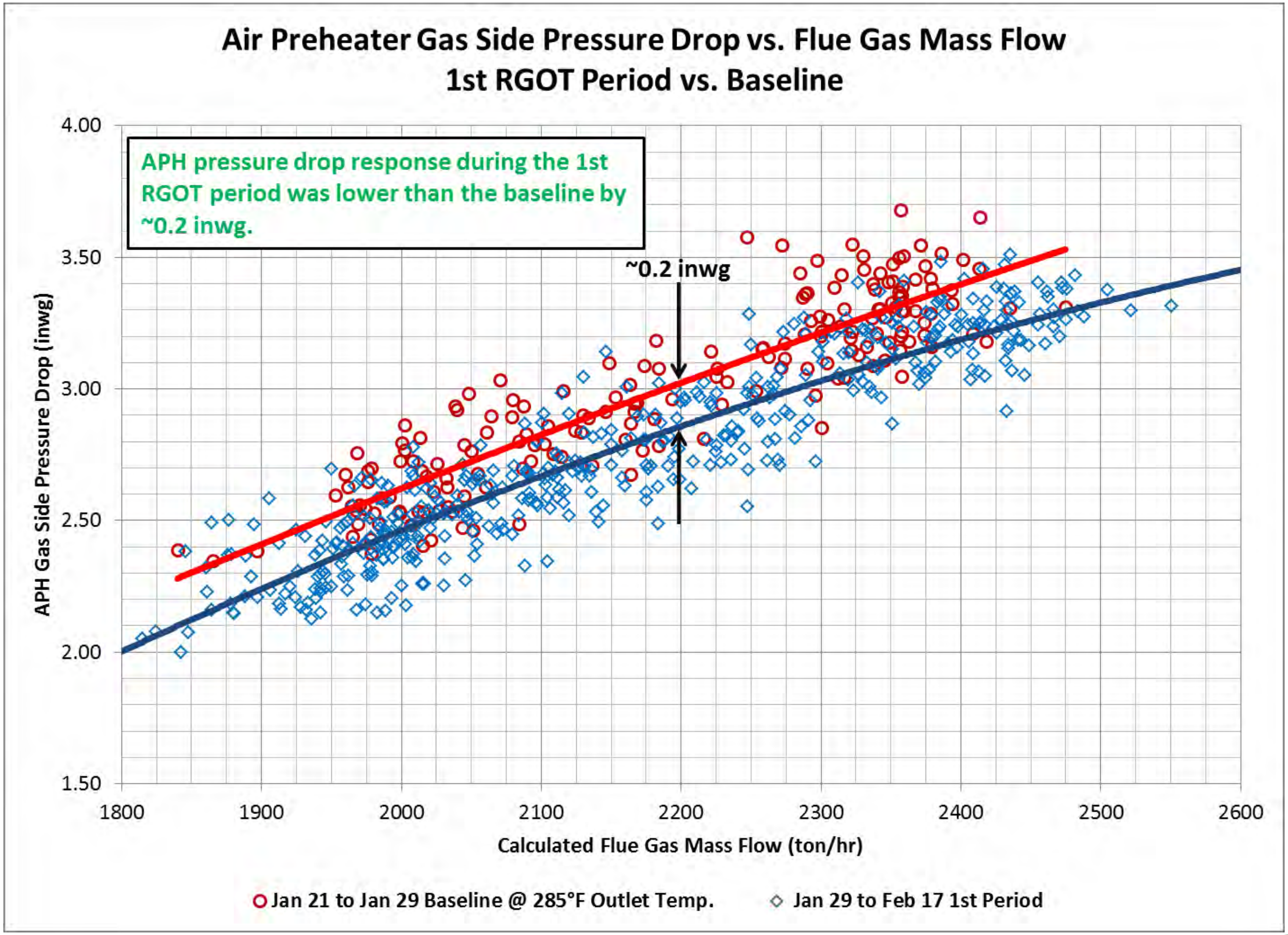
APH PRESSURE DROP VS. GAS FLOW

LJUNGSTRÖM | ARVOS GROUP



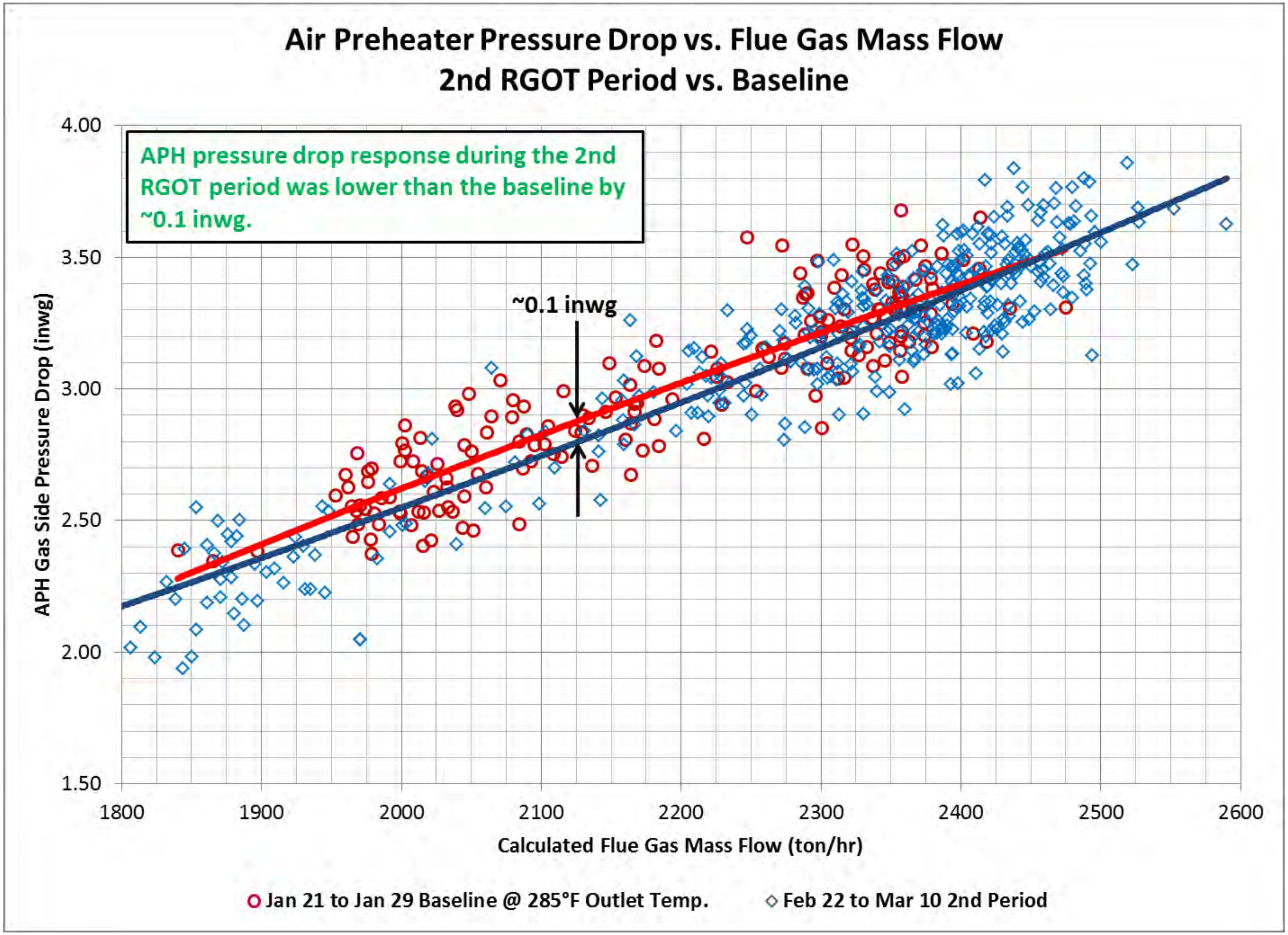
AIR PREHEATER PRESSURE DROP
1ST RGOT PERIOD VS. BASELINE

LJUNGSTRÖM | ARVOS GROUP



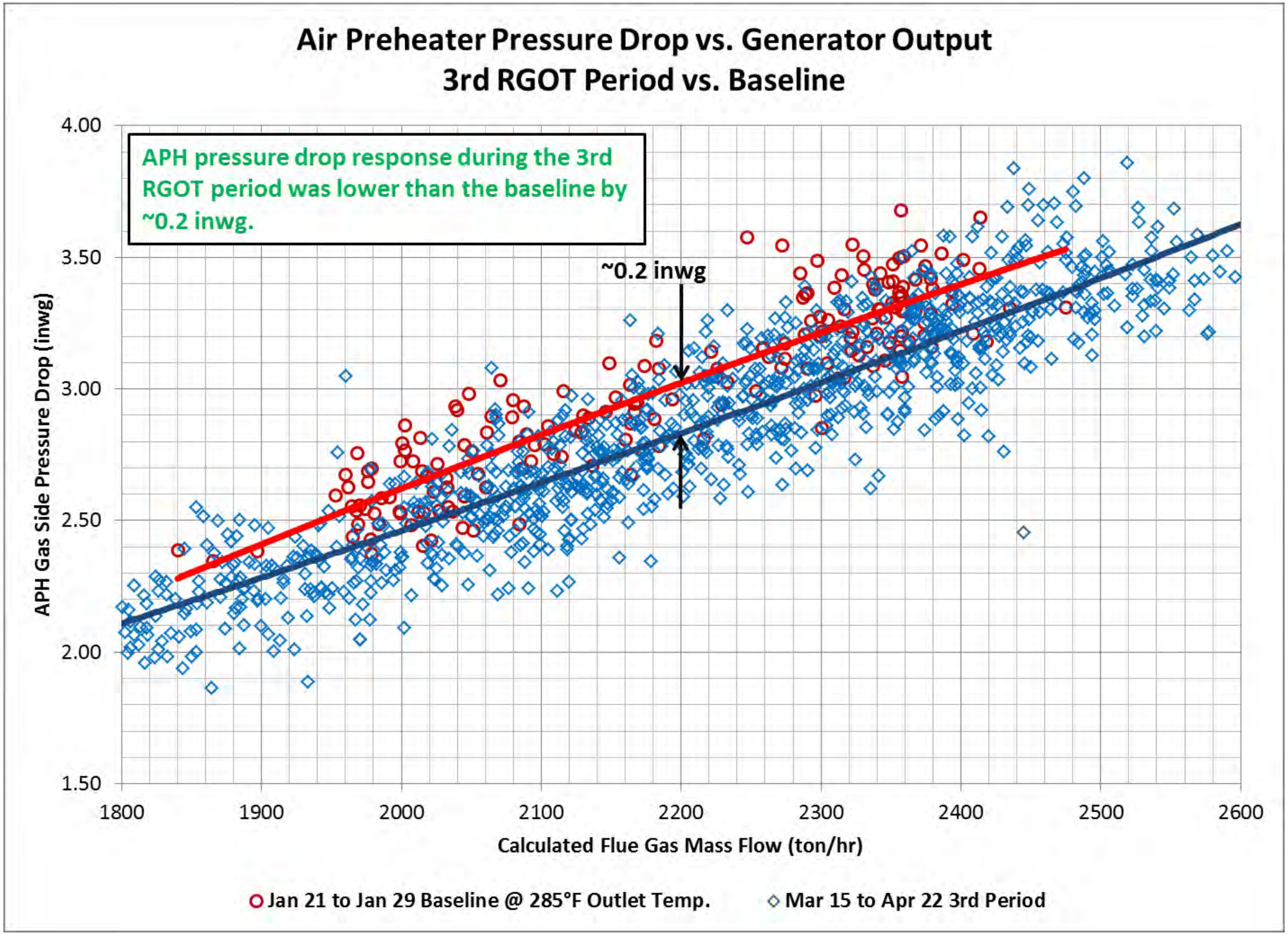
AIR PREHEATER PRESSURE DROP
2ND RGOT PERIOD VS. BASELINE

LJUNGSTRÖM | ARVOS GROUP



AIR PREHEATER PRESSURE DROP
3RD RGOT PERIOD VS. BASELINE

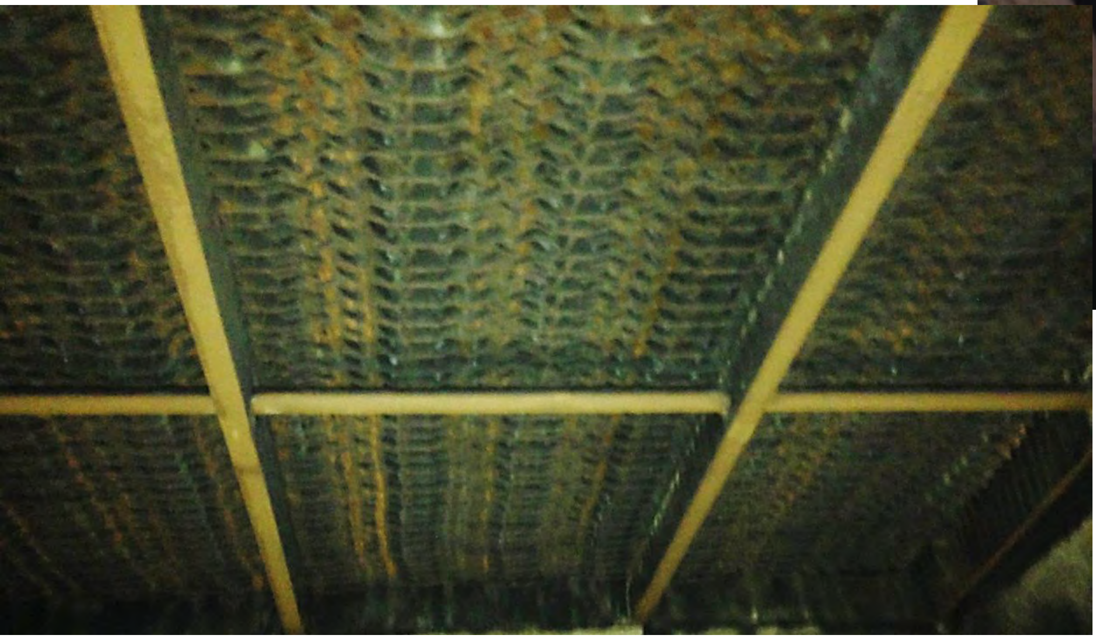
LJUNGSTRÖM | ARVOS GROUP



APH INSPECTION RESULTS AFTER THE DEMO

LJUNGSTRÖM | ARVOS GROUP

A scheduled unit outage facilitated a May 26, 2015 inspection of these APHs. The heat transfer surface had not been water washed prior to this inspection and was found to have no significant evidence of fouling or corrosion.



APH DEMO CONCLUSIONS
FOULING & PRESSURE DROP

- **Based on pressure drop results and the inspection ...**
  - No evidence of significant pressure drop increases during the demonstration
  - No evidence of significant fouling or corrosion during the inspection
  - It is clear that the demonstration was successful; the ARVOS/AECOM approach works!
- **Further Work**
  - So far only the APH pressure drop has been fully studied
  - Further work will include analysis of the other beneficial effects of RGOT

I. SO_3 Impacts and Removal

II. APH R&D and Efficiency Upgrades

III. Long-Term APH Efficiency Demo

IV. Summary and Conclusions

Summary and Conclusions

- SBS Injection™ highly effective for SO_3 removal
- APH protection requires < 5 ppm SO_3 at inlet
- Utility APH upgrade demonstration successful
  - Gas outlet temperature reduced by ~ 70°F
  - No APH fouling or pressure drop increase
  - No APH corrosion
- Utility benefits realized:
  - Heat rate improvement (O&M fuel savings)
  - CO_2 reduction (Clean Power Plan)
  - Enhanced mercury capture (MATS)
- Utility evaluating even more efficient APH design

Further APH Testing Planned in Future

AECOM

Thank You

sterling.gray@aecom.com
louis.bondurant@arvos-group.com

AECOM Booth # 72