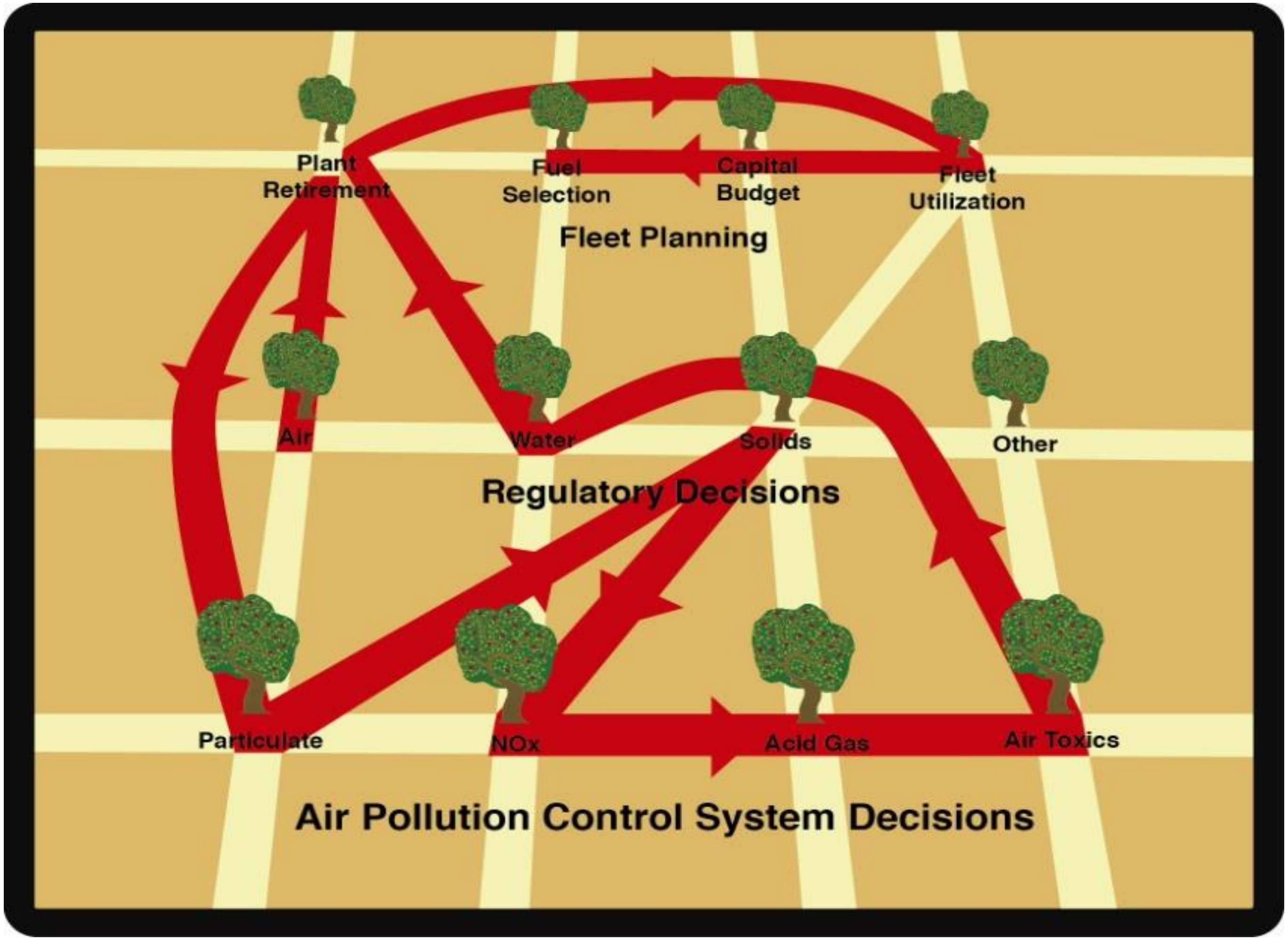
SO3 Decisions Guide

The S03 mitigation options and impacts on the regulatory, economic, maintenance and operational decisions.

- **To be used in conjunction with Power Plant Air Quality Decisions.**
- **Power points extracted from Mcilvaine webinars.**

GdPS for SO3 impacts many decisions



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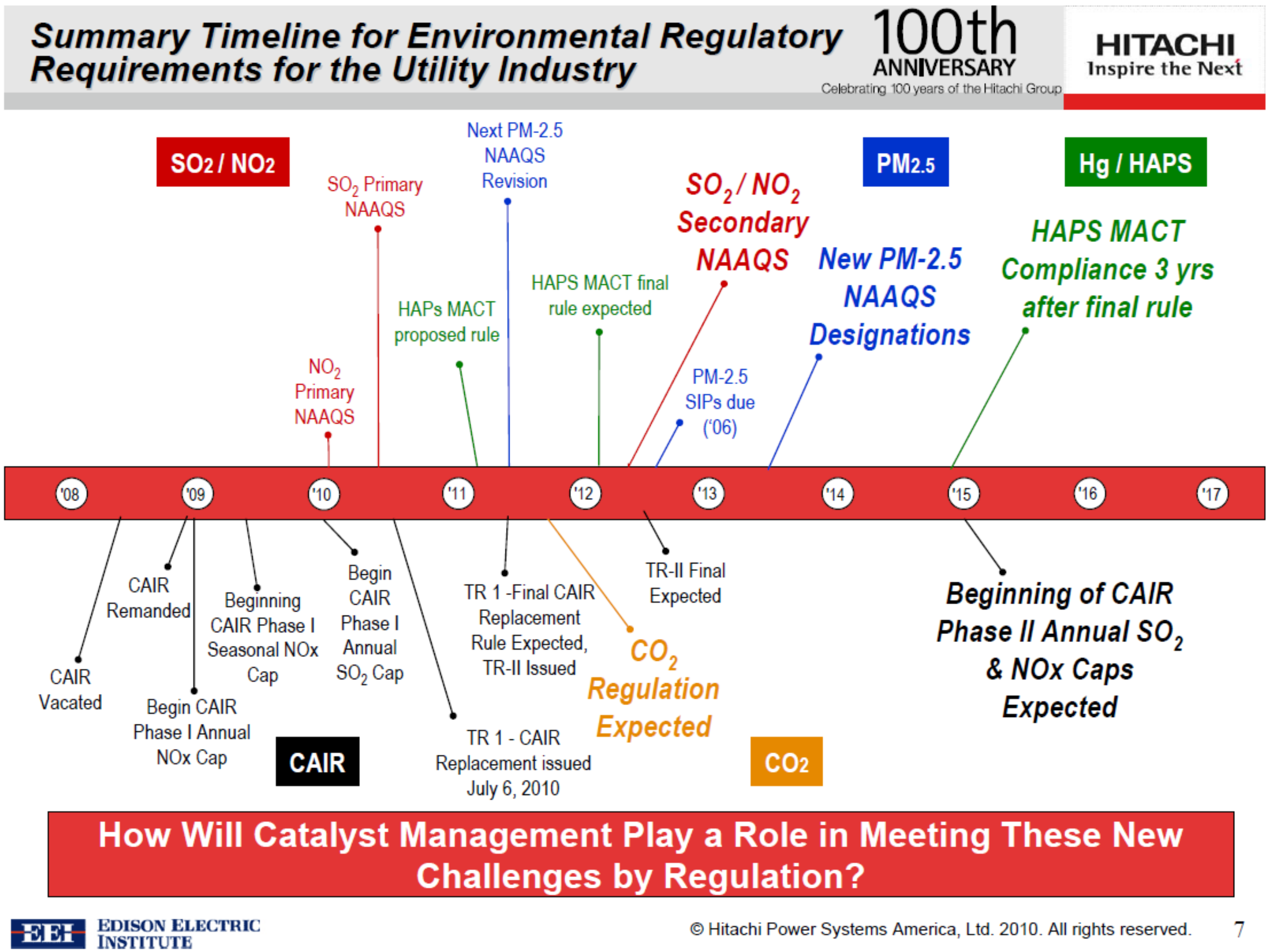
S03 reduction investment is tied to the many air, water, and waste rules being promulgated. New PM 2.5 NAAQS may be the most important. Will not be resolved until 2018 or later



U.S regulations will cause SO3 to be an issue

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MATS and CSAPR

Mercury and Air Toxics Standards (MATS)

- Limits emissions of toxic air pollutants from coal and oil fired power plants
- Primary pollutants of concern are mercury, hydrogen chloride (HCl) and fine particulates ($PM_{2.5}$)
- FINAL RULE: Compliance by April 2015 with possible extensions of up to 2 years

Cross State Air Pollution Rule (CSAPR)

- Referred to as the "Good Neighbor" rule
- Regulates emissions from one state that may have a negative impact on air quality in a downwind state
- 28 states in the eastern half of the U.S. must limit state-wide emissions of precursors to ozone formation (NOx, SO_2 and $PM_{2.5}$)
- FINAL RULE issued August 2011 with first phase to begin in 2012
  - But, the rule did not take effect as scheduled due to litigation
  - August 2012: US Court of Appeals vacated the rule and remanded it to EPA
  - April 2014: US Supreme Court reversed Court of Appeals and reinstated CSAPR
  - November 2014: EPA issued new compliance dates of 2015 to 2017

Together, MATS and CSAPR will require coal plants to install:

- FGD or Dry Sorbent Injection (DSI) to control SO_2 and acid gases (HCl)
- SCR or SNCR to control NOx
- Fabric filters or electrostatic precipitators to control particulate matter
- Activated carbon injection units to reduce mercury

PM 2.5 ambient standards will require SO3 reduction

Fine Particulate Matter ($PM_{2.5}$)

- Lowered annual standard to 12 ug/m^3 in December 2012
- EPA expects all areas to attain without new control requirements (except CA)
- Vacatur of de minimis levels (SILs and SMCs) could make permitting difficult
  - w/o SMCs, could require onsite monitoring
  - w/o SILs, could make modeling more difficult
- EPA's implementation rule also vacated
- EPA resets the baseline date; NC objects

S03 reacts to create small sulfate particulate . Significant impact level could be the most stringent and therefore governing regulation

TROUTMAN SANDERS
ATTORNEYS AT LAW

$PM_{2.5}$ SILs and SMCs

- **Significant Impact Level (SIL)**

42 U.S.C. § 7475(a)(3): requires sources to demonstrate they will not cause or contribute to a violation

- SIL allows source to avoid cumulative modeling—evaluating all nearby sources—if impacts are below the SIL
- Cumulative modeling compares baseline to future expected air quality

$PM_{2.5}$ SIL: 1.2 ug/m^3

S03 can impact plant economics, operations, maintenance and the emission of other pollutants

- **Economics**: the remaining plant life can determine whether it is worth considering high capital cost approaches for SO_3 and particulate control e.g wet precipitators The potential to inject sorbents ahead of the air heater and improve the capture of exhaust heat can add 1% to boiler efficiency. The cost of SCR catalyst is a function of the SO_2/SO_3 conversion activity. The amount of activated carbon for mercury control can be affected by SO_3 If the plant must meet total particulate rather than discrete particulate limits, SO_3 is a big consideration.

- **Operations:** Does the plant want to purchase high sulfur coal? SO_3 mitigation choices can determine the maximum coal sulfur content. How often will NO_x catalyst be replaced? Should flue gas conditioning be employed

- **Maintenance:** Sulfuric acid corrosion can be a problem in the air heater and ductwork. With ammonia injection ammonium bisulfate builds up on surfaces of the air heater and reduces heat transfer. . If you utilize a fabric filter will there be bag plugging problems.

- **Air Emissions**: Are there limits on total particulate emissions including condensibles? The new federal air toxic rules were revised to eliminate condensibles but States may have or are planning total particulate limits. If so SO_3 can create 80% of the total particulate. Just 10 ppm of SO_3 will cause particulate emissions of 0.03 lbs/ mm btu. A blue plume will also be an opacity problem

S03 at 10 ppm or greater causes a blue plume and mass of 0.03 lbs/mm btu.

FLSMIDTH

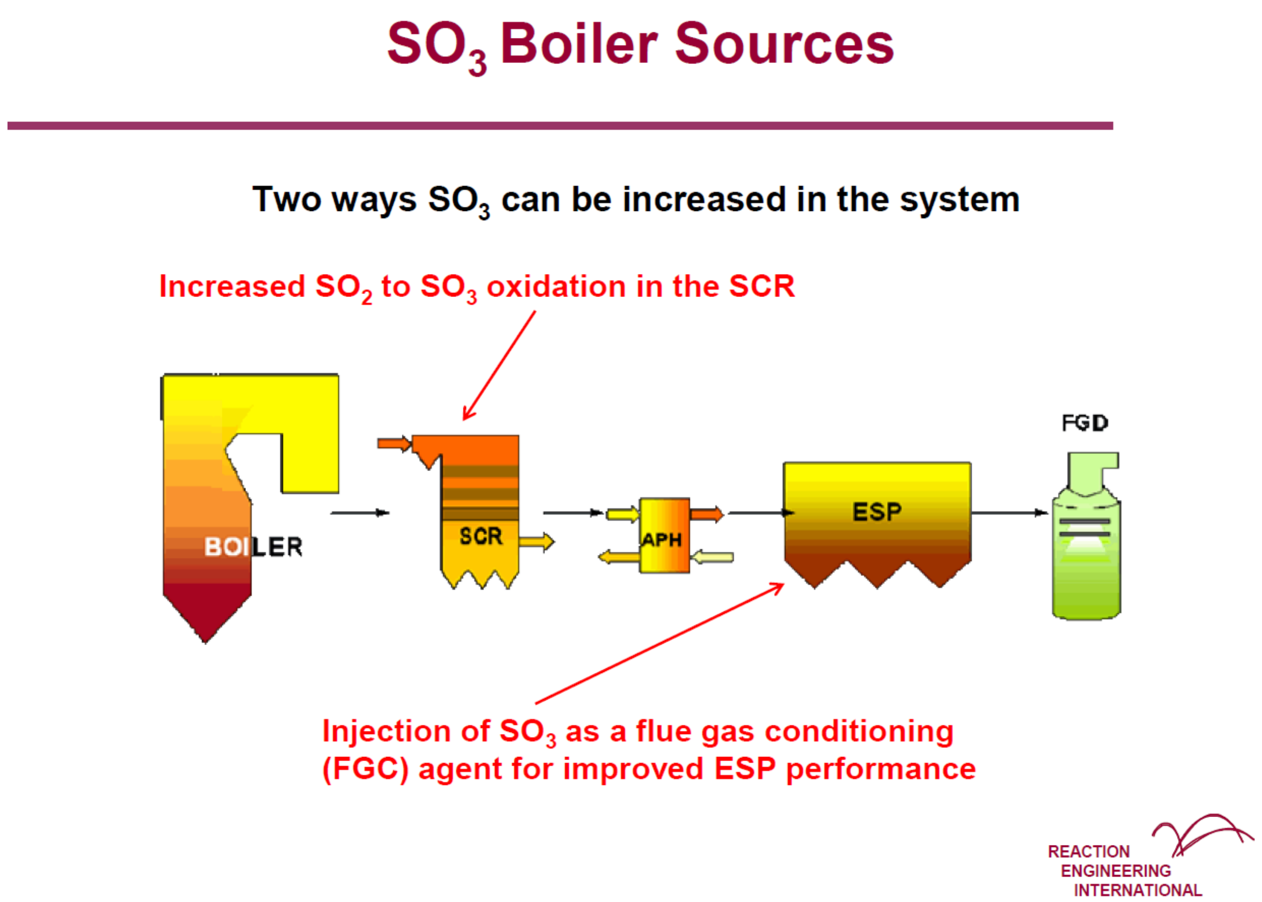
2002 – The Blue Plume

- High Sulfur Coal
- SCR
- Wet scrubber

- SO_3

- Gravimetric metering
- Delivery

About 1 % of the SO2 is oxidized to SO3 in combustion. The SCR can add equal amouts. FGC is another source



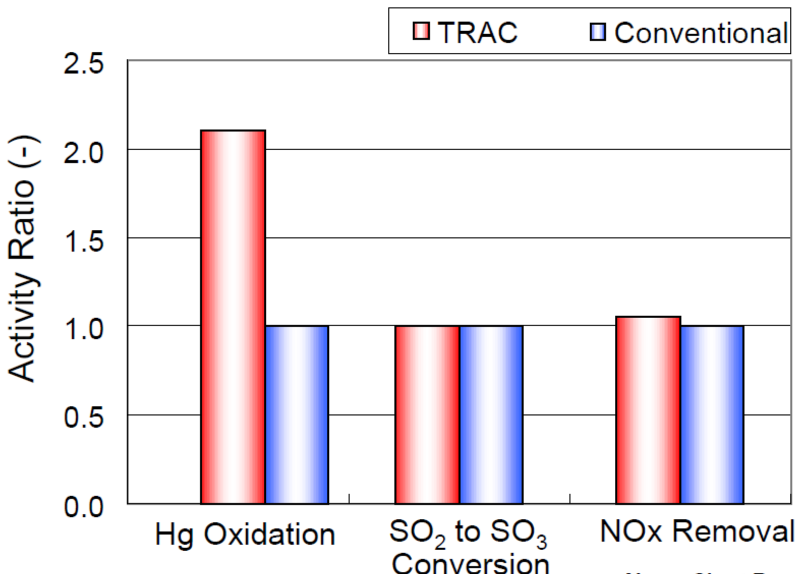
New catalysts reduce Nox,oxidize mercury and minimize SO3 conversion

Relative Performance of TRAC®

1st High Mercury Oxidation

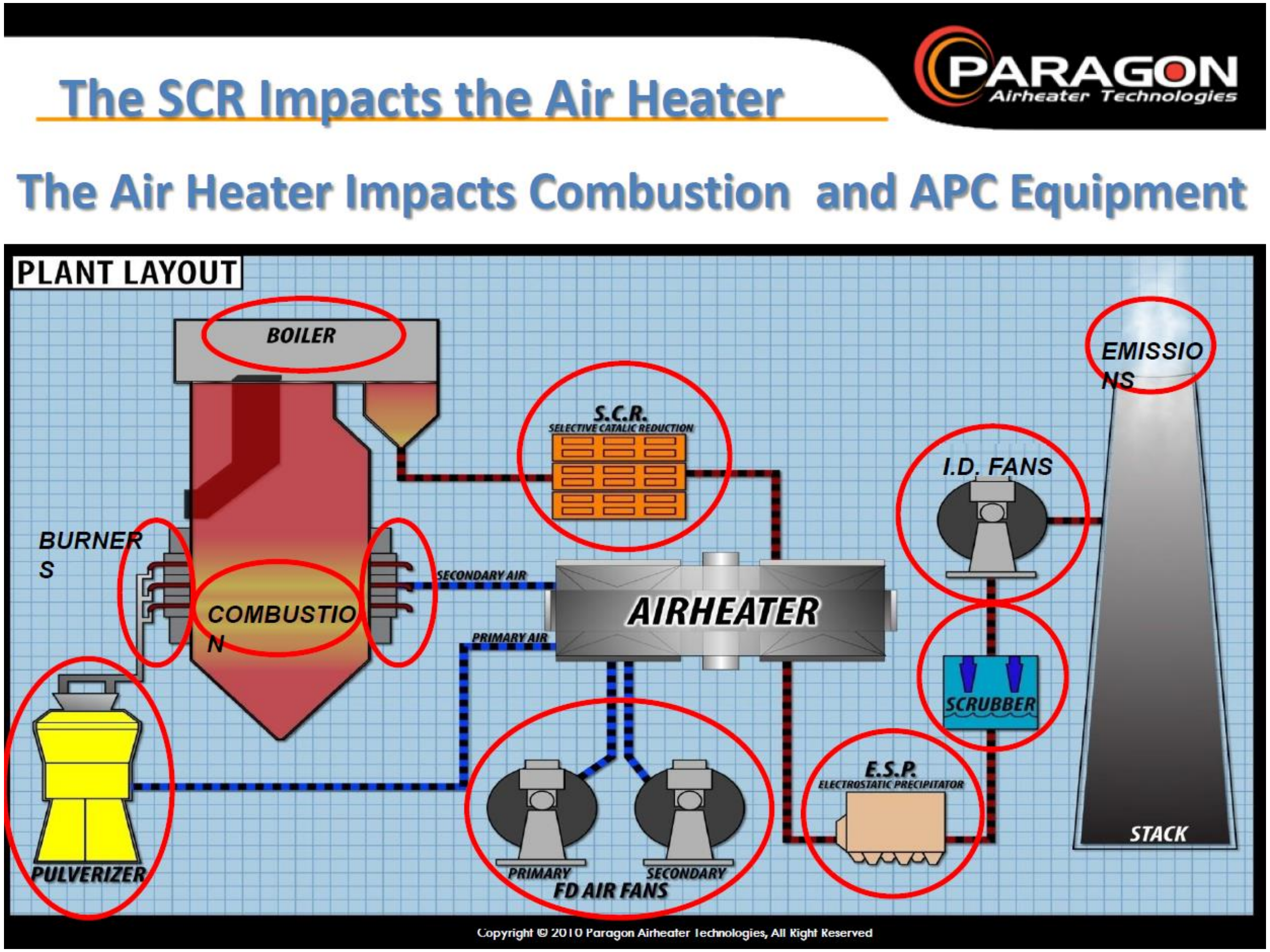
2nd High DeNOx Performance

3rd Low SO_2 to SO_3 Conversion

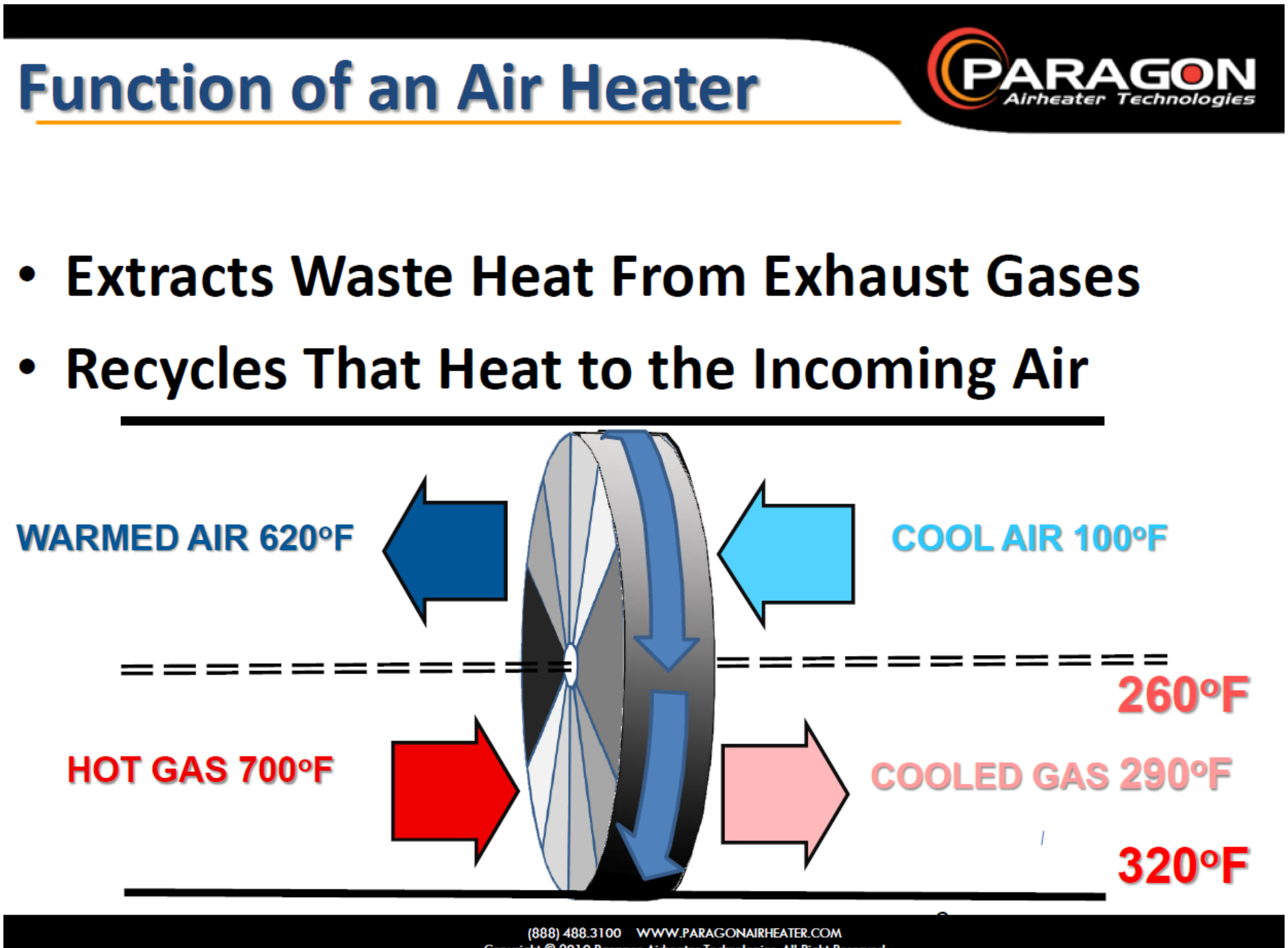


Above Chart Represents Typical Results

SO3 can impact the entire back end system



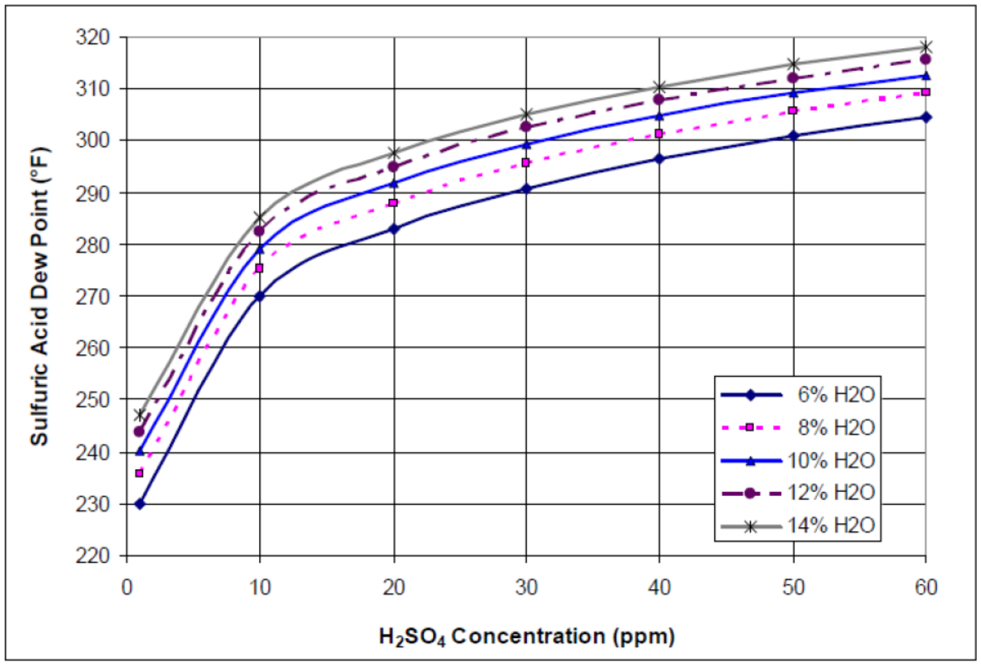
Boiler efficiency is a function of heat transfer in the air heater but limited by the acid dew point



S03 dewpoint based on concentration ,

SO_3 Vs. Sulfuric Acid Dew Point Temp.

PARAGON Airheater Technologies



Ref. A&WMA, 2008 Mega Symposium,
"The Effect of SO_3 Sorbents on Electrostatic Precipitator Performance", Paper

SO3 removal in air heater is a function of temperature

SO_3 REMOVAL TEMPERATURES

PARAGON Airheater Technologies

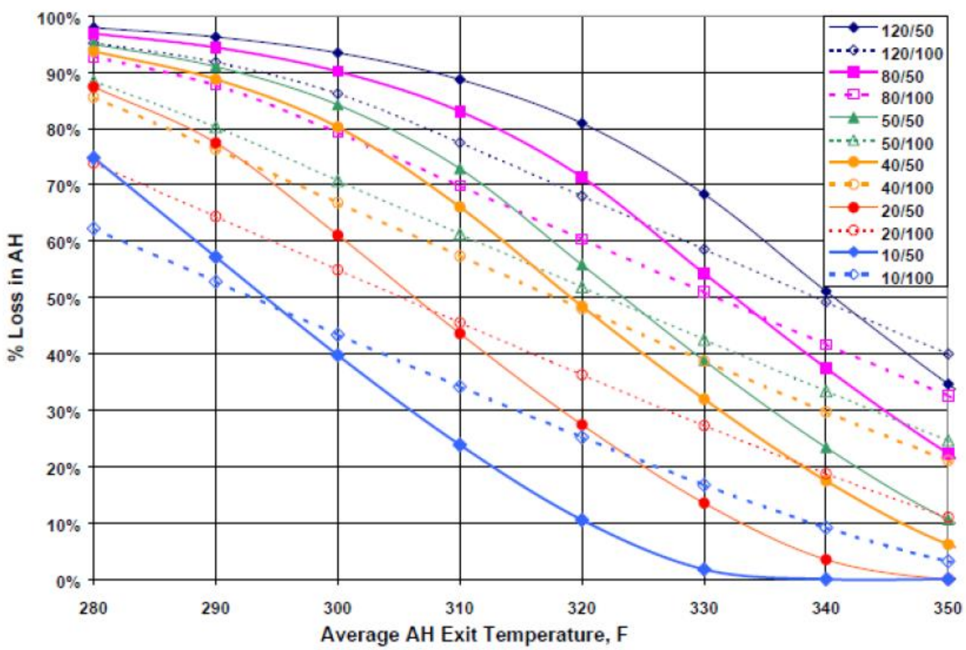


Figure 6.1. Estimated SO_3/H_2SO_4 losses across combustion air preheaters versus average air preheater exit temperature for a temperature offset of 35 °F. The first value of each pair in the legend is the preheater inlet SO_3/H_2SO_4 concentration in ppm and the second value of the pair is the spread in exit gas temperature between the cold side and the hot side of the preheater exit.

SO3 air heater exit concentration is a function of temperature, inlet concentration and cold side temperature differential

SO_3 EXIT CONCENTRATION

PARAGON Airheater Technologies

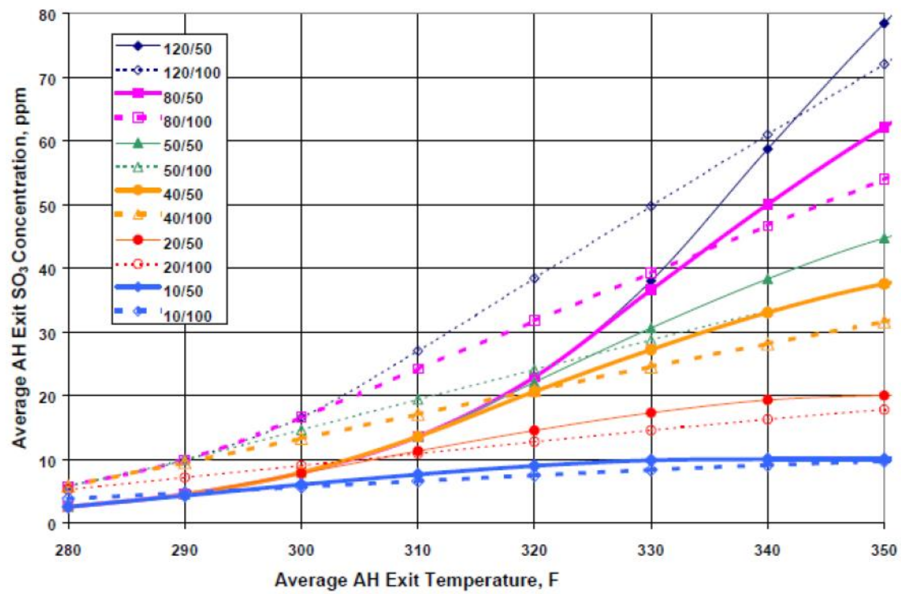


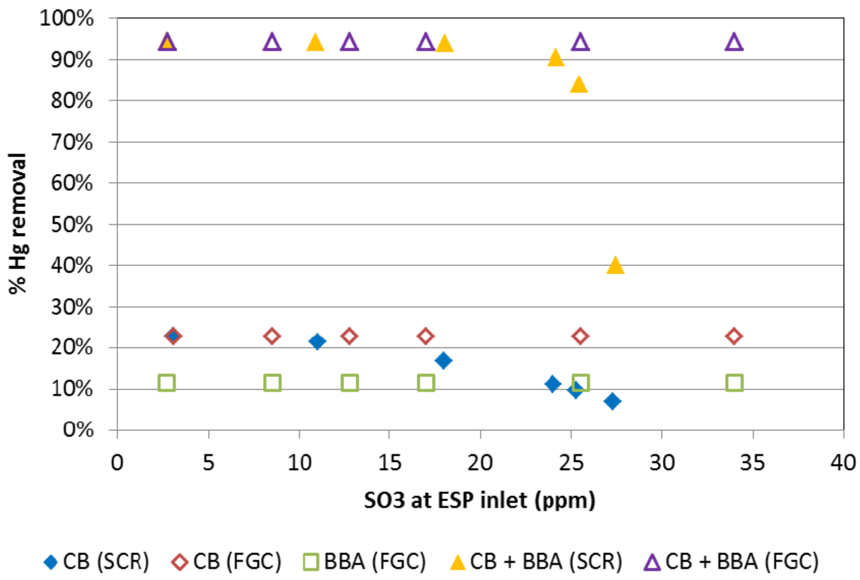
Figure 6.2. Estimated air preheater exit SO_3/H_2SO_4 concentration versus average air preheater exit temperature for a temperature offset of 35 °F. The first value of each pair in the legend is the preheater inlet SO_3/H_2SO_4 concentration in ppm and the second value of the pair is the spread in exit gas temperature between the cold side and the hot side of the preheater exit.

Co –Benefits in mercury removal vs SO3 interference

SO_3 Interference

CB, BBA, ESP

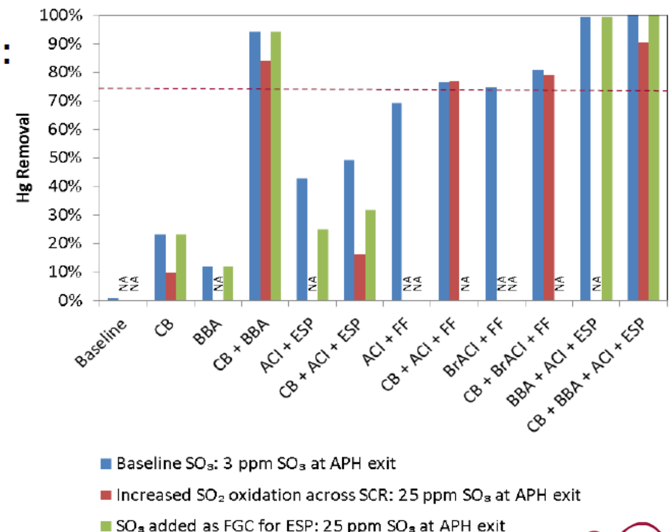
- Increased SO_3 early in the system (SCR and APH oxidation) reduces Hg oxidation and reduces removal for CB and BBA
- Increased SO_3 later in the system (FGC at ESP) avoids upstream interference and has little impact on Hg removal



REACTION ENGINEERING INTERNATIONAL

SO_3 Interference Conclusions

- **High SO_3 concentrations can interfere with Hg removal**
  - **Interferences are larger when SO_3 is introduced early in the system (increased SO_2 oxidation in SCR) compared to later (FGC for enhanced ESP performance)**
- **High Hg removal maintained:**
  - **Fabric Filter scenarios**
  - **BBA with co-benefit if SO_3 from FGC**
  - **BBA + ACI (with or without CB) if SO_3 from FGC**
- **High Hg removal degraded:**
  - **BBA with co-benefit if SO_3 from SCR**
  - **BBA+ACI with co-benefit if SO_3 from SCR**



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PM 2.5 includes fiterables and condensibles

SIEMENS

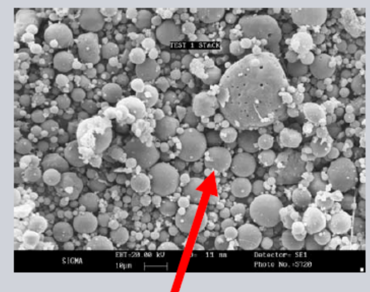
What is $PM_{2.5}$?

Filterable Particulate

- <2.5 microns in size
- Exists as solid particulate at temperatures of 250°F or higher
- Collected in “front-half” filter of PM test apparatus
- Represents @ 25% of $PM_{2.5}$ emitted by sources

Condensable Particulate

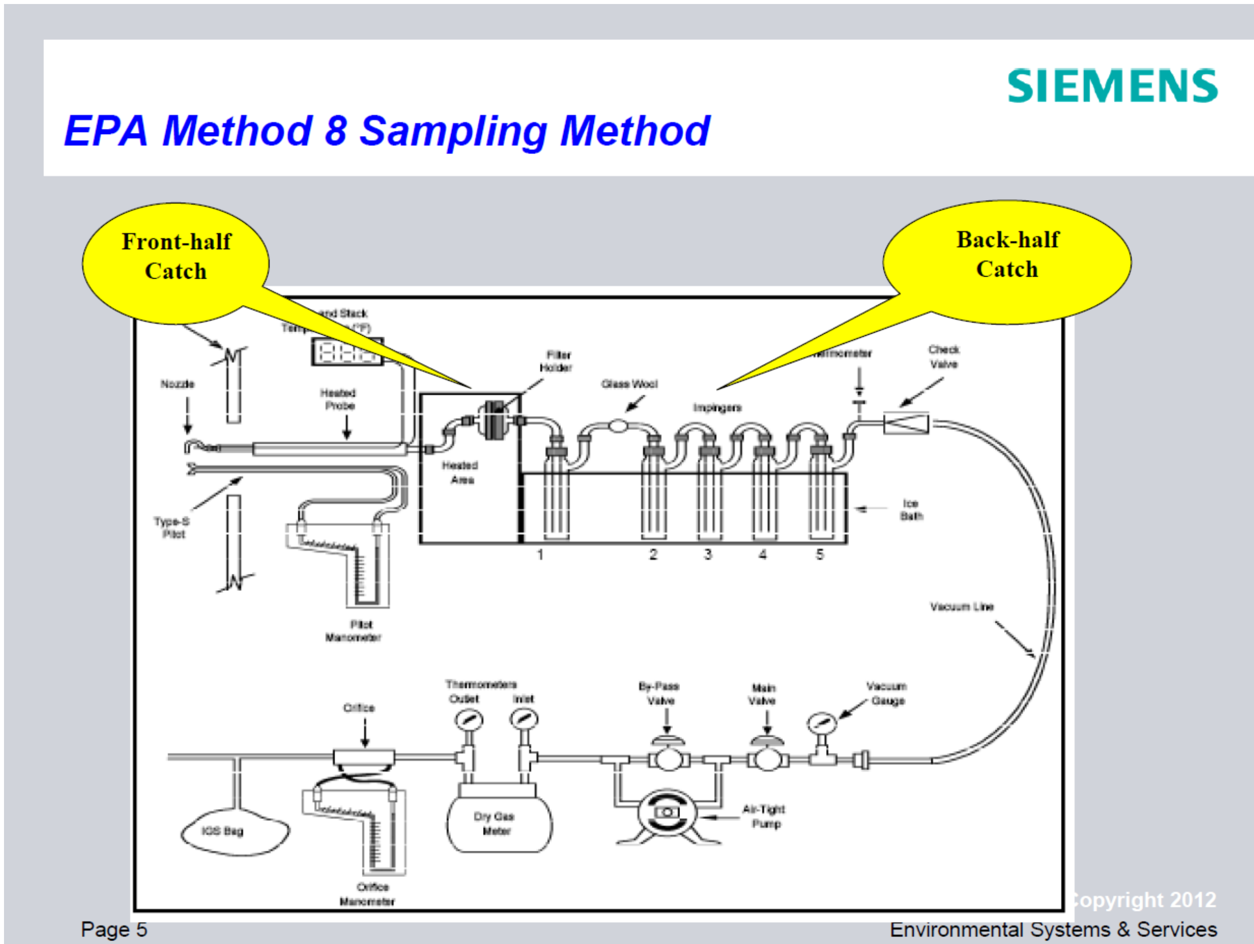
- <2.5 microns in size
- Vapors that condense at ambient temperatures
  - SO_3 – H_2SO_4 sulfuric acid mist (@ 0.5 micron)
  - Toxic metals – cadmium, chromium, lead, magnesium
- Collected in “back-half” impingers in PM test apparatus
- Represents @ 75% of $PM_{2.5}$ emitted by sources
- Has not been required to date to meet PM_{10} standards



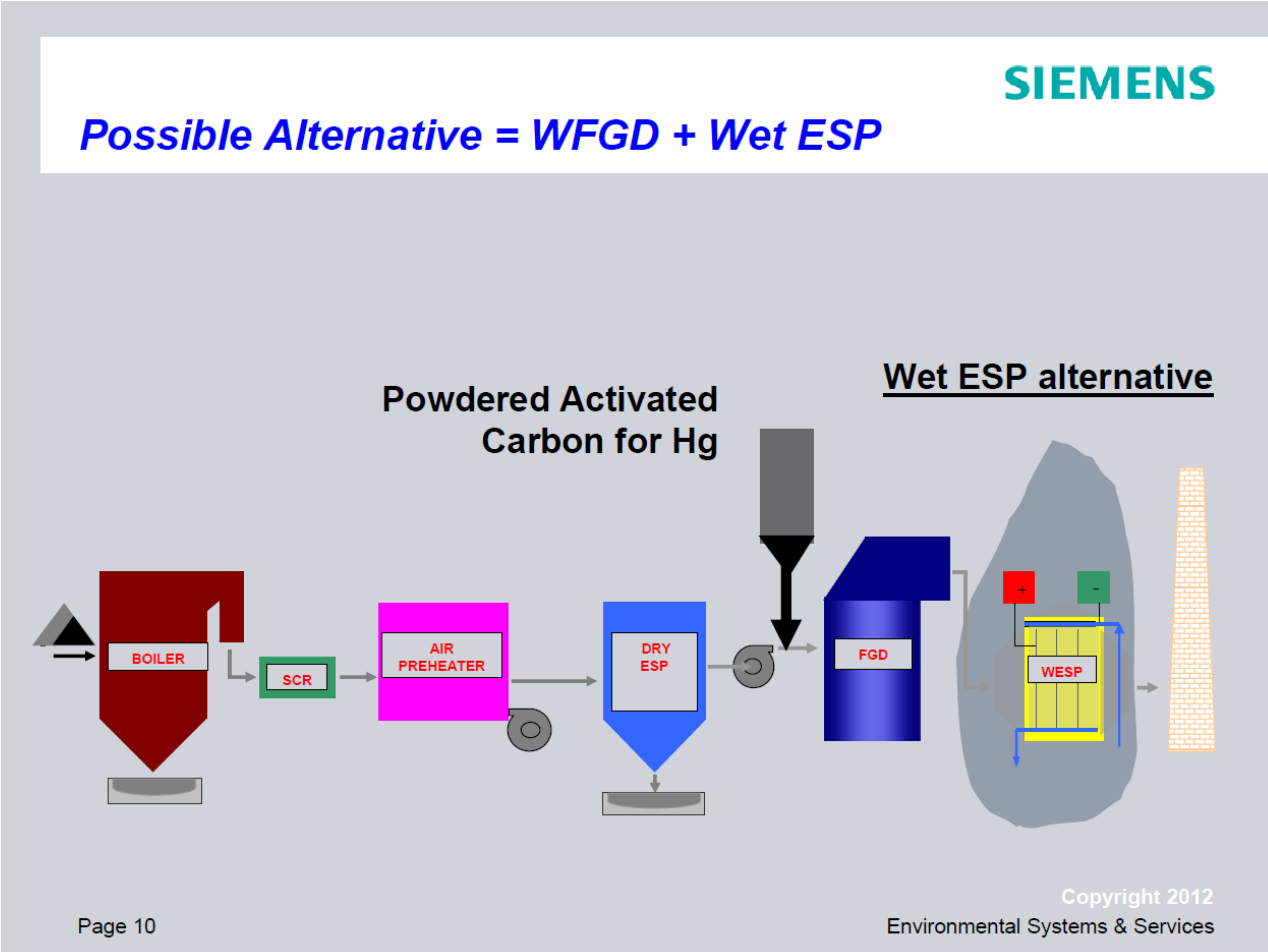
10 µ particle

Environmental Systems & Services

Condensibles captured in back half of sampling train



Wet ESP is very efficient device for SO3 and total particulate capture



Wet ESPS for SO3 and fine particulate

- Several WESPS were installed in U.S. to reduce the SO3 plume in the period around 2000
- Subsequently the solution to SO3 was determined to be dry injection
- However, WESPS have been installed on new plants to capture both the SO3 and fine particulate
- Siemens was the major supplier (now Foster Wheeler)

Wet precips used for PM 2.5 and H2SO4 at some new U.S. plants

SIEMENS

New Coal Plant WESPs not in ICR Data

Facility	Unit Size (MW)	Fuel	APC Control Technology	Status
Elm Road	2 x 615	Pittsburgh #8	FF / WFGD / WESP	Online
Trimble County	750	Blend of Bituminous & Sub-bituminous	ESP / FF / WFGD / WESP	Online 2011
Prairie States	2 x 750	Southern IL Bituminous	ESP / WFGD / WESP	Summer 2012 & Fall 2012

Scrubber capture of SO3

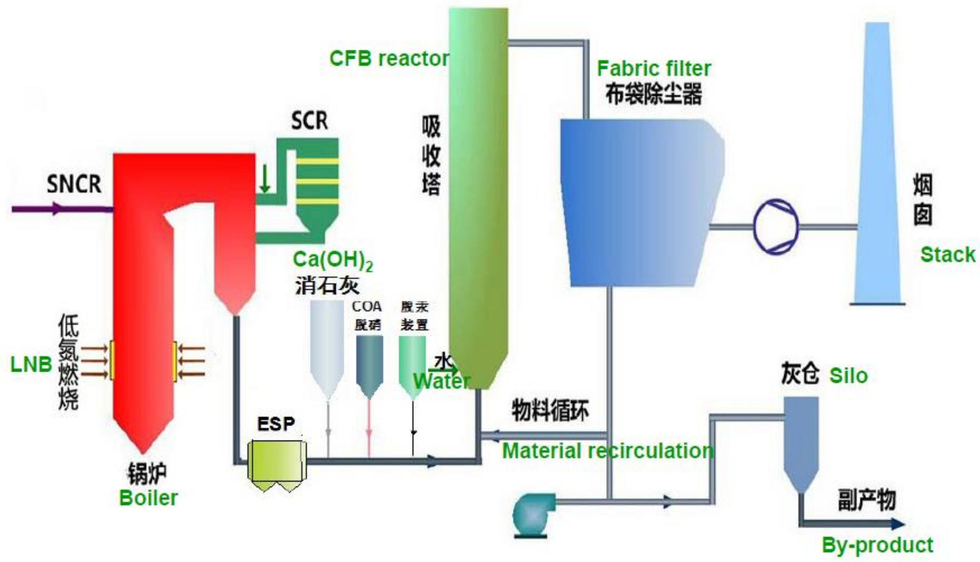
- Typical spray tower wet scrubbers do not remove much SO3
- Circulating fluid bed and spray drier scrubbers can remove most of the SO3
- DSI followed by a baghouse removes most SO3
- DSI followed by the wet scrubber is also a high efficiency route. The injected reagent can also remove S02 as it is captured in the scrubber
- Removal of SO3 at the air heater has the added advantage of allowing more heat extraction
- If condensibles are included as part of an .03 lbs/ mmbtu total particulate requirement, the SO3 reduction will need to be very high and only some of the above combinations will be candidates.

Dry scrubber , fabric filter to meet the low emission rates.

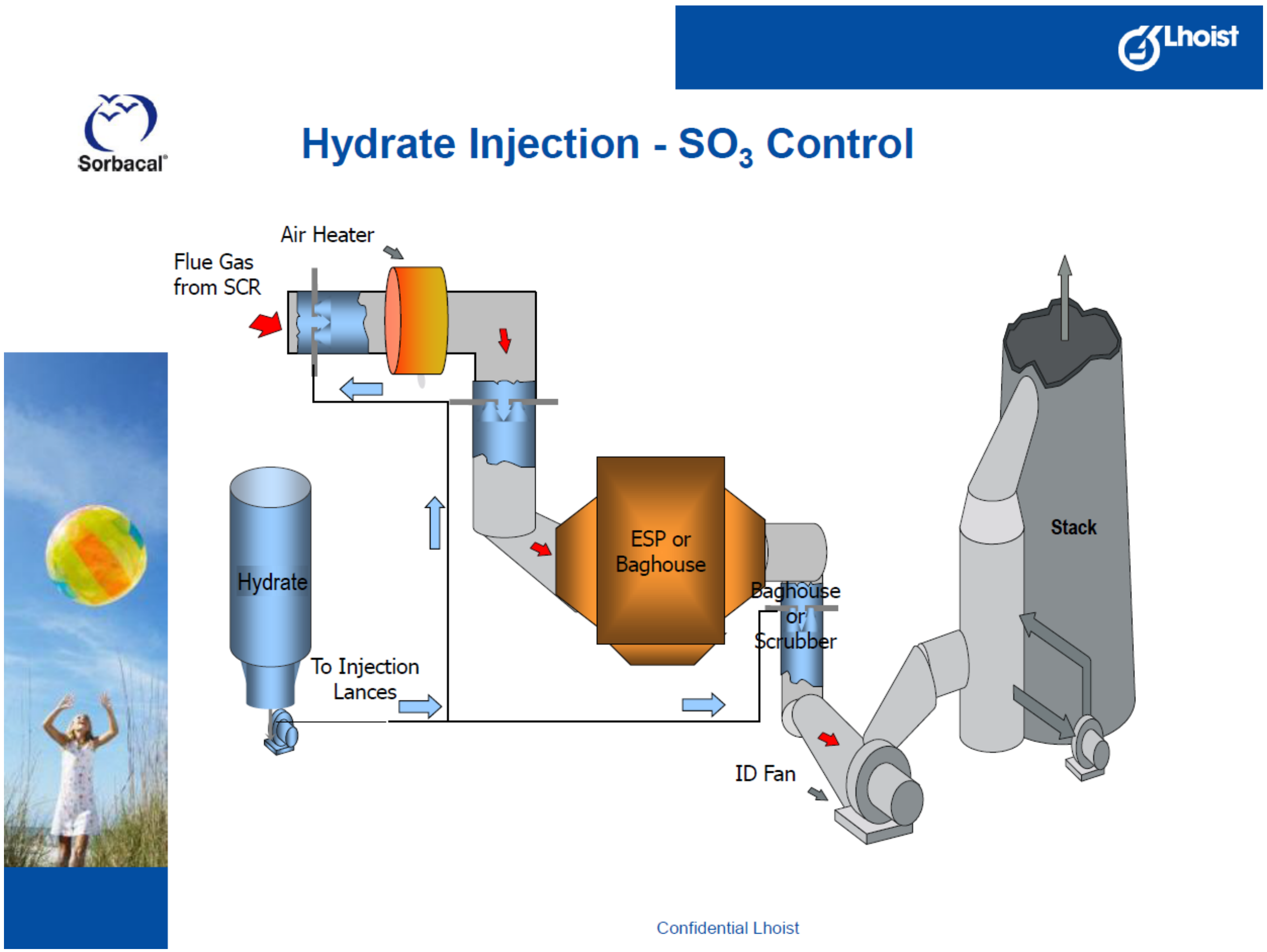
Fujian Longking

How to meet the 50/35/5+5/3 requirements?

Dry process : SCR/SNCR + Advanced CFB-FGD + COA



Hydrated lime injection at 3 points



URS uses SBS to reduce H2SO4 below 1 ppm

URS

Sulfuric Acid Emission Results

Plant	Inlet SO_3 (ppmvd - 3% O_2)	Stack SO_3 (ppmvd - 3% O_2)	SO_3 Removal (%)	H_2SO_4 Emissions (lb/MMBtu)	Particulate Control Device	SO_2 Control Device
A	32	1.3	95.9%	0.0038	ESP	WFGD
B	65	1.6	97.5%	0.0046	Venturi Scrubber	WFGD
C	36	1.3	96.4%	0.0038	ESP	None
D	66	1.2	98.2%	0.0035	ESP	WFGD
E	45	0.2	99.6%	0.0006	ESP	WFGD
F	15	0.6	96.0%	0.0017	ESP	WFGD
G	44	0.5	98.9%	0.0015	ESP	WFGD

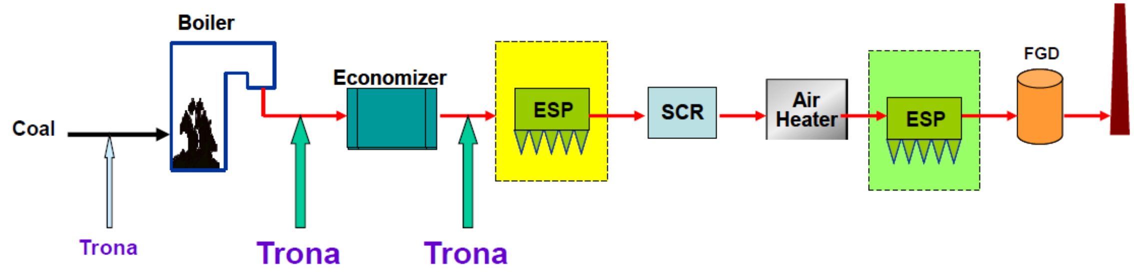
Recent installations demonstrate <1 ppm SO_3 and <0.003 lb/MMBtu SAM

Trona is an alternative to other sodium compounds and can be more cost effective

SOLVAir PRODUCTS

Solutions

- Introduce a low-cost sodium compound downstream of combustion zone (< 1500 °F).
- Use trona instead of Na_2CO_3 and Na_2SO_4 as the source of sodium.
- Spray trona onto coal only IF a small amount of additional sodium is needed.



Low capital and O&M costs!

TVA Shawnee keeps H2SO4 below 1 ppm with DSI and fabric filters

Acid Gas Emission Control – Baghouse Shawnee

DSI Program targeting HCl emissions to meet 2015 MATS

- Baghouse seasoning is essential for test program *(yellow vs green)*
- HCl limits easily met with low hydrate requirements
    - Lower limit of feeder capability for consistency
- Results of follow-up study also optimistic

Hydrate Injection Rate	HCl (lb/MMBTU)	HF (lb/MMBTU)	H_2SO_4 (ppmvd)
0 lb/hr - Baseline	0.0030	0.0045	1.3
600 lb/hr (in flight)	0.0016	0.0046	**0.46**
1,000 lb/hr (in flight)	0.0016	0.0043	**0.42**
350 lb/hr	**0.0005**	**0.0006**	**0.37**
350 lb/hr	**0.0007**	**0.0007**	**0.35**
300 lb/hr	**0.0008**	**0.0006**	**0.35**

Hydrated lime injection reduces SO3 to low levels –Mississippi lime

Typical SO_3 Removal Rates - ESP systems

- Residence time effects
  - Short (<2 sec) will require more sorbent
- Injection system efficiencies
  - Flue gas coverage
  - Feed system

Removal Rate Examples Using Hydrated Lime

Plant	*lb hydrate: lb SO_3*	Treated Stack
550 MW	3.9 : 1	<1.5 ppm
1300 MW	3.9 : 1	3 ppm
700 MW	3.5 : 1	3.5 ppm
>500 MW	1.9 : 1 3.8 : 1	<6 ppm <2 ppm
>500 MW	2.5 : 1 3.9 : 1	4 ppm <2 ppm

Continuous monitors used with Sorbent injection to minimize SO3 emission

Why SO_2 and SO_3 Monitoring?

- $SO_3 + H_2O \rightarrow H_2SO_4$ mist at the stack, i.e. "Blue Plume"
- SO_3 significantly reduces the efficiency of activated carbon for mercury capture
- SO_3/H_2SO_4 corrodes equipment
- $SO_3 + NH_3$ forms ABS, which clogs catalysts, air heaters and other equipment
- SO_2 oxidation changes over time in the SCR, which can actually <u>increase</u> SO_3
- <u>Continuous</u> measurement of SO_2/SO_3 allows for the optimization of sorbent injection toward its removal

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