REINHOLD ENVIRONMENTAL Ltd.

2019 REINHOLD Round Table Presentation

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EVALUATING DSI PERFORMANCE AND BALANCE OF PLANT EFFECTS

2019 Reinhold Conference

Mark Thomas, P.E.

PRESENTATION OVERVIEW

- Presentation
  - Audience is Panel
  - Discussion Encouraged
  - Scope for New & Experienced
- Q & A/ Discussion

Background & Perspective

- 30+ Years of Utility Power Plant Experience
- 20 Years of SO_3 Mitigation Experience
- Testing, System Design & Construction, O&M

- Designed and/or Operated Systems Using Most Available Reagents
  - Calcium (Hydrated Lime, Limestone, Cao)
  - Sodium (Trona, Sodium Bicarbonate, SBS) (Wet & Dry)
  - Magnesium (Mag Hydroxide (Wet & Dry), Magnesium Sulfate (Wet)

- Various Injection Locations
  - Wet & Dry
  - Furnace to FGD Inlet
  - Coal Additives

- Integrated/ Holistic Approach Critical
- Experience varys significantly though fundamental principles are the same

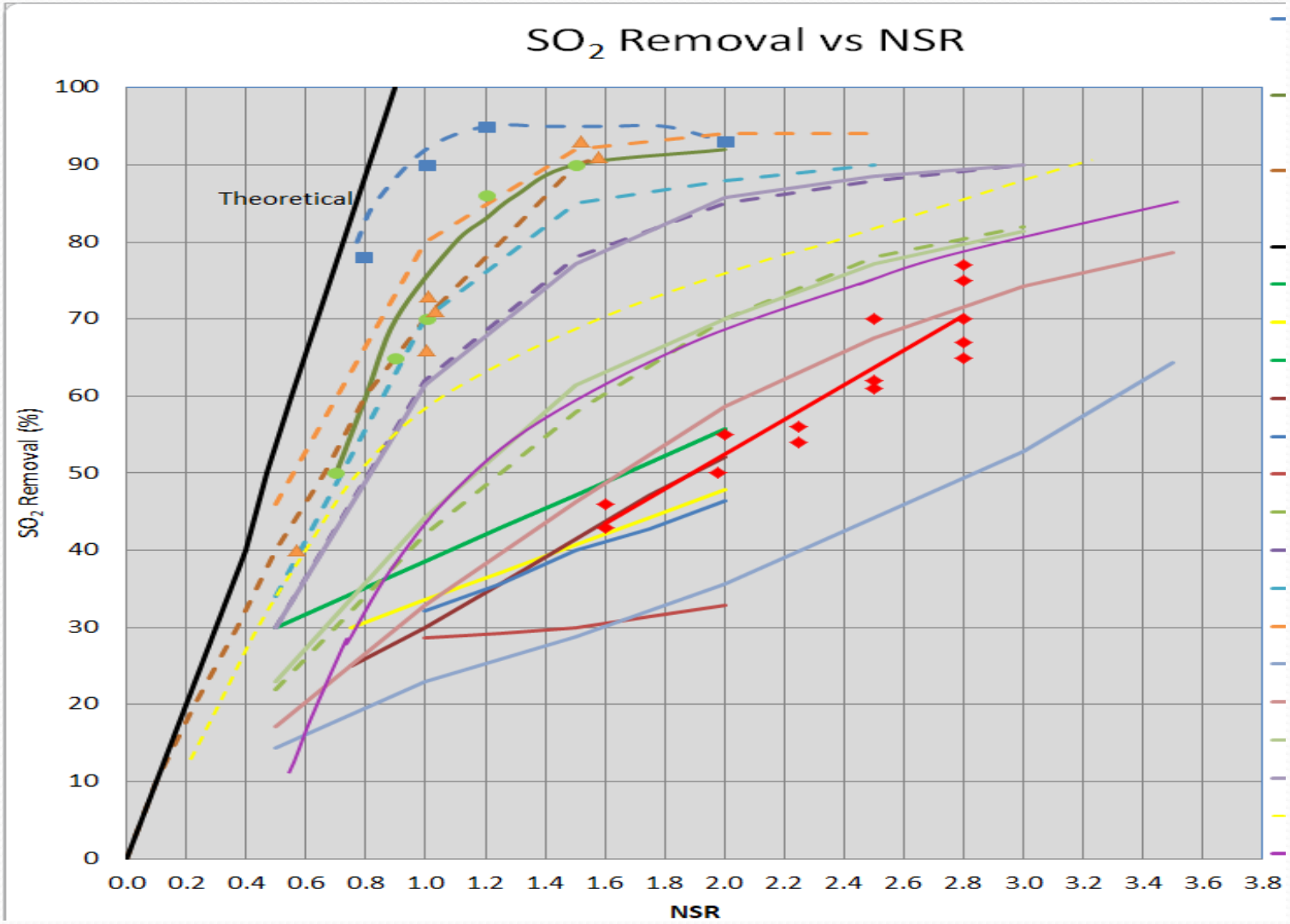
- Past experience critical but past conclusions can be misleading

GENERAL DSI EVALUATION DISCUSSION

- DSI Performance Evaluation
  - Improve Pollutant Capture Effectiveness
    - $SO_3/SO_2/HCl$
    - Se/As?
  - Hg PAC/Capture support
  - Sorbent Comparisons
  - Equipment Comparisons

- Balance of Plant Effects/ Impacts Assessment
  - Air Heater Fouling Reduction
  - SCR Turndown/ MOT Reduction
  - Minimize Fly Ash impacts

EXAMPLE OF PERFORMANCE CURVES



IMPORTANCE OF WELL THOUGHT OUT EVAUATIONS

- Often significant decisions & costs are at stake
- Inaccurate / Incomplete Data or Wrong Conclusions can be very, very costly!!
  - Minimum may require re-testing
  - Worse could lead to wrong decisions regarding compliance strategies
  - Could Lead to Costly Capital and Operating Decisions
  - Could lead to significant BOP Impacts
- Want to Maximize Useful Data @ Least Cost

DSI TRIAL PLANNING – GENERAL CONSIDERATIONS

- Iterative process
- Cost
- Practicality
- Data Prioritization
- Whole Unit vs Part unit DSI
- Unit Conditions
- Input from station - Critical
  - More complex >>more input & planning, meetings required

UNDERSTAND CHALLENGES OF SO3 MEASUREMENT

- SO_3 Measurement is Not an Exact Science!
  - Controlled Condensate is currently the 'Gold Standard' but can vary significantly between testers
    - Some Experts say best precision is +/- 0.5 to 1 ppm not 0.01 ppm as is often shown on test reports
  - Acid Dewpoint Measurement & SO_3 Correlation
  - Sorbent Traps
  - Newer SO_3 CEMS
- All have limitations and significant potential biases
- Impacted by sorbent in gas stream
- Impacted by sampling location
- Impacted by other constituents (eg HCl, etc)
- Impacted by sampling technique

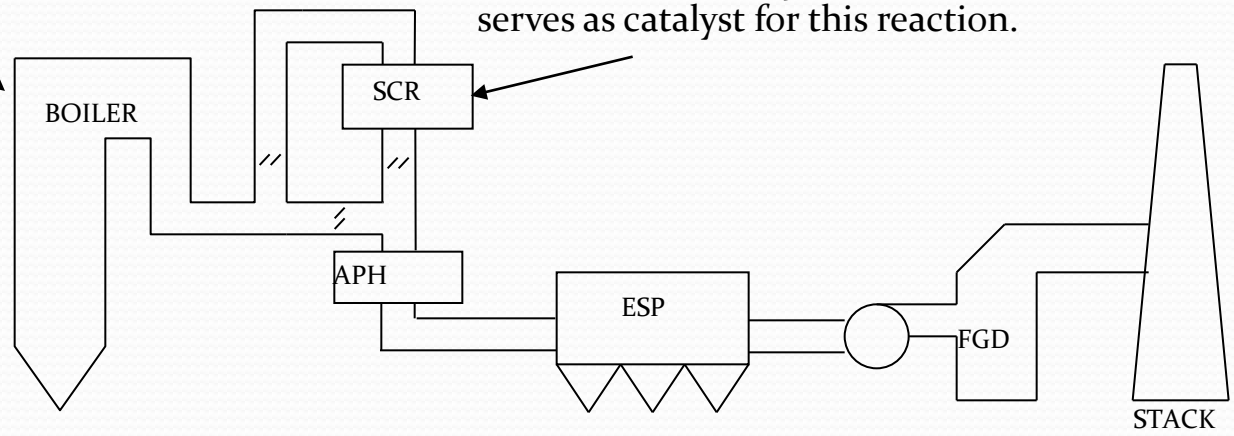
VISIBLE PLUME

- Opacity due to small quantities of H_2SO_4 (Sulfuric Acid) Aerosols in Flue Gas
- Aerosols produced from SO_3 in flue gas when quenched in Absorber Mods

HOW SO_3 IS FORMED

In Boiler aprox 1% of SO_2 oxidizes to form SO_3

In SCR additional 0.75% -to-1.5% of SO_2 oxidizes to form So_3. Vanadium in SCR serves as catalyst for this reaction.



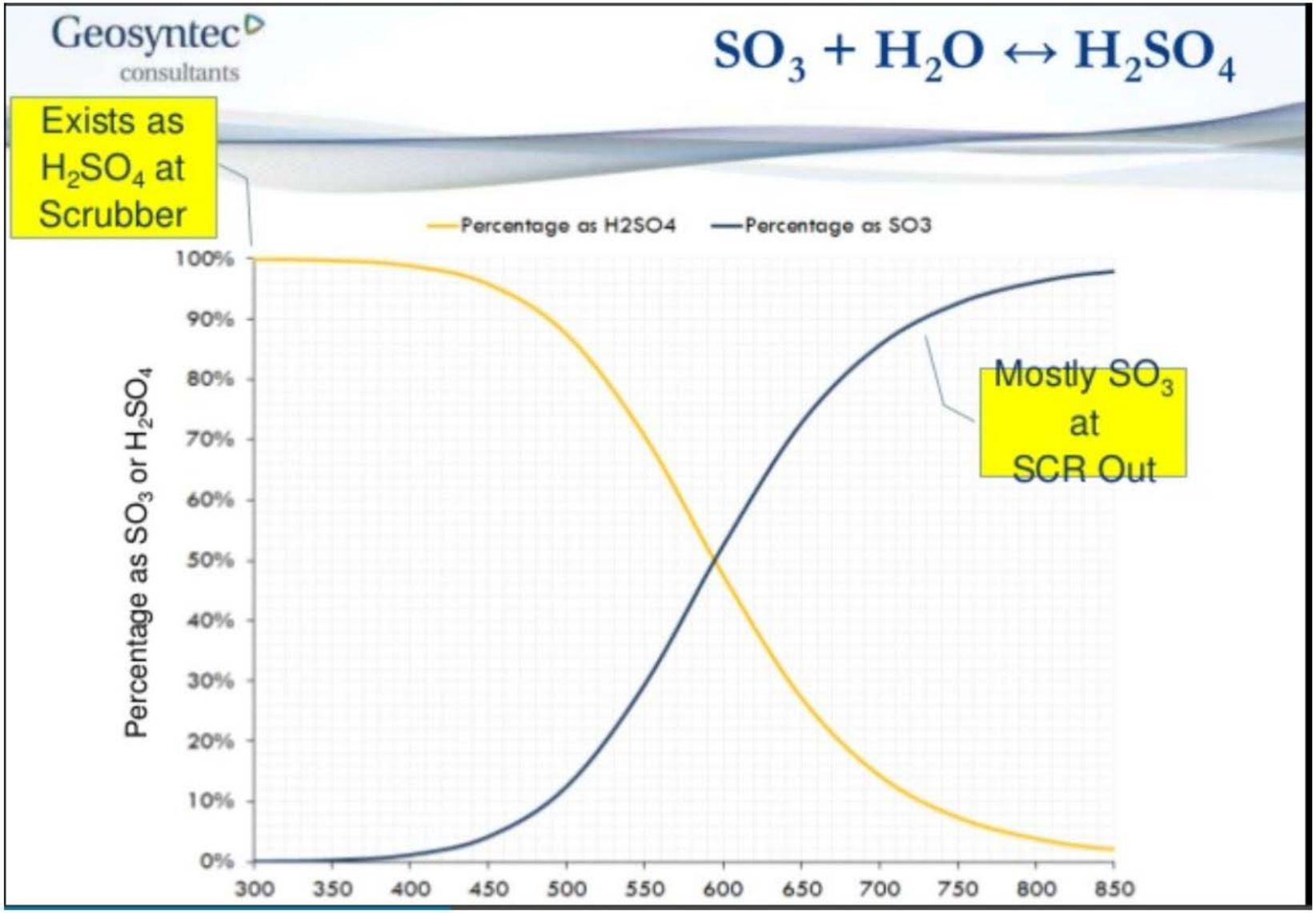
Physical Forms of SO_3

Vaporous SO_3 Converts to Vaporous Sulfuric Acid (H_2SO_4) $SO_{3Vap} + H_2O_{Vap} = H_2SO_{4Vap}$

Vaporous and Condensed Acid (H_2SO_4) @ Temps Below Acid Dewpoint

Sulfuric Acid Mist (Aerosol) H_2SO_4

SO3 vs H2S04 Measurement Considerations



DSI EVALUATION PLANNING

Determine Objectives

- Primary Goals?
  - Quantify/ Confirm Performance
  - Determine Sorbent Choice
  - Determine BOP Impacts
- Secondary Goals? - THINK AHEAD, THINK INTEGRATED
  - Corrosion Mitigation
  - Reduce APH Pluggage
  - Secondary acid gas mitigation
  - SCR Turndown
  - Other Beneficial BOP Impacts?

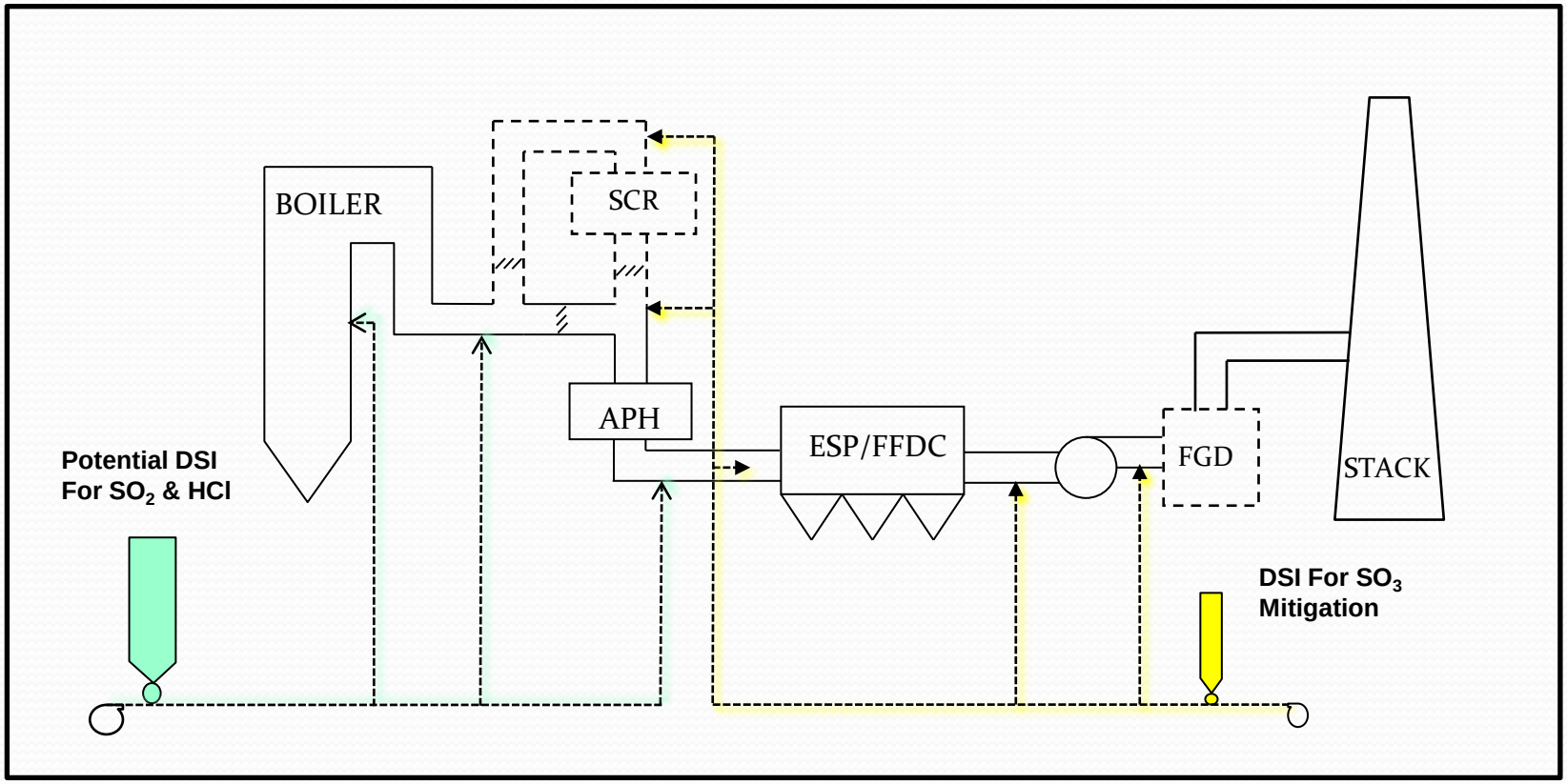
Screening trial –vs-Longer term trial

DSI TRIAL PLANNING

Limitations & Constraints

- Time Constraints
- Cost
- Unit Configuration
  - Current Equip
  - Inject Location Possibilities
    - Residence Time, Etc
- Baseline
- Conditions must be carefully considered
  - Daily ambient temperature effects
  - SCR 'morning sickness'
  - Daily boiler slag building & shedding overnight
- Fuel
  - Type & Variability
  - Delivery Issues

POTENTIAL DSI INJECTION LOCATIONS



DSI TRIAL PLANNING - CONSIDERATIONS

Test System Design

- Reagent Type(s)
- Expected Feed & Turndown
- Expected/ Potential Trial Duration
- Utility Design & Constructed
- Vendor Rental System

Plant Site Planning & Preparation

Sampling Location - Critical

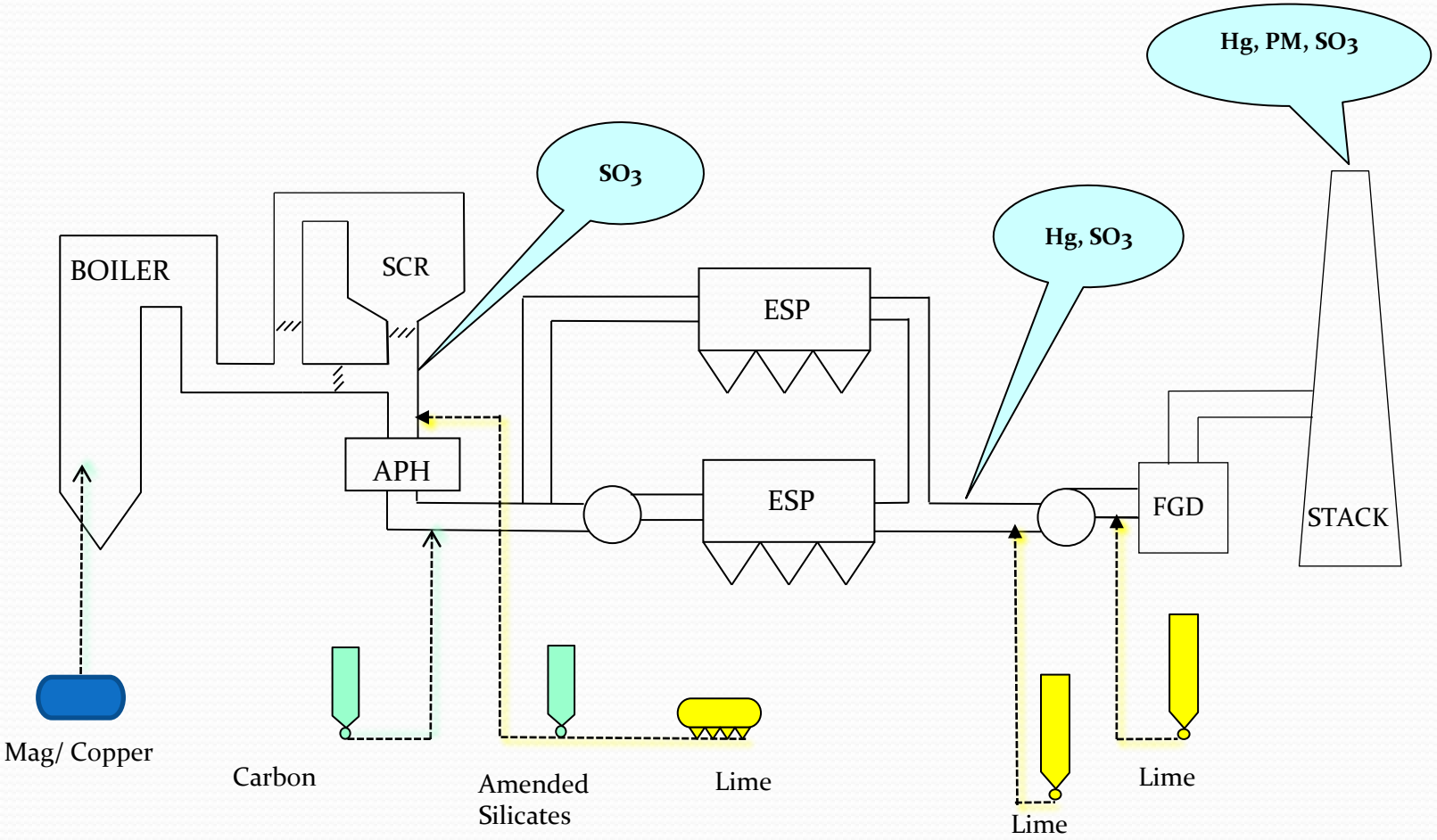
- Stratification
- Gas/ Aerosol State
- Air Inleakage
- Sorbent & Dust Loading

Injection Location – Critical

- Temp
- Gas Flow Pattern

Ports & Internal Obstructions – Verify

COMPLEX TEST LAYOUT



DSI TRIAL PLANNING - CONSIDERATIONS

Sampling & Data Collection

- Selection of Gas Sampling Firm
- Continuous (CEMS) vs. Periodic Sampling
- 'Steady State' determination
- Data Repeatability
- Ash & Gypsum Sampling

DSI TRIAL CONTINGENCY PLANNING

Potential Trial Problems

- DSI Equip Issues
  - Feed Problems
  - Dispersion
  - Reagent Delivery
- Sampling Issues
  - Sampling Equip Problems
  - Unreliable Data
- Plant Issues
  - Unit Load Variability
  - Other Plant Systems
  - Coal Consistency

Know Most important objectives & adjust accordingly

DSI TRIAL PLANNING & EXECUTION

Unit Conditions

- Full Load vs. Cycling
- Coal Loading Schedule
- Furnace Conditions
  - NOx Set Point
  - Sootblowing Schedule

AQCS Conditions

- SCR Operation
- ESP & FFDC Condition
  - Rapping Schedule
  - Ash Sampling
  - Bag Cleaning schedule
  - Ash Sampling
    - Hopper Evacuation
- FGD Conditions

DSI TRIAL EXECUTION & DATA COLLECTION

Prelim-Testing

- DSI System
- Check CEMS
- Determine/ confirm minimum ***acceptable*** conditioning time

Coordinate and Follow Test Plan

Initial Results Review

- Daily Review of results
- Compare to expected

DSI TRIAL – EVALUATION OF BOP IMPACTS

Impacts determined in part by:

- Reagent
- Feed rate
- Injection Location
- Residence Time
- Dispersion Pattern
- Fuel
- Existing Equipment & Systems Issues
- Ash Disposal
- Unit Cycling

EVALUATION OF POSSILE BOP IMPACTS

SORBENT IMPACTS BASED ON INJECTION LOCATION

- Pre-FGD
  - PM Emissions
  - ME Pluggage
  - Duct Layout
- Pre ID Fan
  - Fan Deposits
  - Erosion
- Pre ESP
  - Resistivity
  - Mass Loading
  - Ash Handling
  - Ash Disposal
- Pre APH
  - Hg Impacts
  - Pluggage Concern
- Pre SCR
  - Catalyst Impacts
  - Hg Impacts (HCl)
- Boiler
  - Pluggage
  - Deposits

DSI TRIAL – EVALUATION OF BOP IMPACTS

- Many BOP Impacts take time to show
  - Allow sufficient time if necessary
- Many BOP impacts require inspections to confirm
  - Sooner is better
- Careful not to blame DSI for other root cause

DSI TRIAL – EVALUATION OF BOP IMPACTS

- Poor Dispersion is often the cause of BOP problems
  - General sorbent overfeed
  - Localized sorbent overfeed
- Improved dispersion can reduce and possibly eliminate some BOP problems
- When comparing sorbents or injection system options make sure the existing system is cleaned and in good operating condition
  - Don't Assume problems cannot be fixed!

HYDRATE DISPERSION

EXAMPLE OF MISDIAGNOSED PROBLEM
Hydrate Deposits Typically Only A Problem With Moisture

EXAMPLE OF CONSIDERATIONS FOR APH IMPACTS EVALUATION

- APH Fouling is typically due to condensation of H_2SO_4 on element and ash surfaces and leads to sticky buildups
- SCR additions led to formation of ABS deeper in elements. Soot blowers typically can't reach

- Reducing SO_3 Concentration has been shown repeatedly to reduce APH Fouling

2 LAYER AIR HTR w/ SCR & Increased NH3 SLip

GAS INLET TEMP = 700F

Plate = 660F

Plate = 640F

Plate = 620F

Plate = 600F

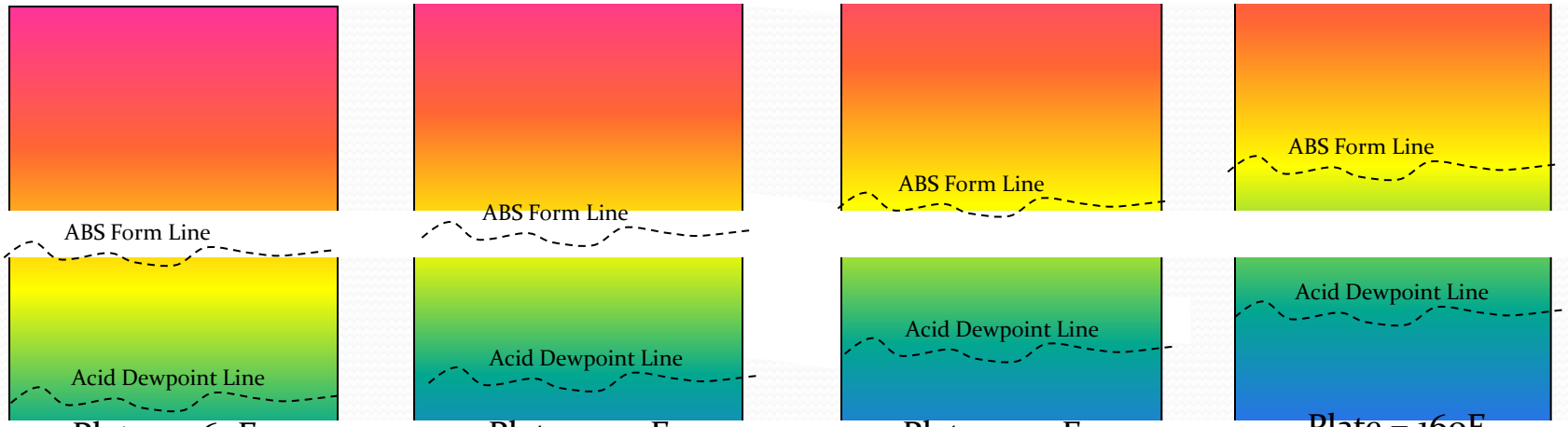


Plate = 260F

Plate = 230F

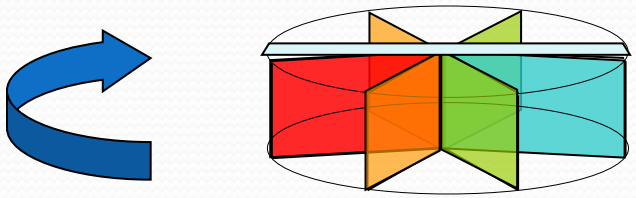
Plate = 190F

Plate = 160F

Hot Side Gas 320 F

AVG GAS OUTLET TEMP = 290F

Cold Side Gas 260 F



AIR HTR w/ SCR & Increased NH3 Slip & Pre APH SO3 Mitigation

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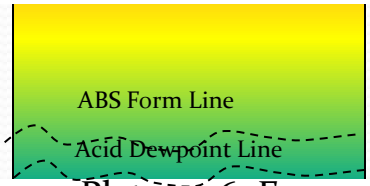

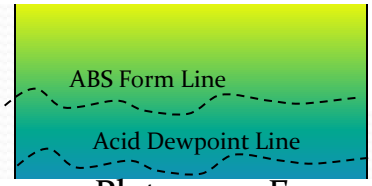

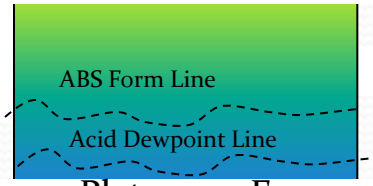

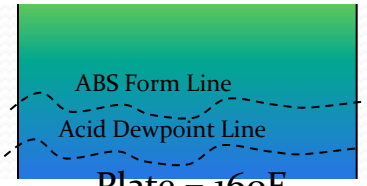

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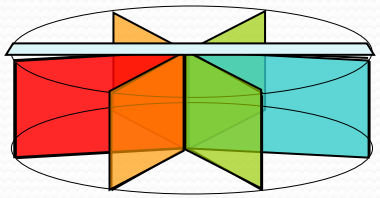
AVG GAS OUTLET TEMP = 290F

Cold Side
Gas 260 F



EXAMPLE OF CONSIDERATIONS FOR APH IMPACTS EVALUATION

- Significant Potential for Fouling Reduction by reducing SO_3 Pre-APH.
- The question is what should the target be?
- Elimination of SO_3/H_2SO_4 will eliminate fouling
  - Can however lead to significant overinjection and BOP problems
- Another option is to find what SO_3 levels are actually needed to reduce fouling to levels that the soot blowers are capable of handling
  - Requires a careful evaluation of AHDP vs sorbent feeds and possibly of H_2SO_4 Dewpoints or SO_3

EXAMPLE OF CONSIDERATIONS FOR APH IMPACTS EVALUATION

Additional Considerations

- If station wants to consider lowering APH temps by changing APH elements:
  - Need to consider DP impacts
  - Will LPA be a problem?
  - Materials of construction
  - Can coatings be eliminated
  - How low can temps be taken?
- May need to test varying SAH inlet temps ahead of an outage incase probs occur
- Testing needs to be done in time for capital budgeting and material acquisition
- Next opportunity could be 4-7 years if miss chance to prove

DSI TRIAL – COMPLETION

- Review Data Immediately
  - Does data make sense?
  - Were plant conditions varying enough to be problematic
- Determine if additional testing needed before removing Test Equipment if possible

SUMMARY & CONCLUSION

- Planning is Critical to Success of Evaluations
- Know Objectives
  - Primary
  - Secondary
  - Potential Future Needs
- Understand Measurement Uncertainties
- Know Data Priority
- Expect Problems and Be Ready to Adjust
- Consult with Plant
- Consult with Experienced Personnel

SUMMARY & CONCLUSION

- Be Practical
  - Consider limitations of station personnel
- Know the basis of “Targets’
  - Don’t expend disproportionate cost & effort trying to solve minor ‘problems’
- Understand Measurement Uncertainties

Questions