CONDUCTING A SUCCESSFUL MERCURY CONTROL DEMONSTRATION TEST AT A COAL-FIRED POWER BOILER

INSTITUTE OF CLEAN AIR COMPANIES

Given to MARAMA on March 21, 2013
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Outline

1. Planning a Test Program
   a. Defining objectives
   b. What to test depends on the plants ACQS and fuel
2. Measurements
   a. Quantifying emissions of mercury and other flue gas components
   b. Where to sample
   c. Detection limits
   d. Other samples and balance of plant
3. How to use the test results
   a. Test duration: matched to the technology being tested
   b. Limitations on using the data, application to longer term operation

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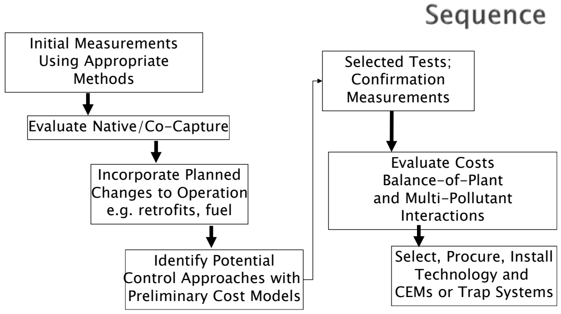
Mercury Strategic Planning Sequence



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Successful Test Planning

- Make a plan
  - Who?
  - What?
  - Where?
  - When?
  - Why ?

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Test Objective Definition – Why Does a Unit need to test?

- Planning for Compliance?
  - Coal now and in the future
  - Configuration details
  - Timing of decision making for procurements, installation and startup / compliance deadline
  - Balance-of-plant goals
  - Tradeoffs between technologies, suppliers
  - Cost evaluation and prediction, capital management
  - Schedule management

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Unit Data and Considerations

- Unit Name
- Unit Number
- Full Load MW
- Air Emission Train
- Residence time and Temperature
  - Economizer to APH
  - APH to PM Device
- Injection Location(s)
  - Installed ports
  - New ports needed
- Flue gas Chemistry
  - SO_3 content
  - SO_2 content
  - Cl content
- Other Considerations
  - Fly ash sales
  - Gypsum sales
  - Coal additives
  - Boiler additives
  - Post combustion additive

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WHO?

- WHO…
  - Who is managing test and demonstration project?
  - Who is requesting the State to approve the test?
  - Who needs to be at the test location? Who are the operations contacts?
  - Who makes real-time decisions when results are unexpected?
  - Who will prepare a bid for the test and demonstration program?
  - Who will be doing the injection?
  - Who will be doing the emission testing?
    - Traps, CEMS or both? Wet Chemistry methods?
  - Who will supply activated carbon or other sorbents?
  - Who will supply additives?
  - Who has tools to help?

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WHAT?

- WHAT…
  - What emissions do you have to test for?
  - What is your budget?
  - What is your current emission equipment?
    - Temperature profile
    - Flue gas chemistry
  - What is your future emission equipment?
  - What are the unit, plant or company expectations?
  - What emission reductions technologies are you demonstrating?
  - What about the fly ash?
  - What about impacts to primary emissions control equipment?
  - What kind of coal will be burned?
  - What unit load should be tested?

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WHERE?

- WHERE…
  - Where is the plant safety training?
  - Where in the emission system will the demonstration occur?
  - Where are the injection points?
  - Where do injection ports need to be added?
  - Where is the test plan?
  - Where is the set up area for injection equipment?
  - Where will the demonstration materials be stored?
  - Where will the results of the demonstration go?
  - Where are the demonstration materials??

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WHEN?

- WHEN…
  - When do you need to test by?
  - What dates and times of day will the demonstration test start / stop?
  - When is the State approval for?
  - When is company approval needed?
  - When does injection equipment need to be ready to operate?
  - When does testing equipment need to be in place?
  - When do the demonstration materials need to arrive?
  - When are results needed by?
  - How long should a test be run to demonstrate a given technology?
  - When it goes wrong …

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Test Planning Reveals Many priorities for EGUs to sort through…

- Control technology experience base
- Active vs. passive control
- Duration of demonstration and commensurate risk of long-term compliance and costs
- Reliability, reliability, reliability
- Conditions of the EGU
  - Short residence time for capture
  - High temperature capture
  - Sell fly ash and/or gypsum
  - ESP SO_3 conditioning
  - High SO_3
  - Load following / turndown

  -Fuel flexibility
  -Future change in configuration
  -Refined coal or additives
  -Impacts to equipment (corrosion, emissions control)
  -Other future regulations

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Mercury Measurement

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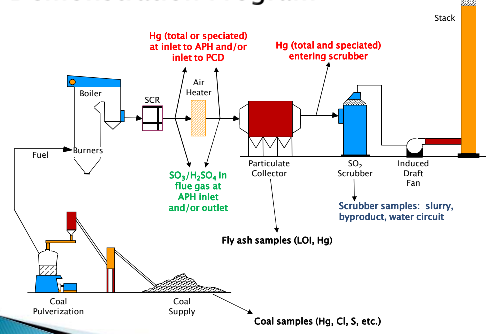
What Do We Mean by Speciation?

- Gas-phase mercury:
  - Elemental: Hg^0
  - Oxidized: Hg^{+2} ($HgCl_2$, other species?)
- Particulate mercury
  - Hg_p
  - Mercury (adsorbed on particles)

The Sampling Plan: Critical Part of Demonstration Program



SCR = Selective Catalytic Reduction

What Type of Measurement Needed?

- Purpose of measurement
- How will the data be used?
- What time-response is needed?

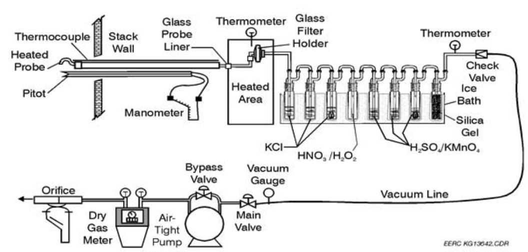
Batch Methods

- EPA Method 101A existed for measuring total Hg
  - 3 liquid impinger in series (10% H_2SO_4/4% $KMnO_4$)
  - Total mercury, no speciation
- Ontario Hydro Method (OHM)
  - Developed by Dr. Keith Curtis and others at Ontario Hydro Technologies, Toronto, Ontario, Canada
  - Extensive validation by Method 301A; dynamic spiking of Hg^0 and $HgCl_2$ in the flue gas
- Sorbent trap methods
  - Method 30B, FAMSS, etc.

Wet (Impinger-Based) Methods

- More than just glassware….

OHM Method

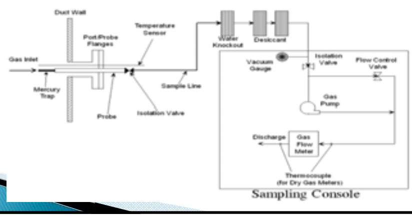


Refer to ASTM Method D6784-02 for more details

Sorbent Trap Sampling System

Performance-based monitoring approach, which means:

- Any sorbent media capable of capturing and recovering total gaseous mercury for analysis
- Any applicable sampling technology
- Any suitable analytical technique c*an be used as long as performance criteria are met*



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Dry Batch Method: Method PS-12B

- Sorbent trap monitoring system for compliance monitoring at coal-fired boilers and cement kilns
- Appropriate for total vapor-phase Hg emissions testing at boilers
- Intended for use only under relatively low particulate conditions (i.e., sampling after all pollution control devices)

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Dry Batch Method: Method 30B

- Reference method for relative accuracy test audits (RATAs) of Hg CEMS and sorbent trap monitoring systems installed at coal-fired boilers
- Appropriate for total vapor-phase Hg emissions testing at boilers
- Intended for use only under relatively low particulate conditions (i.e., sampling after all pollution control devices)

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Dry Batch Method: Speciation Trap

- Measured oxidized Hg and elemental Hg separately
- Components of Speciation Trap:
  - PM filter
  - Acid gas scrubber
  - Oxidized Hg analytical bed
  - Oxidized Hg breakthrough bed
  - Elemental Hg analytical bed
  - Elemental Hg breakthrough bed

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Sorbent Trap Systems

- Have thus far compared well to CEMS, OHM in demonstrations
- Major Issues: QA/QC requirements, long-term dependability of current hardware systems, analytical improvements
- Sideline activities: on-site analysis, reference method

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How Hg CEMS Work

- Atomic Absorption (AA) or Atomic Fluorescence (AF) detect gaseous Hg^0 form only
  - To report Total Hg and Hg^{2+}, requires conversion of oxidized forms to quantify total Hg
    - Liquid reagent, catalytic, thermal
  - Particulate component not measured
- X-Ray Fluorescence (XRF)
  - Total Hg measurement
  - Gaseous only or gaseous+particulate Hg

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CEMS Measurement Issues

- Transporting the sample from the stack to the analyzer while preserving sample integrity
  - SO_3 and wet stacks can be challenges
- Measuring small amounts of mercury in the presence of large amounts of combustion gases that may interfere with the measurement
- Measuring mercury that may exist in multiple chemical forms
- Calibration and spiking

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Advantages of Sorbent Traps vs CEMS

- Significantly lower capital cost – The principal advantage of STs over Hg CEMS is much lower capital cost – about $100-150k versus about $250-500k.
- Simpler system to operate and maintain
  - Sorbent trap systems are less complex than Hg CEMS and do not require as sophisticated a technical staff to support
  - However, the personnel involved in STs do need training on how to properly handle the traps to avoid contamination and other problems that could introduce errors
- Lower concentrations – STs able to measure to lower concentrations than Hg CEMS, but this is very methodology dependent
- No hazardous chemicals to be handled on site

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Disadvantages of Sorbent Traps vs CEMS

- No real-time, or near real-time data – With CEMS, information is available in minutes, which can offer advantages in process control
  - Time averaging can mask cause if spike or problem
- Loss of Data – Problem with a ST sample may not be discovered until after the sample is completed, and data lost for the full sampling period
- Speciation -Speciated Hg measurement approaches available, but not part of a formal method
- Trap Analysis – Analysis of the trap (thermal desorption or wet chemical analysis) destroys the sample
- Few suppliers of traps

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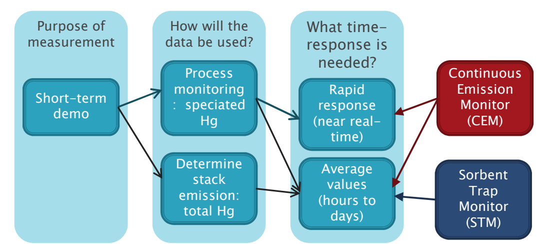
What Type of Measurement Needed?



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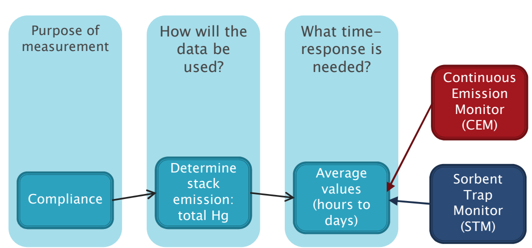
What Type of Measurement Needed?



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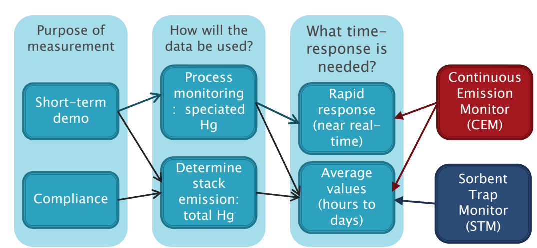
What Type of Measurement Needed?



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Mercury Flue Gas Measurement Summary

- Select appropriate technique(s) to meet the need:
  - Research
  - Process design/benchmarking
  - Compliance
- Available Methods
  - Batch or grab samples: days to weeks for result
  - Continuous emission monitoring: results in minutes
- Interferences, biases, and limitations associated with different measurement methods
- Multiple methods for validation

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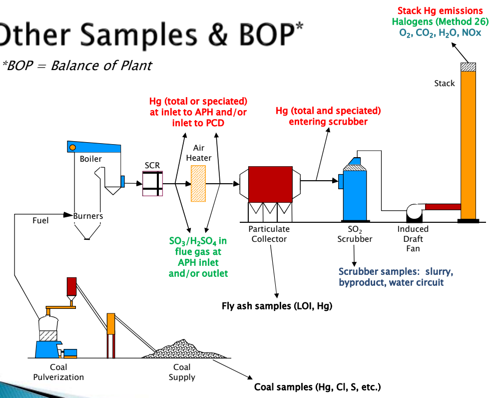
Other Samples & BOP*

BOP = Balance of Plant



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How to use the results

EGU Configurations, Solutions, and Test Duration

Are there limitations to the data?

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Mercury Control Technologies

- Background
- Technology Approach
- Types of Technologies

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Mercury Control Strategies for EGUs

A. Flue Gas Mercury Speciation

1. Elemental Mercury, Hg^0
2. Oxidized Mercury, Hg^{2+}
3. Particulate Mercury, Hg_p

B. Mercury Capture

1. Operations (Increase LOI of ash)
2. Co-benefits of available EGU AQCDs
3. Sorbents with existing EGU AQCDs
4. New AQCDs

EGU = Energy Generating Unit

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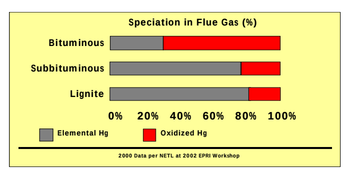
Flue Gas Mercury Speciation

$[Hg^{2+}]$ in flue gas correlates with chlorine content of coal.



1. Elemental Mercury, Hg^0
2. Oxidized Mercury, Hg^{2+}
3. Particulate Mercury, Hg_p

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Flue Gas Hg Speciation Control

- Fuel Blending to increase halogen content
- Boiler additives: Halogen-based salts
- Post-Boiler Halogen-based Additives
- Fixed Catalysts, e.g. SCRs
- Halogenated Sorbent Injection

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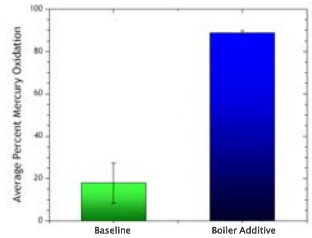
Flue Gas Hg Speciation Control



Boiler additive to increase flue gas mercury oxidation.

Condition	Percent Hg Oxidation
Baseline	17.90 ± 9.42
Boiler Additive	88.8 ± 1.04

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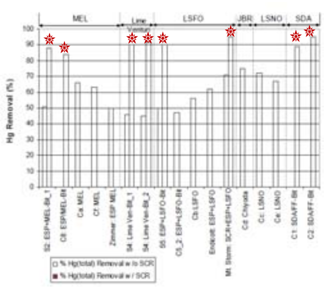
Impact of Type/Chemistry of Scrubber



KEY:
MEL=Magnesium Enhanced Limeston
LSFO=Limestone Forced Oxidation
JBR=Jet Bubbler Reactor
LSNO=Limestone No Oxidation
SDA=Spray Dryer Absorber

Observed Hg Capture Efficiencies:

50 – 80%

R. Strivastava, "Control of Mercury Emissions from Coal Fired Electric Utility Boilers: An Update," EPA/600/R-10/006, February 2012.

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Mercury Capture

- Operations (Increase LOI of ash)
- Co-benefits of existing EGU AQCDs
- Sorbent Injection with existing, upgraded or additional PCDs
- New AQCDs (FF, SDA/CDS, WFGD)

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Some Practical Examples

1. AQCDs = PCD(s)
2. AQCDs = PCD + WFGD
3. AQCDs = ACID GAS Control + PCD + WFGD

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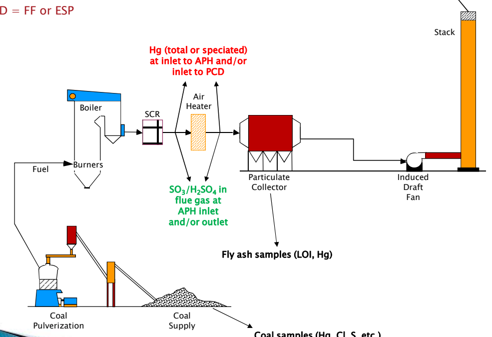
Particulate Control Devices

PCD = FF or ESP



FF = Fabric Filter or Baghouse
ESP = Electrostatic Precipitator

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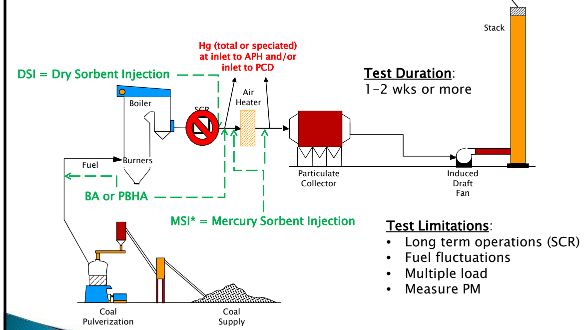
Particulate Control Devices



DSI = Acid gas control, i.e. SO_3
MSI = Activated Carbon-based or Inorganic-based Sorbents*
BA = Boiler Additives for Hg Speciation Control
PBHA= Post-Boiler Halogen-based Injection

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Some Practical Examples

1. AQCDs = PCD(s)
2. **AQCDs = PCD + WFGD**
3. AQCDs = ACID GAS Control + PCD + WFGD

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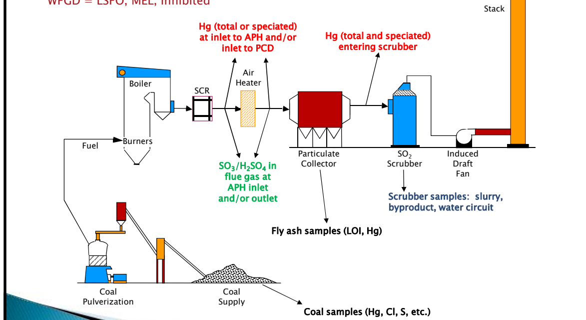
PCD + WFGD

PCD = FF or ESP
WFGD = LSFO, MEL, Inhibited



FF = Fabric Filter or Baghouse
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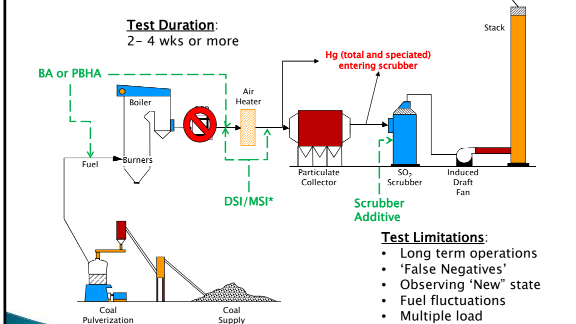
PCD + WFGD



Test Limitations:
- Long term operations
- 'False Negatives'
- Observing 'New" state
- Fuel fluctuations
- Multiple load

DSI = Acid gas control, i.e. SO_3
MSI = Activated Carbon-based or Inorganic-based Sorbents*
BA = Boiler Additives for Hg Speciation Control
PBHA= Post-Boiler Halogen-based Injection
SA = Scrubber Additives

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Some Practical Examples

1. AQCDs = PCD(s)
2. AQCDs = PCD + WFGD
3. **AQCDs = ACID GAS Control + PCD + WFGD**

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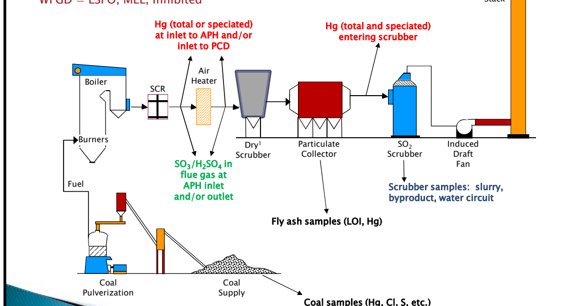
AGC + PCD + WFGD

AGC = Acid Gas Control
PCD = FF or ESP
WFGD = LSFO, MEL, Inhibited



[1]Dry Scrubber = Spray Dryer Absorber or Circulating Dry Scrubber or NID

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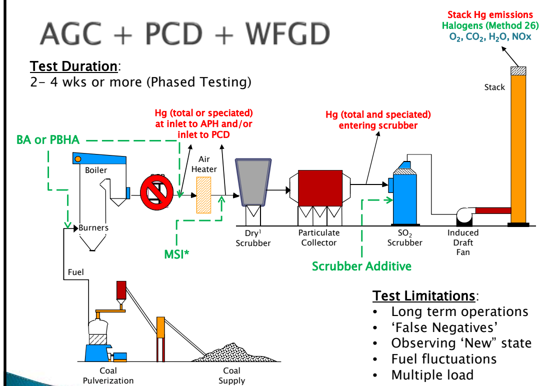
AGC + PCD + WFGD

Test Duration:
2- 4 wks or more (Phased Testing)



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MSI = Activated Carbon-based or Inorganic-based Sorbents or SDA additives*
BA = Boiler Additives for Hg Speciation Control
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Conclusion

- Flue Gas Mercury Measurements
  - Use the "appropriate" methods (more than one)
- Take Samples (more is better, decide later)
- Know what you want before starting
- Plan for "Murphy" to attend test
- Manage Cost

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Acknowledgements

- Doug Austin, ICAC
- Connie Senior, ADA-ES, Inc.
- All the contributors to the ICAC White Paper:

"*Conducting a Successful Mercury Control Demonstration Test at a Coal-fired Power Boiler*."

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ICAC White Papers

- "Bid Specification and Information Requirements and Bid Evaluation Form for Activated Carbon Injection Systems"
- "Conducting a Successful Mercury Control Demonstration Test at a Coal-Fired Power Boiler."

Available at www.icac.com

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