Key Factors in Activated Carbon Injection

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Where are we now…

• Approximately 55-60 units injecting activated carbon for mercury control across the US and Canada.
• Approximately 50 units using CaBr2 injection.
• Mercury and Air Toxics Standard requires compliance in April 2015.
• Activated carbon is the accepted technology for meeting state and MATS mercury emissions limits
• New approaches, new technologies, and better carbons are under development.
Two pieces of the puzzle to consider

• Equipment Selection/Design
  – Key lessons learned
  – Key equipment

• Activated Carbon Selection
  – Understanding your unit & mercury
  – Selecting the right carbon
First step → define your problem

- Current Hg emission rate
- Required Hg emission rate

Does a solution that fits your unit and fuel choice(s) exist?

Testing is the best method to determine right solution for your unit(s)
Factors impacting equipment design and selection

• Design considerations
• Key lessons learned

Powder Activated Carbon is a unique material

• Abrasive
• Does not convey like other “powders”
• Will free flow like liquid when over aerated
Full Scale Testing – Hg

Best method to determine right solution for your unit

- Large focus on testing – now through MATS implementation
- Necessary to achieve the best, lowest cost solution for your units
- Longer term is better – short term/preliminary results can be misleading
- Work with testing company/engineering company to develop test plan – better plan = better results
- Use results to guide equipment design and carbon selection
Equipment Design Considerations

• Start with flue gas flow rate and PAC injection rate
  – Choose realistic injection rate
  – A large difference in design injection rates can negatively impact system design (turndown)

• Silo
  – Sizing: how many days storage/how many units served
  – Density of PAC varies based on raw material – ≈25 - 55 pcf
  – Truck/rail unloading system

• Feed train
  – 1 -3 per silo
  – Gravimetric vs volumetric
Equipment Design Considerations

- Control building
  - MCC, building, etc

- Controls Type
  - PLC, DCS, local controls

- Other considerations:
  - Roof slope
  - Dry instrument air (fluidizing air, bin vents)
  - Crane
  - Installation
ACI System Supplier Responsibilities

Design, fabricate, and pre-assemble a fully functional and operating system including:

• Silo system
  – Truck unloading
  – Fluidization system
  – Rotary valve

• Feed Train
  – Feeder type (gravimetric vs. volumetric)
  – Blowers (regenerative vs. PD)
  – Eductors
  – Control Instrumentation

• Injection System
  – Distribution Header
  – Injection Lance
Equipment – Key Lessons

Years of systems experience = several lessons learned:

• Rotary valve wear on gravimetric feeders – isolate rotary valve
Equipment – Key Lessons

- Pressure variations in gravimetric feeders lead to erratic feeder accuracy
  - Vent to avoid pressure build up
Equipment – Key Lessons

• High Eductor Inlet Vacuum
  – Install check valve to control inlet vacuum

• High wear on eductor discharge piping and elbows with skirted silo
  – Install wear resistant adapter to discharge piping
  – Minimize elbows and bends in transport piping
  – Use ceramic wrapped pipe at elbows and bends
Equipment – Key Lessons

• Diverter Valves
  – Short stagnant line off of the stream feed can plug
  – Mount diverter valves horizontally
Equipment – Key Lessons

- **Plugged Lances**
  - Lances prone to plugging when there is no air flow through them
  - Diverter valves should be open and blowers running while ACI system is shut down and generating unit is still operating
Key Factors in Activated Carbon Injection

Factors Impacting ACI

- Coal selection
- Air Pollution Control Device Configuration
- High SO3 applications
- Concrete compatibility
- Injection location
- Use of fuel/boiler additives
- Field Service/Optimization
Coal Selection

Coal Selection

• Source
  – Powder River Basin
  – Western Bituminous
  – Eastern Bituminous
  – Lignite

• Key Factors
  – Hg content, %S, ash, and halogen content

• Variability
  – Understanding variance of native mercury content
Air Pollution Control Devices

APC Devices + Coal Selection Impact Injection Rate

• Fabric Filter vs. Cold Side ESP
• SDA vs. WFGD vs. DSI
  – Impact of trona injection
  – Hg re-emission issues
    – Solutions exist – AC or use of an oxidant
    – SDA + FF results
• Impact of SCR
  – Hg Oxidation
  – SO2 to SO3 conversion
ACI with an ESP

Key factors using ACI with an ESP

• Temperature
  - performance declines above 350 F
  - affect moderated with brominated PACs
  - PAC does not work with HS-ESP

• Specific Collection Area (SCA)
  - square ft of plate area per 1000 acfm
  - typical SCA is 300 - 400, range is 100 to 800
ACI with an ESP

- PAC Distribution in the Duct is Critical
  - duct configuration to generate turbulence
  - PAC injection lance design
ACI with a Fabric Filter

Key factors using ACI with a Fabric Filter

• **Temperature Effects**
  - performance declines above 350 F
  - moderated with brominated PACs & baghouse design

• **Air-To-Cloth Ratio**
  - cubic feet of gas flow per square foot of bag surface
  - typical is 8 – 10, newer units may be 6
  - lower number means more contact time with PAC

• **Cleaning Cycle Times**
  - cycle times adjusted for optimum Hg removal using CEMs
ACI with a Fabric Filter

Key factors using ACI with a Fabric Filter

- PAC Distribution in Duct is Less Critical
  - PAC on the bags simulates a packed bed, better contact
  - PAC injection lance design less important
  - ductwork configuration less important
  - carbon is much more efficient than in ESP units
SO3 Laden Flue Gas

Three cases of SO3 laden flue gas:
- Native %S content of coal (Eastern Bituminous)
- SO3 injection for flue gas conditioning
- SO2 to SO3 conversion by SCR catalyst

No easy solution
- SO3 tolerant carbons in development
- DSI for SO3 control – can have other affects, such as trona interfering with oxidation of the mercury
Activated carbon influences fly ash used in concrete:

- Adsorption of air entraining agents (AEA)
- Concrete stability issues
- More variability in AEA needed

• Fly ash containing AC often not acceptable for concrete
  - LOI
  - Relative Foam Index too high
  - Color
Concrete Friendly Applications

• Relative Foam Index (RFI) used as reference measurement

• RFI is the amount of AEA required for a stable foam in concrete mixture

• Lower RFI the better – less AEA required, assume ≤6 for concrete compatible
Residence Time and Mixing are Key!

- **Pre-APH injection**
  - Mixing in air heater
  - Longer residence time

- **Post-APH injection**
  - Goal is long residence time
  - Mixing will not be as good, so may need to compensate with more injection lances
  - Proper lance design
  - CFD modeling is a good option to ensure proper mixing
Boiler additives, such as CaBr2, increase oxidation of elemental mercury.

- Low cost solution may be a combination of CaBr2 addition and standard activated carbon.
- Must be aware of possible BOP effects such as corrosion.
Field Service/Optimization

Optimization is an ongoing process:

• Utilize your activated carbon supplier to optimize your injection rate
• Upgrade/change carbons as better products come to market
• Focus on low cost solution/lowest total cost of ownership
Removing mercury from flue gas is a complex problem

Overcome this challenge by:

- Full scale testing – longer term is better
- Select and install a robust system
- Select the right activated carbon for your unit
  - Understand factors impacting selection
  - Optimize carbon usage