INVESTIGATION OF FLY ASH AND ACTIVATED CARBON OBTAINED FROM PULVERIZED COAL BOILERS

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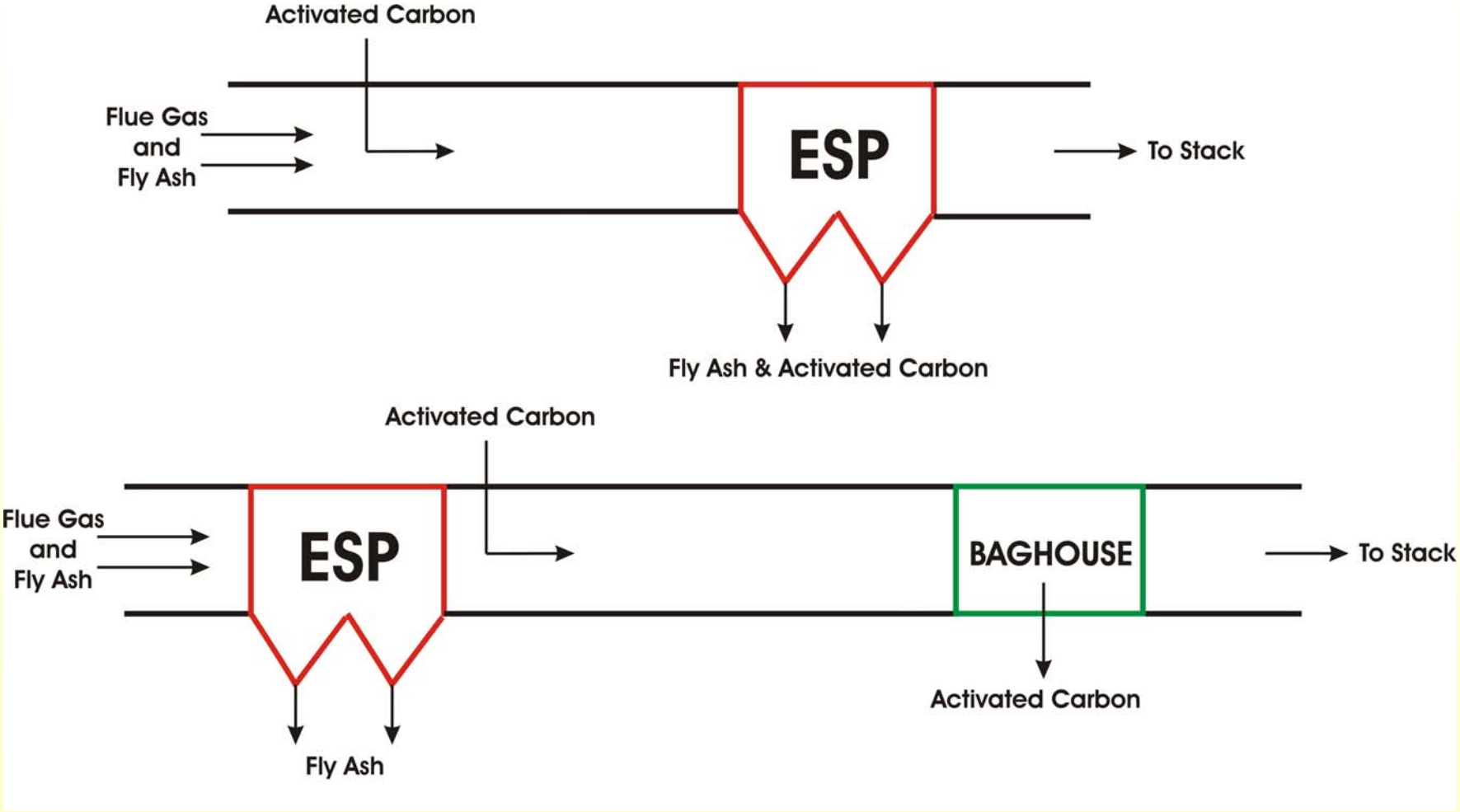
MERCURY CAPTURE

- Hg Leaves Boiler as Vapor Phase Hg and Hg Adsorbed on Fly Ash
- Inject Powdered Activated Carbon to Increase Hg Capture
- Fly Ash and Activated Carbon Captured in Electrostatic Precipitator or Baghouse


Activated Carbon
Flue Gas
and
Fly Ash
ESP
To Stack
Fly Ash & Activated Carbon
Activated Carbon
Flue Gas
and
Fly Ash
ESP
BAGHOUSE
To Stack
Activated Carbon
Fly Ash

- Activated Carbon Injection is Expensive. (Typically $ Millions/Year for a Large Boiler)
- Can We Reduce Amount of Activated Carbon Needed for a Boiler?
- Activated Carbon Contaminates Fly Ash – Reduces Potential for High Value Reuse
- Can We Separate Activated Carbon From Fly Ash?
- Can We Process the Captured Activated Carbon and Reuse It?

OBJECTIVES

- Determine the potential for separation of AC from fly ash in a bubbling fluidized bed
- Determine the temperatures needed to remove Hg from spent AC in a bubbling fluidized bed, thereby creating the possibility of recycling regenerated AC back to the boiler
- Determine which components of fly ash are important for Hg capture
- Determine if SCR reactors affect fly ash chemistry in relation to Hg capture

Task 1: Separation of Activated Carbon and Fly Ash in a Fluidized Bed

Task 2: Removal of Hg From Activated Carbon and Fly Ash

Task 3: Microstructural and Chemical Analyses of Fly Ash and Activated Carbon and Fly Ash

Task 4: Effect of SCR on Ash Properties

FLY ASH CONTAINS:

- Alumina
- Silica
- Fe_2O_3
- Coal Char (Unburned Carbon; LOI)
- Etc.

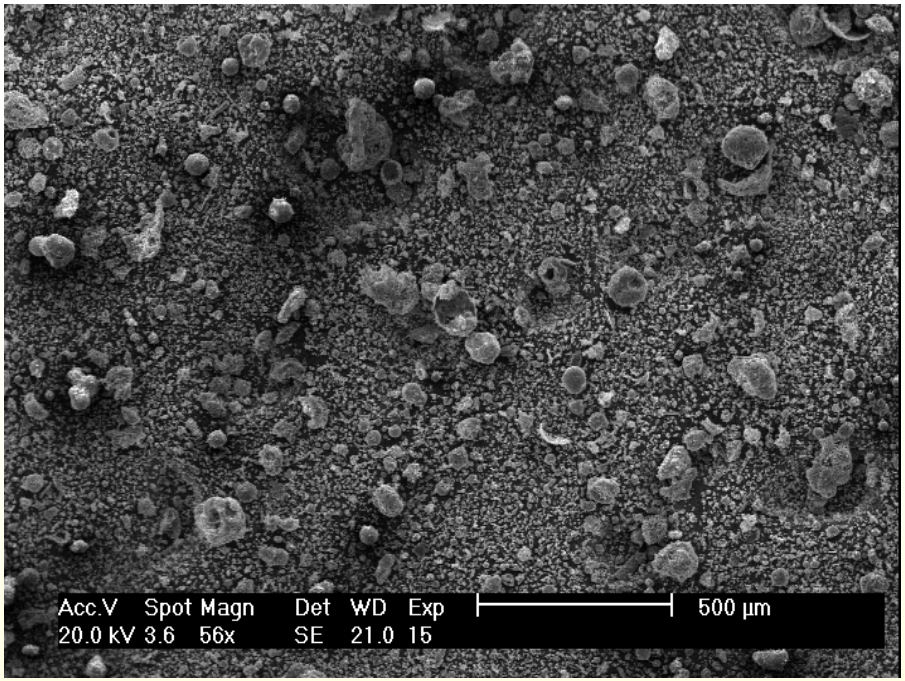
Wide Size Distribution (Submicron to 100 μm)
TYPICAL MEAN DIAMETER; $d_p \approx 10 \rightarrow 20$ μm
Range of Particle Densities

Activated Carbon – DARCO FGD

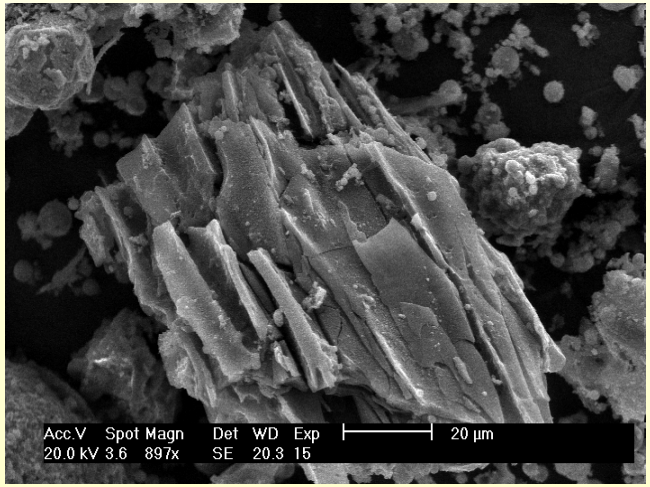
60 – 70% carbon
Remainder inert materials
$d_p \approx 15\ \mu m$

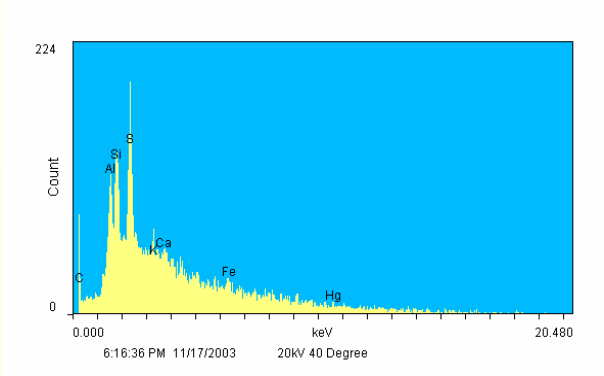
ANALYTICAL INSTRUMENTS

- Scanning Electron Microscopy (SEM) with EDS Spectrometer. Particle Morphology and Chemical Mapping.
- Transmission Electron Microscopy (TEM) with EDS Spectrometer. High Resolution Imaging and EDS Point Analyses.
- Atomic Absorption Spectroscopy – Measure Hg Content of Bulk Samples.
- X-Ray Photoelectron Spectroscopy (XPS) – Surface Chemistry.

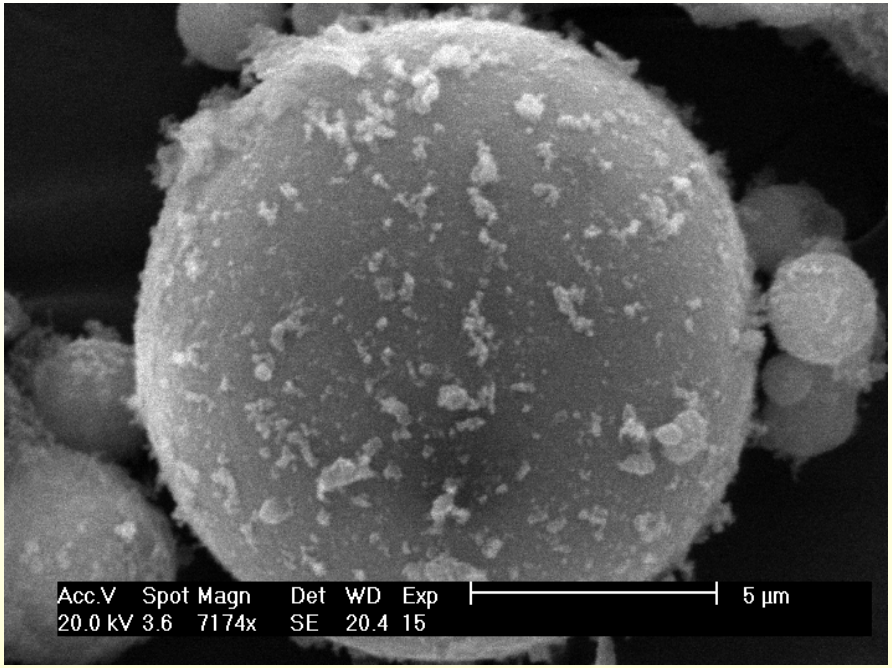


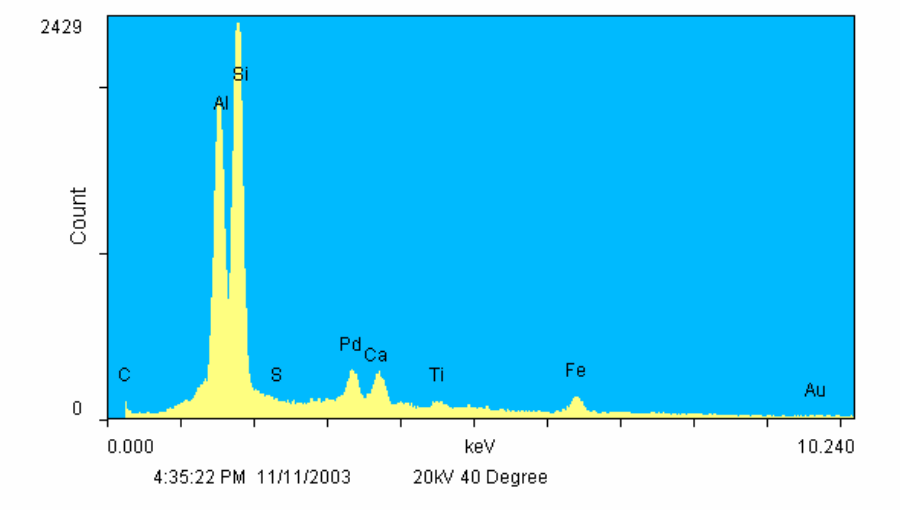
Low Magnification SEM Micrograph of a Fly Ash/AC Sample from Boiler A. Note the Diverse Range of Particle Sizes and Microstructures That Can Co-Exist.



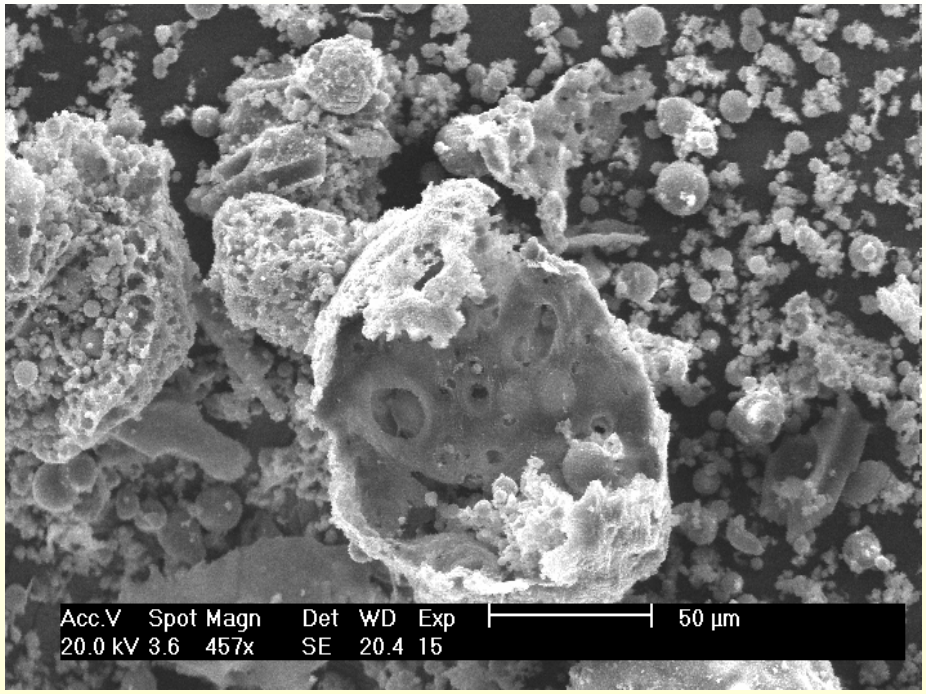


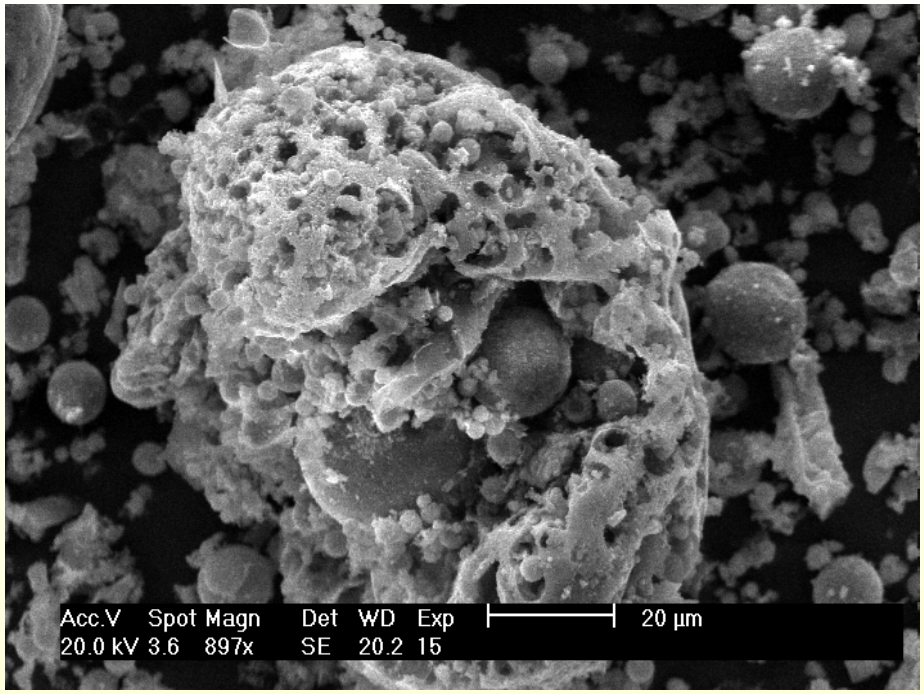
SEM Micrograph (a) and EDS Spectrum (b) From a Typical Particle of unburnt carbon.



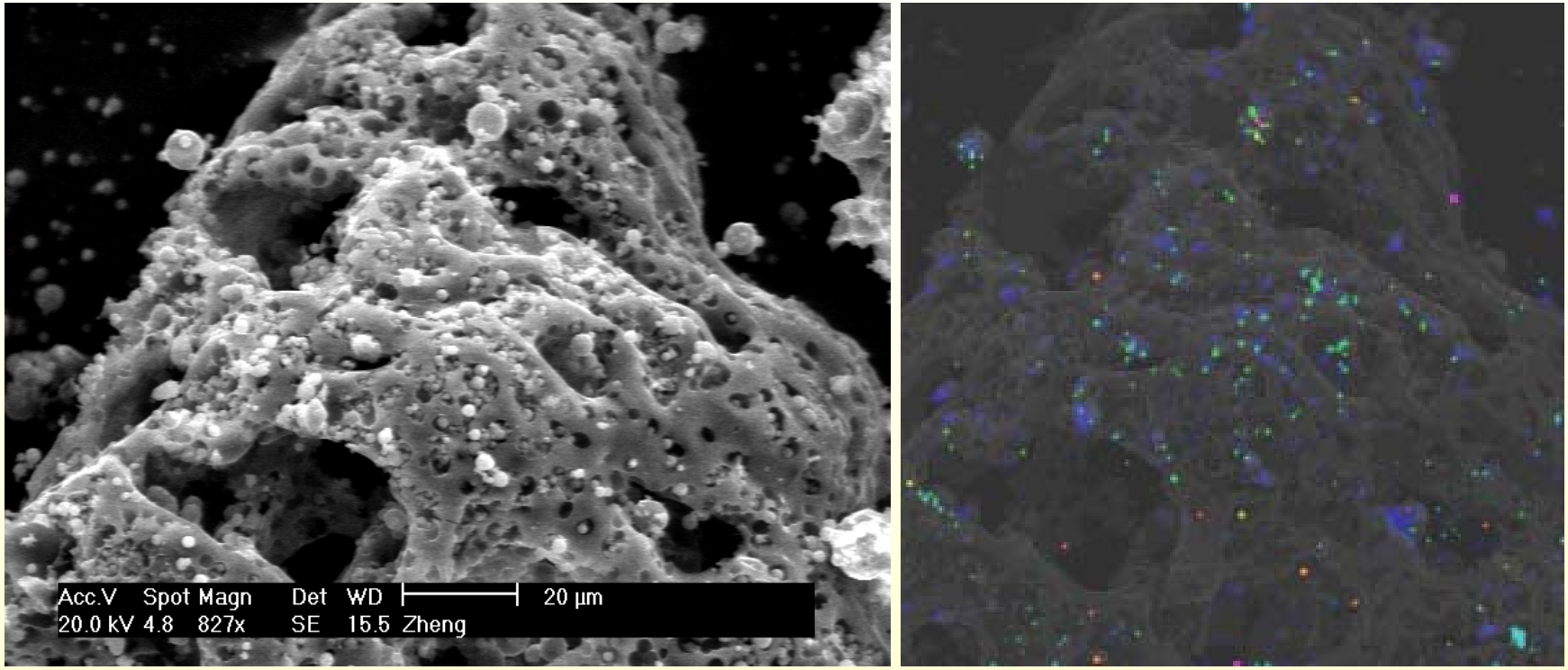


SEM Micrograph (a) and EDS Spectrum (b) From a Typical Spherical Morphology Alumino-Silicate Particle

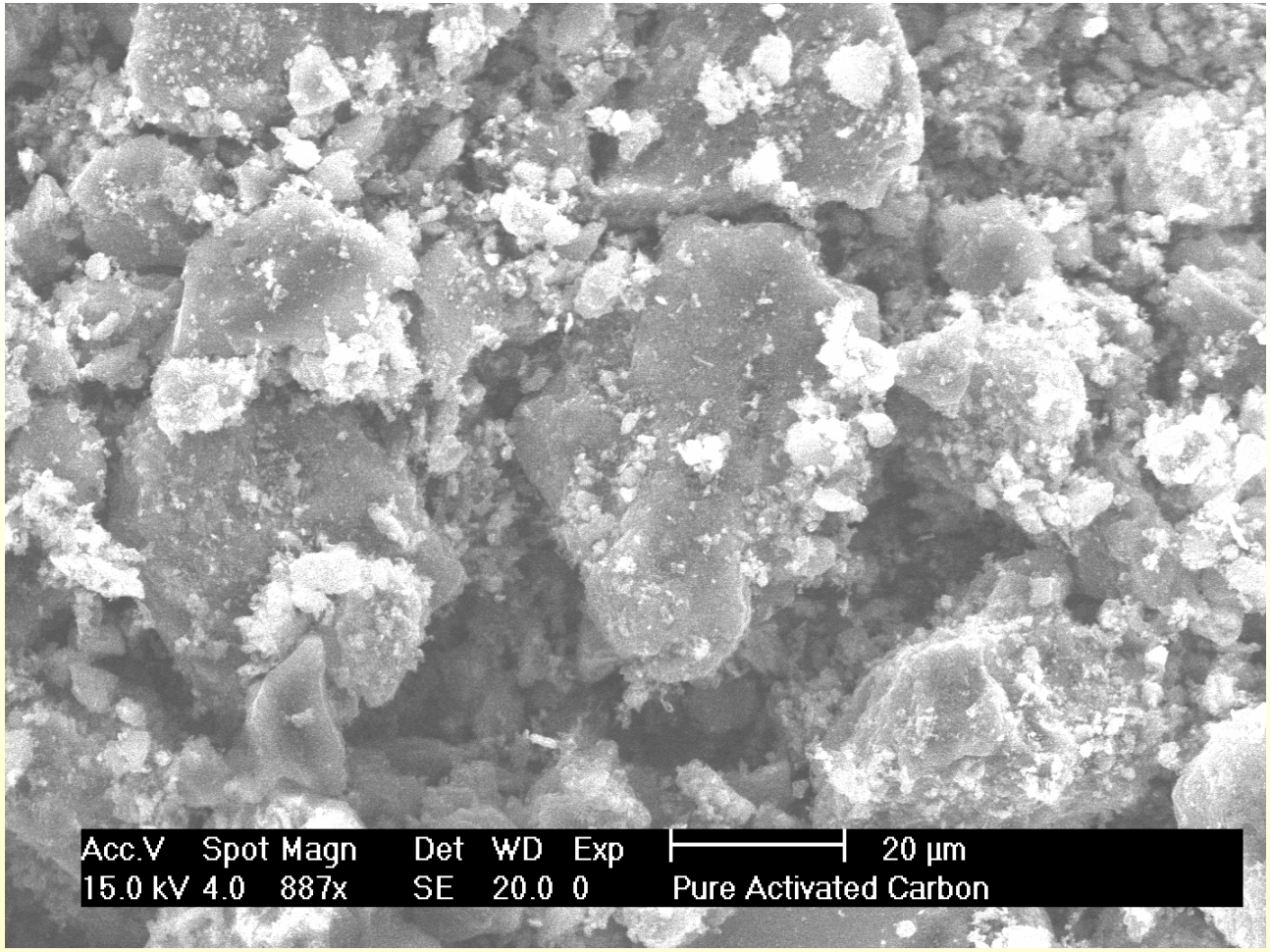




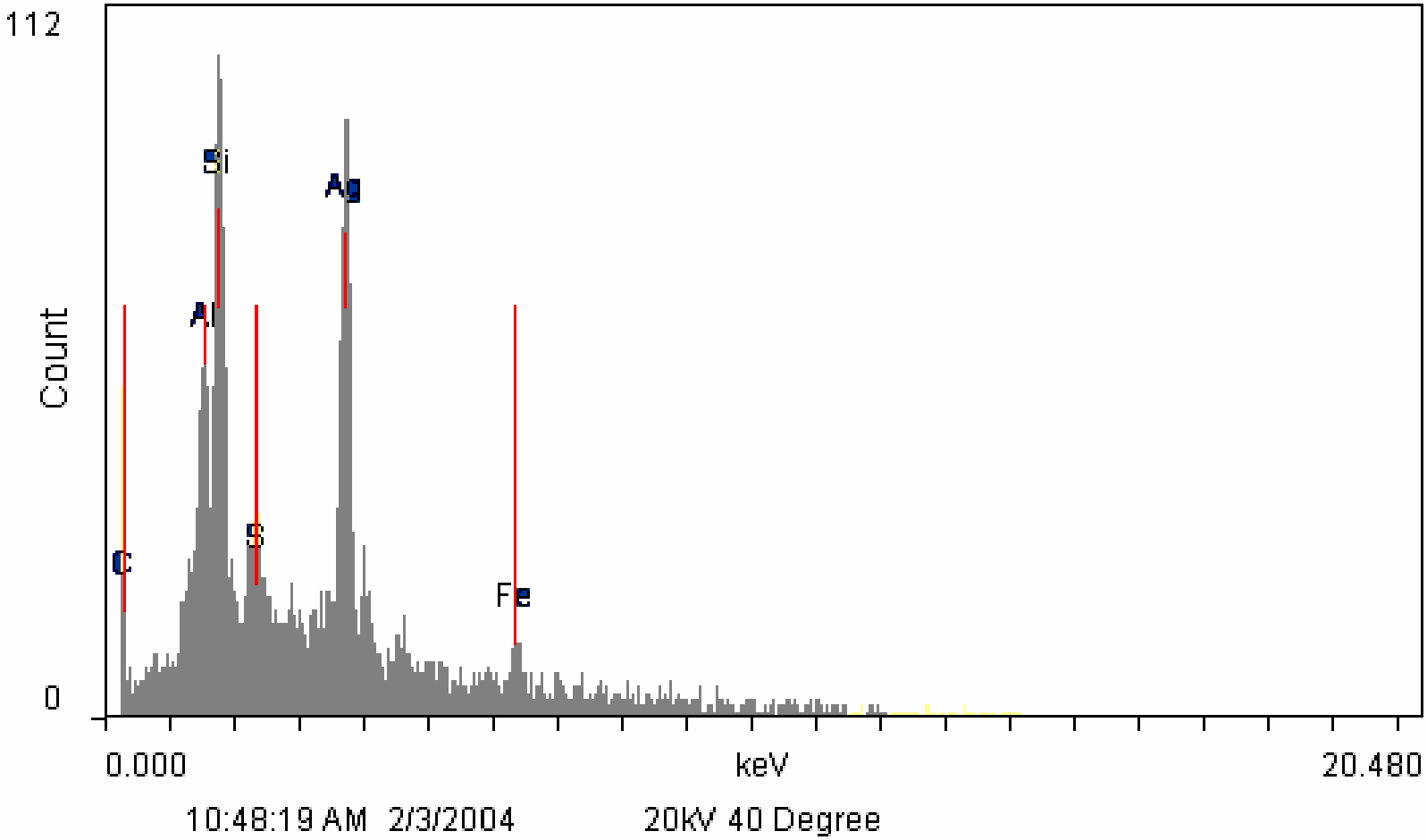
SEM Micrographs From Large Carbon Particles Having a Hollow Shell Morphology.



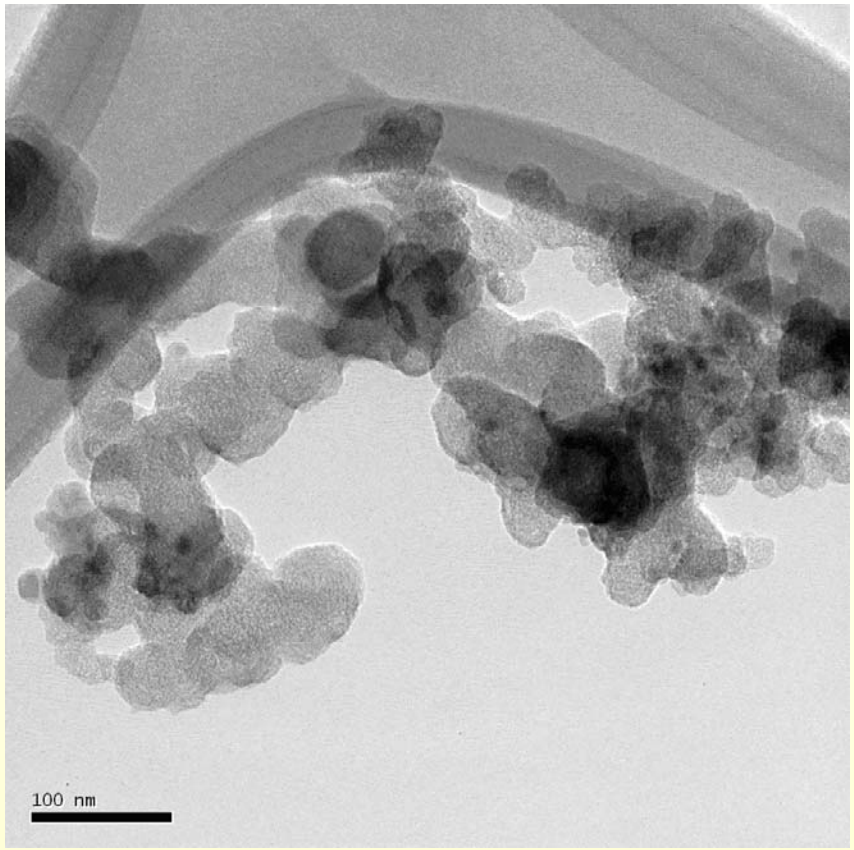
SEM Micrograph (a) and Corresponding EDS Elemental Map (b) From a Typical Hollow Morphology Carbon Particle.



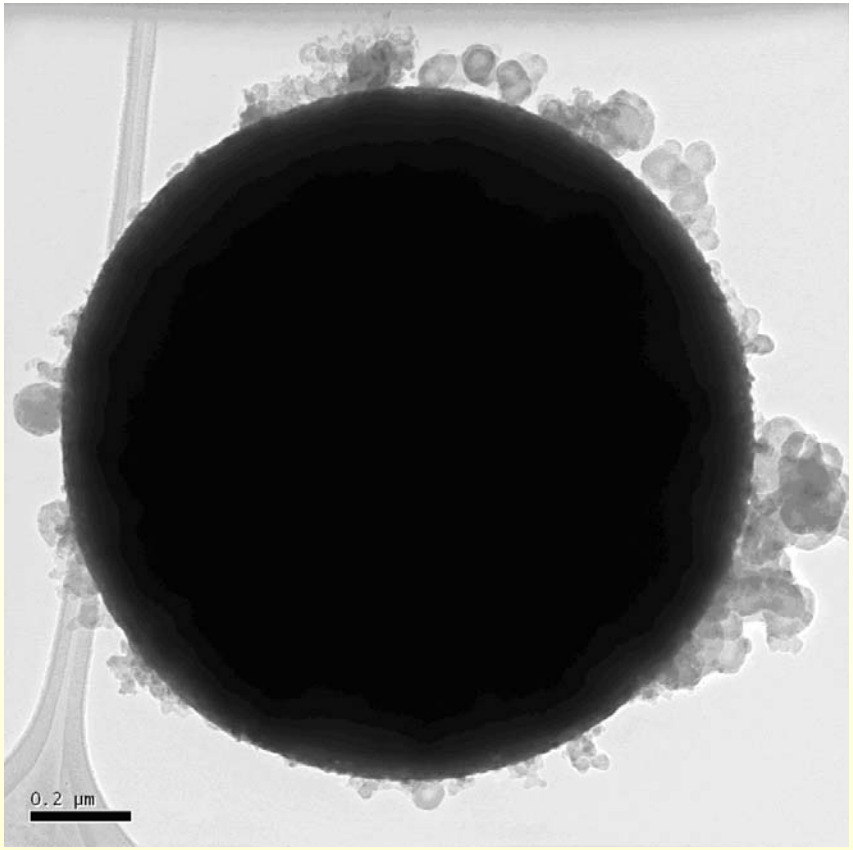
An SEM Micrograph Showing the Typical Morphology of a 'Pure' Activated Carbon Sample (Figure 2.20)



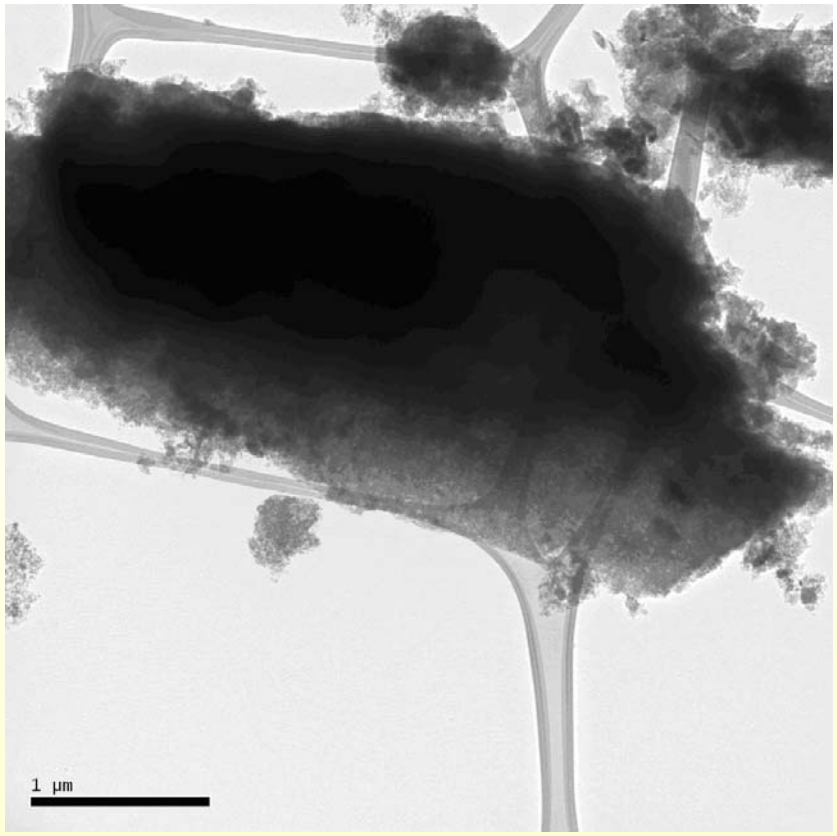
EDS Spectrum Obtained From the Entire Area Imaged in Figure 2.20.



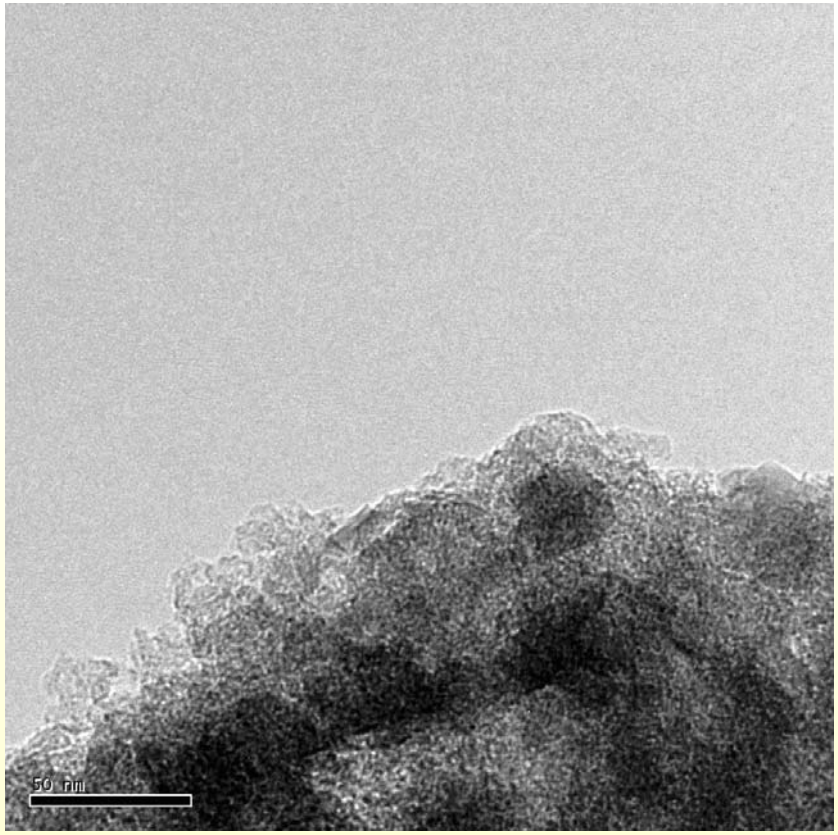
TEM Micrograph of a Typical Agglomerate of Activated Carbon Particles.



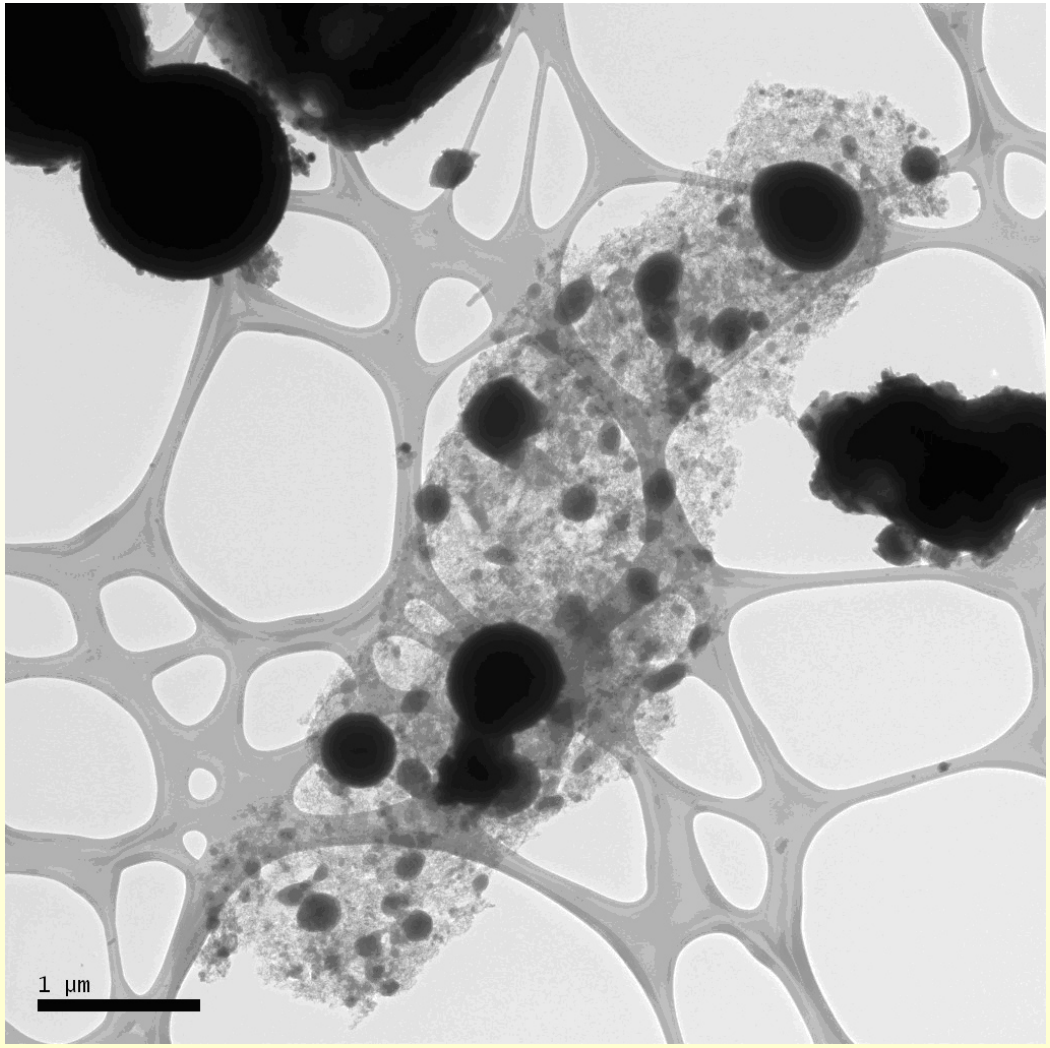
TEM Micrograph of an Alumino-Silicate Sphere Decorated with Activated Carbon Particles.



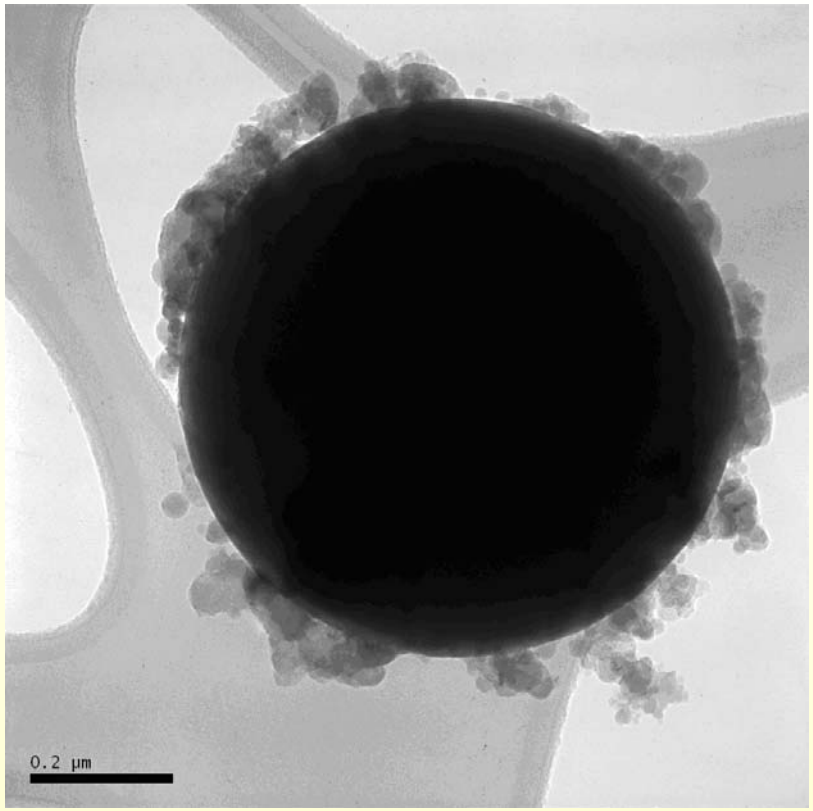
Bright Field TEM Micrograph Showing an Irregular Carbon Particle in the Pure AC Sample Decorated with Smaller Carbon Particles.



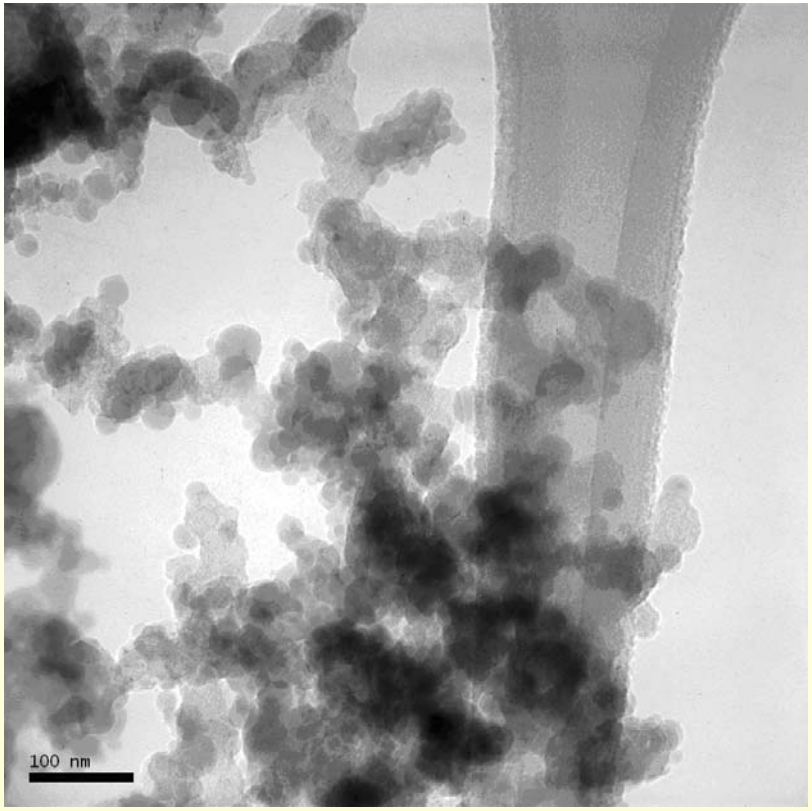
Higher Resolution Electron Micrograph of the Smaller Decoration Particles in Figure 2.22, Showing Them to be Amorphous Carbon.



Bright Field Low Magnification Micrograph of the 'After' SCR Samples.



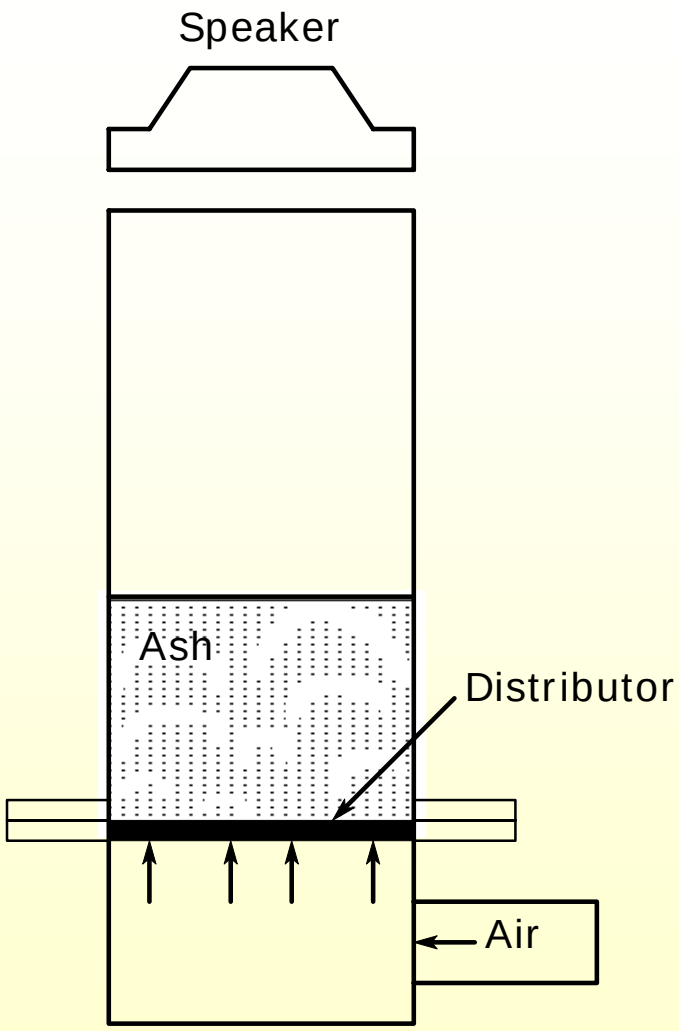
Bright Field Micrograph of a Typical Spherical Fly Ash Sample Showing Surface Decoration with Carbon.



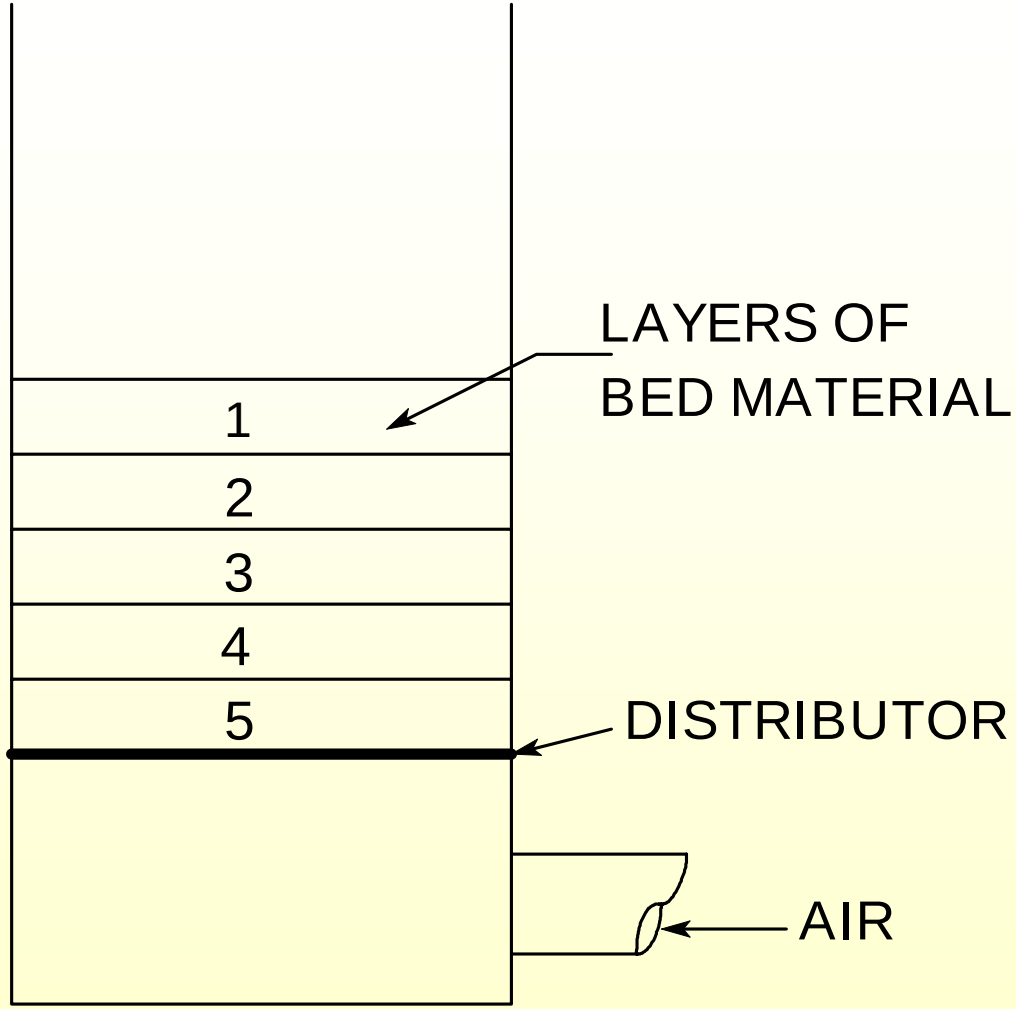
High Resolution Bright Field Micrograph of an Agglomerate Of Amorphous Carbon Particles.

SEPARATION OF CARBON FROM DENSER COMPONENTS IN A AC/ASH MIXTURE

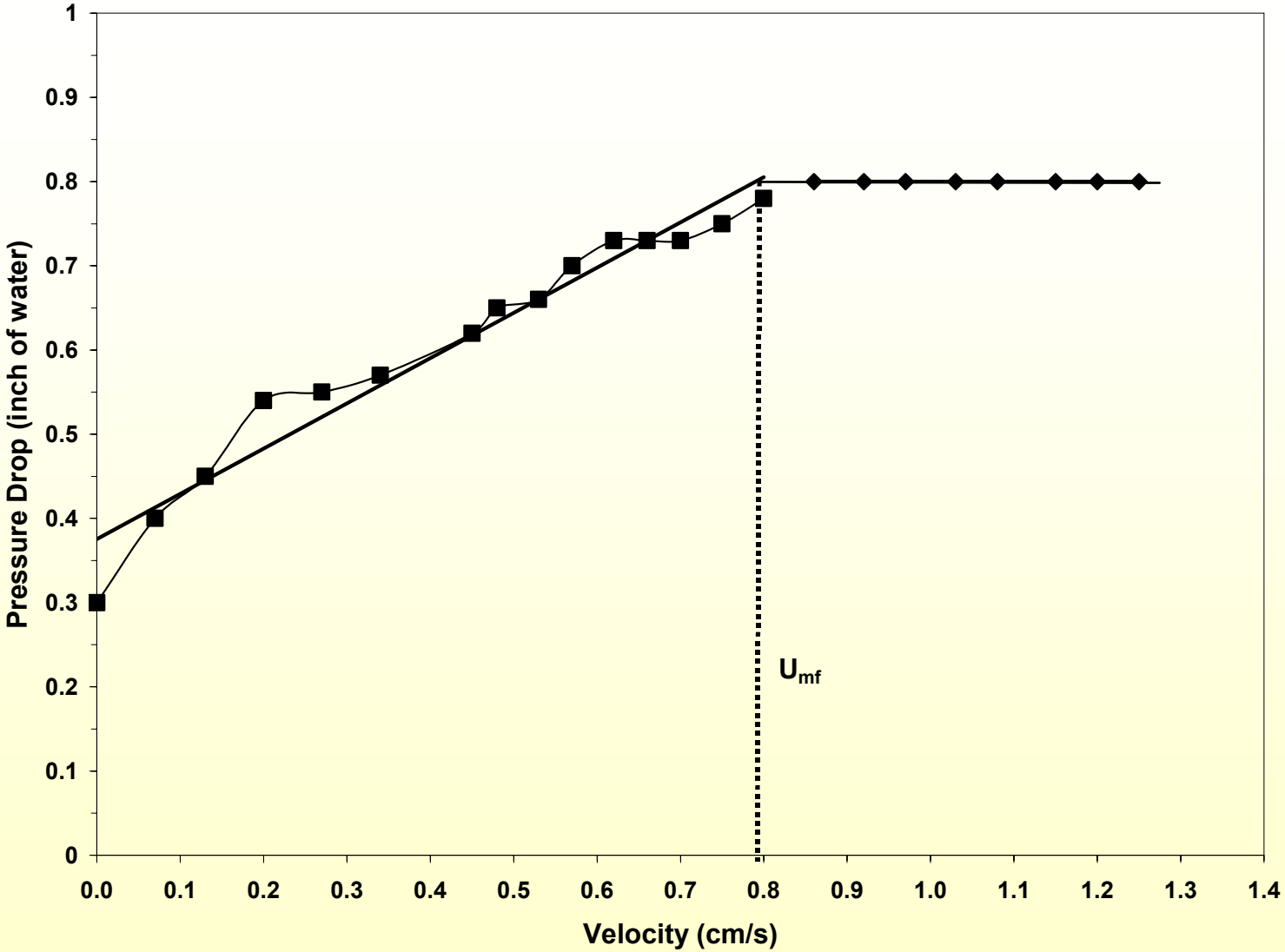
- Separate in a Fluidized Bed with Air
- Fine Powders Difficult to Fluidize Due to Agglomeration of Particles
- Use Acoustic Agitation to Disrupt Particle-Particle Attractive Forces
- Once Fluidized, Particles Segregate Vertically by Density and Particle Size



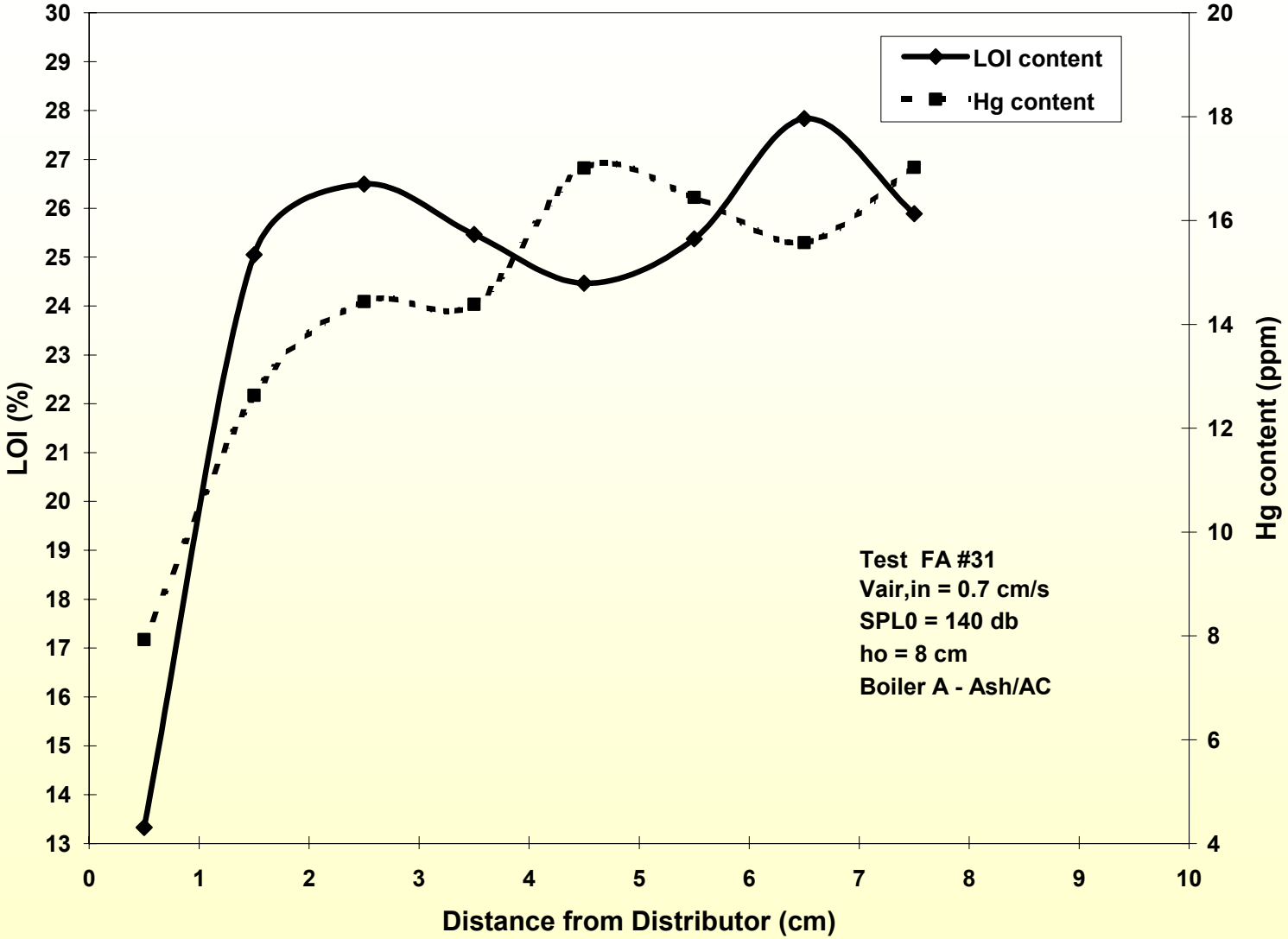
Laboratory Batch Fluidized Bed.



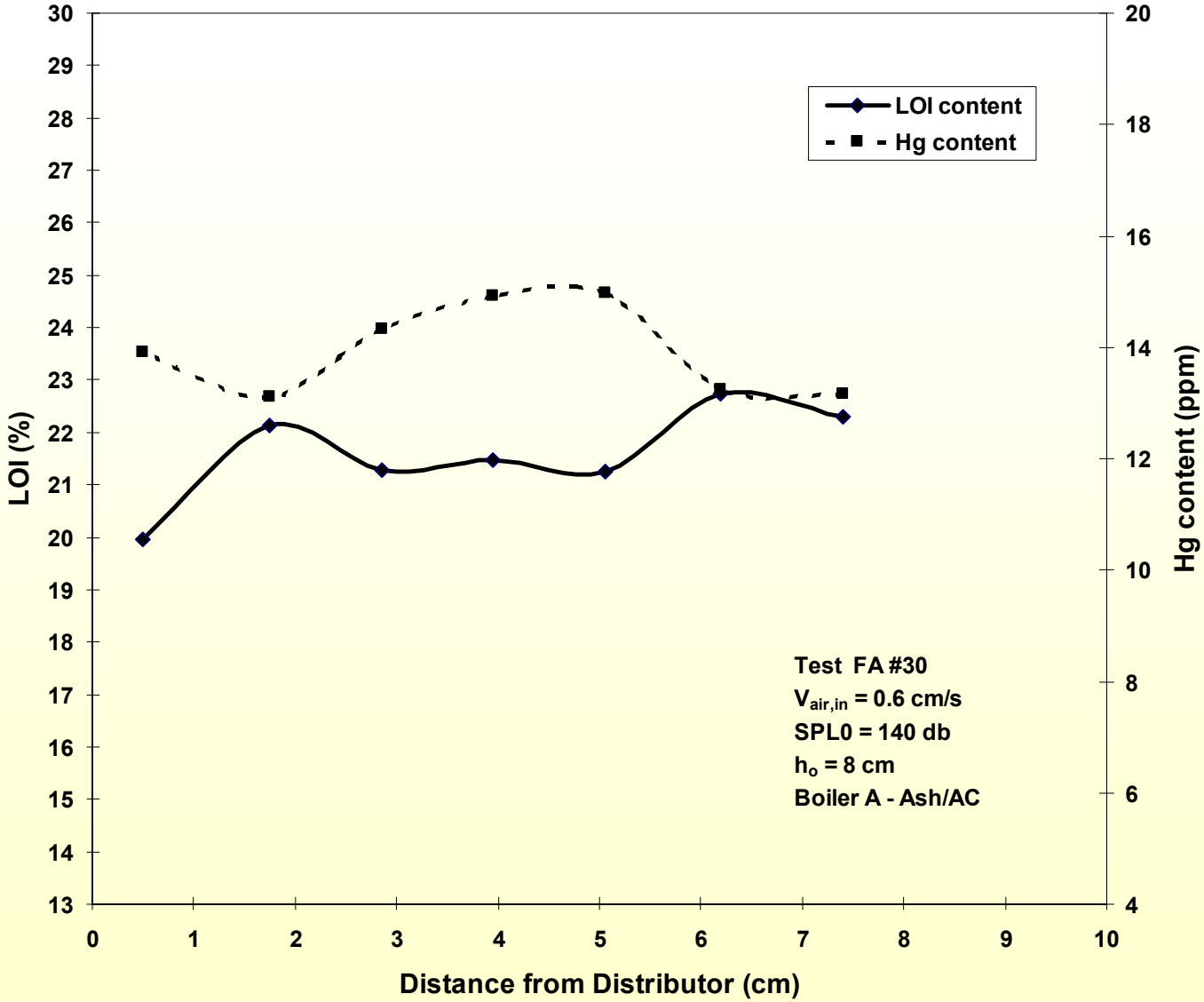
Sketch Showing Layering Technique for Analysis of Carbon Stratification in Fluidized Bed.



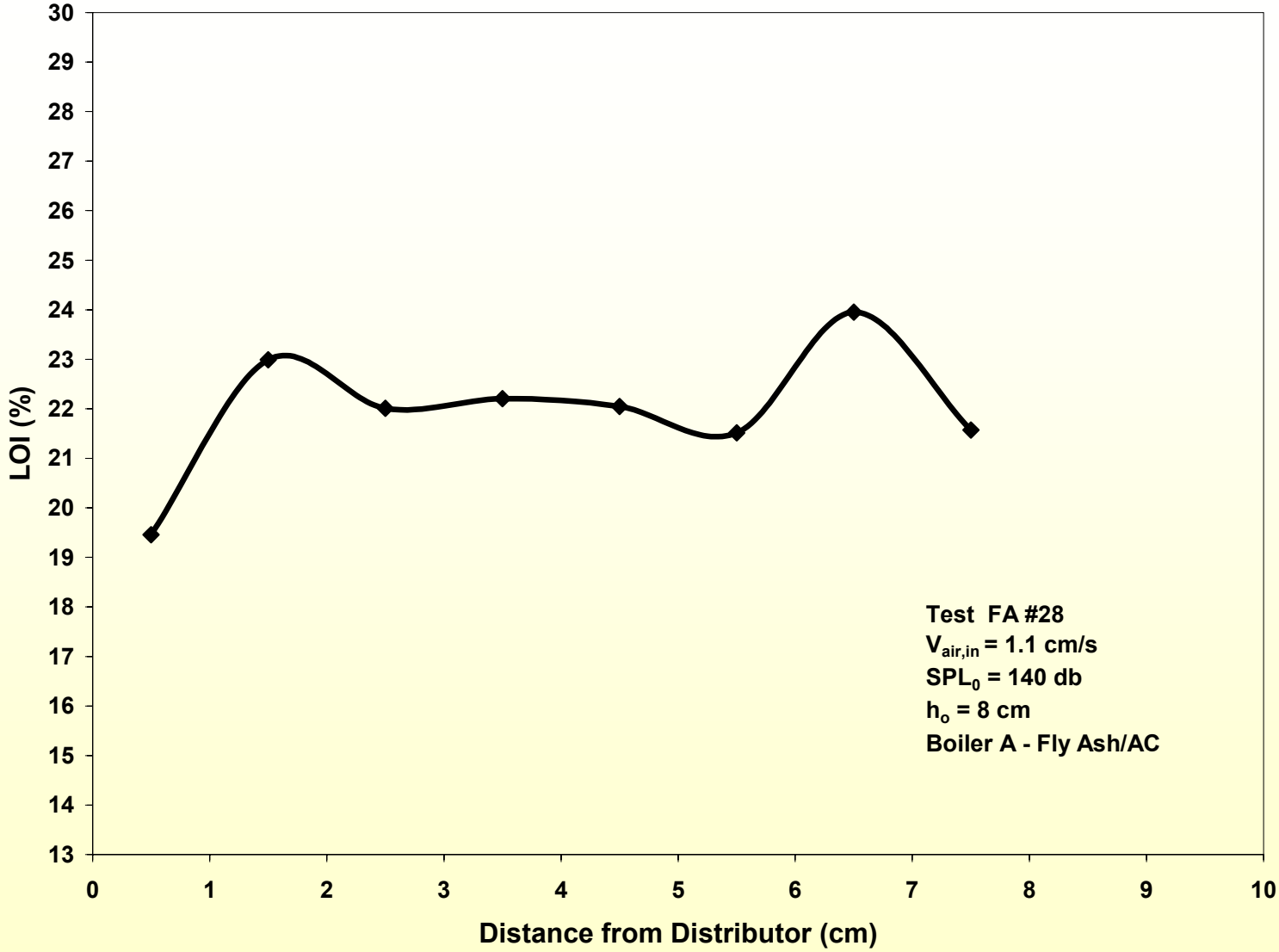
Minimum Fluidization Velocity From Bed Pressure Drop Test.



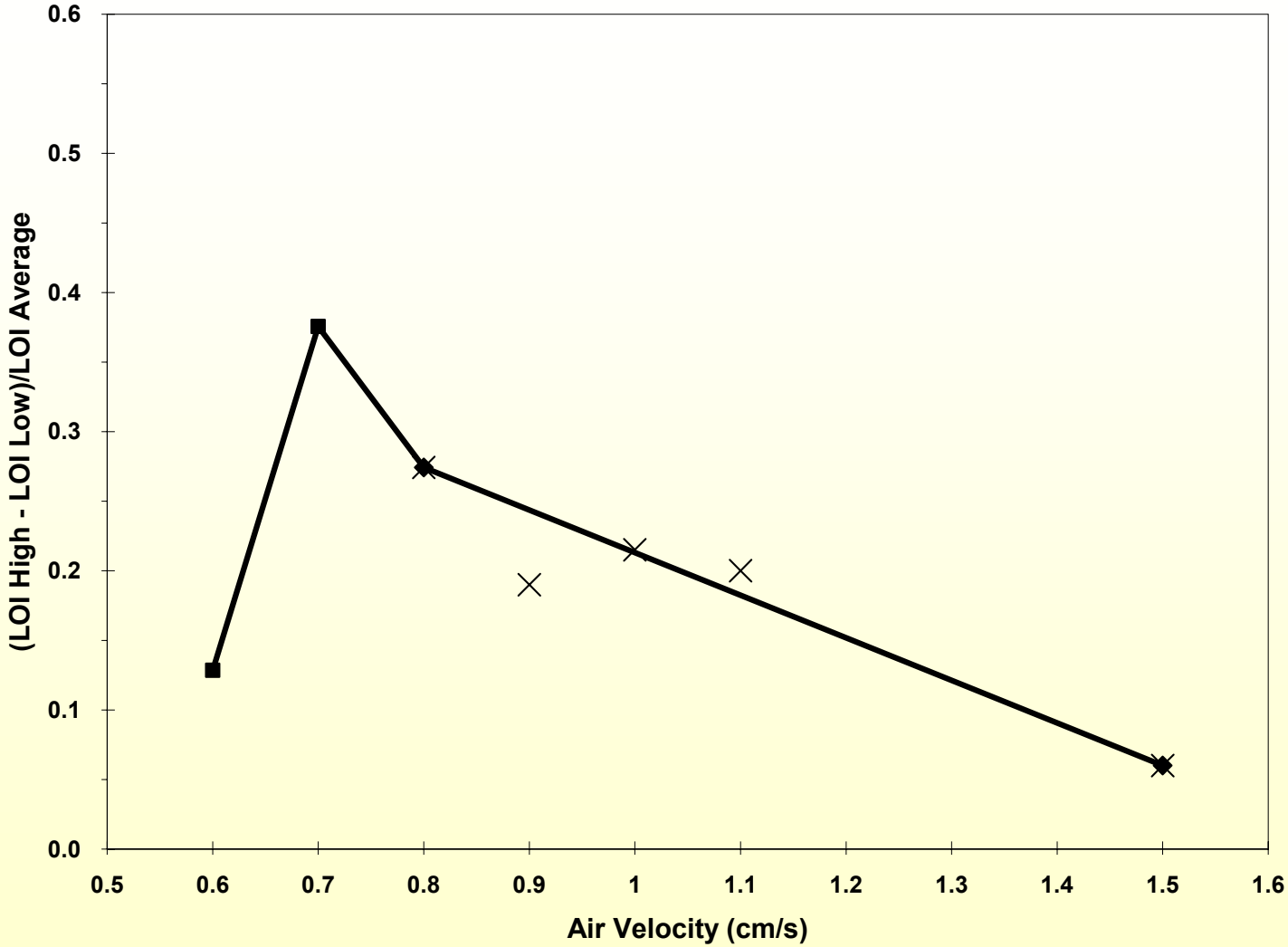
Vertical Stratification of Hg and LOI. V_{air} = 0.7 cm/s.



Vertical Stratification of LOI and Hg. V_{air} = 0.6 cm/s.

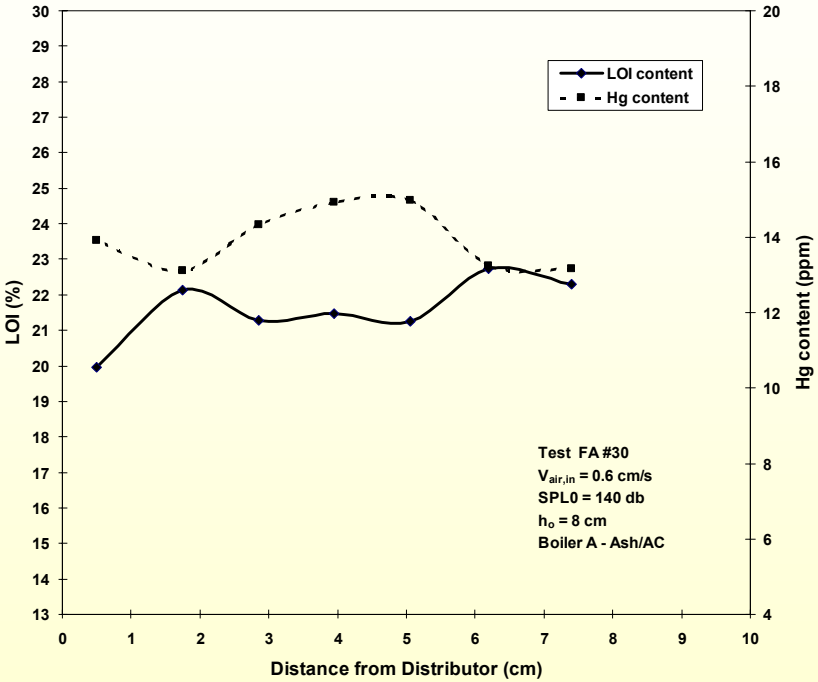


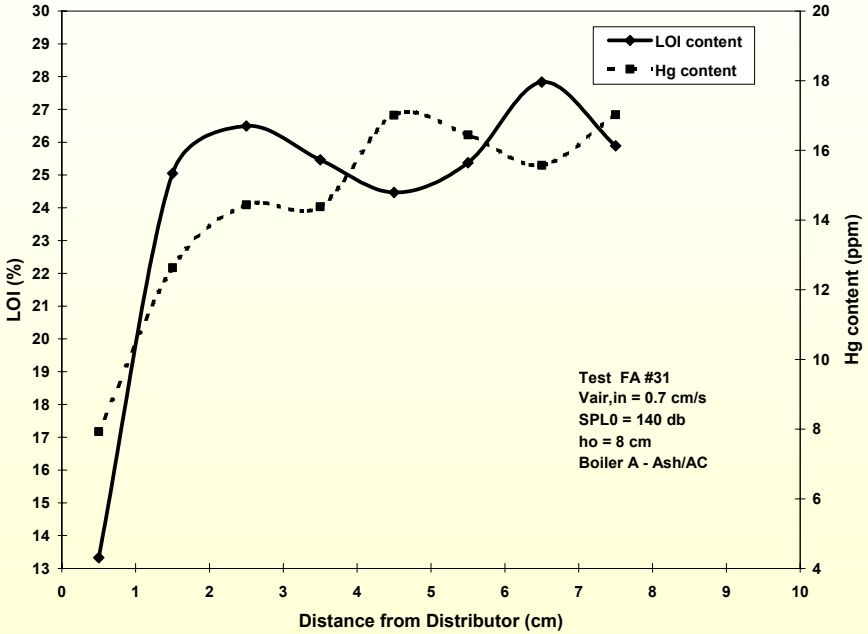
Vertical Stratification of LOI. V_{air} = 1.1 cm/s.



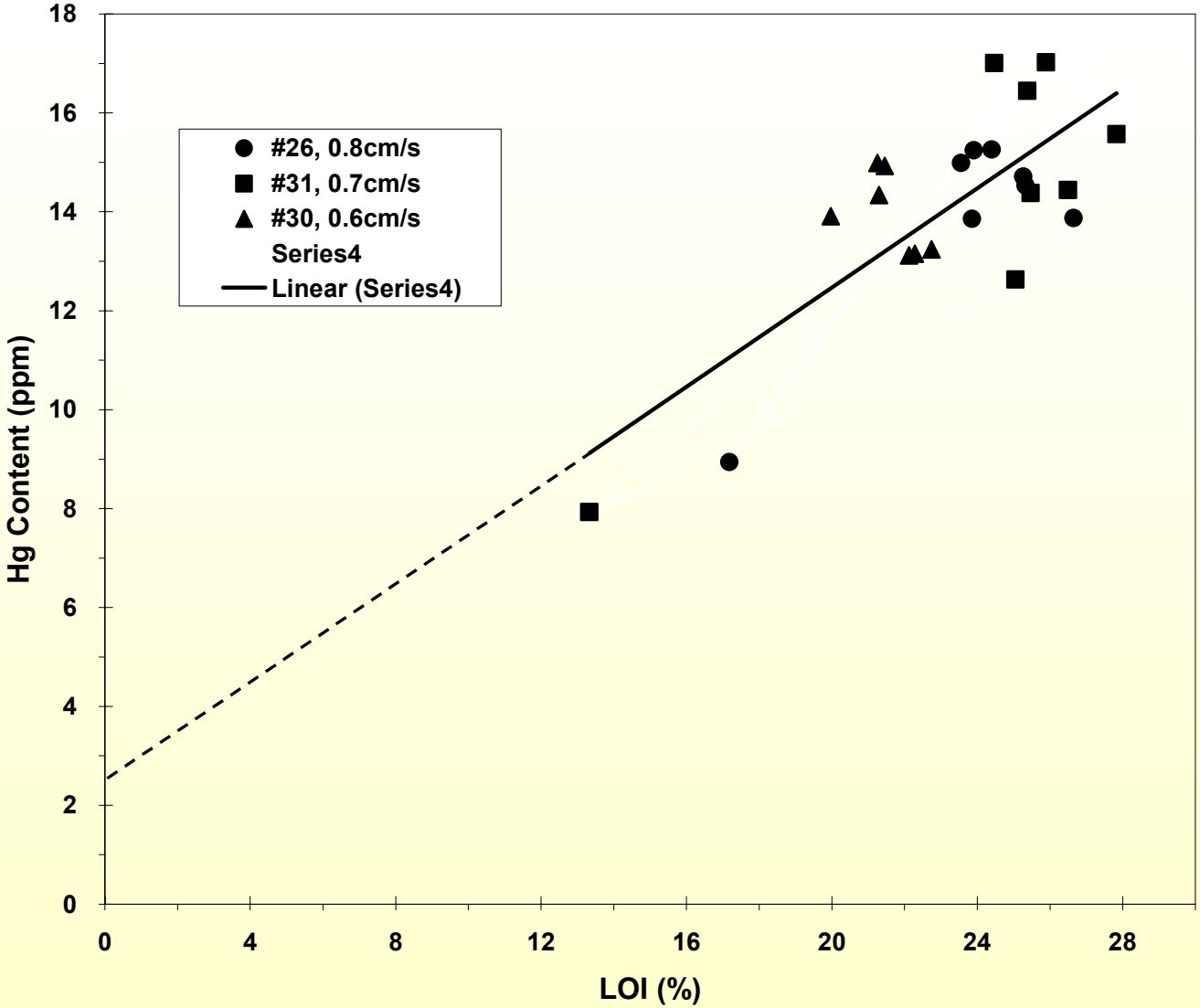
Magnitude of Carbon Stratification Versus Superficial Air Velocity.

- **Analyze Materials From Different Layers for Hg**





- **Hg Content of Mixture Increases with Carbon Content**



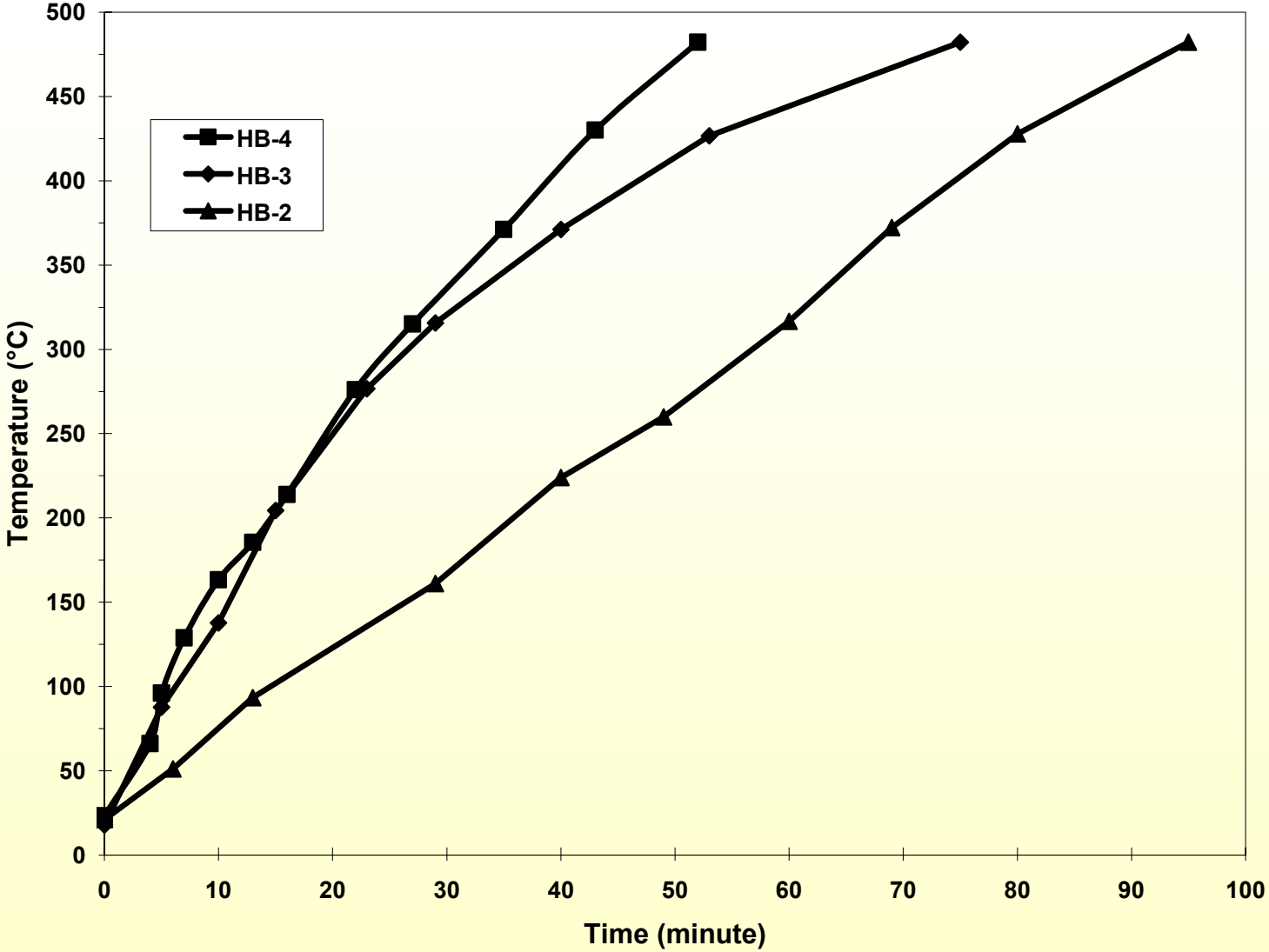
Variation of Hg with LOI. Boiler A Fly Ash/AC Mixture.

REMOVAL OF HG FROM ACTIVATED CARBON AND FLY ASH

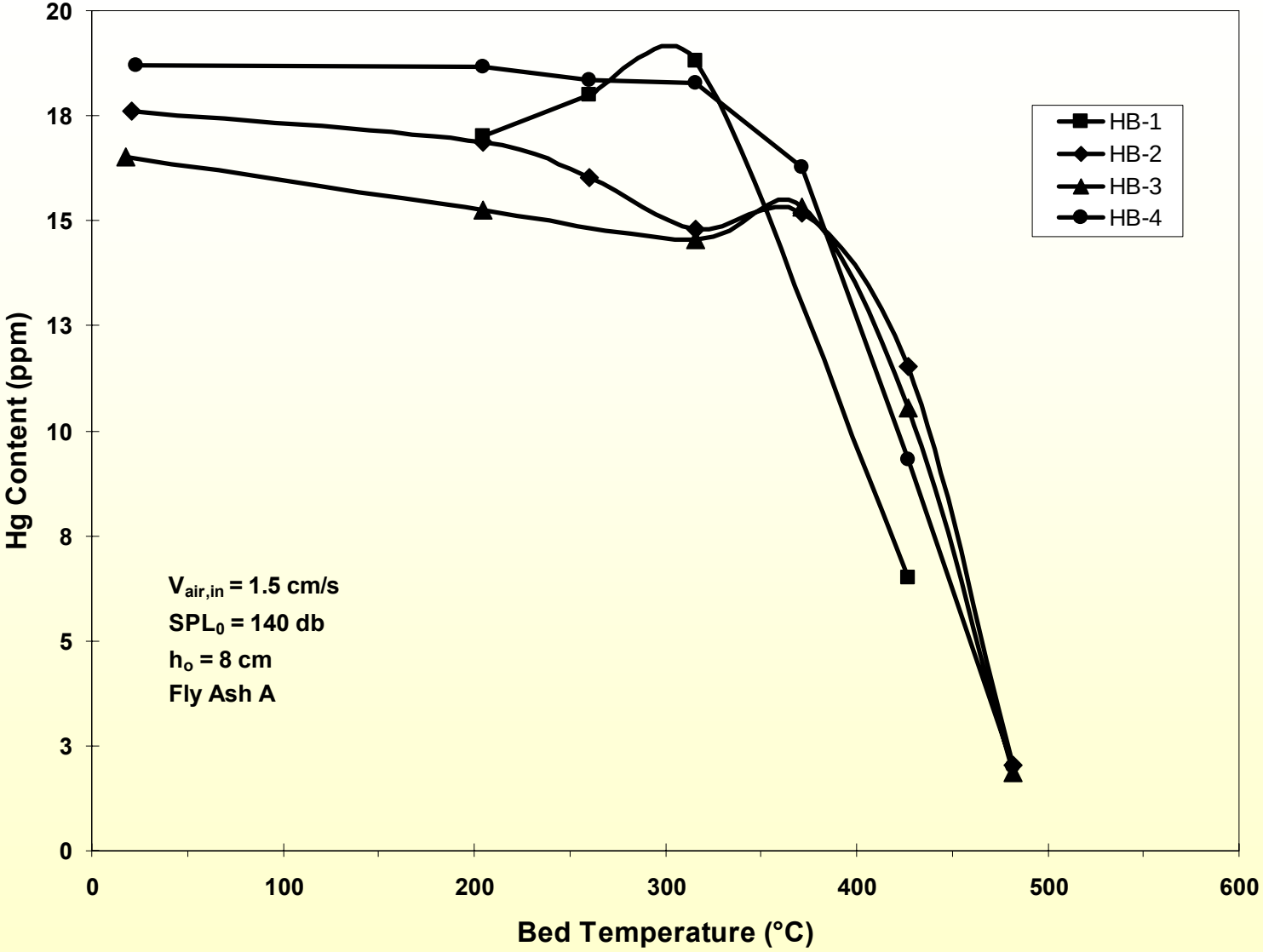
- Raise Temperature of AC/Ash Mixture in Fluidized Bed with Air
- Immersed Electrical Heater
- Remove Samples of Bed Material As Bed Heats Up
- Analyze for Hg

ISSUES:

- What Temperature?
- What Affects Temperature?

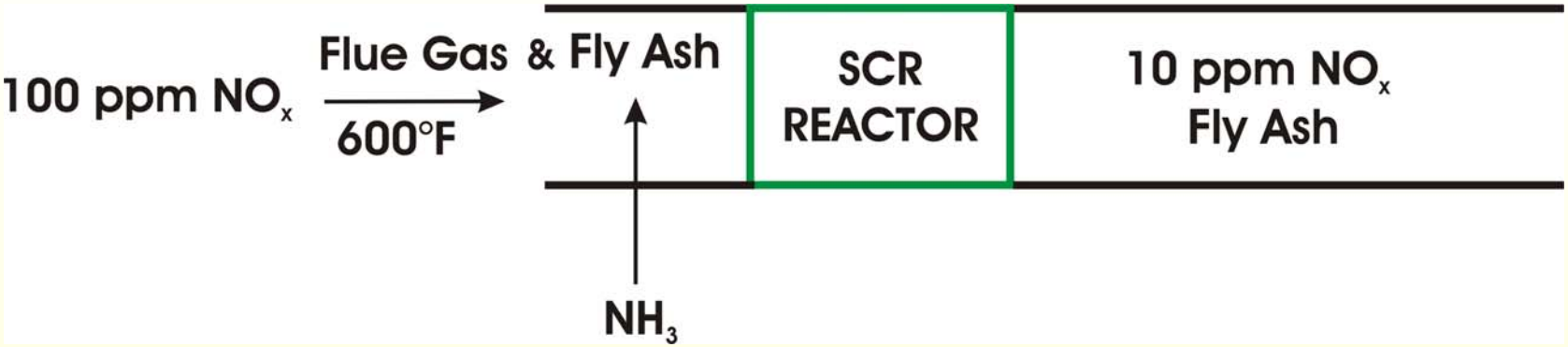


Hot Bed Tests. Bed Temperature Versus Time.



Hot Bed Tests. Hg Versus Bed Temperature.

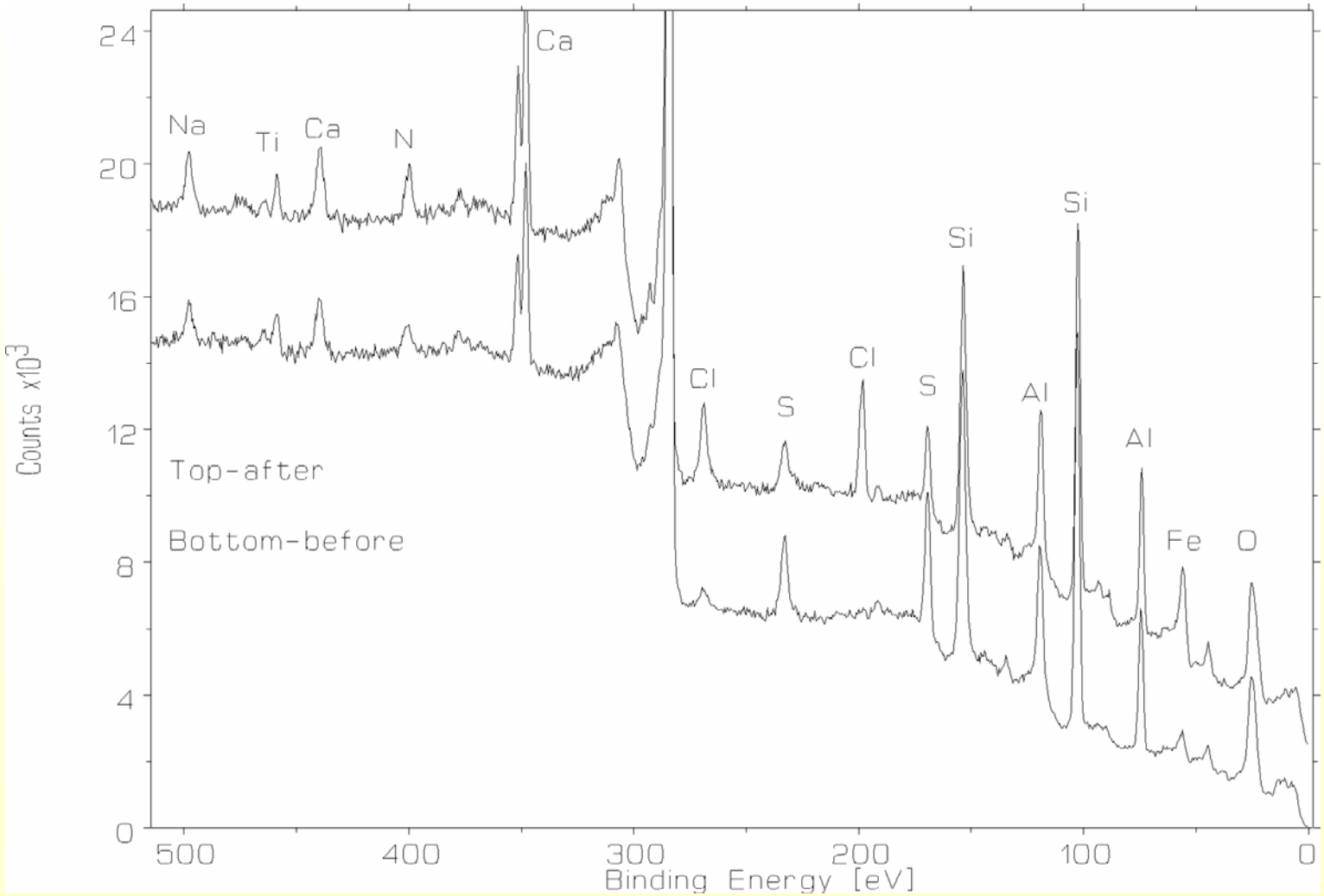
EFFECT OF SCR ON ASH PROPERTIES



- But SCR Reactors Also Oxidize Hg^0 and Promote Enhanced Hg Capture
- Mechanisms?
- Effect of SCR on Surface Chemistry of Fly Ash?

APPROACH

- Obtained Samples of Fly Ash Obtained From Upstream and Downstream of SCR Reactors.
- Used TEM and X-Ray Photoelectron Spectroscopy.



Higher Resolution XPS Spectra From the 'Before' and 'After' SCR Materials.

FINDINGS

- The ‘after’ SCR material has a significant surface Cl content, while the ‘before’ SCR material is essentially devoid of Cl.
- The surface S signal in the ‘after’ SCR sample is about half of that observed in the ‘before’ SCR sample.
- The surface Fe content shows the opposite trend to the S signal. It *increases* by about 50% in the ‘after’ SCR sample.

WHAT'S NEXT?

- Limited by Availability of Suitable AC/Ash Samples. More Will Become Available This Fall and Next Spring.
- Plan to Continue Tasks with New Samples.