

REINHOLD ENVIRONMENTAL Ltd.



**2013 APC Round Table
& Expo Presentation**

July 8-9, 2013, in St. Louis, MO / Hosted by Ameren

All presentations posted on this website are copyrighted by Reinhold Environmental, Ltd (RE). Any unauthorized downloading, attempts to modify or to incorporate into other presentations, link to other websites, or obtain copies for any other uses than the training of attendees to RE's Conferences is expressly prohibited, unless approved in writing by RE or the original presenter. RE does not assume any liability for the accuracy or contents of any materials contained in this library which were presented and/or created by persons who were not employees of RE.

SOLUTIONS . PERFORMANCE . RELATIONSHIPS



Reinhold Environmental 2013 APC Round Table

Converting an ESP To FF

By Tom Lugar

www.met.net

Issues When Considering the Option of ESP Replacement or Conversion with a Fabric Filter:

- ESP not Meeting Outlet Emissions/Opacity Requirements
- Fuel Switching Affect on ESP Performance
- Adding a Scrubber Upstream or Downstream
- MATS Compliance: Control of Mercury Emissions and HCL with PAC/DSI, PM requirements



Conversion Advantages

- Lower Cost Option Than Replacing with a new Filter Filter
- Installed in the Existing ESP Footprint
- Minimal Ductwork Modification/Addition
- Reuse Existing Hoppers and Ash Conveying System
- Fuel Flexibility – FF More Forgiving Than an ESP
- More Efficient/Consistent Mercury Emission Reduction With Activated Carbon Injection



ESP to FF Conversion

Other Considerations

- Due to the Additional Pressure Drop, ID Fans may have to be Rebuilt or Replaced
- Structural Reinforcements may be Required to ESP Casing and Ductwork if Design Pressure will be Exceeded

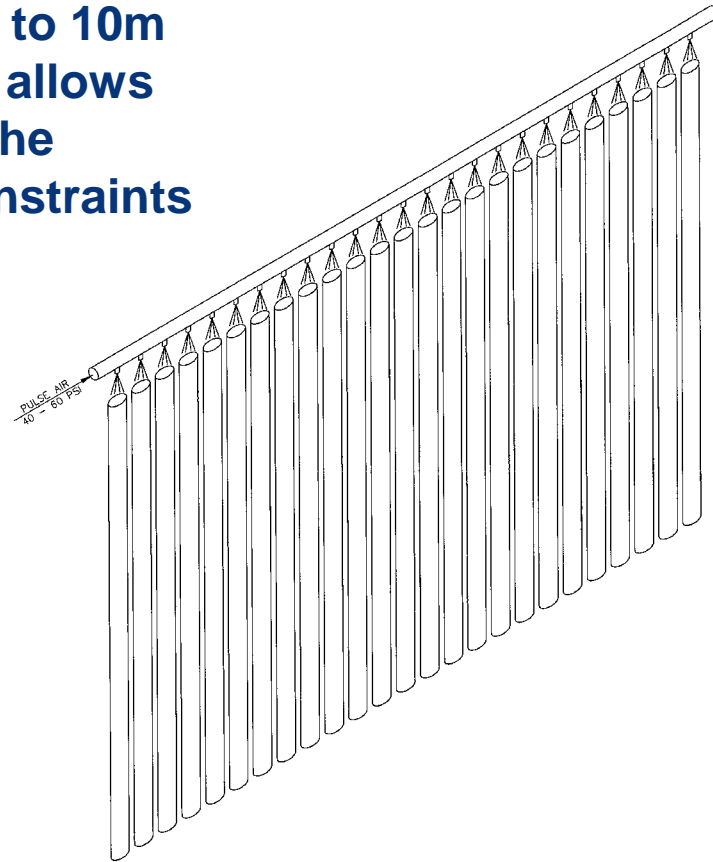


What Makes a Good ESP to FF Candidate?

- Casing Large Enough in Volume to Accommodate Required Cloth Area, $SCA > 250$
- ESP Casing in Good Shape with Minimal Corrosion



Applying current medium pressure pulse jet technology with long bags up to 10m and up to 30 bags on a blowpipe allows the flexibility needed to cram in the required cloth area within the constraints of the ESP casing volume.



Air-to-Cloth Ratio

Describes how much dust-laden gas passes through a given surface area of filter in a given time.

Air-to-Cloth Ratio (A/C) = Gas Volume/Cloth Area = ft/min

Gross A/C = The total amount of cloth area is used for filtration of the flue gas.

Net A/C = The net amount of cloth area is used when one baghouse compartment is off-line for maintenance or cleaning.



Example: Adding a Scrubber for SO₂ Reduction
Southeastern Public Service Authority (SPSA)
Portsmouth Virginia

Application

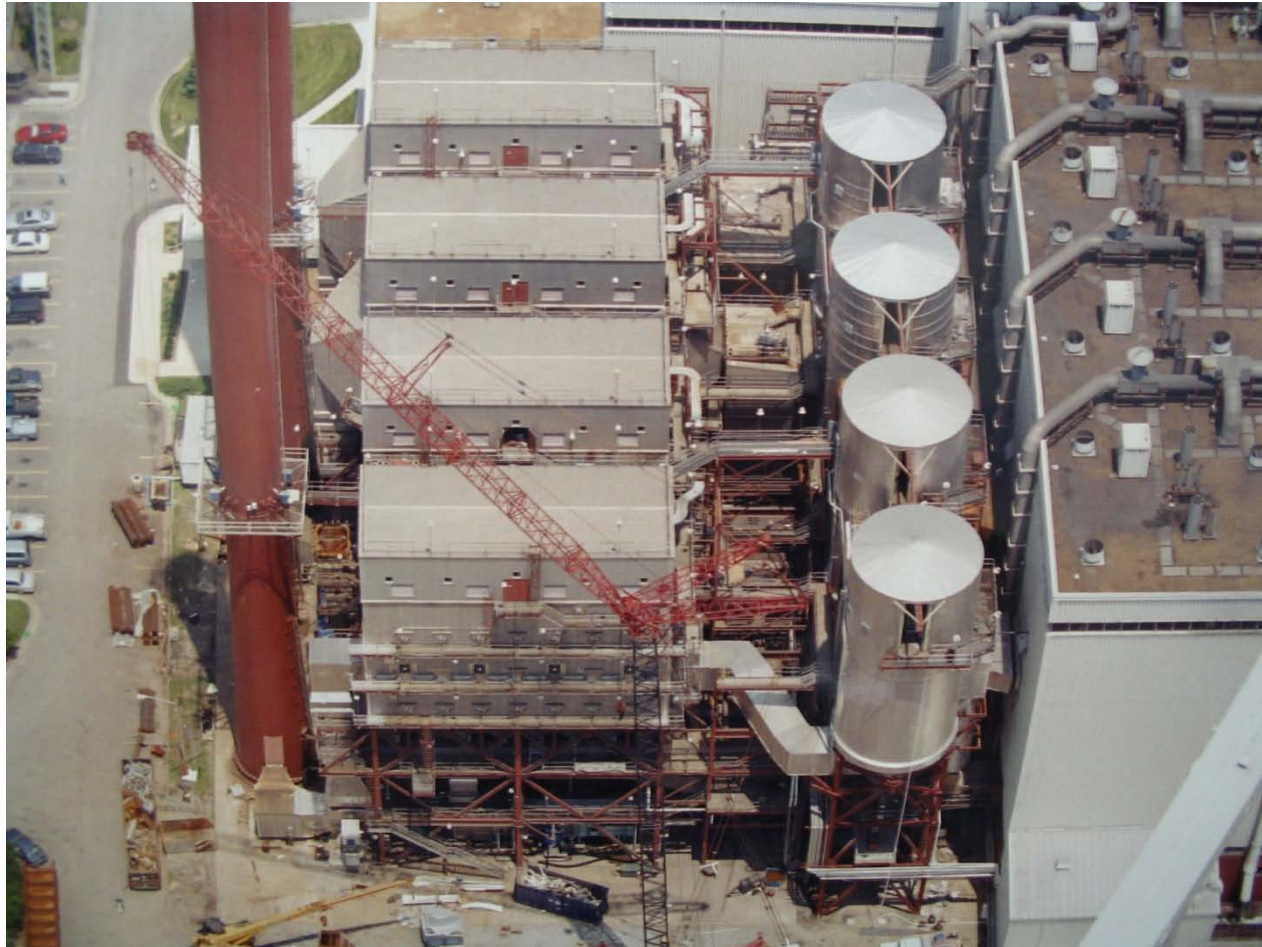
4 Identical Coal/RDF Fired Boilers
Gas Flow – 150,000 ACFM/Boiler
Add DFGD System Upstream of Existing ESP
Convert each ESP to a Pulse Jet Fabric Filter

Pulse Jet Design

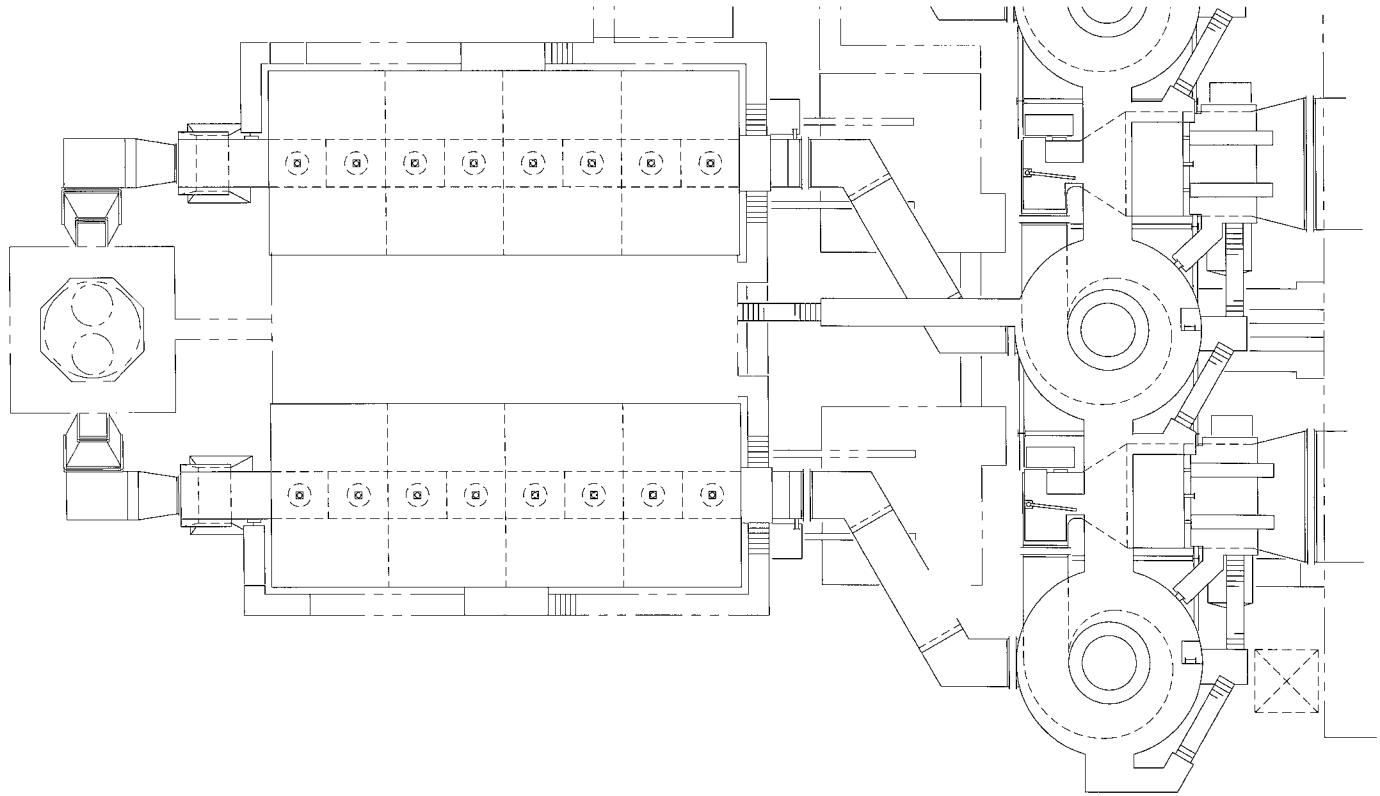
8 Compartments, Walk-in Plenum Design
A/C Gross: 3.5, Net 1: 4.0

Startup: 1996-1997





Southeastern Public Service Authority, VA, ESP to FF Conversions and Scrubber Addition



SPSA PJFF Layout, Plan View

Case Study

Otter Tail Power Company, Big Stone Unit #1, Big Stone City, SD
ESP to FF Conversion, Completed 2008



Big Stone Unit #1

Application: 475 MW Cyclone-Fired Boiler
Vintage 1975 Wheelabrator ESP

Problems/Concerns:

- Performance Problems with Fuel Switch to Burning of PRB Coal - High Resistivity, Back Corona Formation
- Future Mercury Emission Control (MATS)





Big Stone ESP, Four Chambers

Buell APC Proposed Approach

- ESP Casing Met Criteria to Convert to FF : Casing Volume Large Enough for Required A/C; Casing in Good Mechanical Condition.
- ESP Conversion Would be Less Than Half the Turnkey Cost of Replacement with a Stand-Alone Baghouse.
- Added Benefit: With 4 Independent Chambers, each Chamber or pair of Chambers could be Blanked off during a Short Outage and each Chamber Converted while On-line at a Reduced Load.



Big Stone Application

Gas Volume: 2,100,000 ACFM
Gas Temperature: 340 F
Inlet Loading: 0.9 to 1.7 gr/acf
Mean Particle Size: 6 microns

Guarantees

Outlet: 0.01 lb/MMBTU
Opacity : 10%



Big Stone Pulse Jet FF Design

A/C Gross: 3.4 A/C Net 1: 3.6 (Off-Line Cleaning)
16 Compartments Total, 4 Compartments per Chamber

Bags: 21 oz. Woven Fiberglass with PTFE Membrane
acid resistant coating, 6" Diameter, 25' Long

Cages: Split Cage, Carbon Steel, 24 Wire

Bags/Chamber = 4028 Total Bags = 16,112
27 Bags/Blowpipe, 2 Blowpipes per Bag Row



Conversion to PJFF

- Gut the ESP internals
- Add Tubesheets, Pulse Headers, Blowpipes and Control System
- Add Partition Walls to Compartmentalize each Chamber, 4 Compartments/Chamber, 16 Total
- Add Inlet Transition Duct within Existing ESP Nozzle to the Baghouse Inlet Plenum internal to the ESP Casing



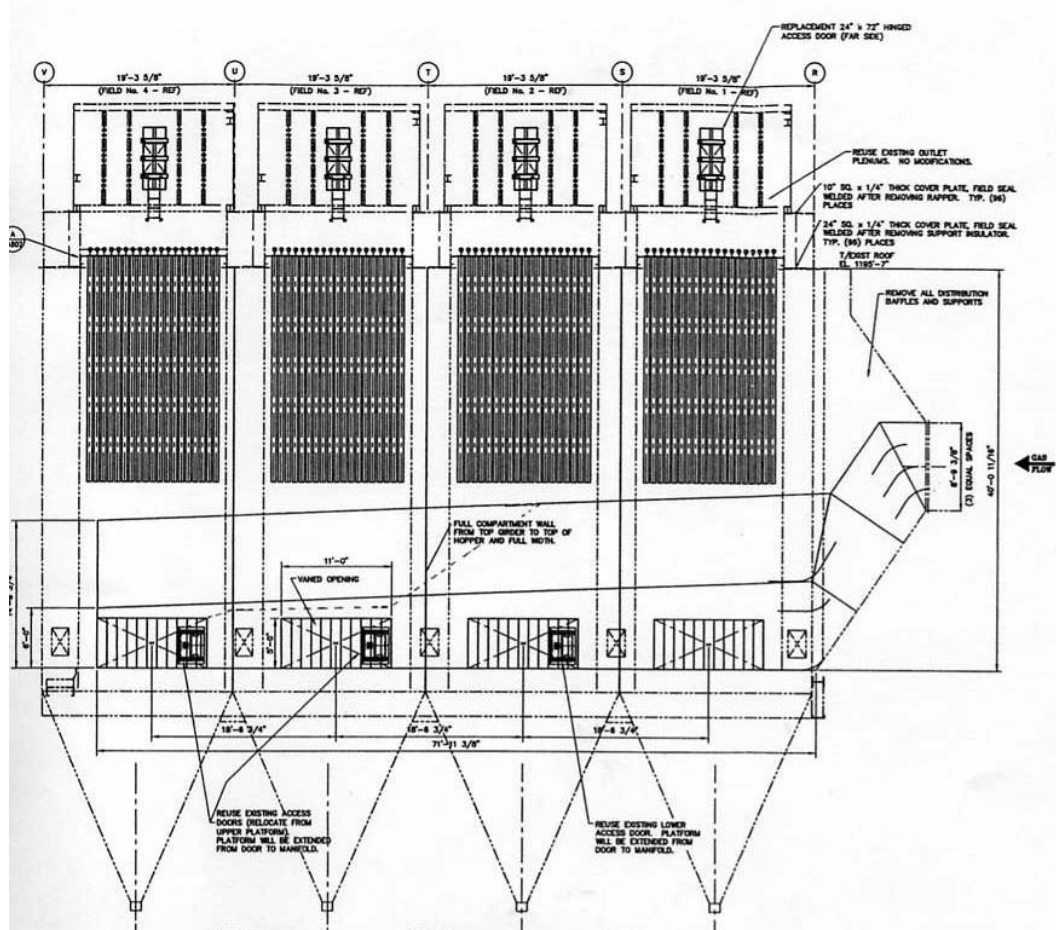
Baghouse Inlet Design

- Low velocity inlet into compartments, 1200ft/min
- With low velocity inlet design, no baffling was required below the bags
- Gas entrance into compartments is above hoppers and is vaned to optimize flow distribution entering the compartment and in the plane below the bags.
- Inlet Plenum maximum entrance velocity is 3600 ft/min with decreasing cross section in direction of flow to assure equal volumes of flue gas enter the compartments as gas flow rate decreases to the end of the plenum to meet ICAC F-7.





Big Stone ESP, Four Chambers

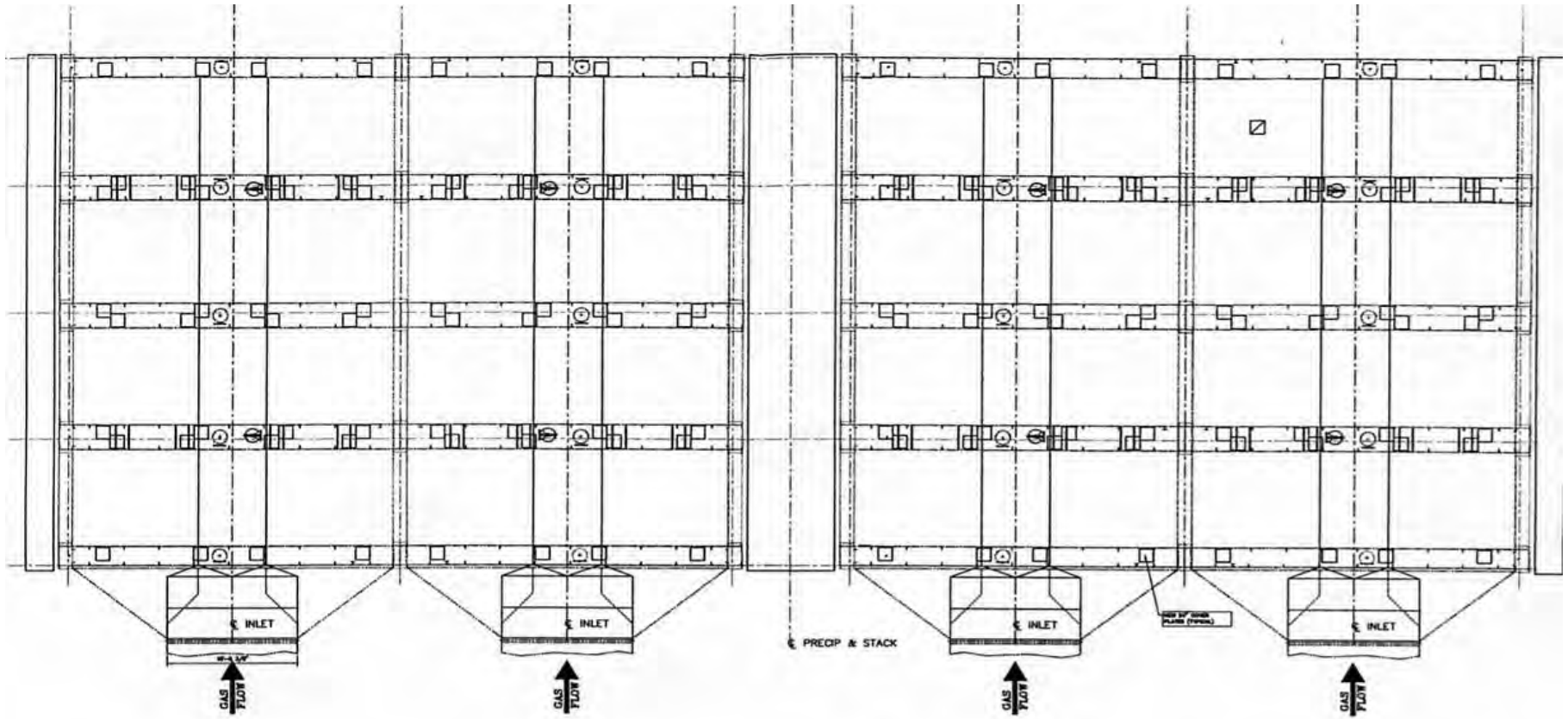


Otter Tail Big Stone Side Elevation

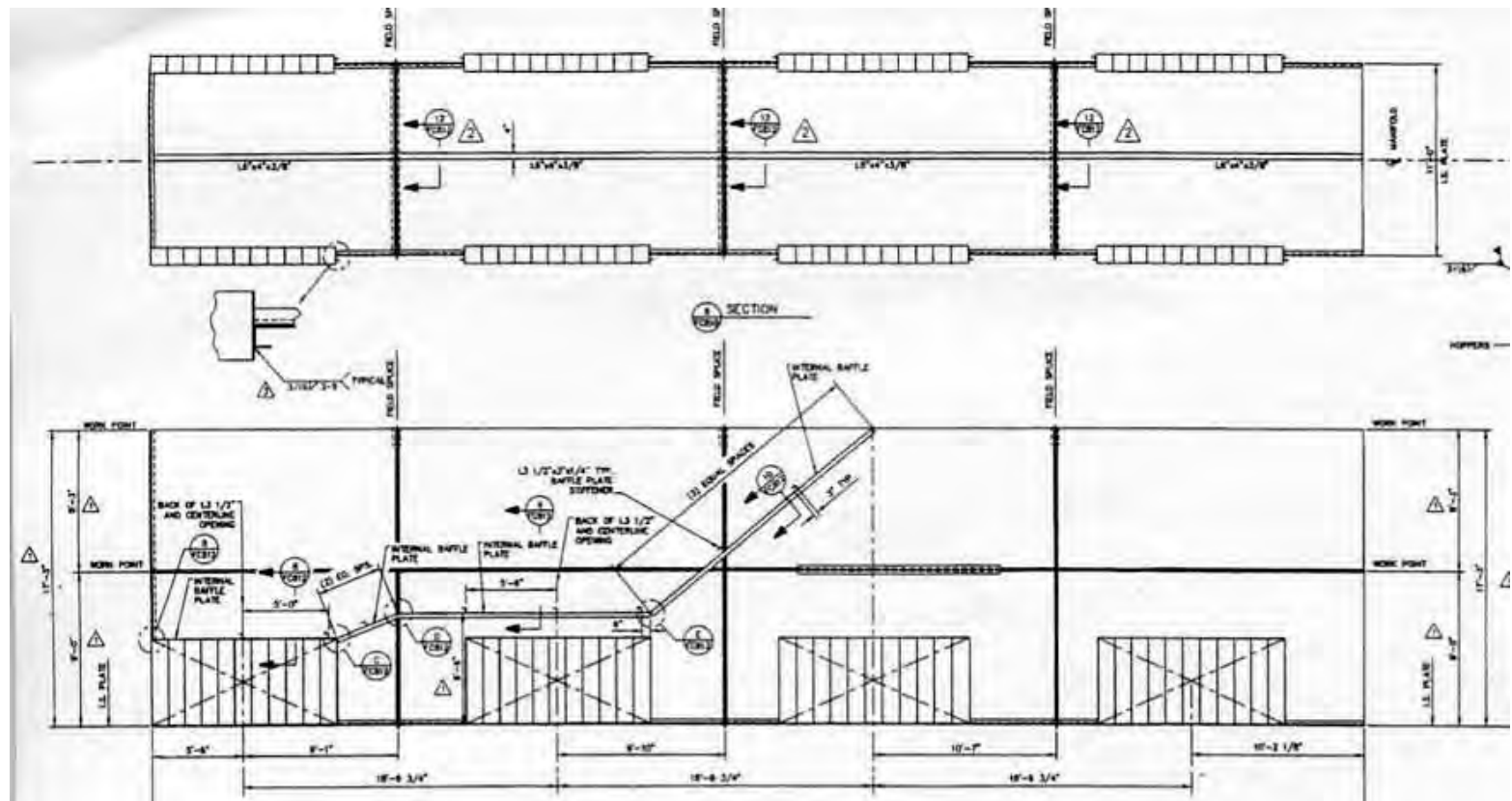




Four Chamber Plan View



Inlet Manifold, Plan View

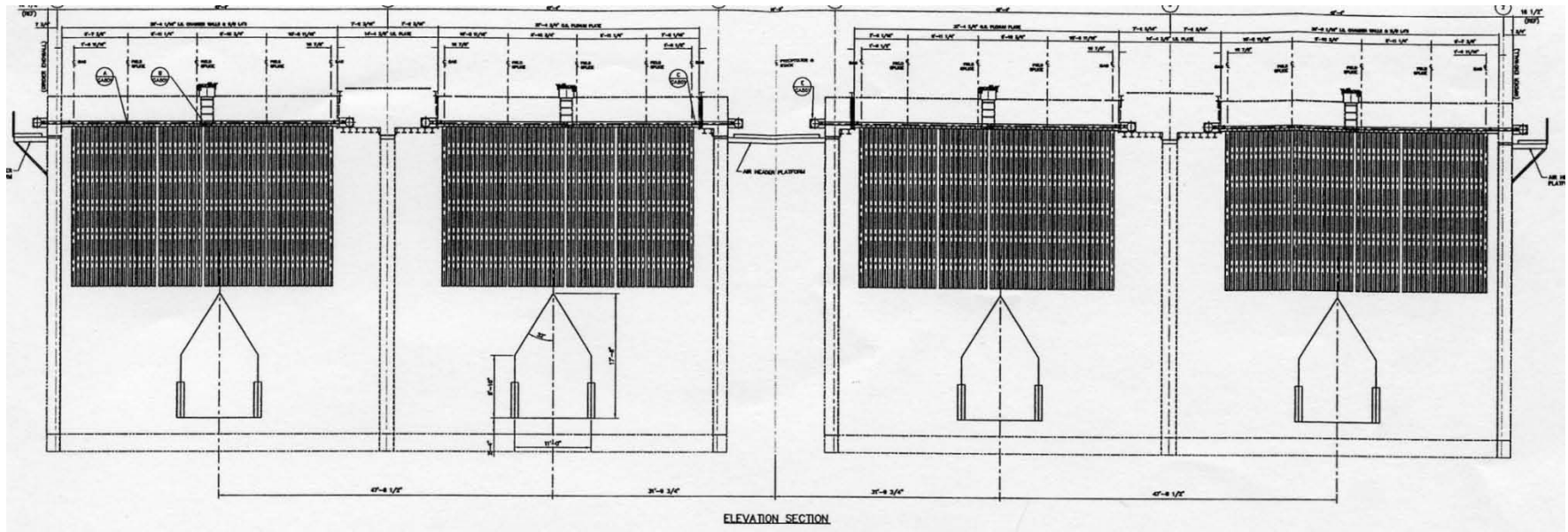


Inlet Low Velocity Inlet Plenum Design





Inlet Plenum Vaned Compartment Entrance



Big Stone Front Inlet Elevation

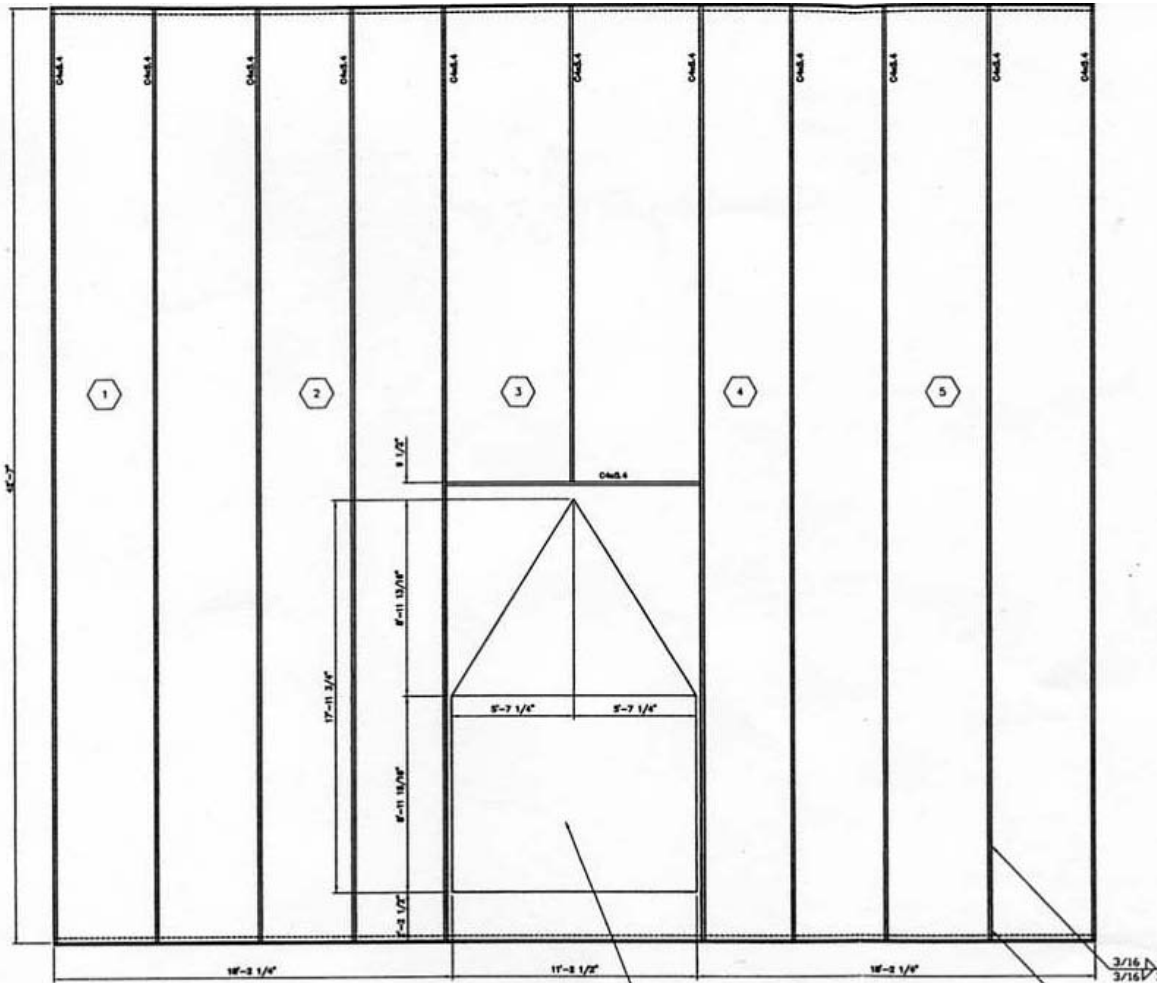


PAC/DSI Concerns

Upstream of the baghouse inlet plenum requires good distribution of PAC with air lance design and mixing. If PAC distribution is not optimum, some baghouse compartments may receive more carbon than others.

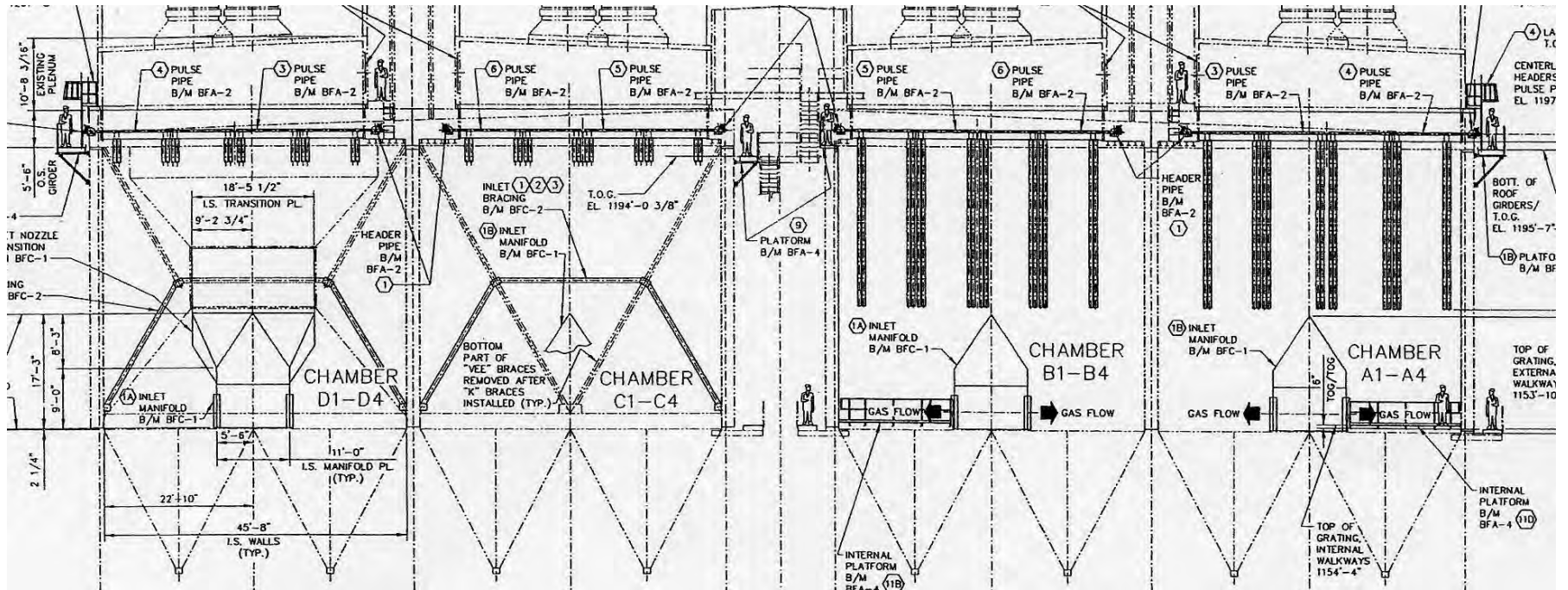
If PAC/DSI distribution is optimized but baghouse compartments do not have equal gas flow distribution (ICAC-7), then bag cake thickness will not build up equally over time and will be variable as gas flow tries to compensate with tubesheet ΔP varying with unequal compartment flows.





Partition wall between compartments, front elevation





Big Stone Inlet Details



Baghouse Outlet Plenum Design

- **Walk-In Plenum with 6' x 2' Doors**
- **Louvre Type Outlet Dampers**



Big Stone Outlet Plenum
6' x 2' IMTEC(BTA) door;
door cover shown





Outlet Plenum Louvre Dampers

Bag Cleaning:

Pulse jet cleaning has adjustable pulse air pressure, pulse on-time, cleaning frequency and blowpipe cleaning sequencing to address changing filter cake properties, recovery after a boiler/process upset, different ash loadings and particle size distributions. Cleaning modes can be on-line or off-line.

- Off-line cleaning specified by Otter Tail Power due to concerns with bag life and PAC injection for mercury removal.
- With on-line cleaning, the preferred method today, there is still gas flow into the bags when pulse air is supplied during cleaning. Thus, a portion of the same ash (especially the fines) released from the bags will be re-suspended and collect on the same bag and neighboring bags.
- On-line cleaning is normally used on pulse jets with a small number of compartments, i.e., 4 and 6 compartments. Off-line cleaning would cause a relatively large ΔP increase and resulting effect on the ID fan with a compartment off-line and especially with a compartment off-line for maintenance at the same time.



Bag Cleaning (cont.)

- With pulse jets applied to treat the very large gas volumes of coal-fired utility boilers, there are many compartments per casing (i.e., 10 to 16) and the rise in pressure drop is minimized with off-line cleaning of a compartment.
- Examples of clean-down with off-line versus on-line cleaning:

Big Stone: 0.75" to 1" W.G. better cleandown
EPRI Evaluation: 1" to 2" better cleandown reported



Bag Cleaning: PAC/DSI Concerns

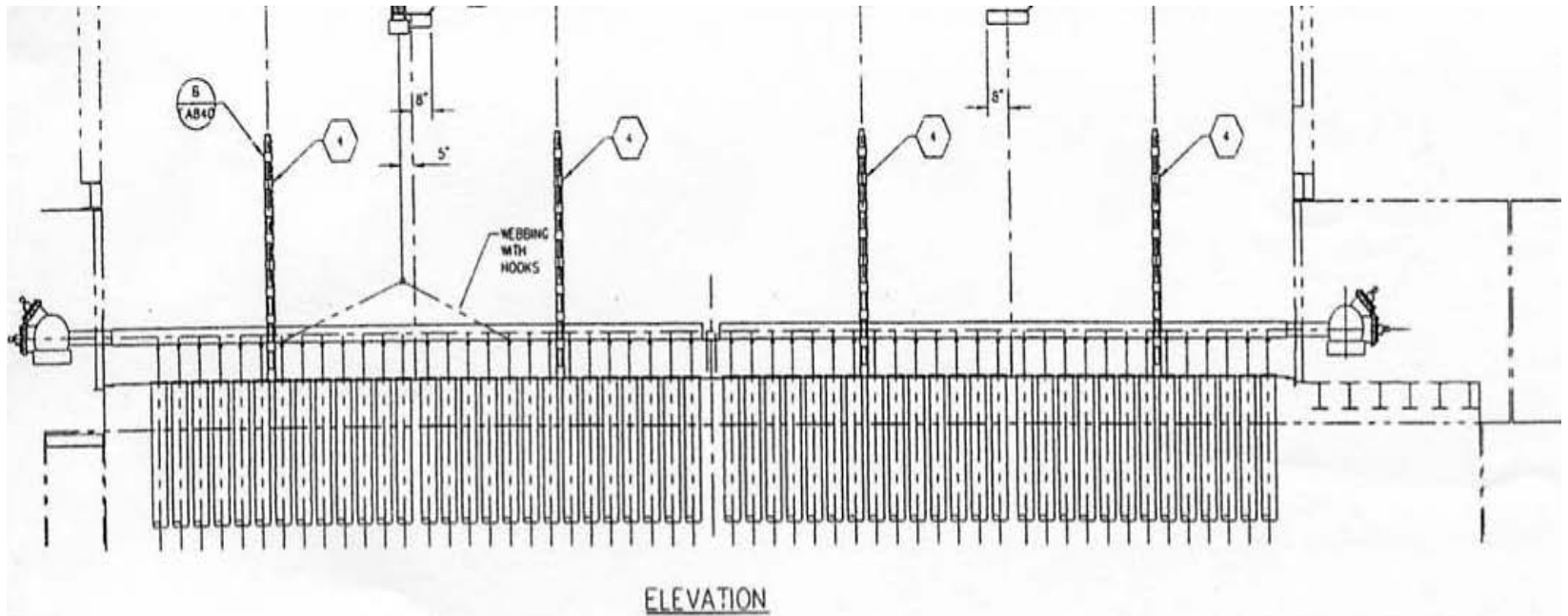
- If bag cleaning is not fully effective, then increased amounts of saturated sorbent will be left on the bags reducing the filter cake contribution to mercury and/or HCL.



Big Stone Blowpipe Design & Optimization For Pulse Cleaning

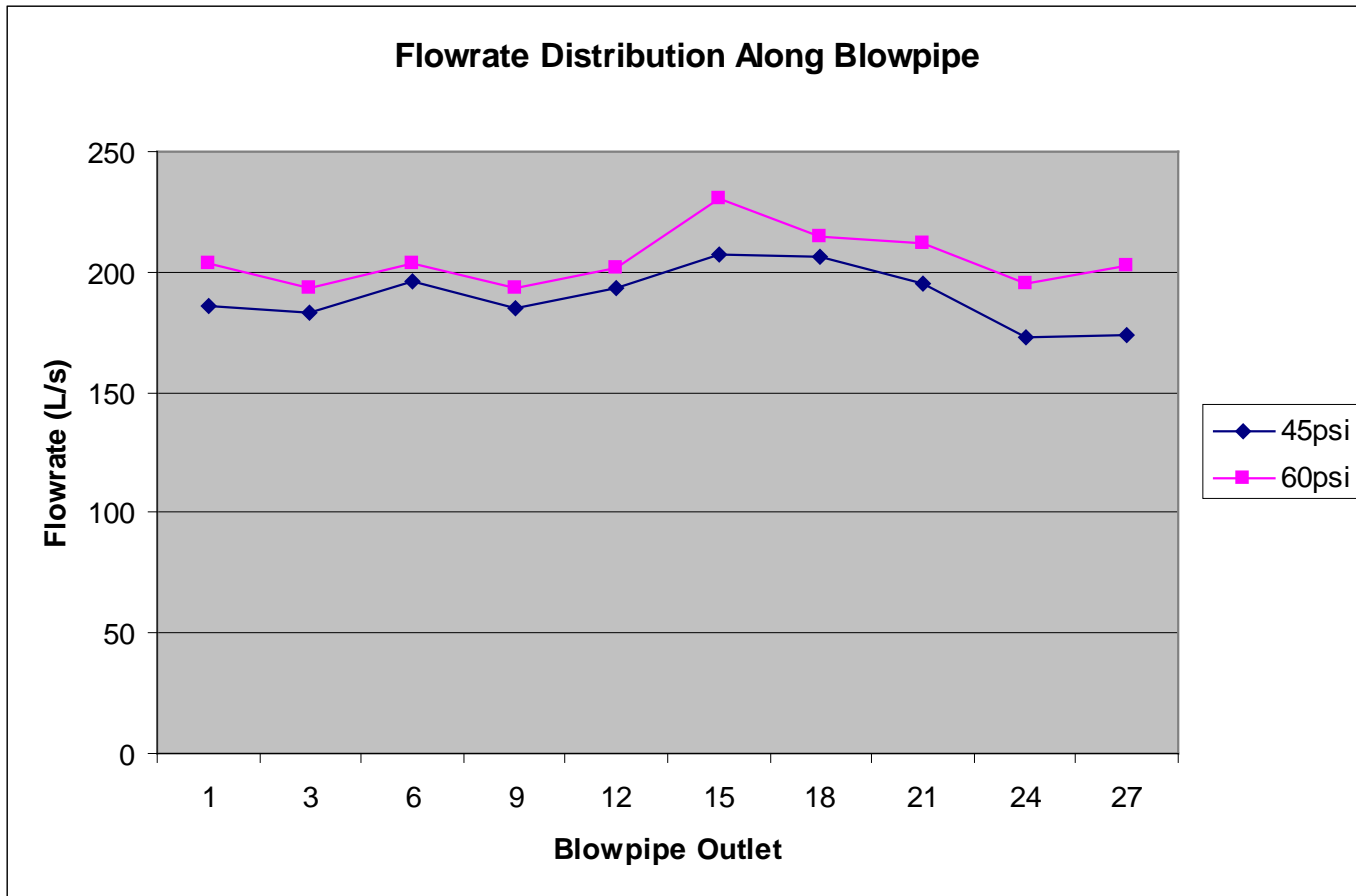
- Due to the pulse cleaning air flow required for 27 bags per blowpipe, 4" blowpipes and valves were selected.
- Tests were performed on a 27 bag blowpipe to determine the staggered pipe orifice sizes along the pipe to provide equal pulse air volume to each bag (within +/-10%).
- Tests were performed to determine the optimum blowpipe pulse air straightening nozzle diameter, length and height above the tubesheet.
- The the air consumption required per blowpipe for different pulse pressures was determined.





Big Stone Dual Blowpipe Arrangement, 27 Bags per Blowpipe

Flowrate Distribution Along Blowpipe



Big Stone Pulse Blowpipe Design Tests





PAC/DSI Concerns

Obviously, each bag on a blowpipe should receive equal cleaning air volume, otherwise some bags will not be effectively cleaned and have saturated PAC which would reduce the overall Hg removal efficiency.





Big Stone Blowpipes



Pulse Air Orifice and Straightening Nozzle



Pulse Valve Header Assemblies

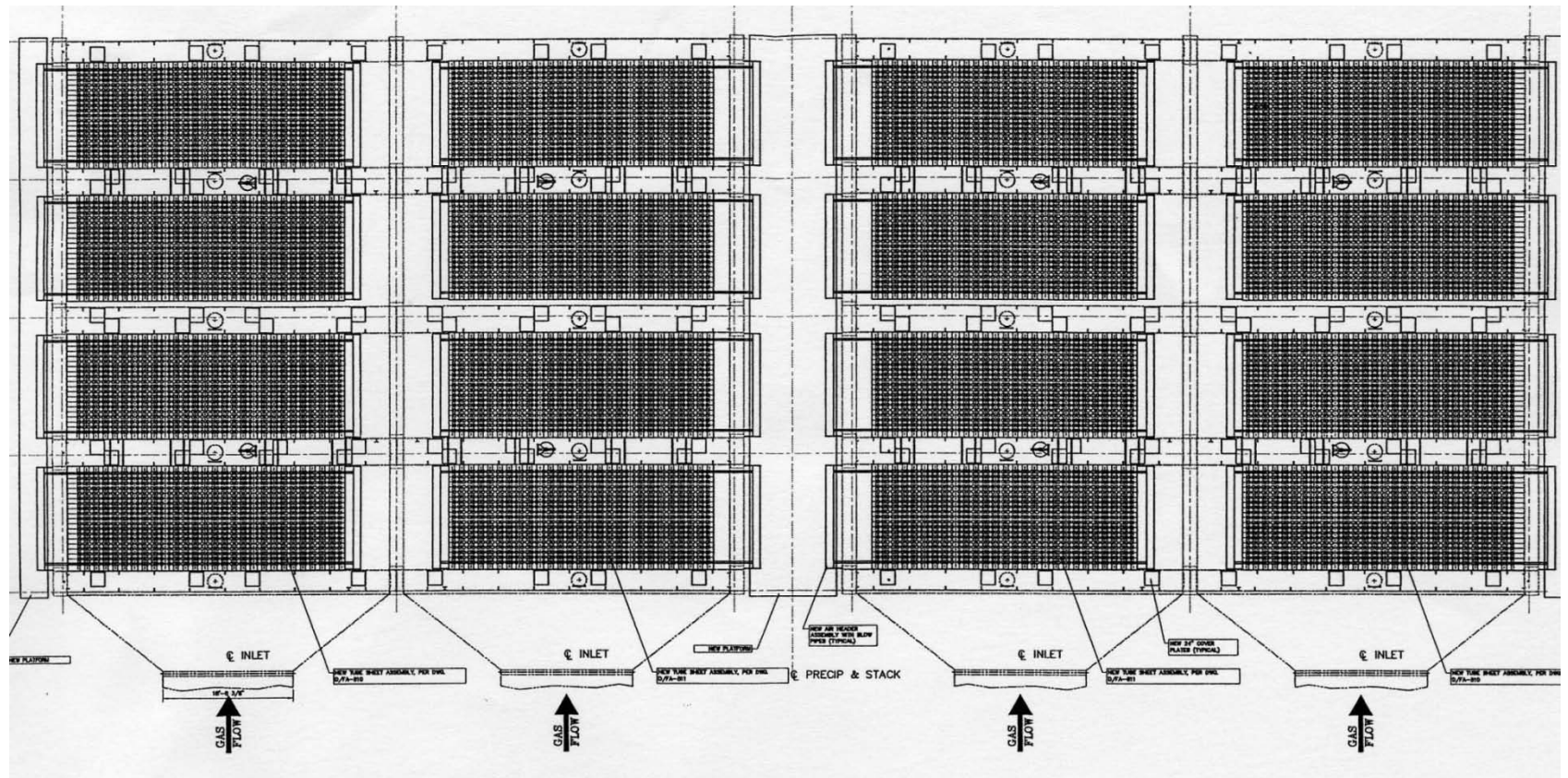


Big Stone Pulse Headers - 4" Valves

Compartment Tubesheets

- Precise tubesheet hole tolerances and edge design are required for proper snap band fit. Sample tubesheet hole plates are sent to the bag manufacturer to assure fit and hole edge conformance.
- Tolerances of tubesheet must assure flatness under bag load with proper stiffening applied, otherwise bags will touch at bottoms and erode.
- MET Buell APC Tolerances: maximum $+3/8$ " camber, negative camber not allowed. Welding: Shop and field welds must be applied in a staggered pattern to eliminate warpage.





Big Stone Tubesheets, Plan View





Big Stone Tubesheets



Big Stone Compartment Tubesheet

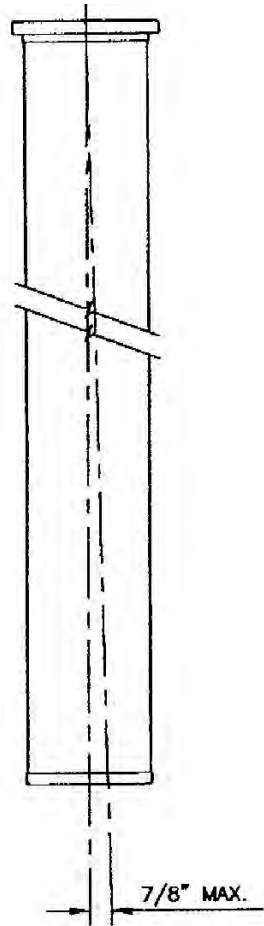
Bags and Cages

- Bags and cages were obtained from the same supplier to assure accountability for the required bag and cage fit.
- For the split cages used for the long bags, perpendicularity tolerance (top flange to vertical centerline) is critical to avoid bags touching at the bottom and eroding holes in the bags. Samples of the assembled cages from different batches were hung vertically in the supplier's shop to assure perpendicularity tolerance was met.





Split Cages



PERPENDICULARITY TOLERANCE
TOP FLANGE TO VERTICAL CENTERLINE



Big Stone Assembled Cage Check



Model Study

- Assures equal flue gas flow into each compartment to comply with ICAC F-7 criteria.
- Assures optimum gas flow distribution into the inlet plenum
- Optimizes gas flow distribution throughout the system to reduce pressure losses
- A model study is a must if applying PAC/DSI

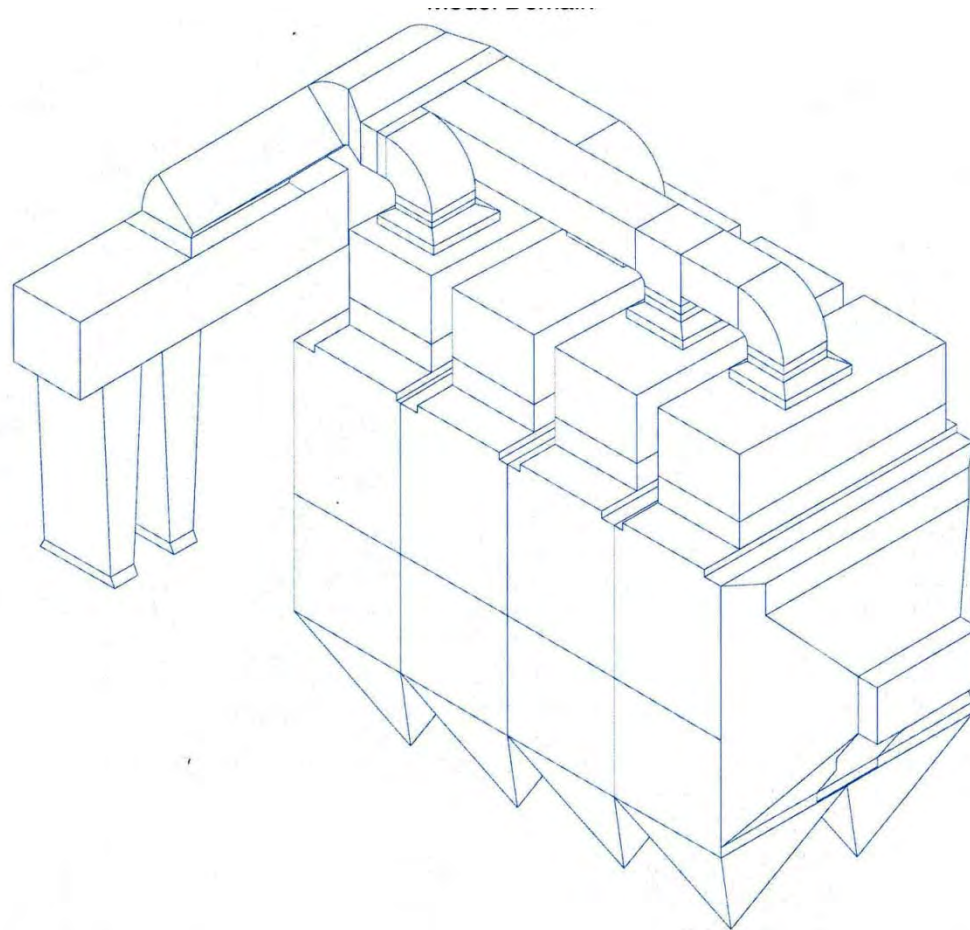




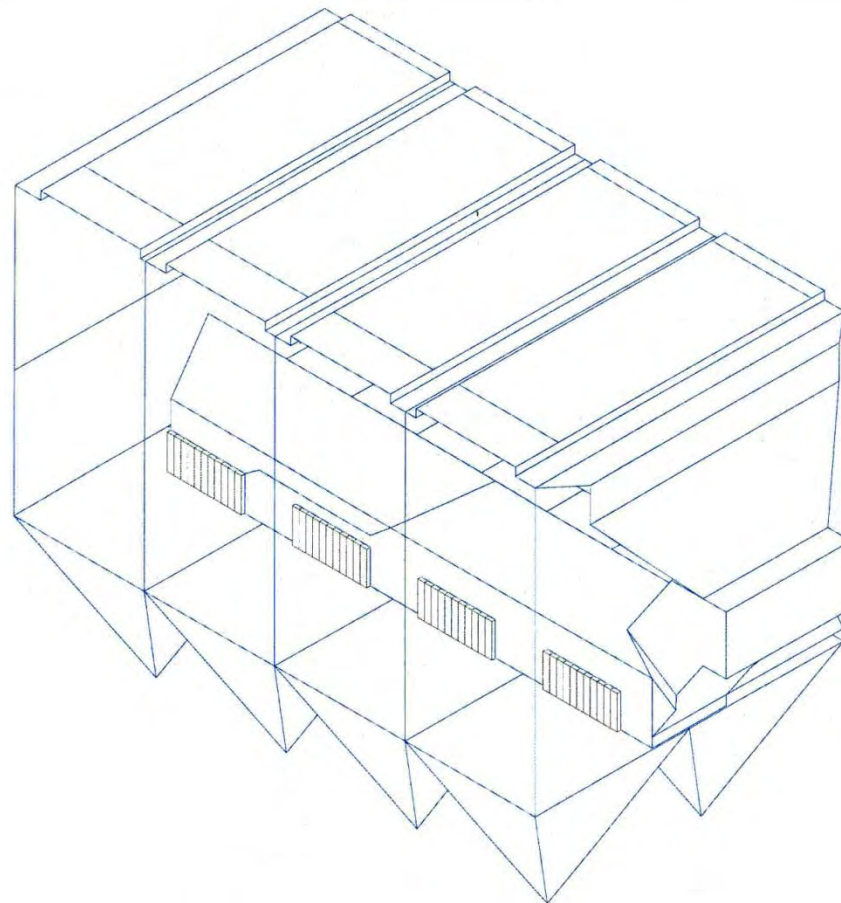
Big Stone Model Study

- Numerical Model Study
- 1/12 Scale Physical Model Study





Big Stone Single Chamber Configuration



Big Stone Single Chamber with Inlet Plenum

CFD Modeling

Goals

- Assure Flow Split Between compartments in a Chamber meets ICAC F-7 Criteria (+/- 10%).
- Optimize Gas Flow Distribution and Minimizes Losses in the Inlet Transition to the FF Inlet Manifold

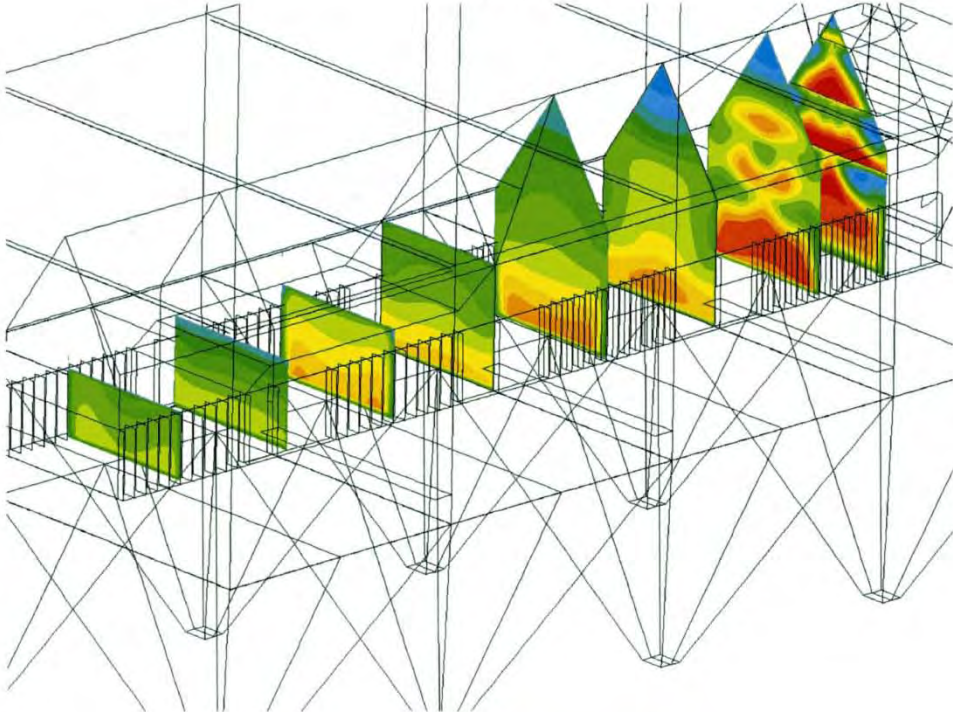
Results

- Flow Split Met ICAC Criteria
- Inlet Transition Flow & Losses Optimized



Design Results

Isometric View
Manifold



Airflow Sciences Corporation 

Big Stone Flow Modeling



Physical Modeling

Goals

- Assure no significant Ash Buildup in Ductwork and Inlet Manifold Floor through Dust Deposition Tests
- Confirm Numerical Modeling Results
- Quantify System Pressure Losses

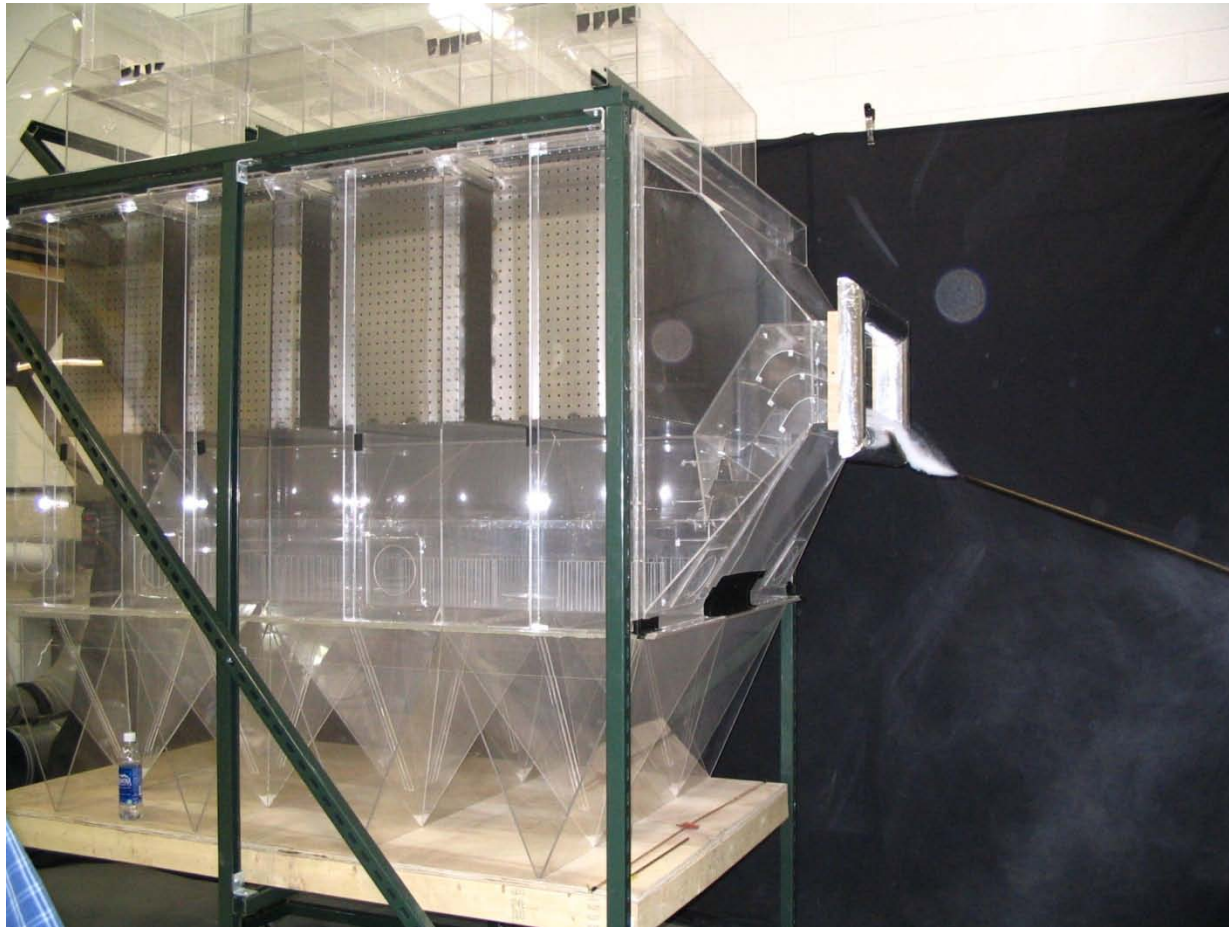
Results

- Good Agreement Between Numeric and Physical Model Results
- Majority of Dust Swept Clean From Inlet Manifold Floor at 75% Full Load Velocity, No Significant Dust Buildup at 100% flow

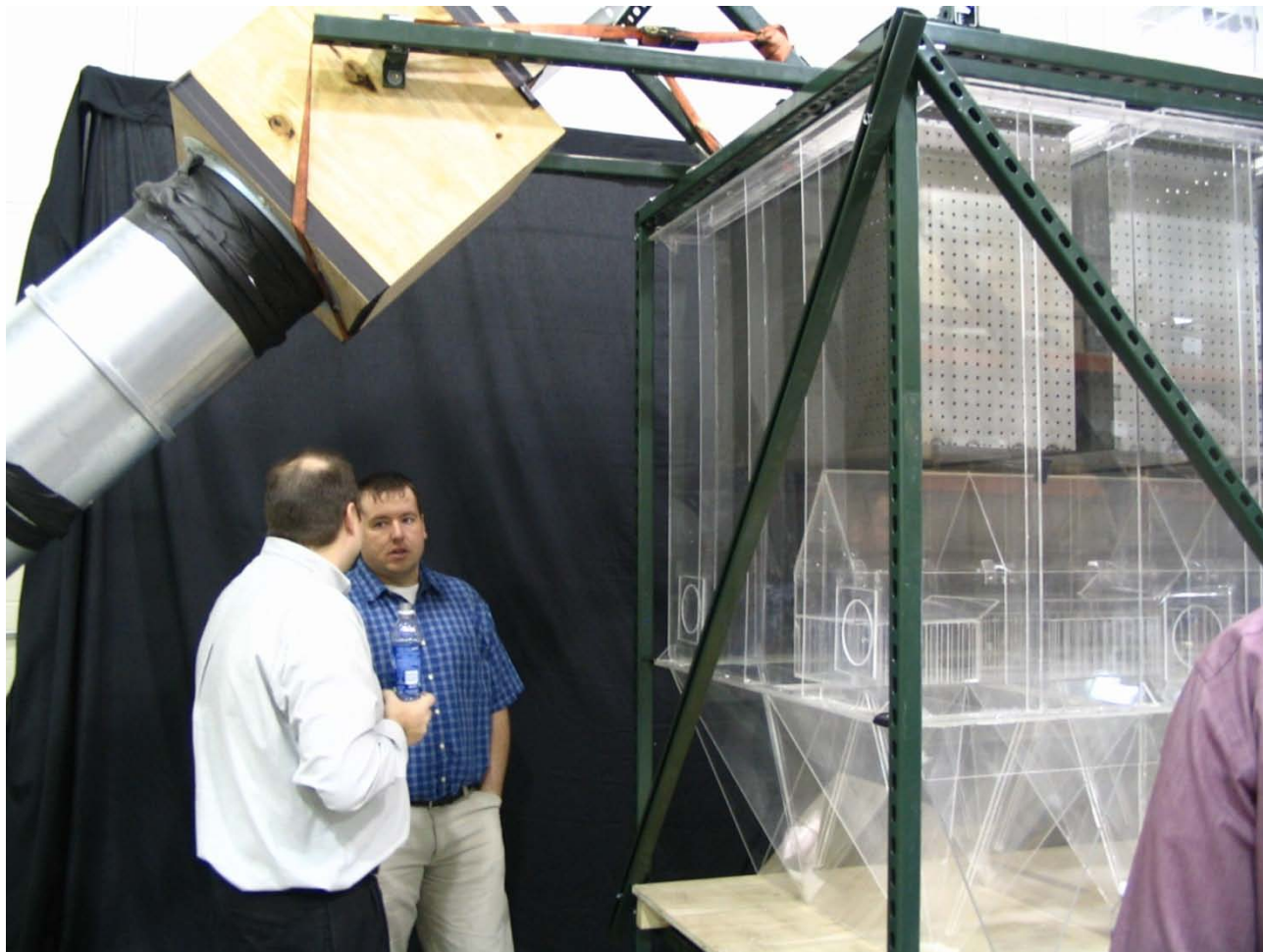




Big Stone Physical Model Side Elevation View



Big Stone Physical Model, One Chamber of 4



Big Stone Physical Model – Inlet Plenum

Big Stone Flow Modeling Results

Flow Split Determination

% of Total Flow

Compartment 1 Inlet	23.1
2	22.8
3	26.6
4	27.5





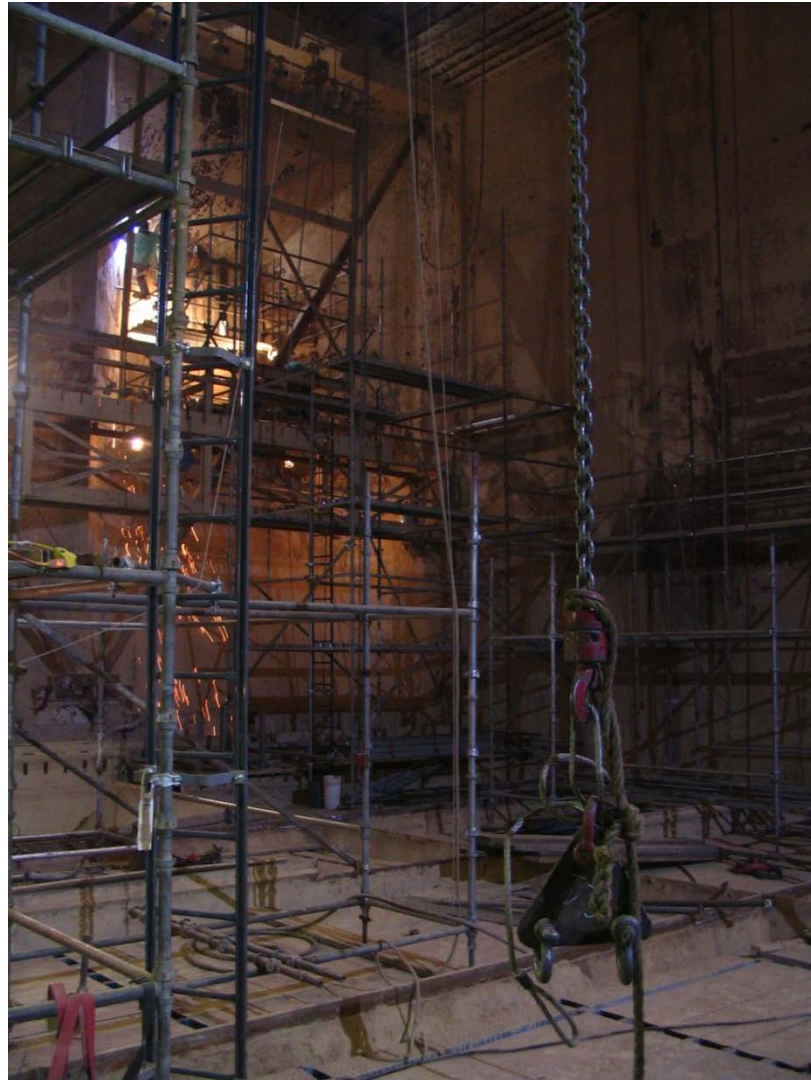
Big Stone Unit 1, Four Parallel ESP Chambers



ESP Side Cut-outs for ESP internals Demolition



Big Stone, Inside One of 4 Casings

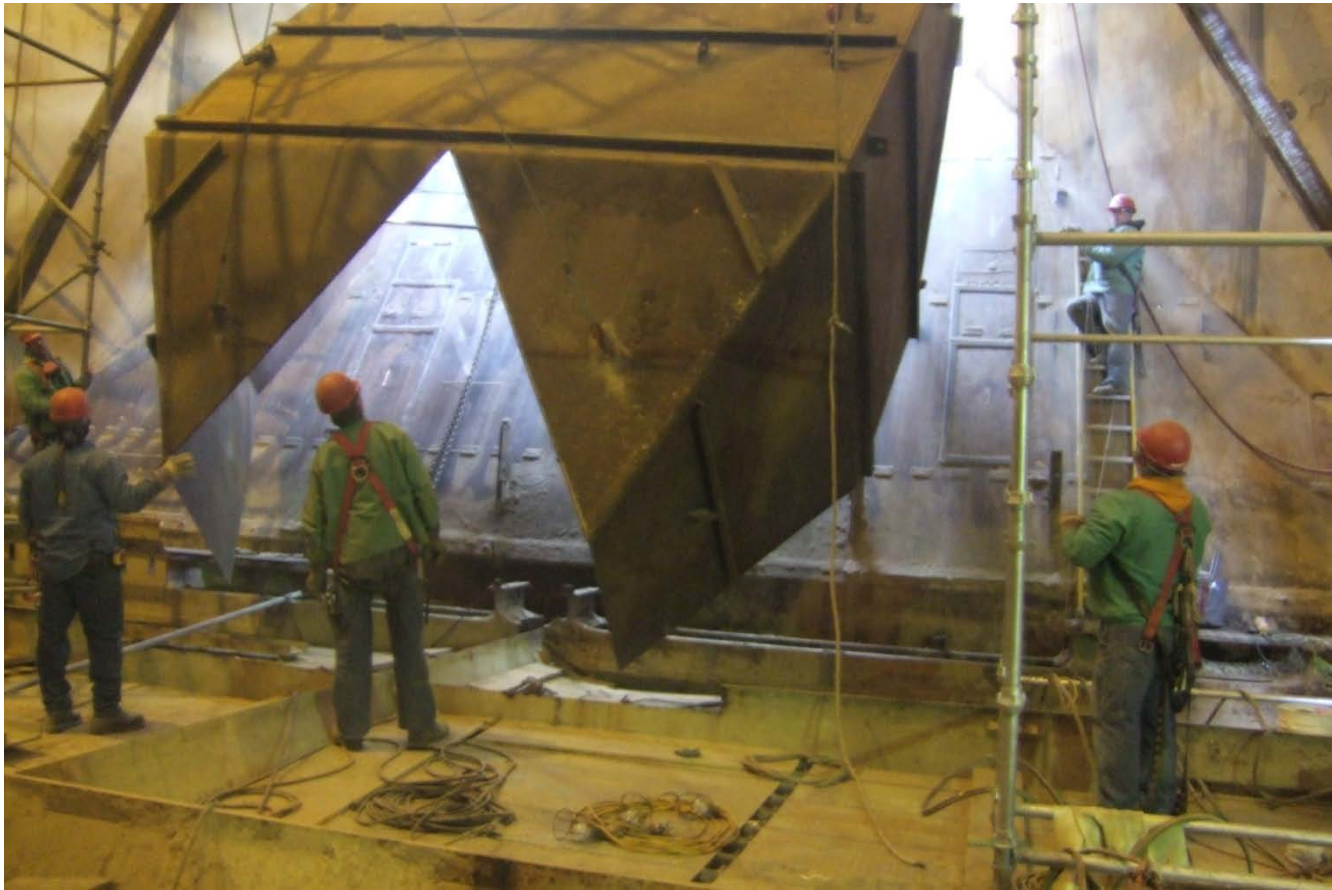


Top of Inlet ESP Nozzle
Cut Out for Installation
Of FF Duct Transition





Pre-Assembly of Inlet Plenum Sections



Inlet Nozzle Transition Being Lowered into Place



Compartment Tubesheet Shelf Installation

Bag Installation

Proper installation of bags and split cages is critical to assure bags are not touching at the bottom which will result in premature bag failure.

Assure competent installation crew (preferably from bag supplier) so that split cages are seated properly to achieve perpendicularity tolerance so no 'dog legs' occur. A major portion of the bottom pan should be seen with a light shining to the bottom of the bag cage.





Bottom of Bag Failure due to Bags Touching





Proper Split Cage Installation Means no Bags Touching at Bottom

Baghouse Control System

The Big Stone baghouse control system has the capability of :

- Off-line or on-line cleaning
- Timer or ΔP cleaning trigger
- Single or dual blowpipe sequential cleaning in off-line cleaning mode and staggered blowpipe sequential cleaning for on-line cleaning mode.
- Capability for simultaneous dual compartment cleaning to reduce total baghouse cleaning time.





Big Stone Allen Bradley Logix 500 Control Cabinet



Control System Display Panel





PAC Concern:

Better Hg removal efficiency with timer control cleaning versus ΔP setpoint cleaning if not a base loaded unit because if carbon is left on the bags too long, it will become saturated and mercury removal in the filter cake will be reduced.



Performance Results

- Pressure Drop Guarantee Met
- Outlet Emission Tests Not Done Due to Opacity Results
- 1 to 2% Opacity

