Worldwide Pollution Control Association

Particulate Control O&M Training

APC/PCUG Conference
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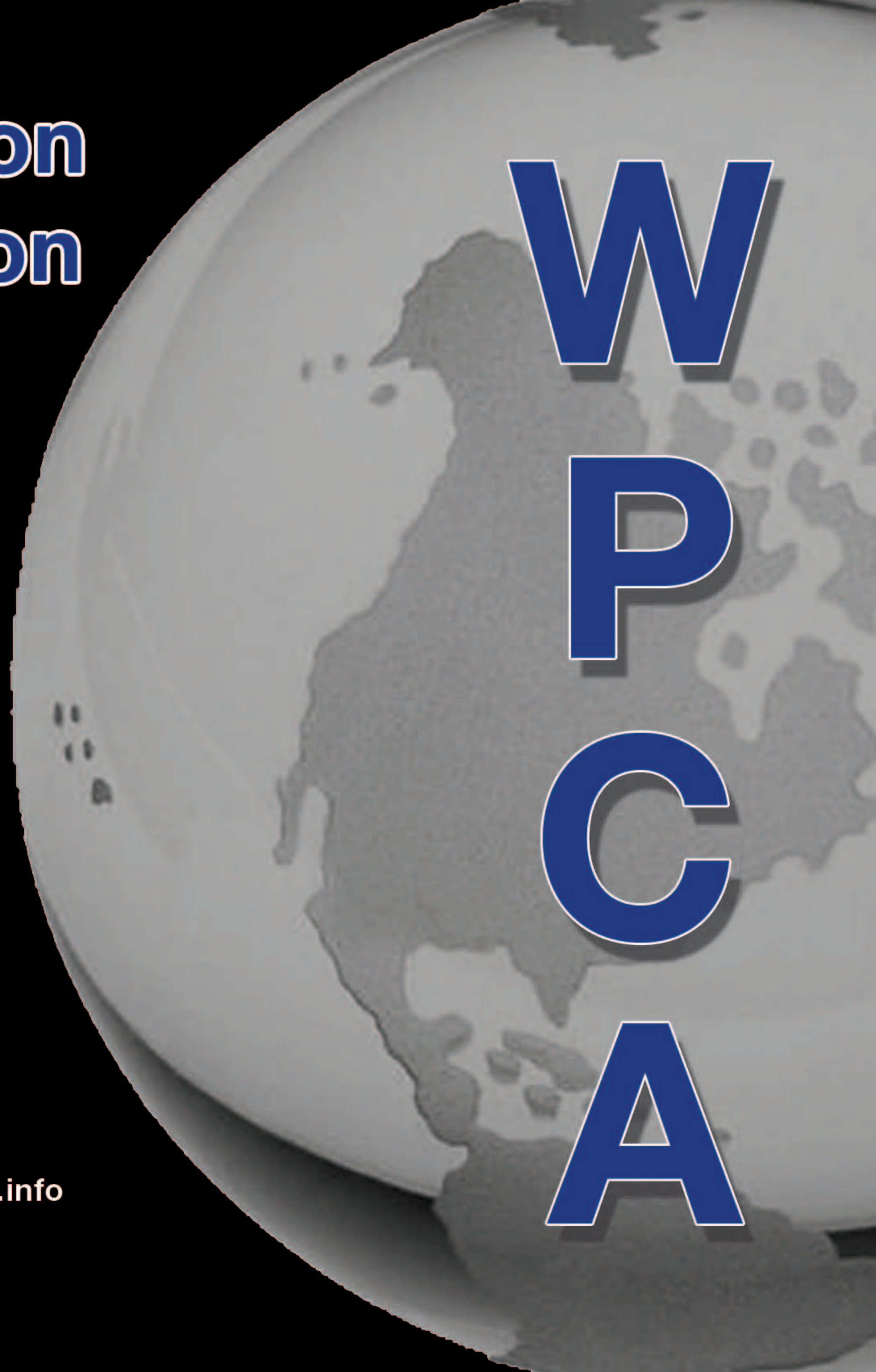

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The Ultimate ESP Rebuild: Casing Conversion to a Pulse Jet Fabric Filter, a Case Study

By
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A CECO Environmental Company

Present and Future 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
- Control of Mercury Emissions
- Control of PM 2.5, Future Fine Particulate Legislation

Adding a Dry Scrubber

- A Baghouse is Required Downstream for Additional SO_2 Capture to Reduce Lime Consumption
- Options: Convert/Replace ESP with PJFF

Adding a Wet Scrubber Downstream of an ESP

- Flyash Emissions Must be Limited for Gypsum Quality and Effective Limestone Dissolution
- Options: Upgrade ESP, Replace/Convert to a PJFF

Present Hot Button:

Mercury Control

EPA’s Clean Air Mercury Rule (CAMR) Limits Emissions From Coal-Fired Electric Generating Units Nationwide.

Phase I by 2010
Phase II by 2018

Mercury Control

Full Scale Testing Results Show Mercury Removal Rates Between 30 to 90% With Rates Highly Dependent on Coal Type.

The Best Option Presently for Consistent, High Removal Efficiencies $\geq$ 90% is Sorbent Injection Followed by a PJFF.

Options Are:

- Convert ESP Casing or Replace With a PJFF if ESP not Large Enough.
- Add PJFF Downstream of the ESP: Standard A/C ratio or High Ratio (EPRI COHPAC)

Control of PM 2.5

Control of fine particulate would also control heavy trace metal emissions such as As, Cd, Ni, Se, etc. that nucleate as submicron particulate or condense in the fine fraction of flyash.

For many older, low SCA (plate area/1000 acfm) ESPs, performance upgrades required to achieve PM2.5 emission limits could be extensive.

Options

- Convert casing to or replace with PJFF
- Add a PJFF downstream (EPRI COHPAC)
- Add wet ESP sections to the outlet

Conversion Advantages

- Lower Cost Option Than Replacing With a New ESP or New Fabric 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
- Ready for More Efficient/Consistent Mercury Emission Reduction With Activated Carbon Injection
- Ready for Future PM2.5 Legislated Particulate Emission Standards

What Makes a Good ESP to FF Candidate?

- Casing Large Enough in Volume to Accommodate Required Cloth Area
- ESP Casing in Good Shape with Minimal Corrosion

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

Case Study

Otter Tail Power Company, Big Stone Unit #1
Big Stone City, South Dakota
ESP to FF Conversion Completed December 2007

Big Stone Unit #1

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

Concerns

- Performance Problems with the Burning of PRB Coal - High Resistivity, Back Corona Formation
- Future Mercury Emission Control

Big Stone Unit 1, Four Parallel ESP Chambers

Remedy

Evaluate a new technology, Advanced Hybrid Particulate Collector (AHPC), patented by the Energy and Environmental Research Center (EERC) of the University of North Dakota and Funded by the DOE National Energy Technology Laboratory

- Slipstream Pilot Testing Completed in 1999

- ESP Converted to AHPC in 2002

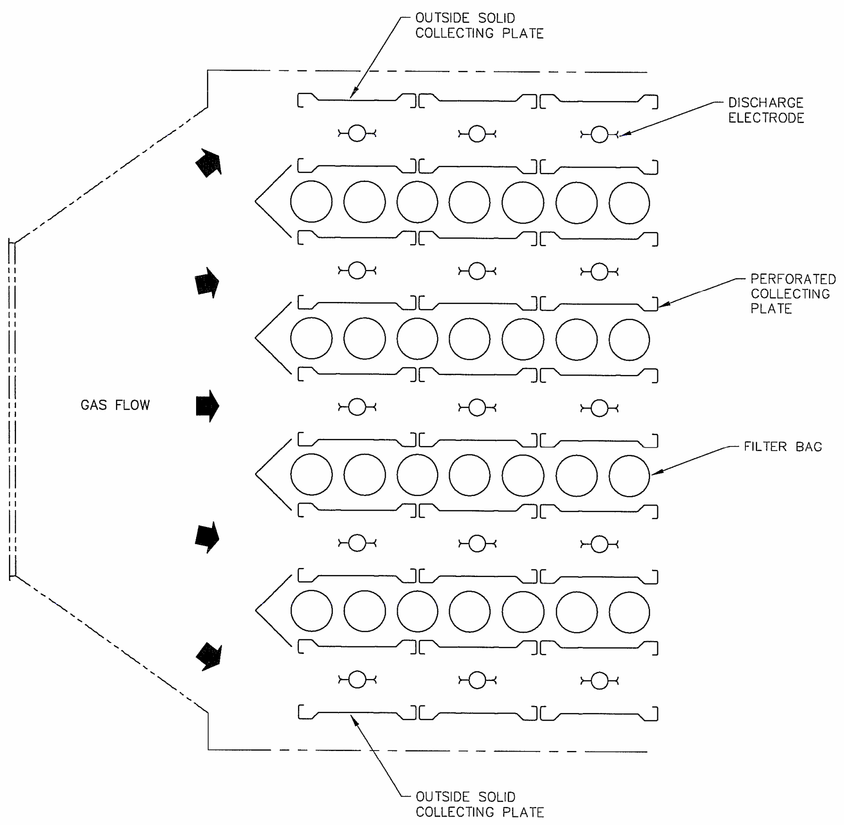
AHPC Concept

Combine ESP and High Ratio (A/C = 12.0) Pulse Jet Technologies in the same casing.

ESP Charging and Collection Zones Alternate Between Rows of Filter Bags (Filtration Zone)

ESP Zone: 45% Open Area Perforated Collecting Plates
Rigid Emitters for Charging

- Remove over 90% of Flyash Prior to Filtration Zone
- Charged Particulate Entering the Filtration Zone would Reduce Bag Filter Cake Pressure Drop due to more Porous Dust Cake.



AHPC Concept Plan View

AHPC Full Scale

Advanced Hybrid Particulate Collector (AHPC) Design Summary

Outlet 3 ESP Fields of Each Chamber Converted in 2002
Inlet Field of Each Chamber Converted in 2004

AHPC Conversion

- Design A/C: 12.0 (2002)
- Final A/C : 9.0 (2004)
- On-Line Cleaning, Intermediate Pressure Pulse
- Filter Bags: 6” diameter, 23’ Long

AHPC Full Scale Results

- High Bag Pressure Drops: >10” W.G.
- Continuous Cleaning with Pulse Pressure Raised to 100 -110 psi
- Bag Failures Within 6 Months
- Opacity limit Exceeded Due to Failed Bags
- Constant 30-50 MW De-Rate Due to Fan Limitation with High Bag Pressure Drops and Opacity Exceeding Limit
- <u>Cause of AHPC Failure:</u> High Resistivity Ash Problem was not Eliminated and Severely Limited Effectiveness of the Electrostatic Zone

Big Stone Conclusions After Failure of AHPC

- Abandon the AHPC Technology
- Replace the Existing ESP/Hybrid with a New PJFF Alongside

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 a Total Replacement.
- Added Benefit: With 4 Independent Chambers, each Chamber could be Blanked Off During a Short Outage and each Chamber Converted while On-line at a Reduced Load.

Big Stone Application

480 MW Cyclone-Fired Boiler
Burning PRB sub-Bituminous Coal

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

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 each Chamber

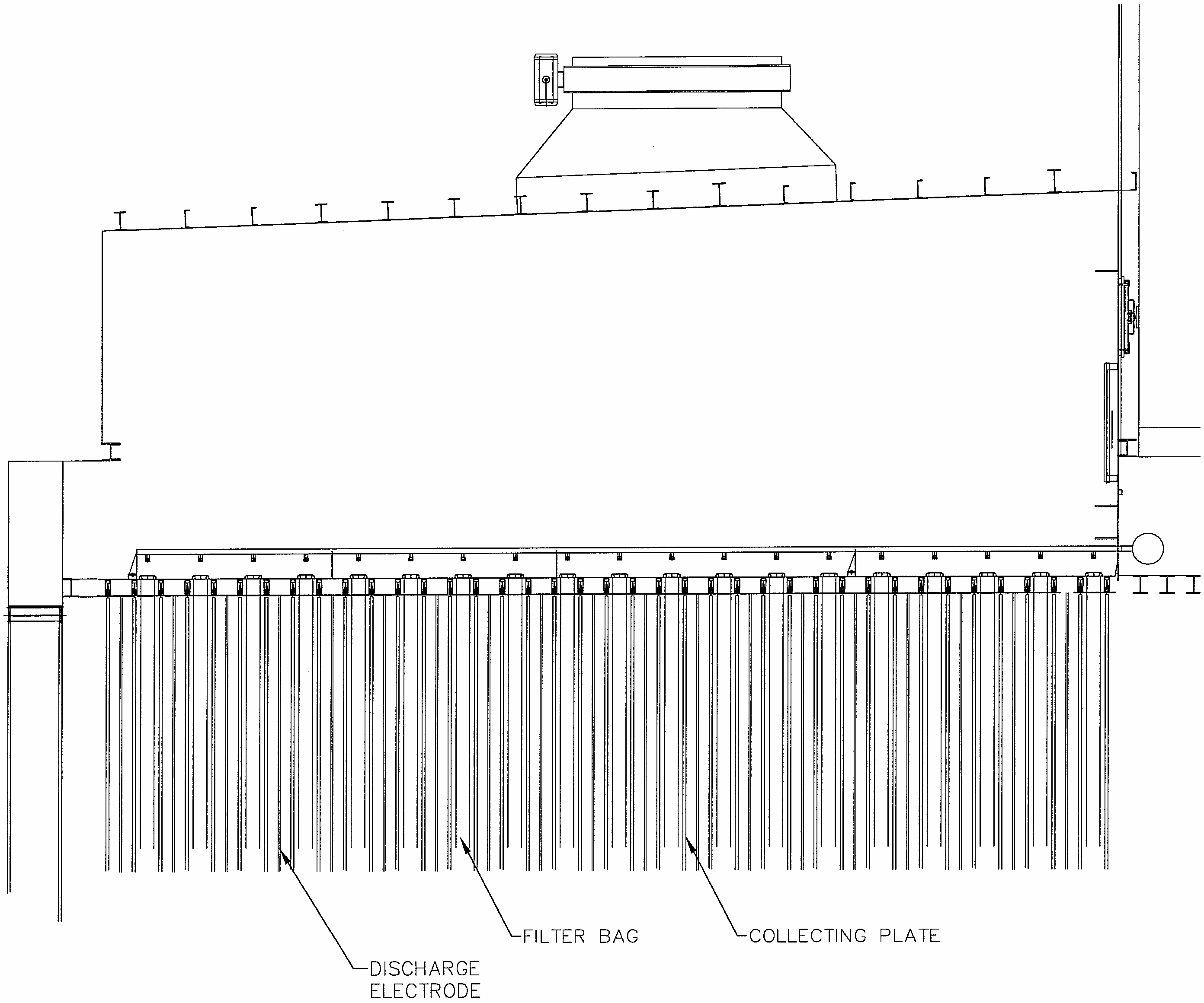
Filter Bags: 21 oz. Woven Fiberglass with PTFE Membrane
acid resistant coating, 6" Diameter, 25' Long
Cages: Split Cage, Carbon Steel, 24 Wire
Interstitial/Can Velocity = 178 ft/min
Bags/Chamber = 4028 Total Bags = 16,112
27 Bags/Blowpipe, 2 Blowpipes Per Bag Row

Guarantees

Opacity - 10%
Outlet Loading - 0.01 lb/MMBTU
Bag Life - 3 Years
Maximum ΔP - 8" W.G.

Conversion to PJFF

- AHPC Hardware Removed along with Tubesheets
- Retained Walk-in Outlet Plenum and Vaned Dampers for Use in Off-Line Cleaning
- Add New Tubesheets, Pulse Headers, Blowpipes and New Control System
- Add Partition Walls to Compartmentalize each Chamber, 4 Compartments/Chamber, 16 Total
- Add Inlet Transition Duct from Existing ESP Nozzle to the Baghouse Inlet Plenum distributing Gas Flow to the Compartments

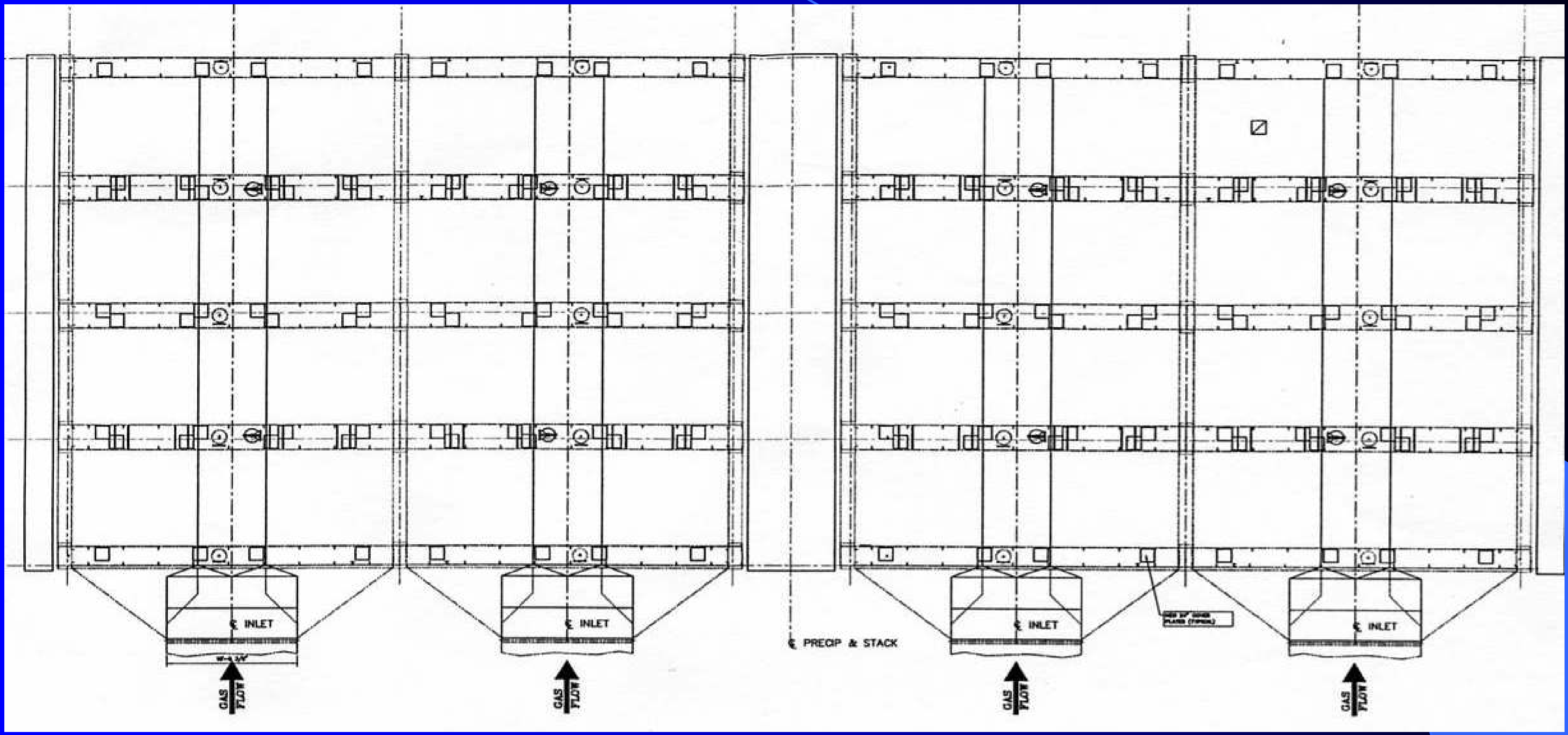


AHPC One Compartment Front Elevation

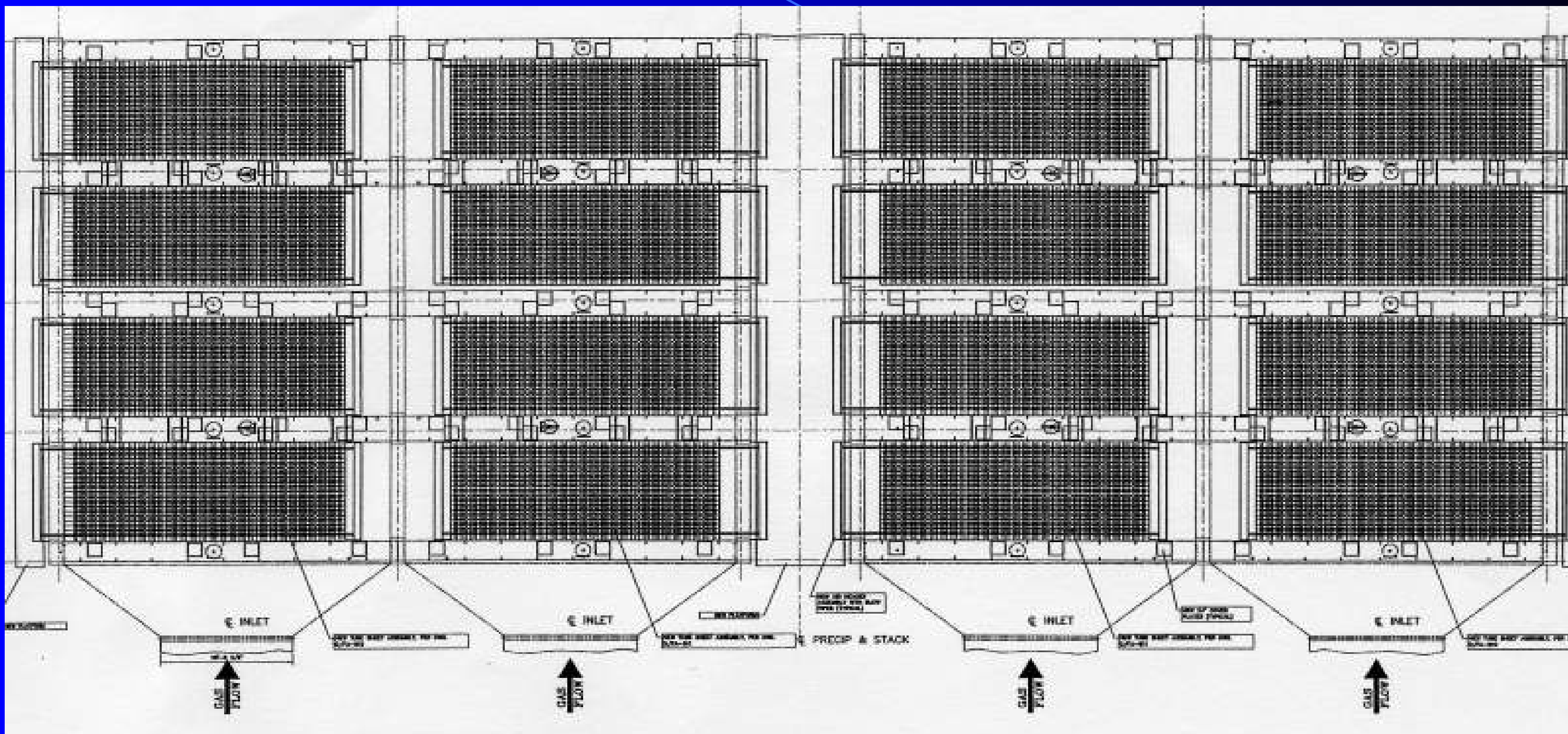
Four Chamber View

Outlet Plenum Vaned Dampers

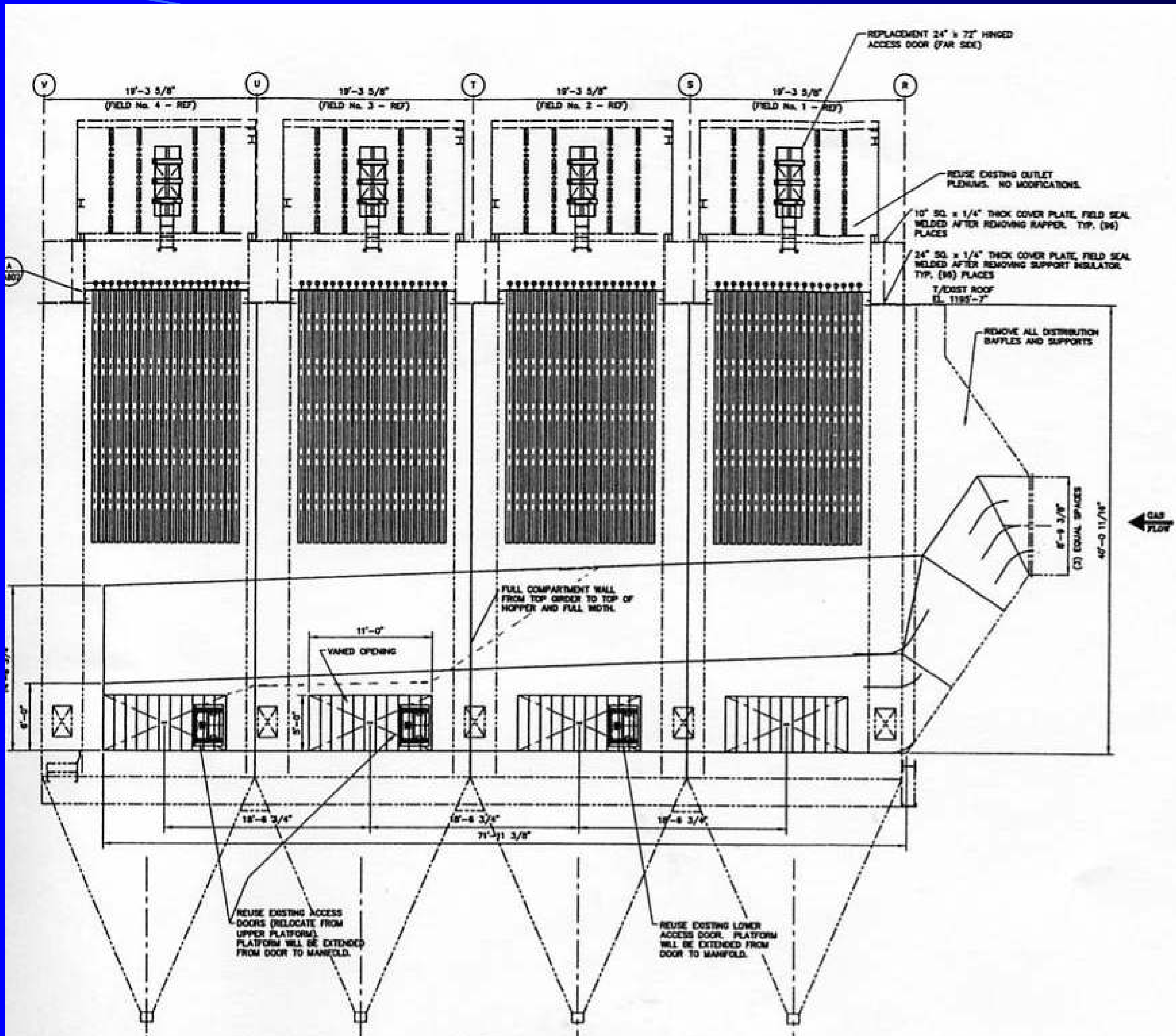
Big Stone ESP – Four Chambers



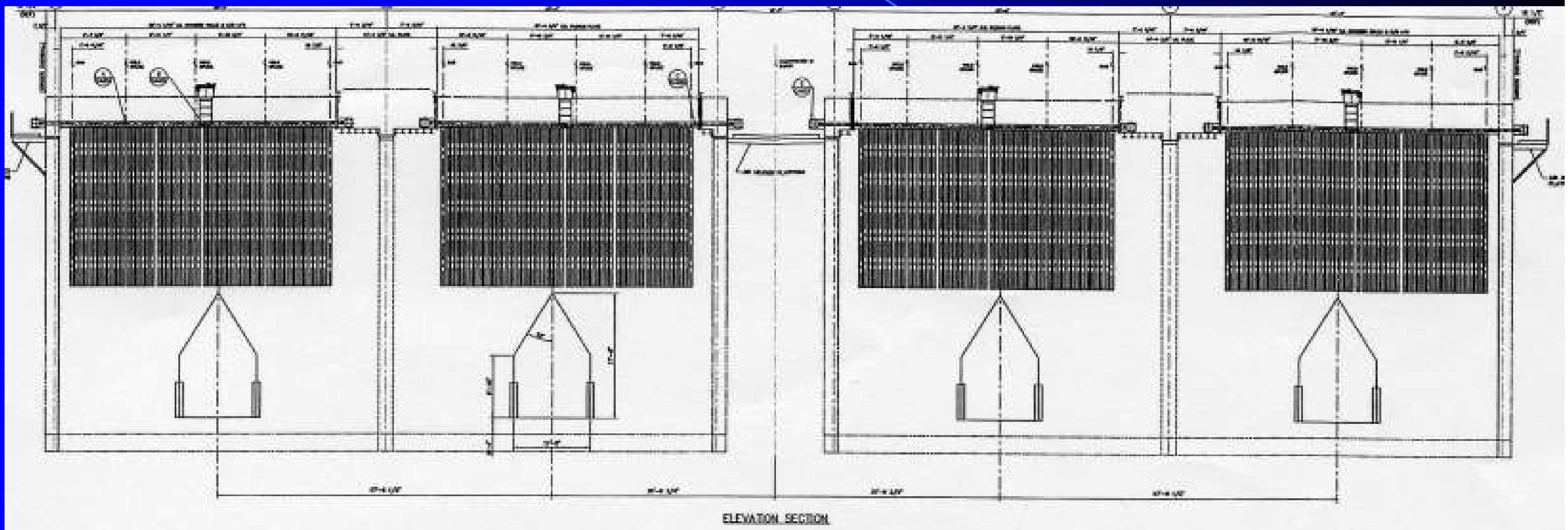
Inlet Manifold, Plan View



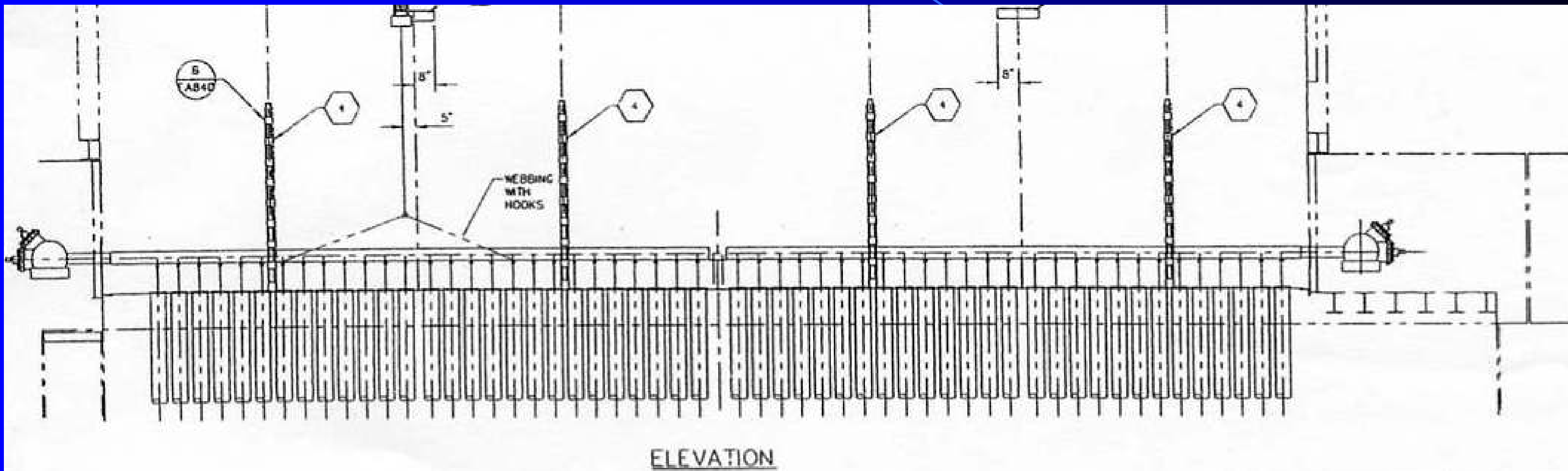
Big Stone Tubesheets, Plan View



Big Stone Side Elevation



Big Stone Front Elevation Inlet

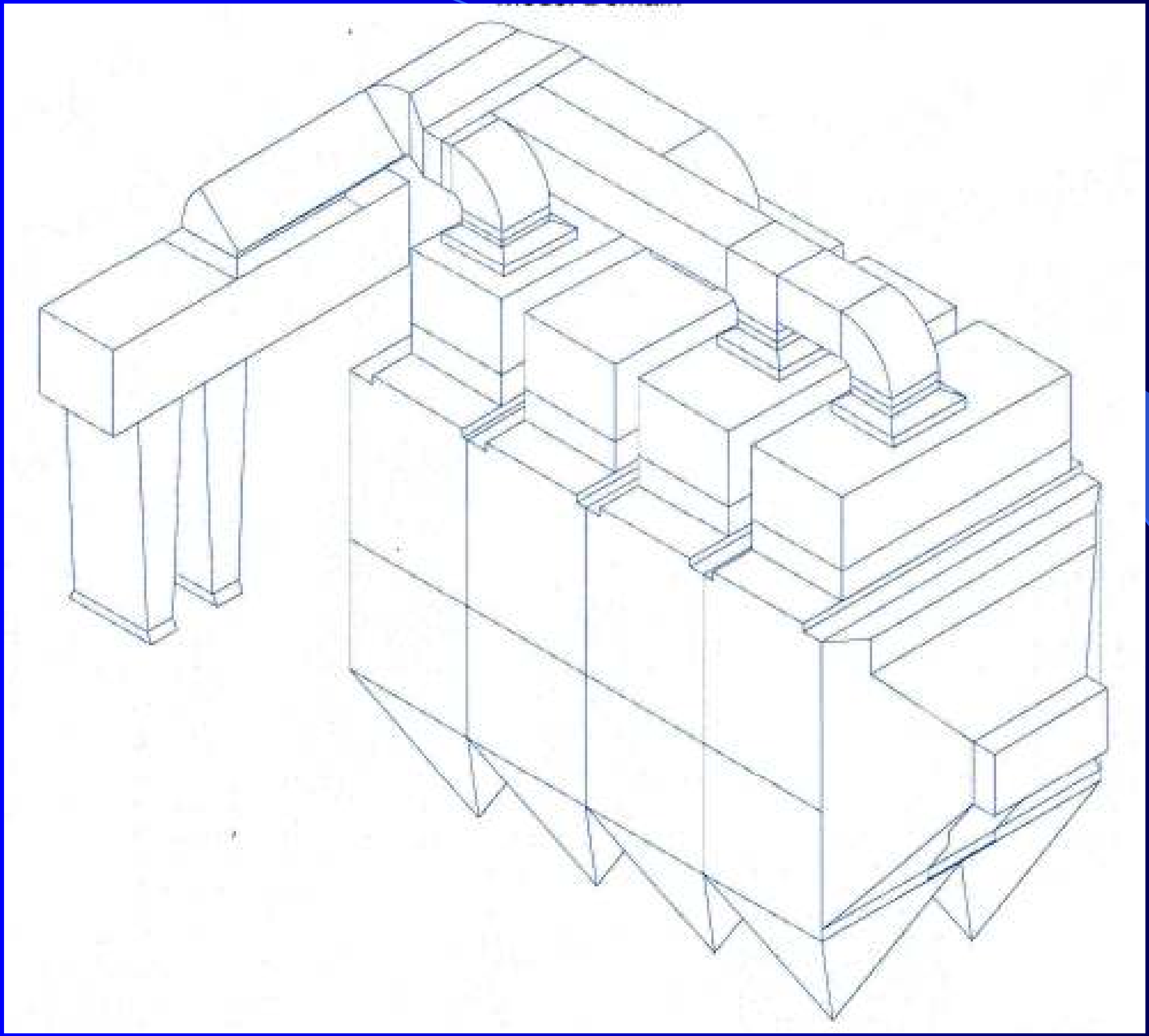


Big Stone, Front Elevation, Dual Blowpipes Per Row

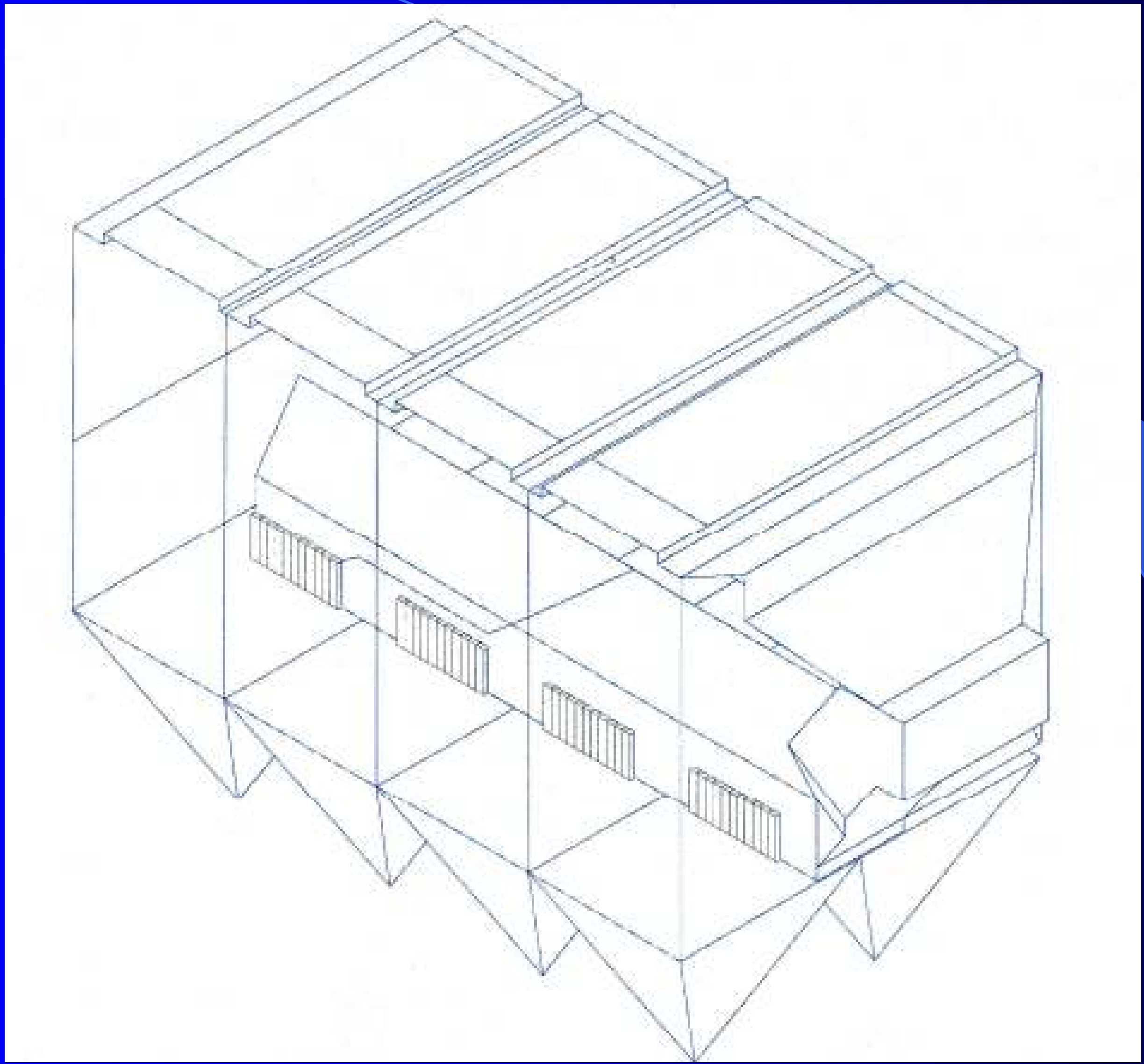
Big Stone Model Study

AirFlow Sciences Corporation

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



Big Stone One Chamber Configuration



Big Stone Single Chamber Configuration

Numerical Modeling

<u>Goals</u>

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

<u>Results</u>

- Flow Split Meets ICAC Criteria
- Inlet Transition Flow & losses Optimized

Physical Modeling

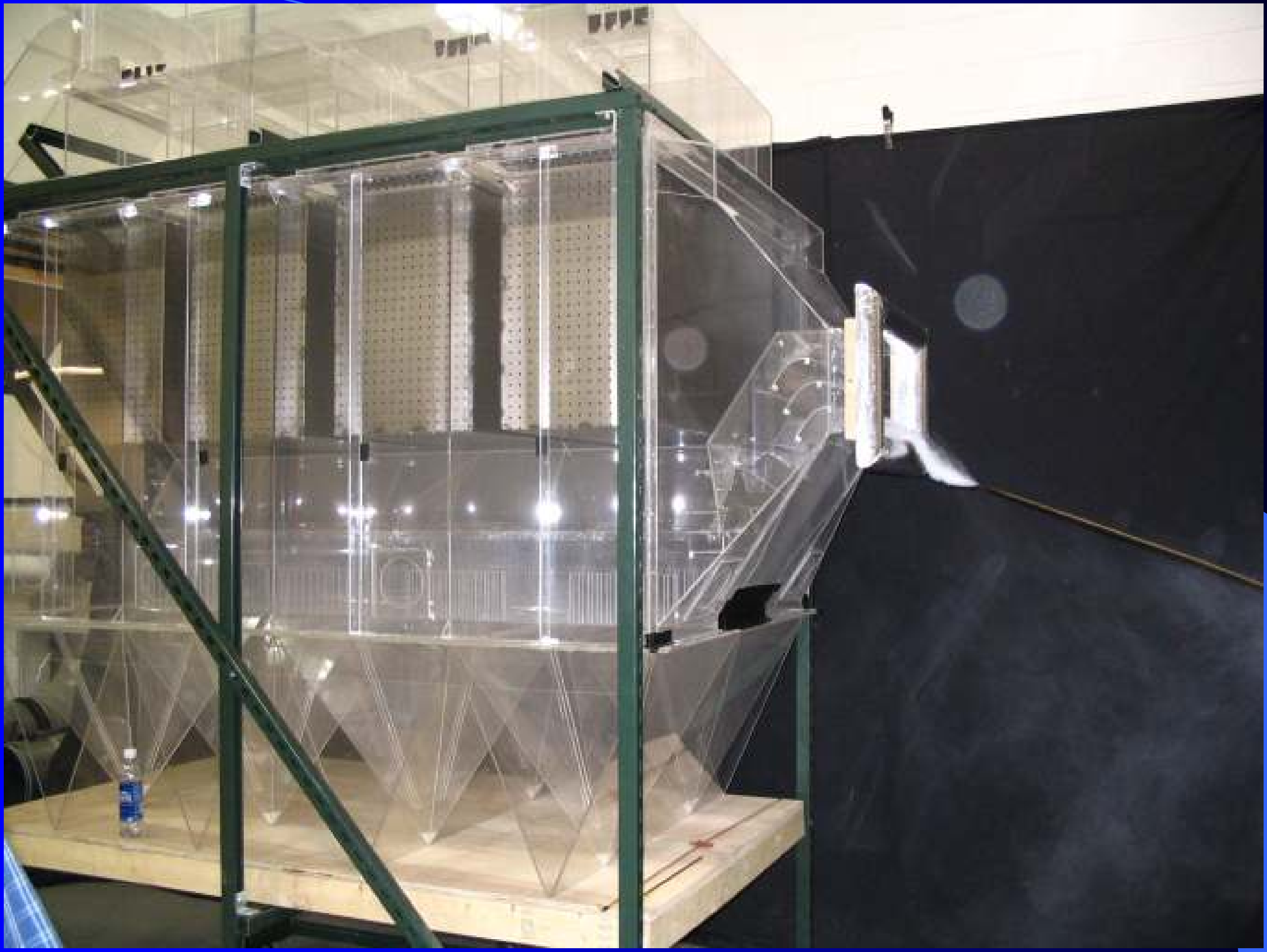
<u>Goals</u>

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

<u>Results</u>

- 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

Physical Model Side Elevation View



Physical Model, One Chamber of 4

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

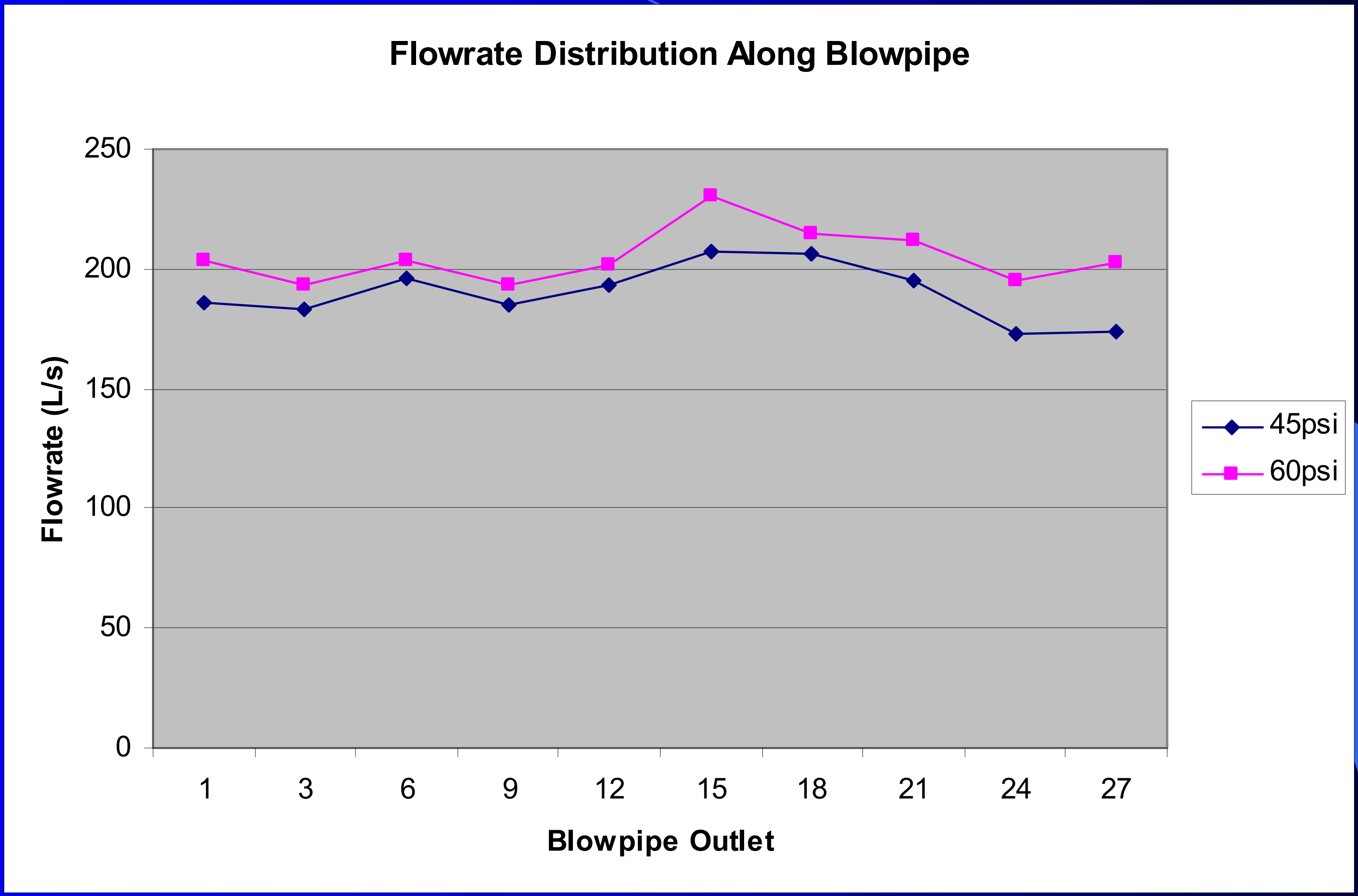
Big Stone
Blowpipe Design & Optimization For Pulse Cleaning

- 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 blow-pipe pulse air straightening nozzle diameter, length and height above the tubesheet.

- The air consumption required per blowpipe was determined.



Big Stone Pulse Blowpipe Design Tests

Big Stone Blowpipes

Compartment Tubesheet Shelf Installation

Big Stone Tubesheets

Pre-Assembly of Inlet Plenum Sections

Inlet Nozzle Transition Being Lowered into Place

Pulse Valve Header Assemblies

ESP Side Cut-outs for AHPC Demolition

Pulse Headers – 4” Valves

One Compartment's Tubesheet

Allen Bradley Logix 500 Control Cabinet

Performance Results

- 0% Opacity
- Pressure Drop Guarantee Met
- Outlet Emission Tests Not Done Due to Opacity Results