Reinhold Environmental Ltd.

2007 APC Round Table & Expo Presentation

July 8-10, 2007
Chattanooga, TN
Hosted by TVA

Retrofitting FFs into ESPs

By
Tom Lugar

Buell Division Fisher-Klosterman, Inc

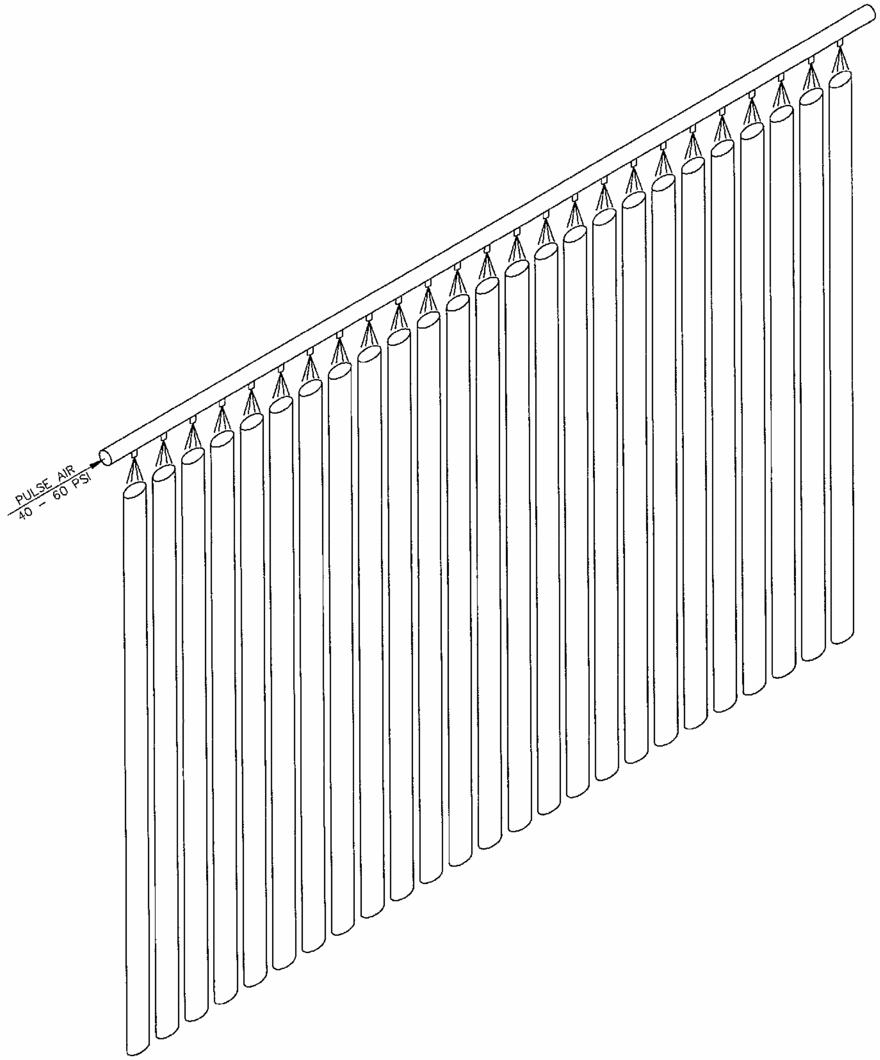
- Retrofitting a Fabric Filter into an ESP is not a new approach.
- Many conversions have been completed in Europe, Australia, South Africa in the past 25 years.
- Several have been installed or are in the process of being installed in the U.S. over the past 10 years.

ESP Conversions Completed to Date

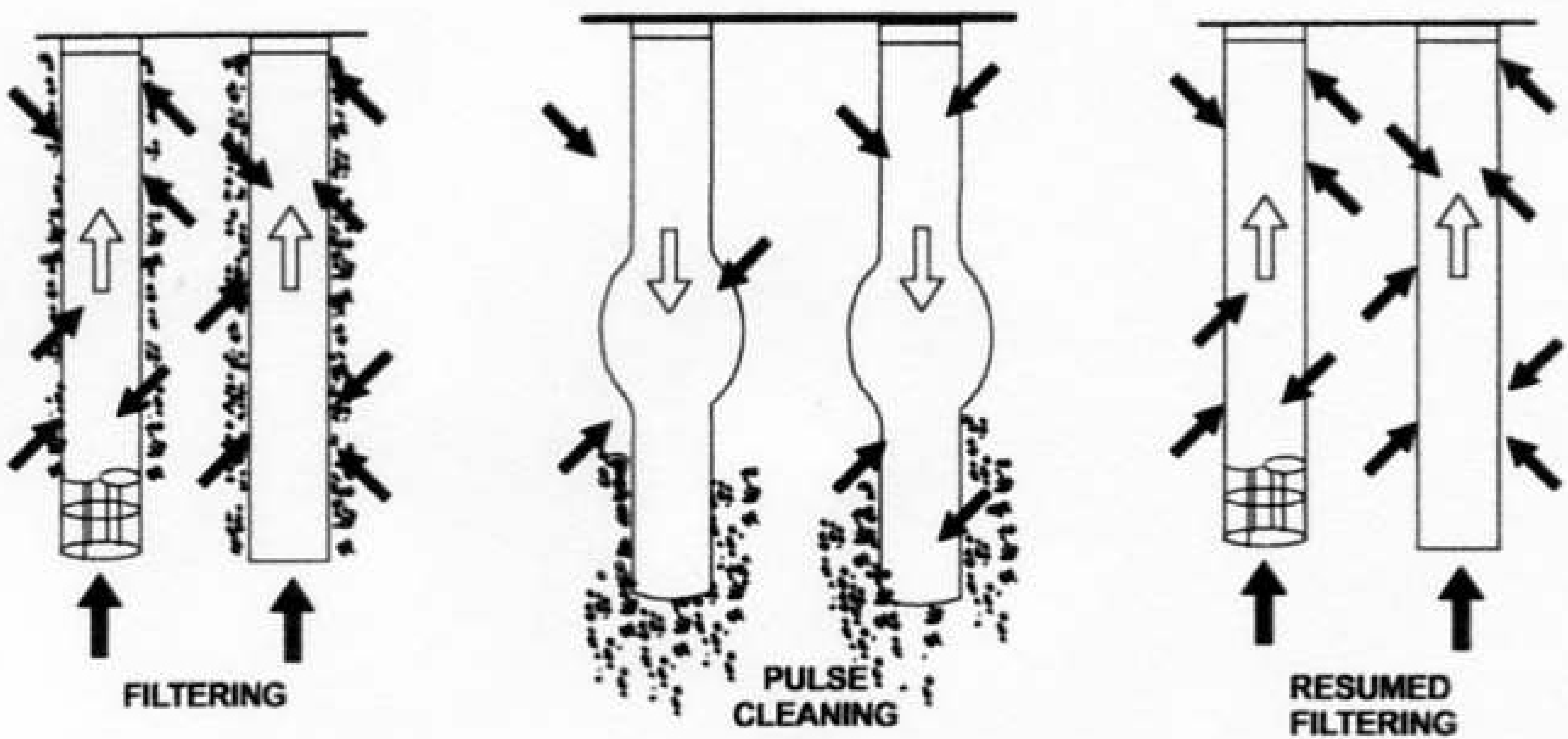
- **Intermediate Pressure Pulse, Long Bag Marketed by Alstom, B&W, Buell Fisher-Klosterman, Wheelabrator**

- **Low Pressure Pulse, Long Bag Marketed by Hamon RC as a Licensee of Howden Technology**

The Design Limits of Pulse Jet Technology are being stretched with up to 30 Bags on a Blowpipe and 10 meter (33’) long bags



Pulse Jet Bag Cleaning



When Does a Conversion of an ESP to a Fabric Filter Become an Option to Consider?

Considering the Option of ESP Conversion Present and Future Issues:

- 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

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

As a Result of Widespread Dissatisfaction With EPA Clean Air Mercury Emissions Rule (CAMR), Many States are Considering or Have Already Passed Mercury Rules More Stringent than CAMR

State Mercury Emission Rules as of August 2006

State	Mercury Reduction	Status
DE	80% by 09, 90% by 2013	Proposed
FL	70% by 2012-2017	Proposed
GA	85% by 2010, 90% 2015	Proposed
IL	90% by2009	Proposed
MD	80% by 2010, 90% 2013	Final
MA	85% by 2008, 95% 2012	Final
MI	90% by 2015	Proposed
MN	90% by 2014	Final
MT	90% by 2010	Proposed
NH	80% by 2013	Final
NJ	90% by 2007	Final
NY	90% by 2015	Proposed
NC	37% by 2010, 90% new	Proposed
OH	90% by 2009	Proposed
OR	90% by 2012	Proposed
PA	90% by 2015	Proposed
VA	64% by 2015	Final
WA	90% by 2010	Proposed
WI	75% by 2015	Proposed

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

If standards are enacted for P2.5 from stationary sources, solid particulate as ≤ PM2.5 would likely be limited to .01 or .015 lb/MMBTU.

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

Options for ESPs with <250 SCA

- Convert casing to or replace with PJFF
- Add a PJFF downstream
- 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

Air-To-Cloth Ratio

Air-To-Cloth Ratio = Gas Volume/Cloth Area

$$\text{Gross A/C} = \frac{\text{Total Inlet Gas Volume}}{\text{Total Cloth Area}}$$

$$\text{Net A/C} = \frac{\text{Total Inlet Gas Volume}}{\text{On-line Cloth Area}}$$

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

Three ESP to FF Examples

1. Addition of an SO_2 Scrubber
2. Reduce Outlet Emissions and Opacity
3. Overcome High Resistivity/Back Corona Problems, Prepare for Mercury Emissions Reduction

Example 1: Adding a Scrubber for SO_2 Reduction
Southeastern Public Service Authority(SPSA)
Portsmouth Virginia

Application

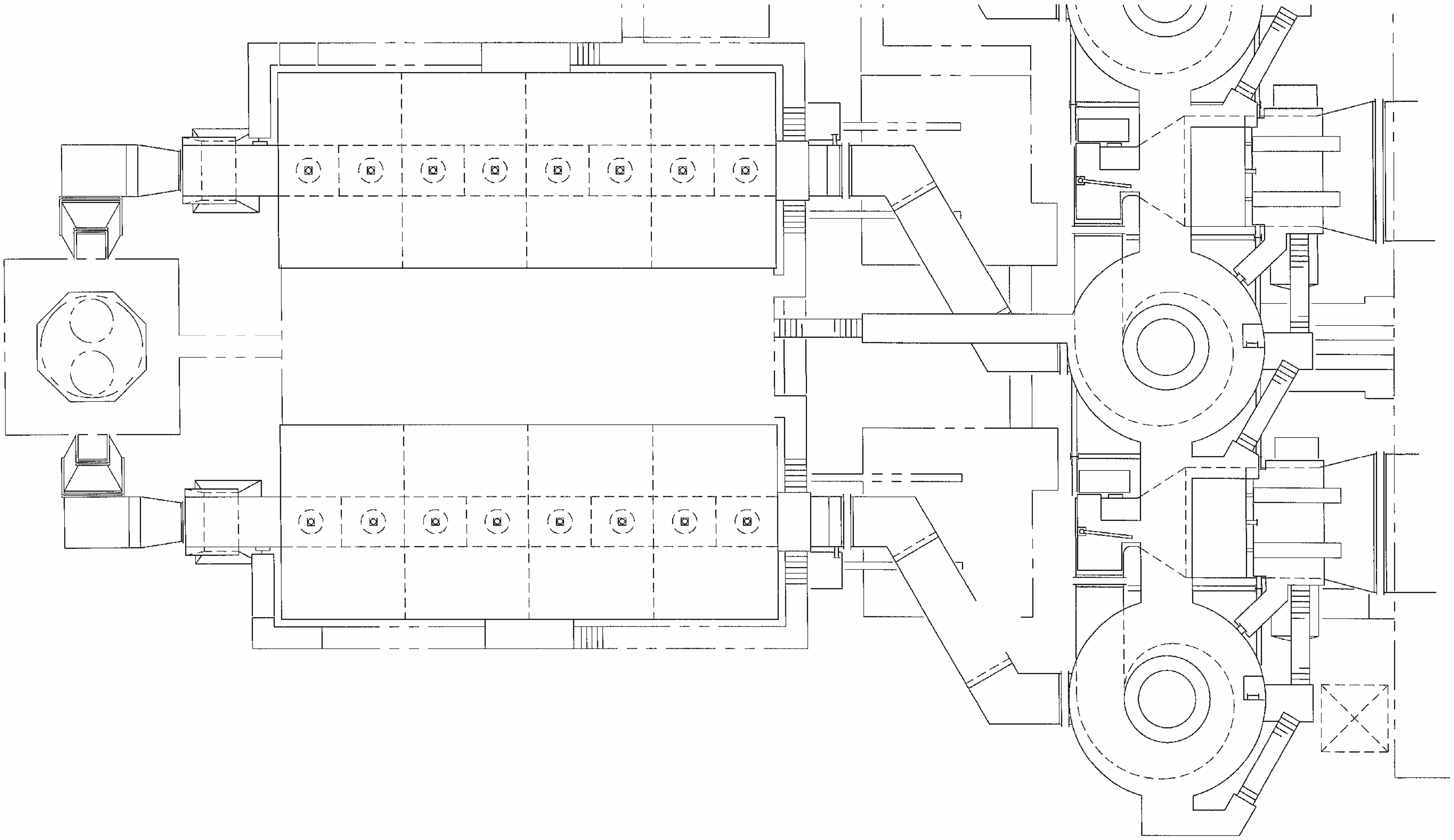
4 Identical Coal/RDF Fired Boilers
Gas Flow – 150,000 ACFM/Boiler
Add DFGD System Upstream of Existing ESP
Convert each ESP to a Pulse Jet Fabric Filter

Pulse Jet Design

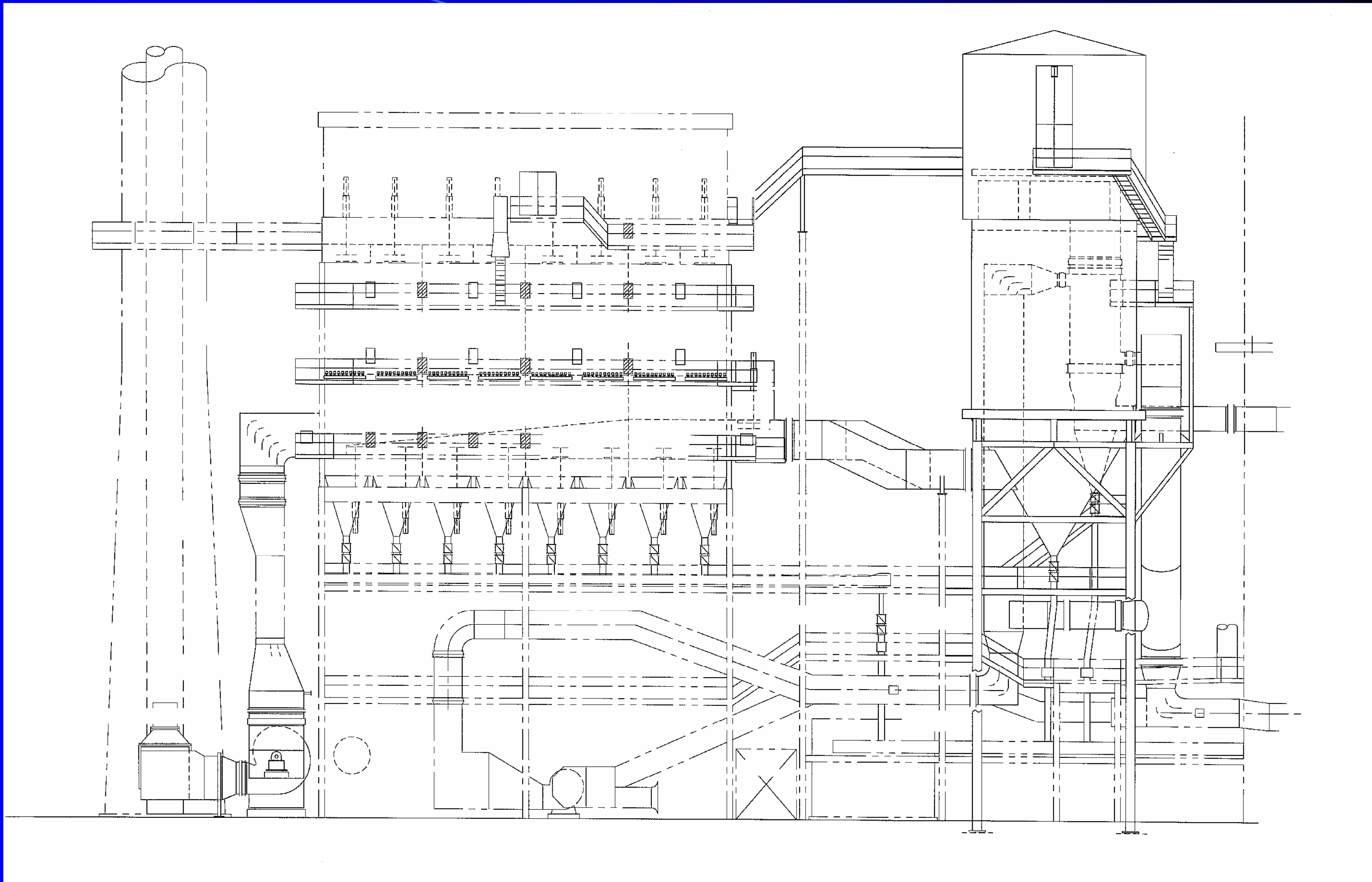
8 Compartments, Walk-in Plenum Design
Off-Line Cleaning, High Pressure Pulse
A/C Gross: 3.5, Net 1: 4.0
Bags: 16’, 16 oz. P84

Startup: 1996-1997

Southeastern Public Service Authority, VA, ESP to FF Conversion



SPSA ESP to FF Conversion, Plan View



SPSA ESP to FF Conversion, Elevation

Example 2: Performance Problems With Fuel Switching
Mid-West Utility

Application

PC Fired Boiler

Gas Volume – 250,000 ACFM

Gas Temp. – 350 F

Pulse Jet Design

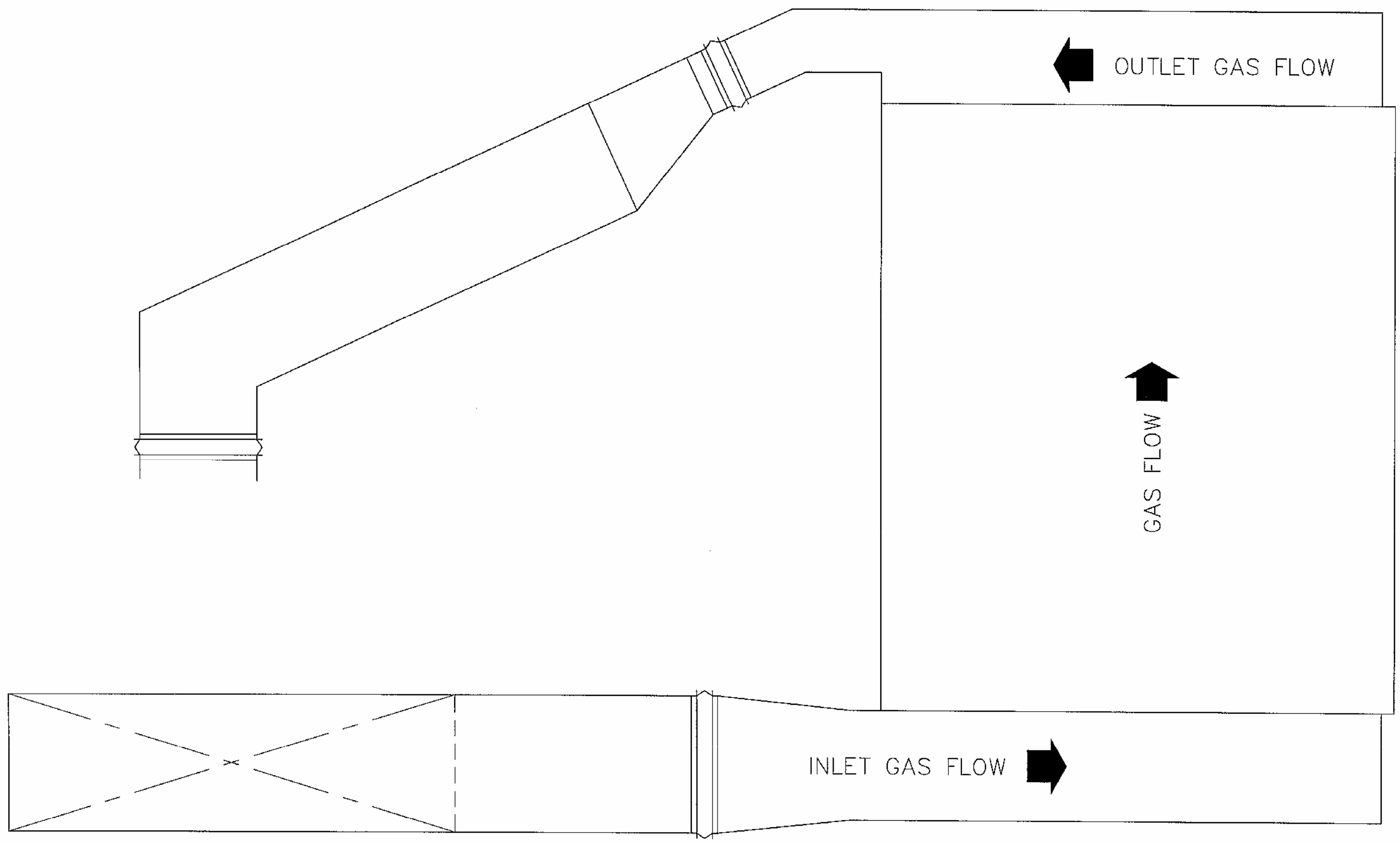
6 Tubesheets, Walk-in Plenum Design

On-Line Cleaning, Intermediate Pressure Pulse

A/C = 4.0

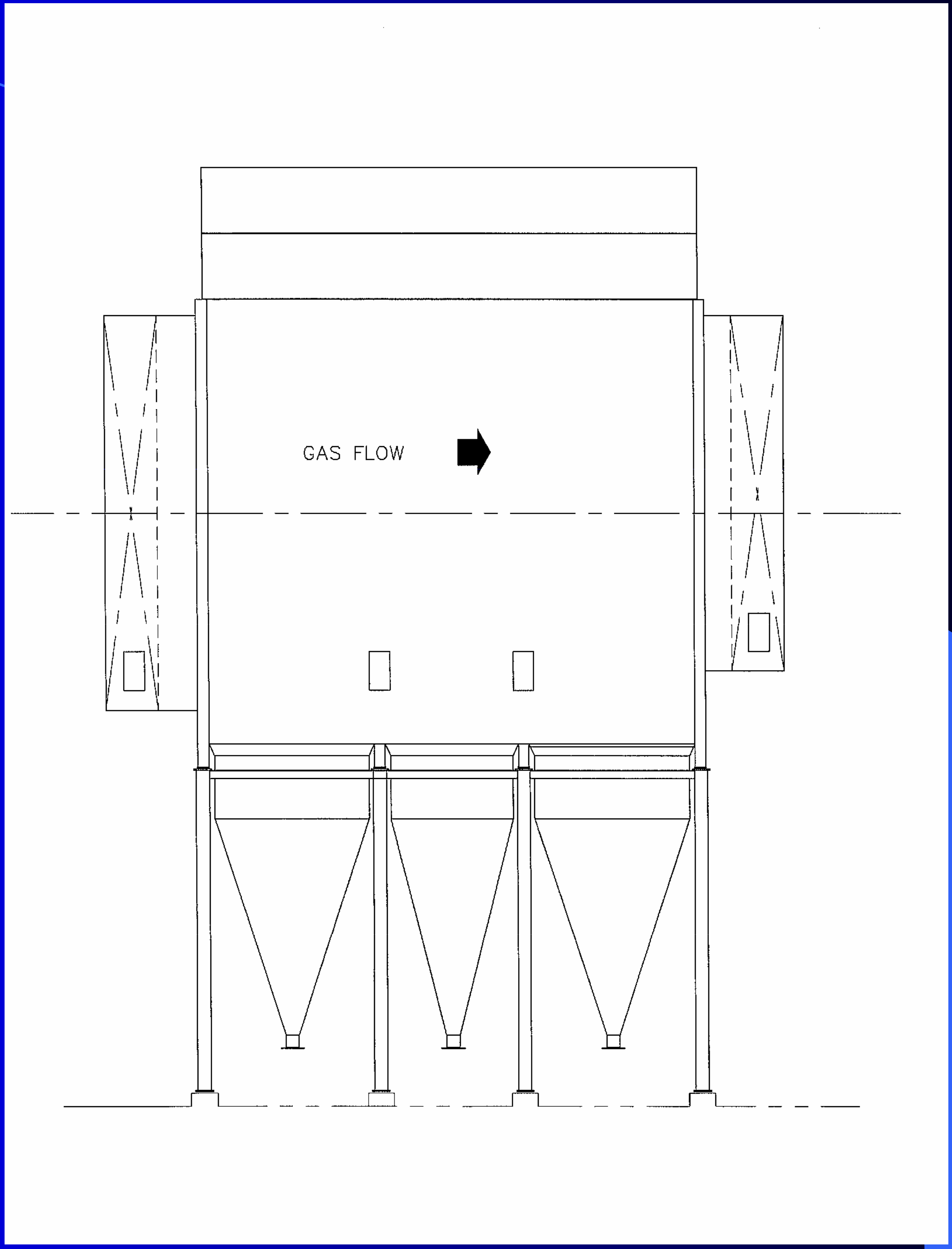
Bags: 23’ Long, 16 oz. P84

Cages: Epoxy Coated, Split Cage

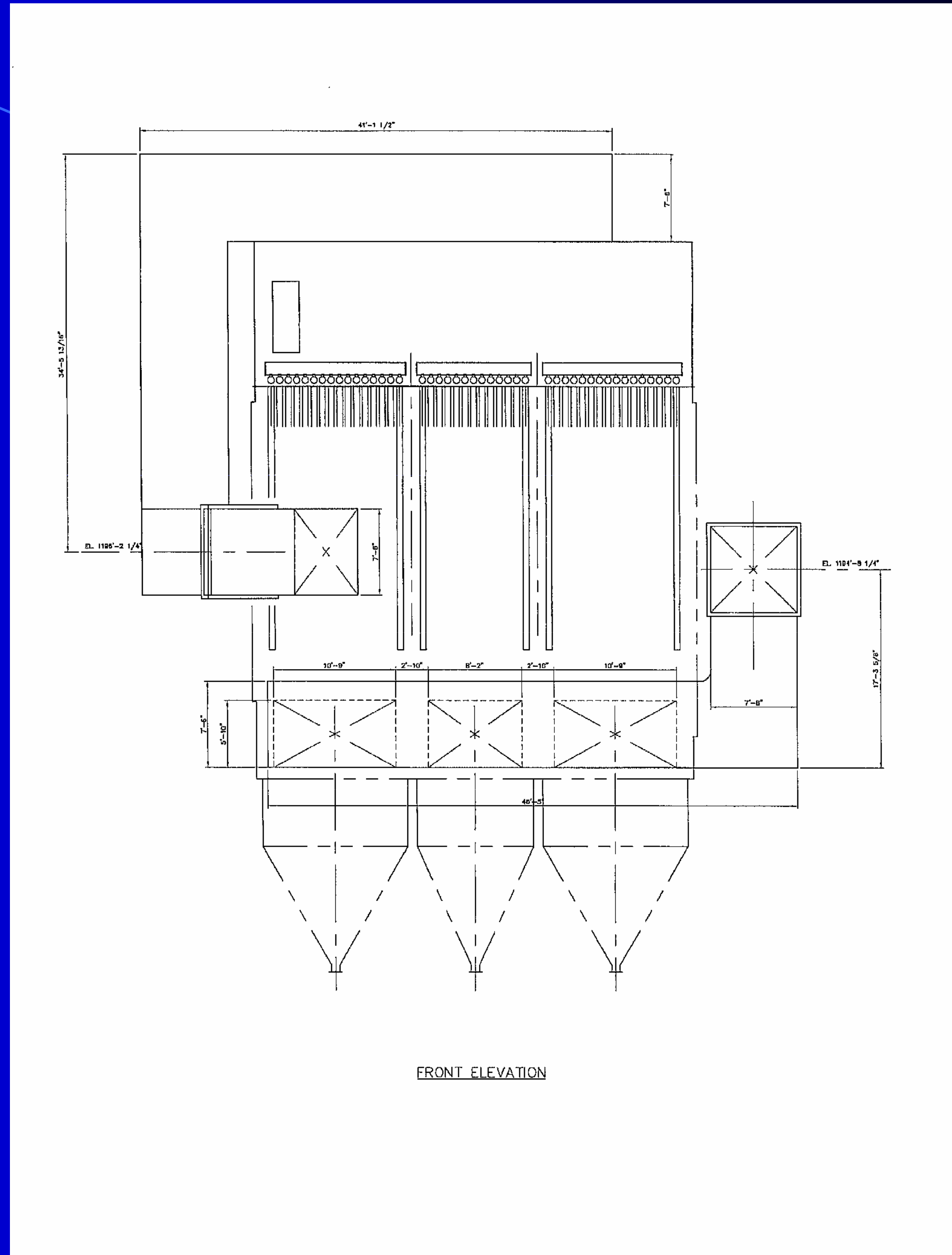


Mid-West Utility ESP, Plan View

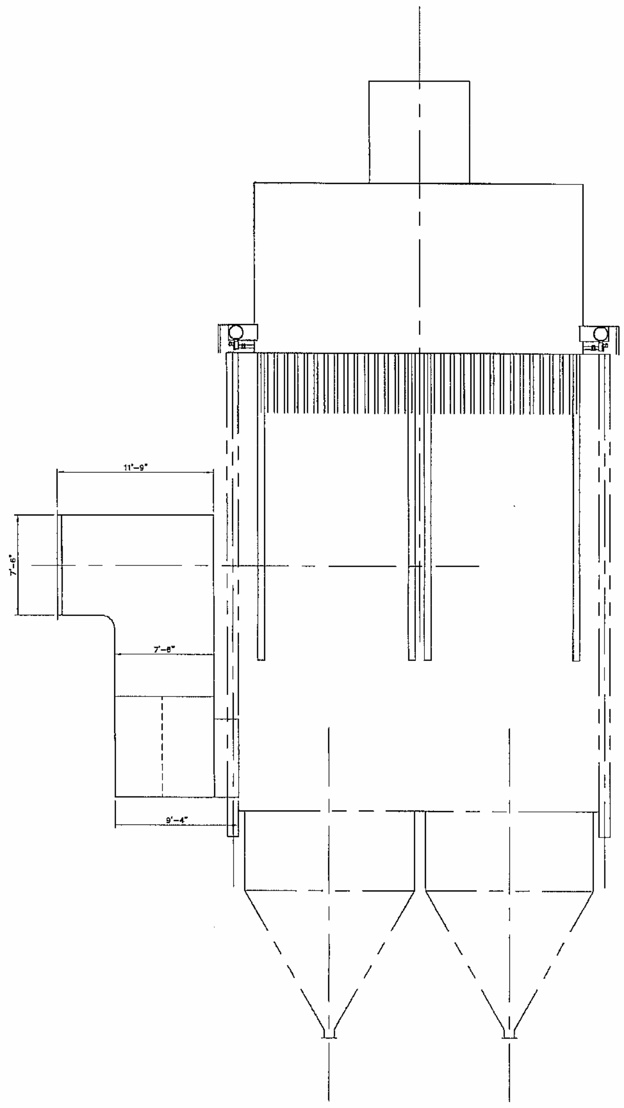
Mid-West Power Plant ESP, Side Elevation



Mid-West Utility
ESP to FF
Conversion
Side Elevation View



Mid-West Utility ESP to FF Conversion Front Elevation



RIGHT SIDE ELEVATION

Example 3: ESP Performance Problems and Mercury Control
Detailed Conversion Case Study
Otter Tail Power Company, Big Stone Unit #1
Big Stone City, South Dakota

Big Stone Unit #1

Application: 480 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

- Slipstream Pilot Testing Completed in 1999
- ESP Converted to AHPC in 2002


Advanced
Hybrid
Particulate
Collector
Demonstration Project
A Joint Effort of:
• Energy & Environmental Research Center at the University of North Dakota
• W.L. Gore & Associates, Inc.
• U.S. Department of Energy National Energy Technology Laboratory
• Big Stone Plant
Operated by:
– Otter Tail Power Company
Co-owned by:
– Otter Tail Power Company
– NorthWestern Public Service
– Montana–Dakota Utilities Co.
GORE
OTTER TAIL
Power Company
NorthWestern

AHPC Concept

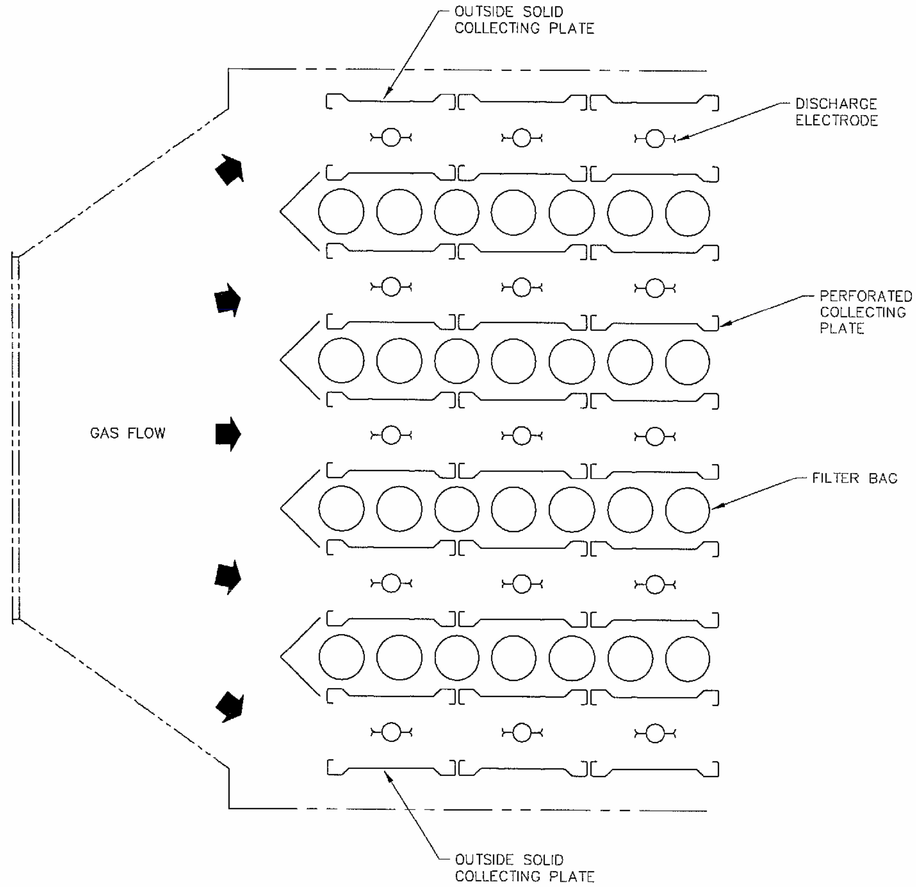
Combine ESP and High Ratio (A/C = 12.0) Pulse Jet Technologies in the same casing.

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
- Charge on Particulate Entering the Filtration Zone would Reduce Bag Filter Cake Pressure Drop due to more Porous Dust Cake.
- During Bag On-Line Cleaning, Most of the Re-entrained Ash from the Bags is Forced Back Through the Perforated Plates into the ESP Zone for Charging and Collection

AHPC Concept
Plan View



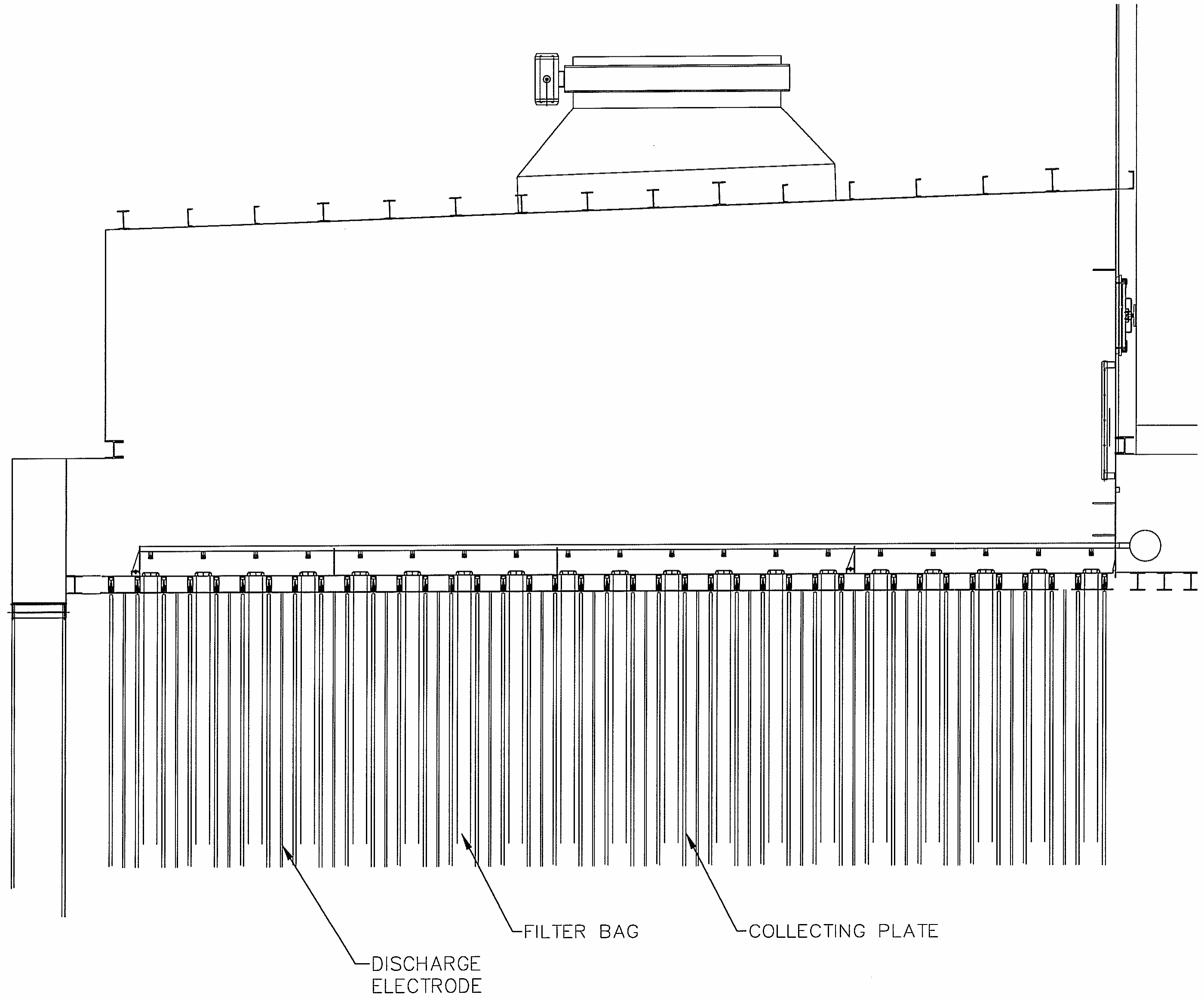
AHPC
Slipstream Pilot
9,000 ACFM

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

- Internal Electrodes and Support Systems Removed
- ESP Hot Roof Replaces with Tubesheets, Walk-in Plenum and Vaned Damper
- Design A/C: 12.0 (2002)
- Final A/C   :   9.0 (2004)
- On-Line Cleaning, Intermediate Pressure Pulse
- Gore Membrane Filter Bags, 6” diameter, 23’ Long



AHPC One Compartment Front Elevation

AHPC Compartment Tubesheet

AHPC Full Scale Results

- High Bag Pressure Drop: 9 to 11" W.G.
- Continuous Cleaning With Pulse Pressure Raised to 100 to 110 psi
- Bag Failures Within 6 Months
- ESP Zone Collection Performance Limited Due to High Ash Resistivity
- Opacity limit Exceeded Due to Failed Bags
- Constant 50-60 MW De-Rate Due to Fan Limitation with High Bag Pressure Drops and Opacity

Big Stone Conclusions After Failure of AHPC

- Abandon the AHPC Technology
- Replace the Existing ESP/Hybrid with a New PJFF Alongside and Demolish Existing ESP after Tie-in of Ductwork to the New Baghouse

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

ESP

4 Chambers in Parallel
4 Electrical Fields in Series/Chamber
40’ High Plates

Big Stone Pulse Jet FF Design

A/C Gross: 3.4 A/C Net 1: 3.6

Interstitial/Can Velocity = 178 ft/min

Bags: 21 oz. Woven Fiberglass with PTFE Membrane
6” Diameter, 25’ Long

Cages: Split Cage, Carbon Steel, 24 Wire, 11 Gauge

Bags/Chamber = 4028 Total Bags = 16,112

27 Bags/Blowpipe, 2 Blowpipes Per Bag Row

<u>Guarantees</u>

Opacity - 10%

Outlet Loading - 0.01 lb/MMBTU

Bag Life - 3 Years

Maximum ΔP - 8” W.G.

Conversion to PJFF

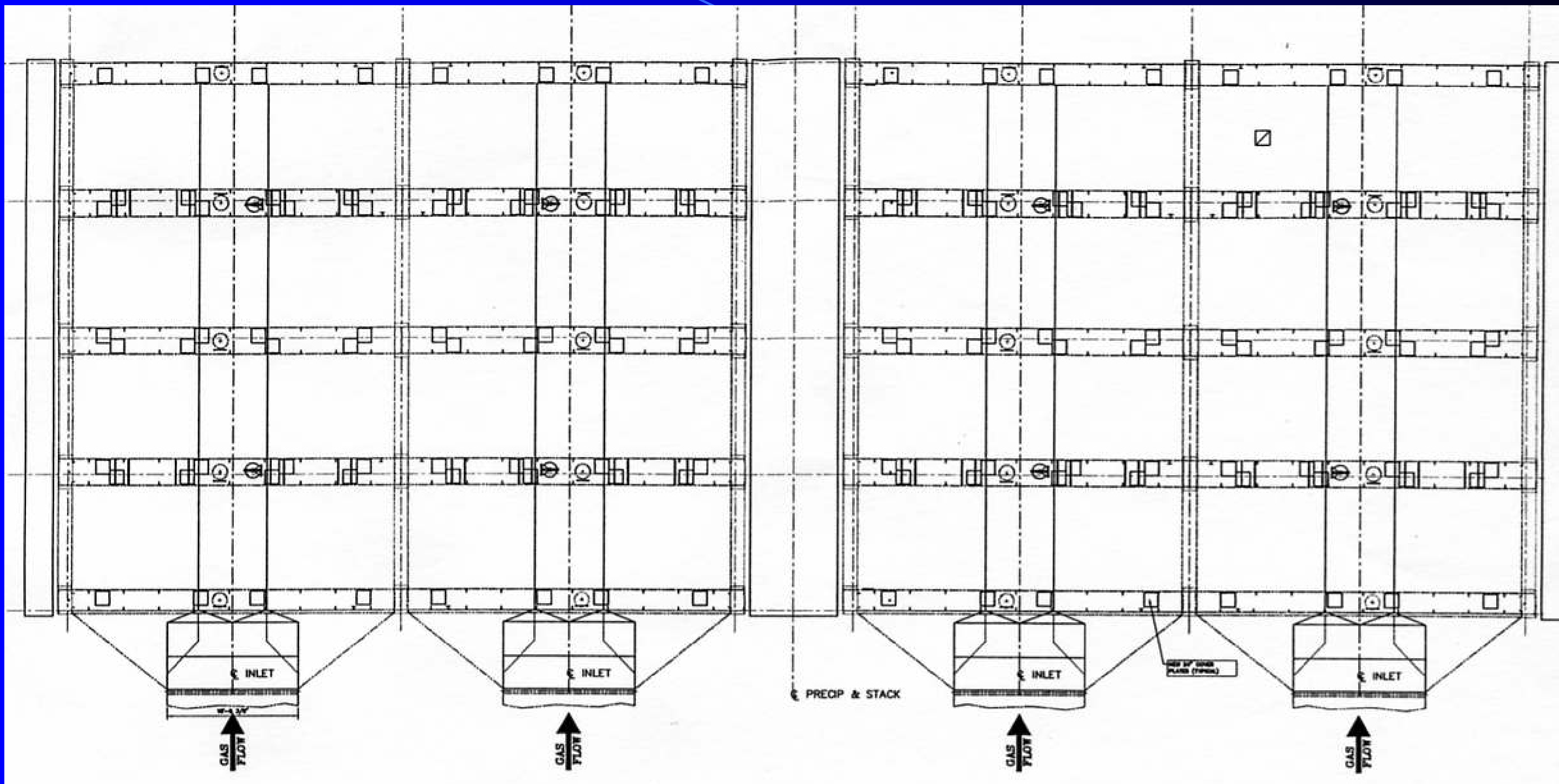
- AHPC Hardware Removed along with Tubesheets
- Retained Walk-in Outlet Plenum and Vaned Dampers for Use in Off-Line Cleaning
- Add New Tubesheets, Pulse Headers, Blowpipes and New Control System
- Add Partition Walls to Compartmentalize each Chamber, 4 Compartments/Chamber, 16 Total
- Add Inlet Transition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

Four Chamber View

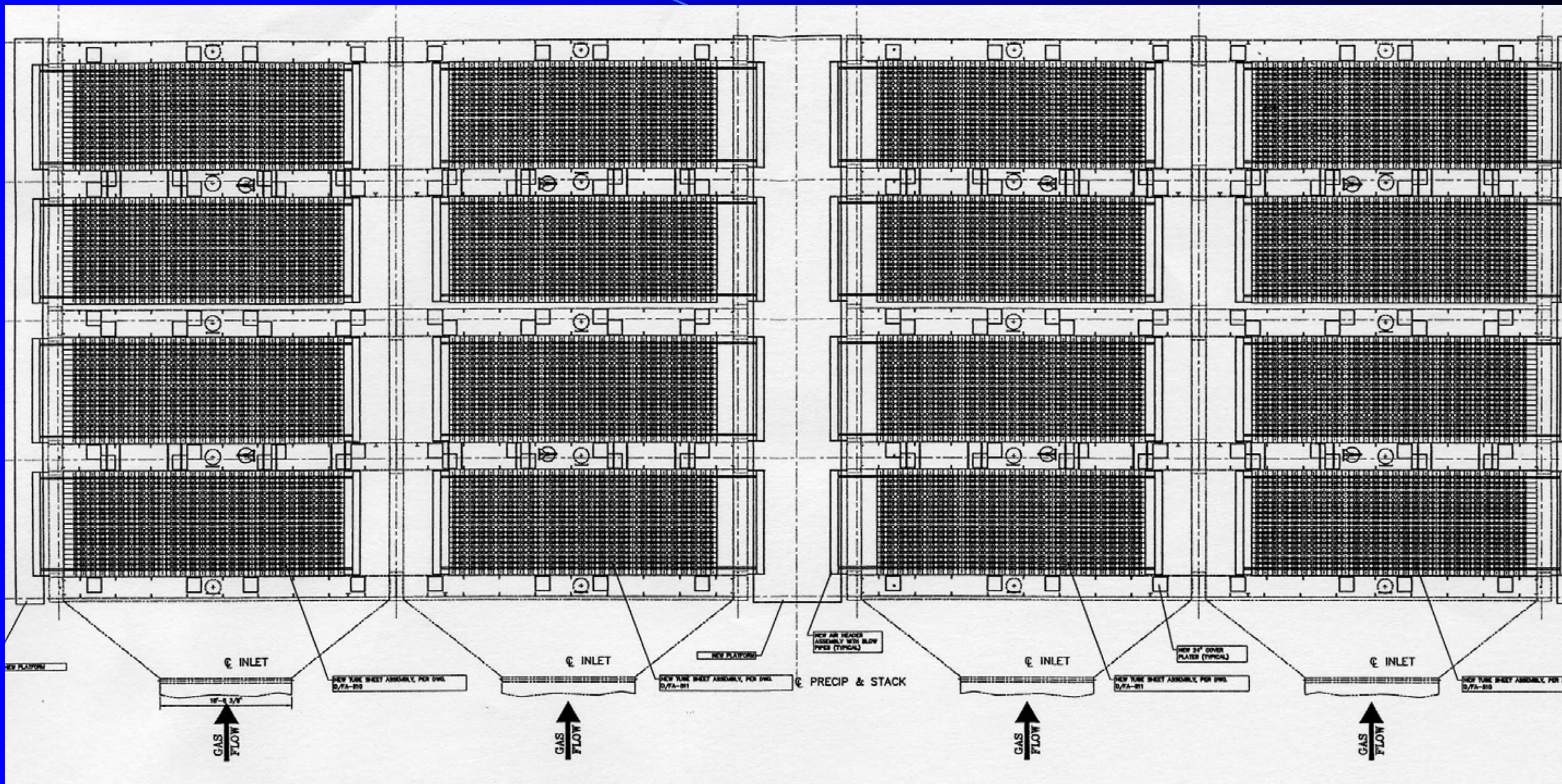
Big Stone Two North Chambers

Outlet Plenum Vaned Dampers

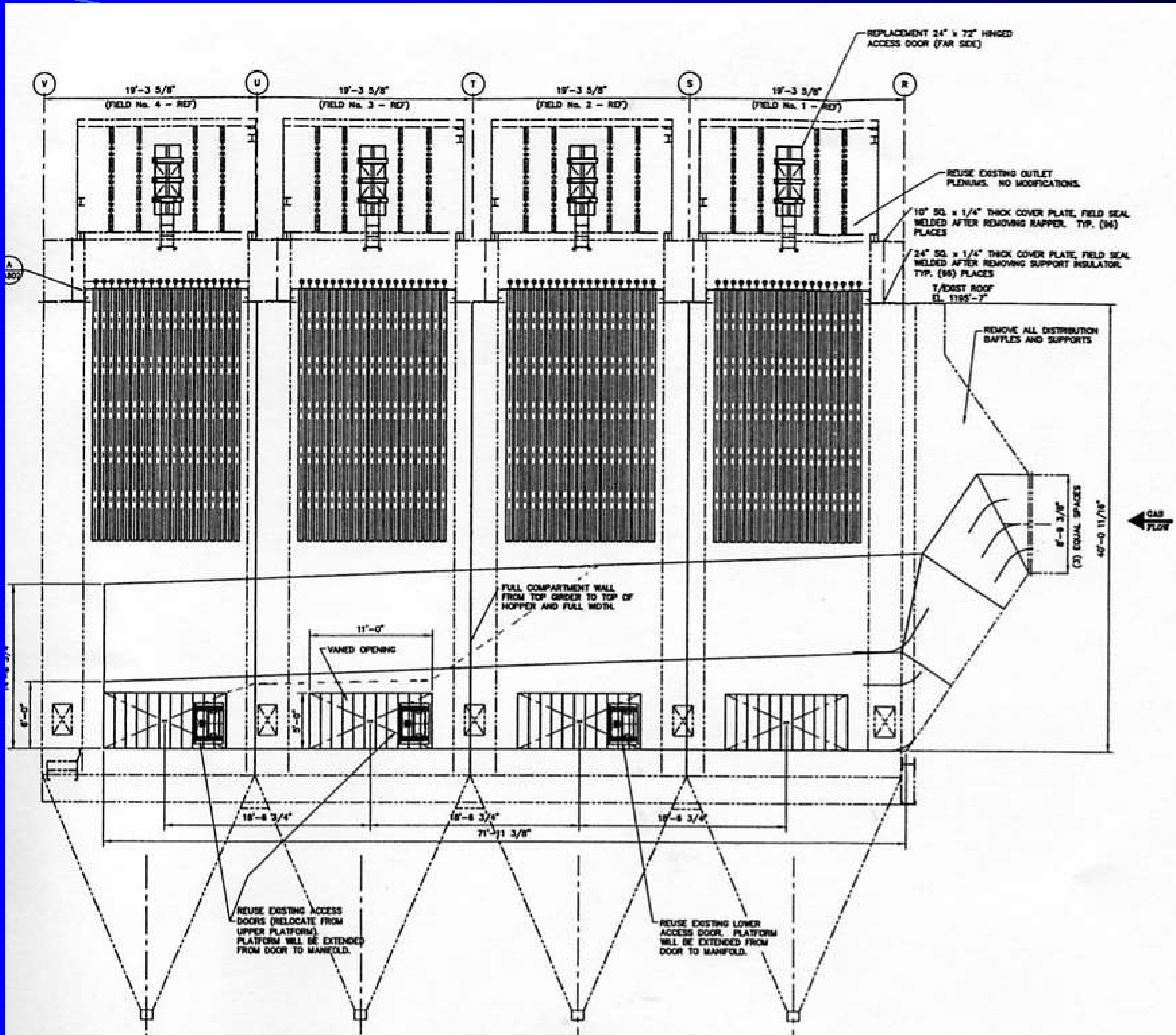
Big Stone ESP – Four Chambers



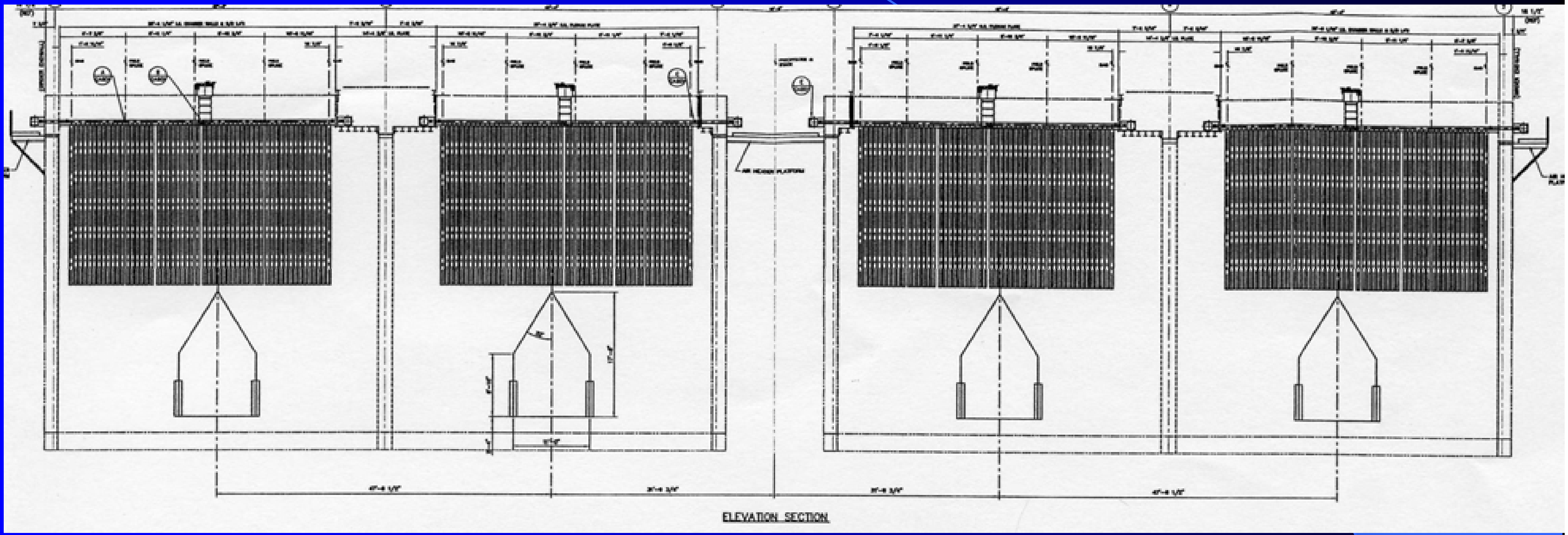
Big Stone, Inlet Manifold, Plan View



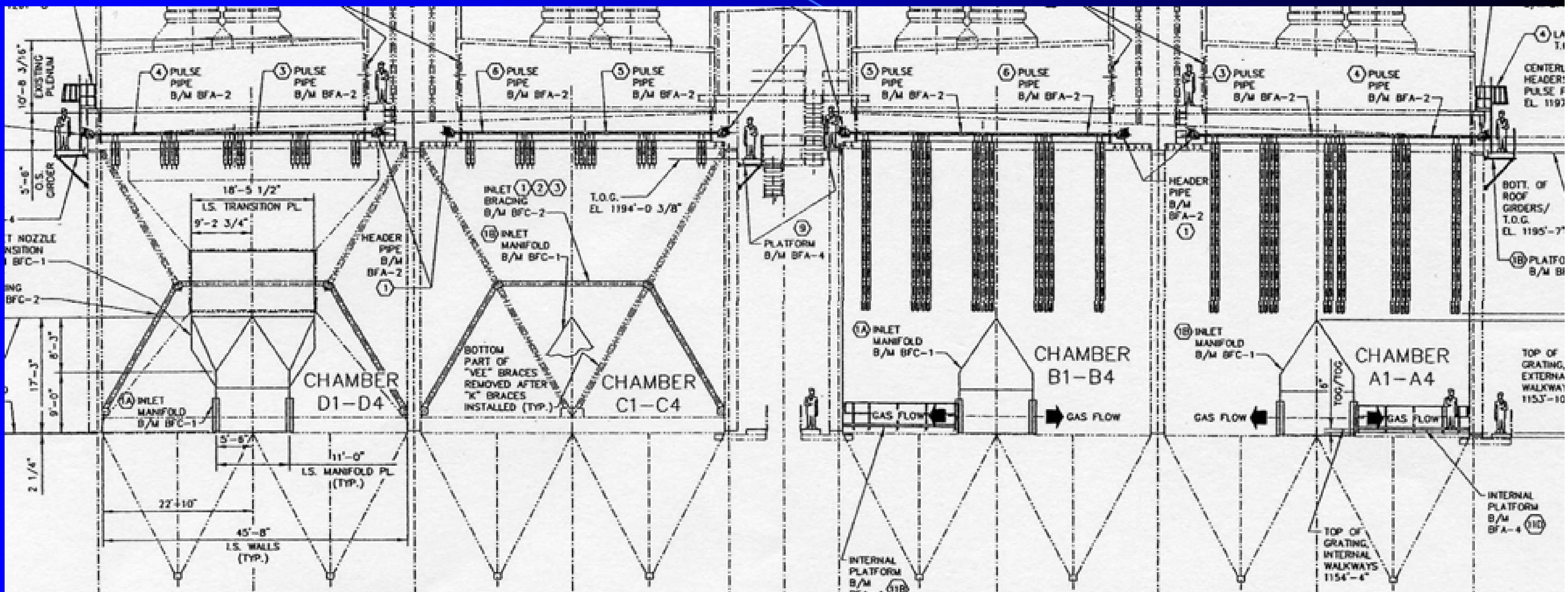
Big Stone Tubesheets, Plan View



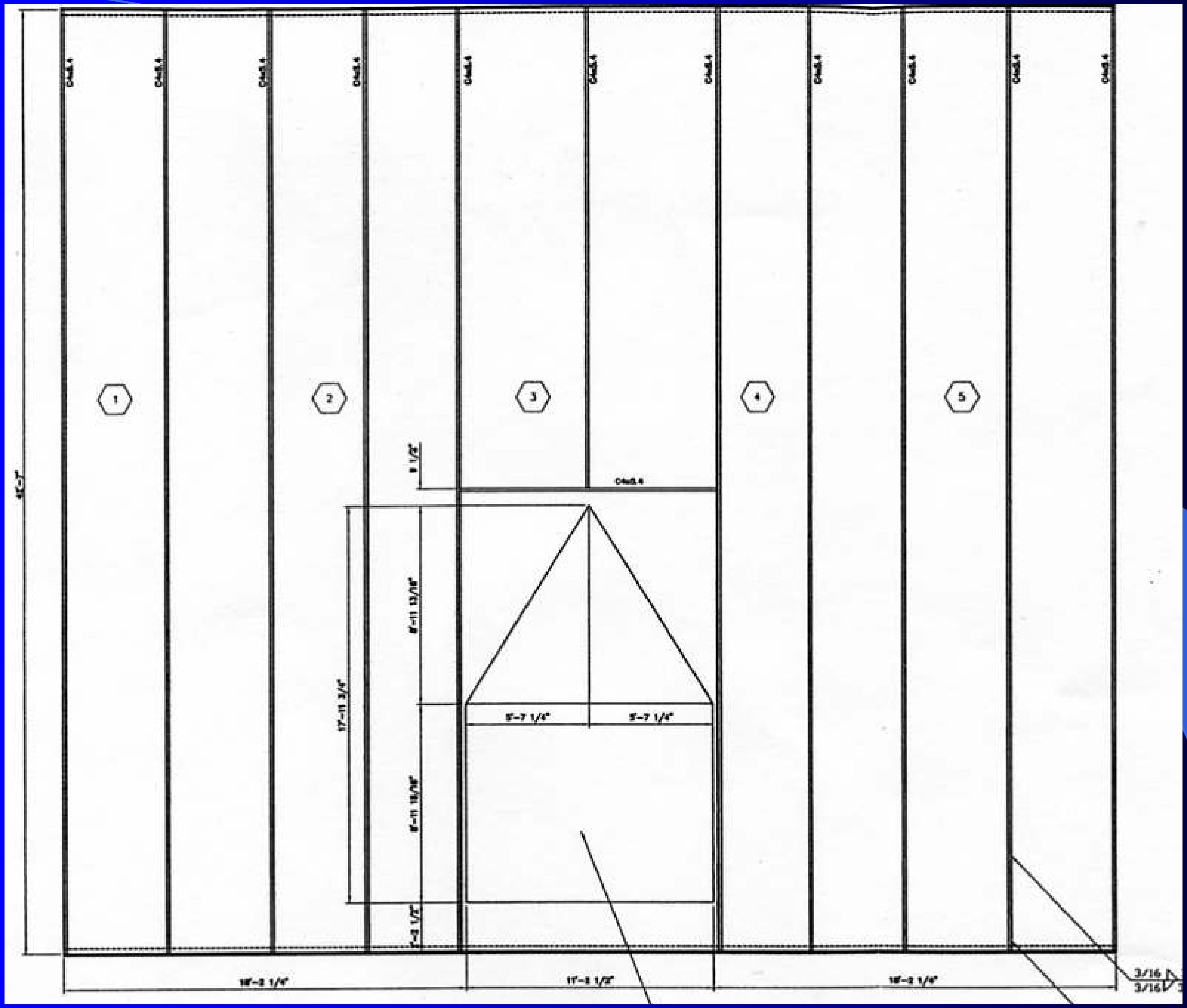
Big Stone Side Elevation



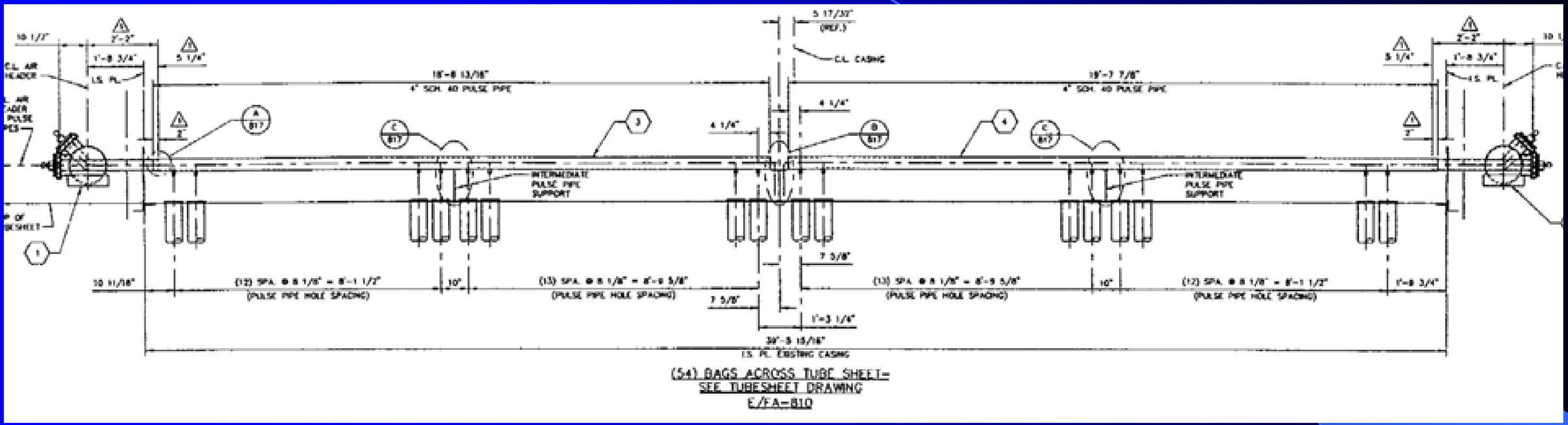
Big Stone Front Elevation Inlet



Big Stone Inlet Details

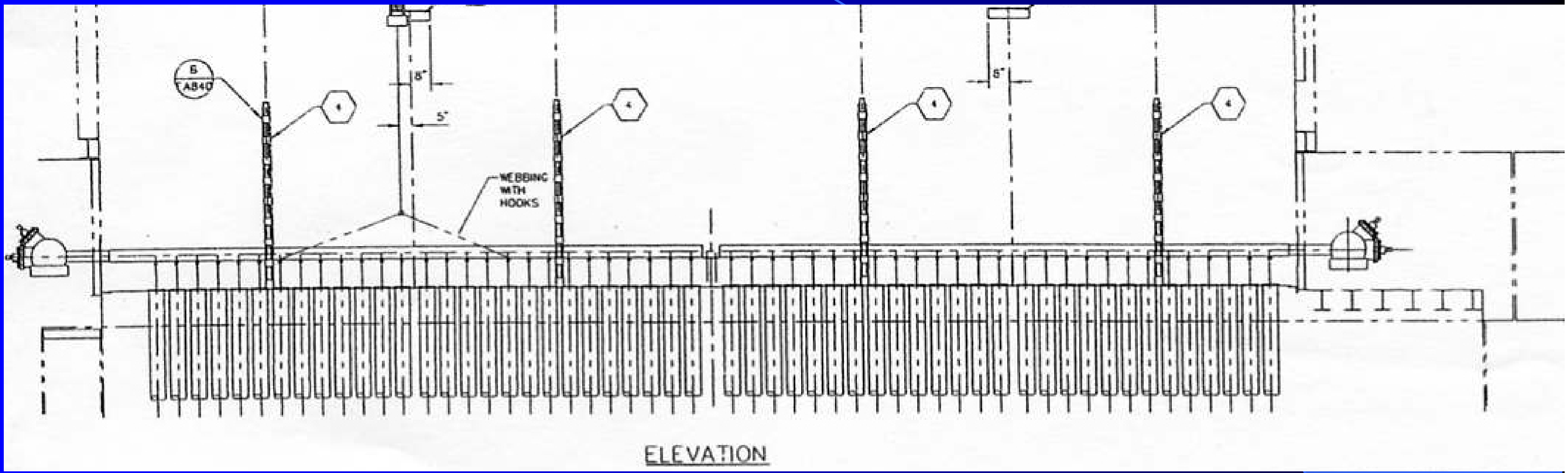


Big Stone, Partition Wall, Front Elevation

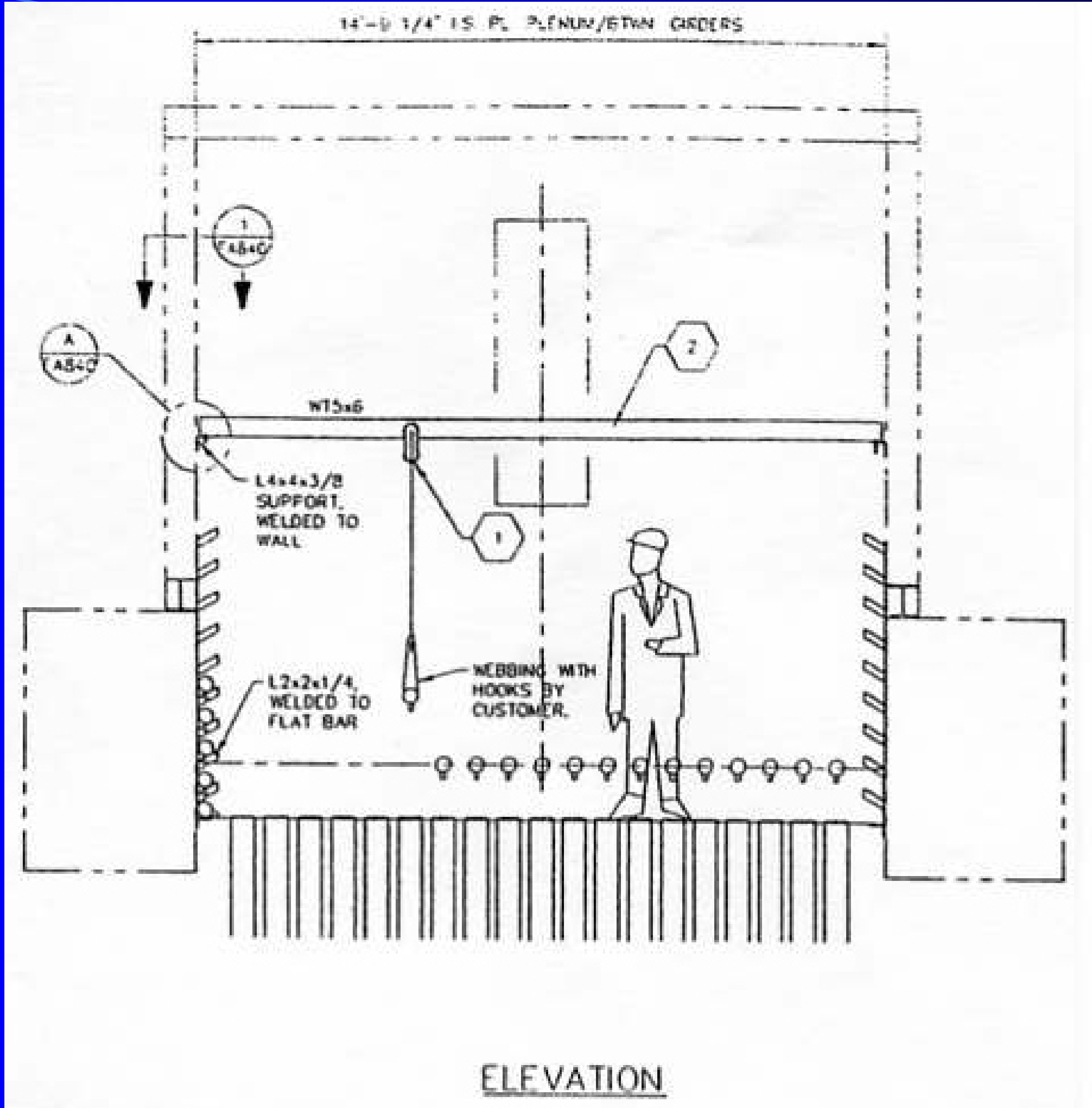


Big Stone Dual Blowpipe Arrangement, Inlet View

27 Bags per Blowpipe



Big Stone, Front Elevation, Outlet Walk-In Plenum



Big Stone Side Elevation, Outlet Plenum