REINHOLD ENVIRONMENTAL Ltd.

2010 APC Round Table
& Expo Presentation

July 18-20, 2010, in Concord, NC / Hosted by Duke Energy

SOUTHERN RESEARCH

Legendary Discoveries. Leading Innovation.

APC with COHPAC® and TOXECON® Fabric Filters

2010 Reinhold APC Roundtable and EXPO
July 19-20, 2010

Overview

- Introduction
- ESP and FF Performance Improvements
- COHPAC® Technology
- TOXECON® Technology
- Summary

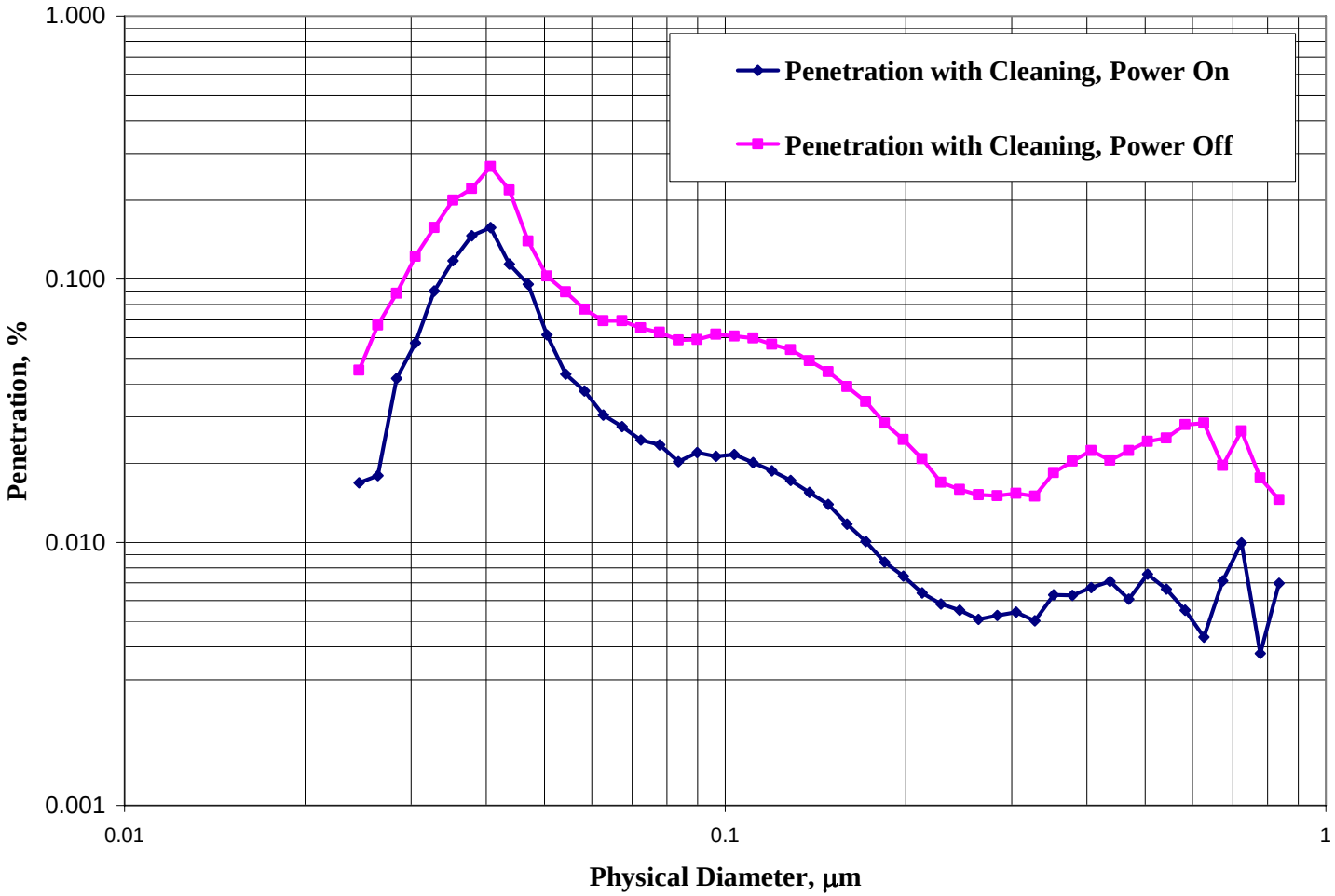
ESP and FF Performance Improvements

- Over the last 30 years there have been a number of developments to improve the particulate collection performance of ESPs and FFs, as well as reduce their O&M costs.
- Precipitators have seen the advent of pulsed power supplies, a variety of RDE styles, digital AVCs with sophisticated GUI displays and data logging capabilities.
- Low ratio baghouses have seen the common use of sonic horns for improved bag cleaning (low ratio) and the development of a number of new pulse-jet filter fabrics for improved collection and lower pressure drop.

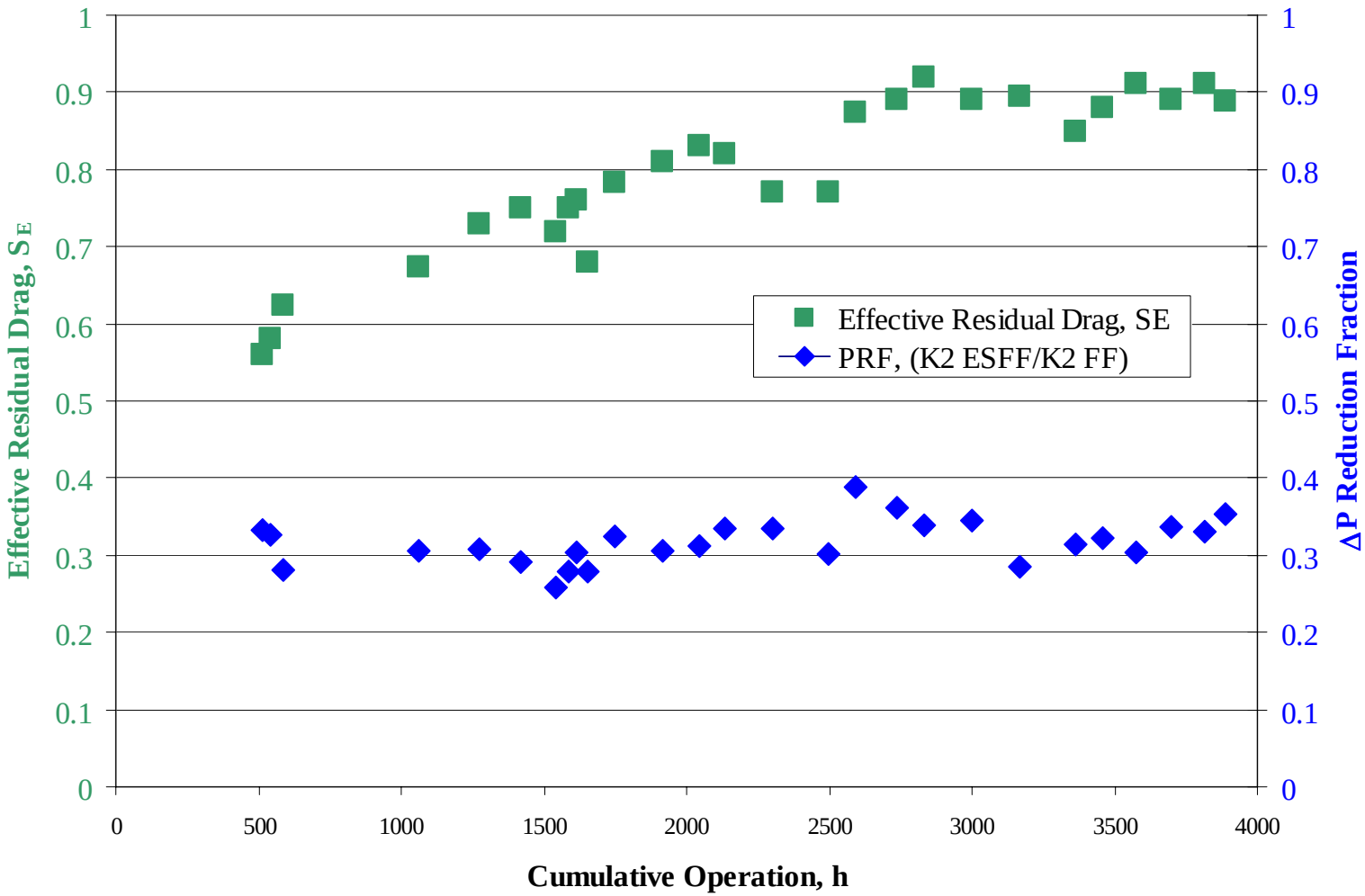
ESP and FF Performance Improvements

- Also, during this time a number of unique APC concepts have been developed or licensed by various organizations to attain a special market niche.
- Electrostatically Stimulated Fabric Filtration (ESFF) was developed by EPA, tested by Southern Research, and licensed by GE (BHA Group) as their MAX-9® design.
- Several pilot-scale tests of the ESFF technology have taken place.
- Pilot-scale testing demonstrated improvement in fine particle collection and a significant decrease in the rate of pressure drop increase during filtration cycles as shown in the next two slides.
- MAX-9® has not yet been installed at full-scale.

Electrostatically Stimulated Fabric Filtration



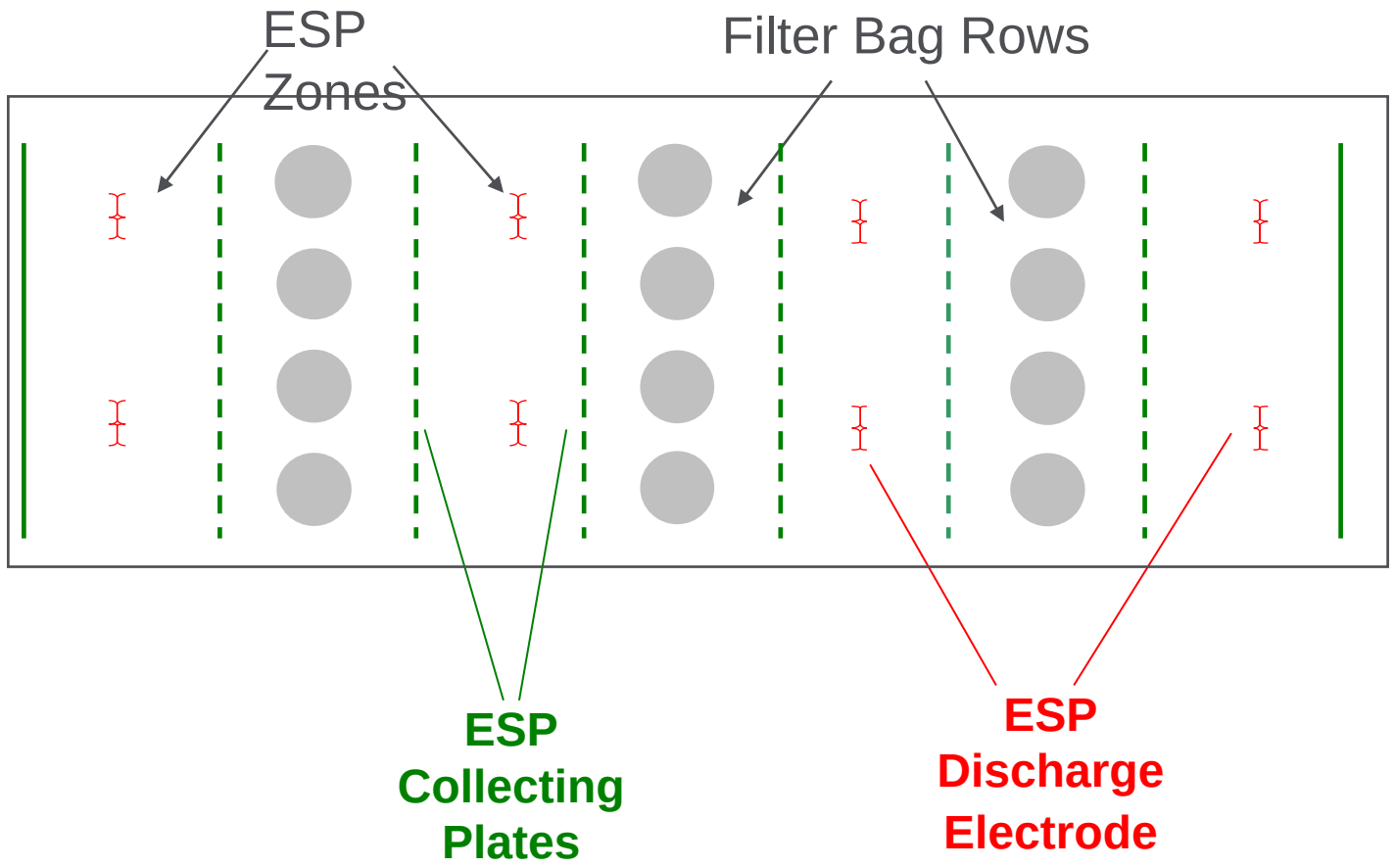
Electrostatically Stimulated Fabric Filtration



Advanced Hybrid Particulate Collector

- The Advanced Hybrid technology was developed by the Energy and Environmental Research Center at the University of North Dakota in partnership with W. L. Gore & Associates, Inc. and DOE's NETL.
- The design used alternating lanes of pulse-jet filters and ESP plates and RDEs in the second, third, etc. fields in an existing ESP. This is shown in the next two slides.
- Baffles kept flue gas exiting the first ESP field from directly impinging on the pulse-jet filter bags.
- A full-scale demonstration of this technology took place at Otter Tail's Big Stone plant in 2002 – 2004.

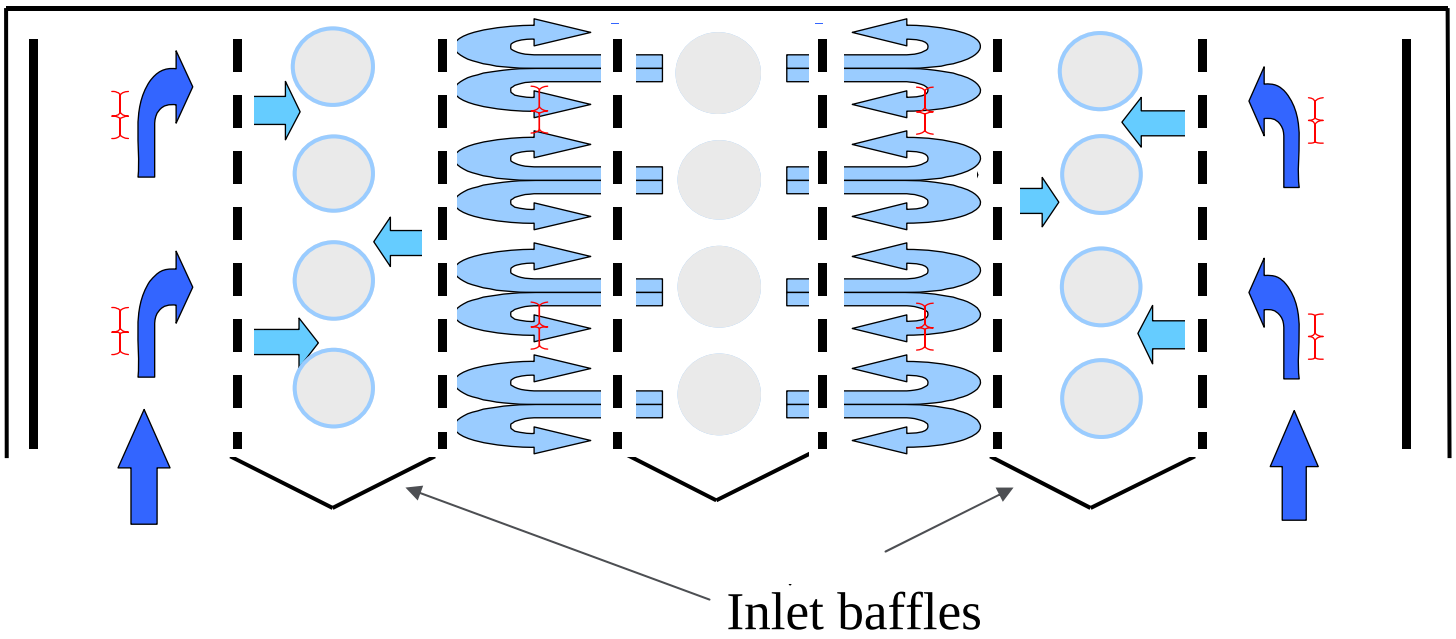
Advanced Hybrid Particulate Collector



Top View of Tubesheet

Advanced Hybrid Particulate Collector

Advanced Hybrid Operation



Fine Particle Agglomerator

- Development work by Environmental Elements Corporation (now Clyde Bergemann EEC) began in 1994 with a DOE SBIR project.
- The concept was to utilize laminar flow in a middle field of an electrostatic precipitator (ESP) to promote contact of fine sub-micron particles with larger particles such that the fine particles form agglomerates with the larger particles.
- These agglomerates would then be easily removed in the remaining portion of the ESP.
- The FPA consists of closely spaced parallel collecting and high voltage plates operating below corona onset.

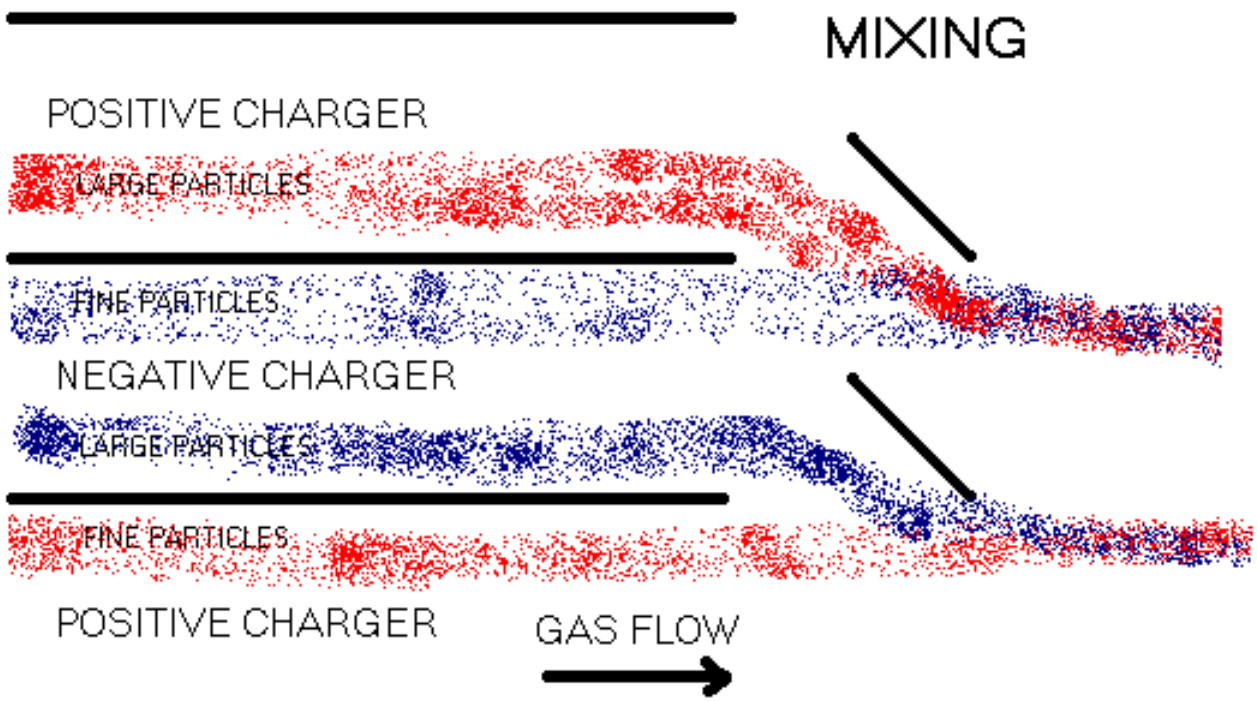
Fine Particle Agglomerator

- A successful demonstration of the FPA technology occurred in 1998 at WE Energies Presque Isle Station.
- The second of three ESP fields for one of the 90 MW units was replaced with the FPA (9' long by 30' high).
- This unit normally used an SO_3 injection system for ESP performance enhancement. To determine a baseline condition, the SO_3 system was turned off. In that situation the nominal opacity was 15%.
- With the FPA, at full load, and no SO_3 injection, the opacity ranged from 5.5 to 7.6%. At half load, 0.6%.
- The migration velocity improvement factor ranged from 1.5 to 2.0, equivalent to increasing the SCA by 50%+.

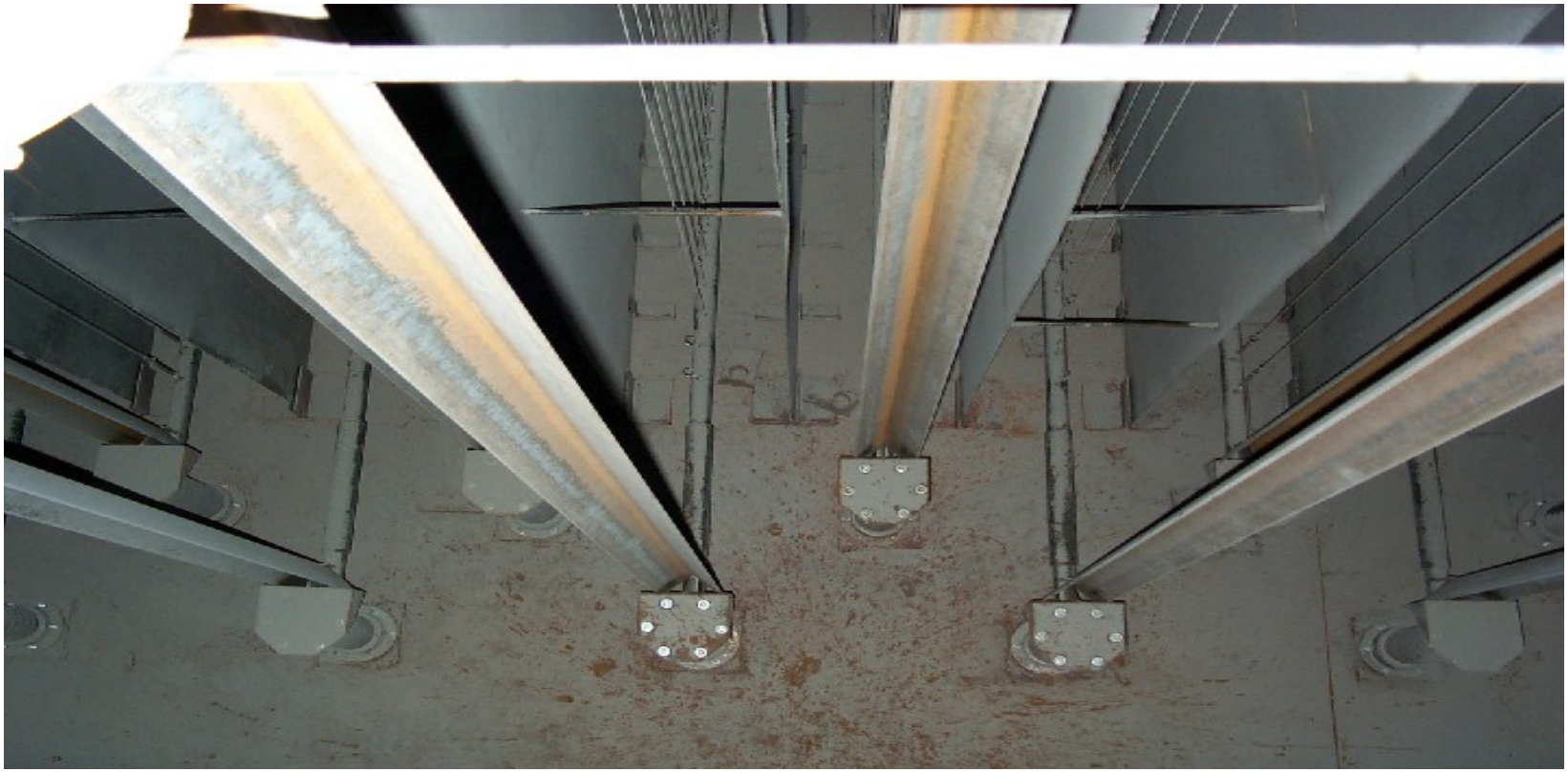
Indigo Technologies Bi-Polar Agglomerator

- The Bi-Polar or Indigo Agglomerator is a unique, patented technology developed by Indigo Technologies of Australia.
- It treats the ash prior to entering the electrostatic precipitator and uses electrostatic forces to attach the fine particulate to larger, more easily collected, particles.
- The key to this technique is the Bi-Polar Charger which charges half of the ash positively and the other half negatively.
- Fine negatively charged particles are mixed with large positively charged particles, and vice versa.

Bi-Polar Agglomerator



Bi-Polar Agglomerator - Outlet



Bi-Polar Agglomerator

- Pilot tests took place in Australia and the United States.
- Tests in the United States took place at Mississippi Power Company's Plant Watson in Gulfport, MS.
- It is a 250 MWe plant with two precipitators each treating half of the boiler output. The bi-polar agglomerator was installed to treat the full flow to one of the two side-by-side ESPs.
- Opacity monitors were installed in the outlet of each precipitator.
- Testing took place during firing of several American and foreign coals.

Bi-Polar Agglomertor – Plant Watson

MEASUREMENT	A Side	B Side
OPACITY %	15	4
PARTICULATE		
Grains / Act. Cubic Ft.	0.012	0.0066
Pounds per Million BTU	0.0382	0.0231
FLOW		
Actual Cubic Ft / Min	408,718	450,700
GAS TEMPERATURE (F)	276.3	272.6

Bi-Polar Agglomerator

- Today Indigo Technologies has installed 13 of their Fine Particle Control Systems, incorporating the Bi-Polar Agglomerator, on eight power plants in the United States, Australia, and China.

COHPAC I and COHPAC II

- COHPAC is an abbreviation for **CO**mpact **H**ybrid **PA**rticulate **C**ollector.
- It is a patented technology developed by EPRI in the early 1990s.
- COHPAC I refers to the concept of a stand-alone pulse-jet baghouse inserted downstream of an existing poorly performing ESP to polish the flue gas prior to the scrubber or stack. This can eliminate the need for a costly refurbishment of the ESP.
- Because most of the particulate matter is removed in the ESP, the pulse jet baghouse can operate at higher A/C ratios and be smaller in size. A/C ratios can be 6 to 8 ft/min compared to normal 4 ft/min values.

COHPAC I and COHPAC II

- Commonly various PPS felted fabrics are used for utility applications of this technology. 7 denier PPS filaments are used today in felt preparation. Felts made from these larger fibers provide adequate filtration and lower pressure drops values.
- There are three large installations of this technology currently in service: Luminant's Big Brown Station, Alabama Power's Gaston Generating Station, and WE Energies' Presque Isle Station.
- The COHPAC II technology does not use a separate baghouse, but replaces the rear ESP field with a compartment of filter bags and a redirected outlet plenum.

COHPAC I and COHPAC II

- Testing of the COHPAC II concept occurred at a pilot test facility installed by EPRI at Alabama Power's Plant Miller Unit 3 in the mid-1990s.
- There are no full-scale commercial installations of the COHPAC II technology.

COHPAC I®

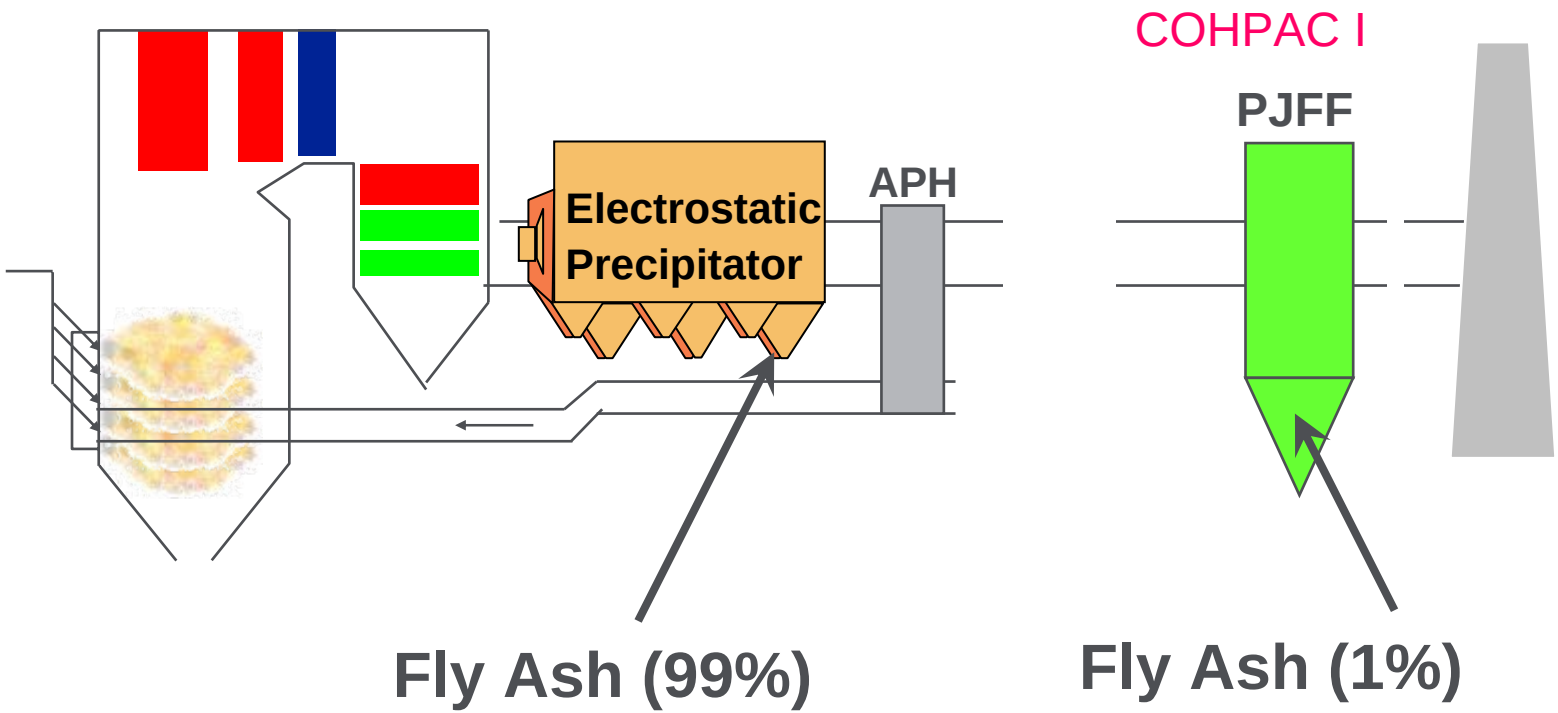


Illustration provided by EPRI

COHPAC II

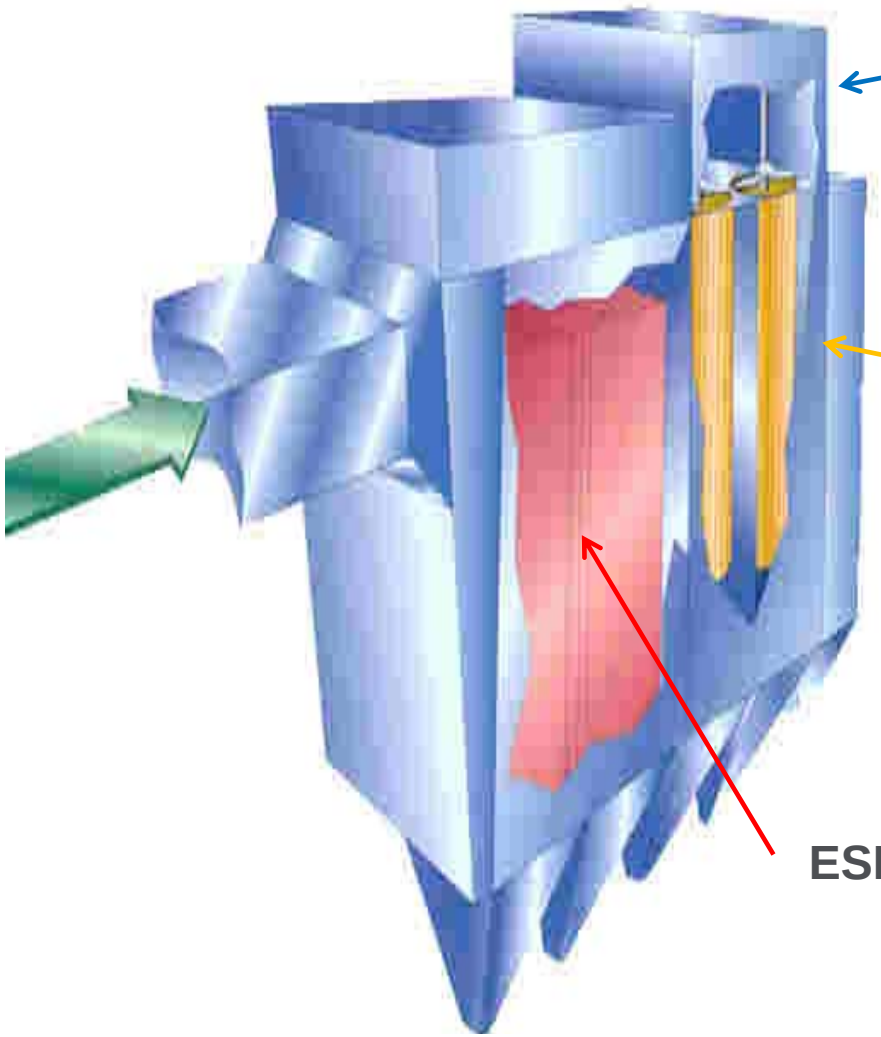
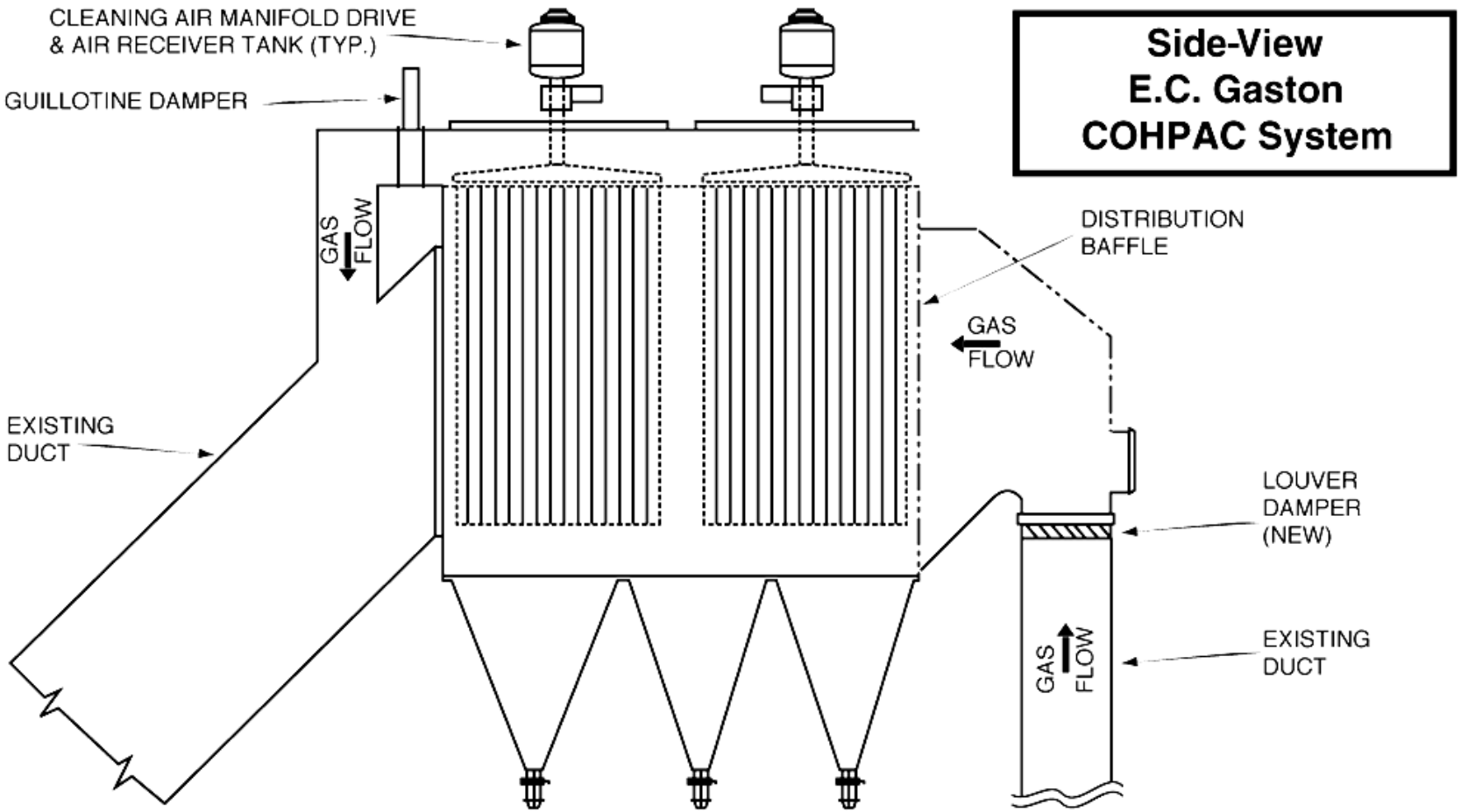


Illustration Provided by EPRI

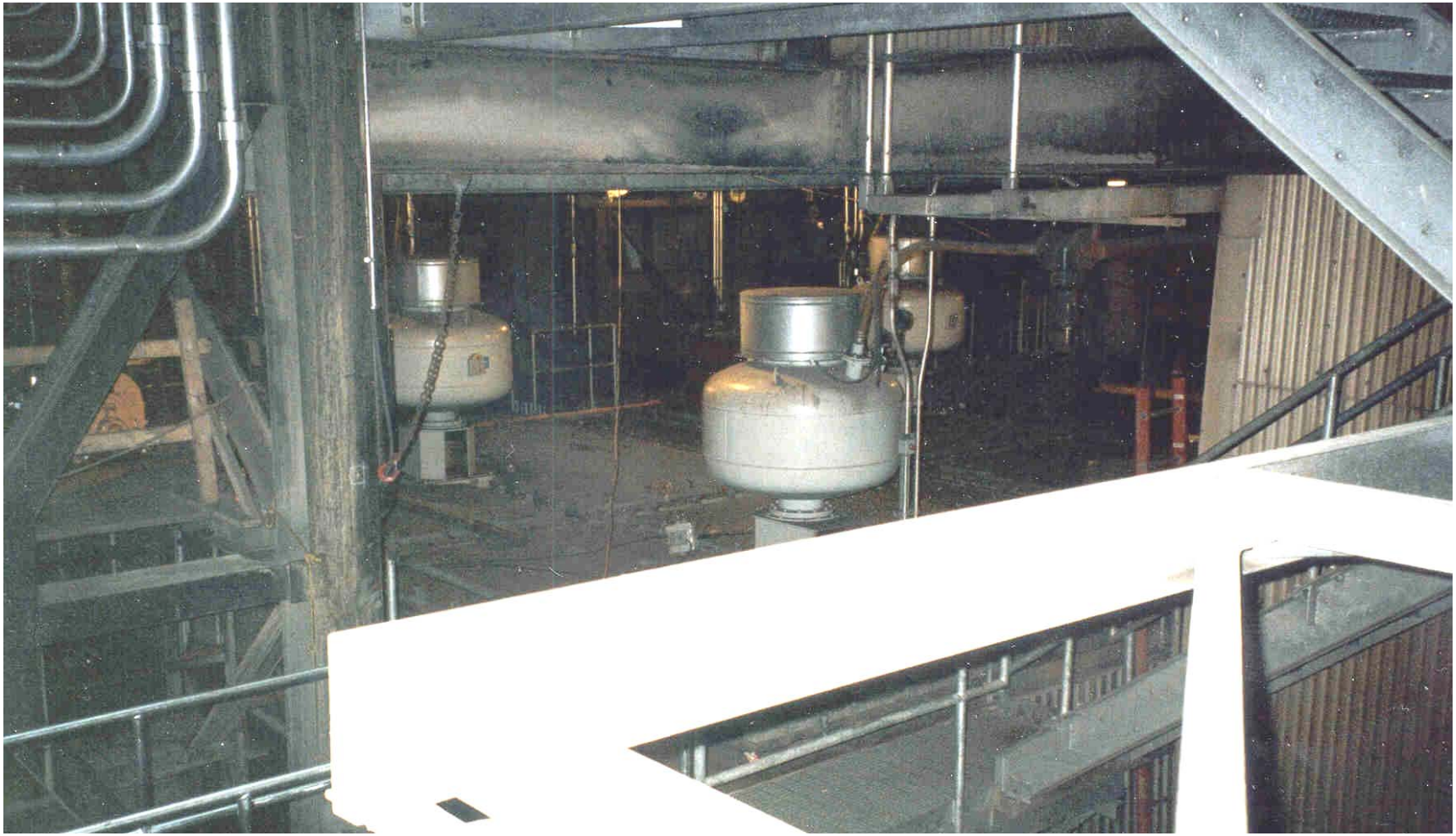
Gaston COHPAC Installation

- Gaston Units 1, 2, 3, and 4 are identical moderate sized units. Units 1 and 2 share a common stack flue, as do Units 3 and 4. To improve opacity and eliminate the cost of sodium addition for the hot-side ESPs, COHPAC baghouses were added to Units 2 and 3.
- The baghouses were installed in the old, unused, cold-side ESP casings. An additional 12 feet of length was added to each casing to accommodate the bag modules.
- The Unit 3 baghouse started up in January 1997; the Unit 2 baghouse started up in June 1999.



ESP to FF Conversion Downstream of Hot-Side ESP.

E. C. Gaston COHPAC Baghouse Tubesheet



E. C. Gaston Unit 3 COHPAC Baghouse Casing and Pulse Reservoirs

Gaston COHPAC Baghouses

- Each casing contains two compartments with a bypass duct between the compartments.
- The bypass duct can handle a full-load bypass, if necessary.
- The low-pressure/high volume pulse-jet cleaning system is the Howden/Carter-Day design with rotating pulse manifolds and filter bags arranged in concentric circles.
- Each of the four bag modules per casing has 544, 23-foot long filter bags arranged in 14 concentric rows.
- Each rotating pulse manifold has two arms to clean the even and odd rows.
- The pulse pressure has been set at 10 or 11 psig.

Gaston Baghouse Performance

- The Unit 3 baghouse has been in operation for 13 ½ years.
- The Unit 2 baghouse has been in operation for 11 years.
- The air-to-cloth ratios have ranged from 4 ft/min (low load) to 9 ft/min (full load).
- Flange-to-flange pressure drop values have ranged from 1 to 7 in. H_2O over the same load range.
- Pulse frequencies around 0.15 to 0.20 p/b/h have been common with the 7.0 denier PPS felts. They were somewhat higher with the 3.0 and 2.7 denier felts – 0.4 to 0.7 p/b/h.

Gaston Baghouse Performance

- Four sets of bags have been installed in the Unit 3 baghouse. Average bag life has been about 32,000 hours. The last set was installed in Spring 2008.
- Bag lives have been somewhat shorter on the Unit 2 baghouse (21,000 hours). Its fifth set of bags were installed in February of this year.
- Baghouse emissions have typically been very low, averaging about 0.005 gr/sdcf, with excursions coincident with bag failures episodes.
- Average opacity values have been halved with the operation of the COHPAC baghouses and sorbent addition upstream of the ESPs has been eliminated.

Gaston Baghouse Performance

- Compared to the average of the two years previous to COHPAC installation on Unit 3, in the 13.5 years since the opacity has declined an average of 53%, even while the average load for Units 3 and 4 has increased 16%.
- Compared to the average of the two years previous to COHPAC installation on Unit 2, in the 11 years since the opacity has declined an average of 44%, while the average load for Units 1 and 2 has increased 4%.

Early Unit 3 bag failures in the upstream bundles were primarily caused by bag-to-bag abrasion resulting from flue gas sweeping between the bag bundle and the compartment walls. The installation of restraining rings, as shown below, greatly reduced the problem.

TOXECON I®

- TOXECON I® is an EPRI-patented process that involves the injection of sorbent materials upstream of a COHPAC I® baghouse to adsorb HAPs, most commonly, mercury.
- The use of the COHPAC I® technology allows the recycling of the dry sorbent material that is mixed with a minimal amount of fly ash, thereby increasing the cost efficiency of the overall process.
- This process is illustrated in the following slide.

TOXECON I®

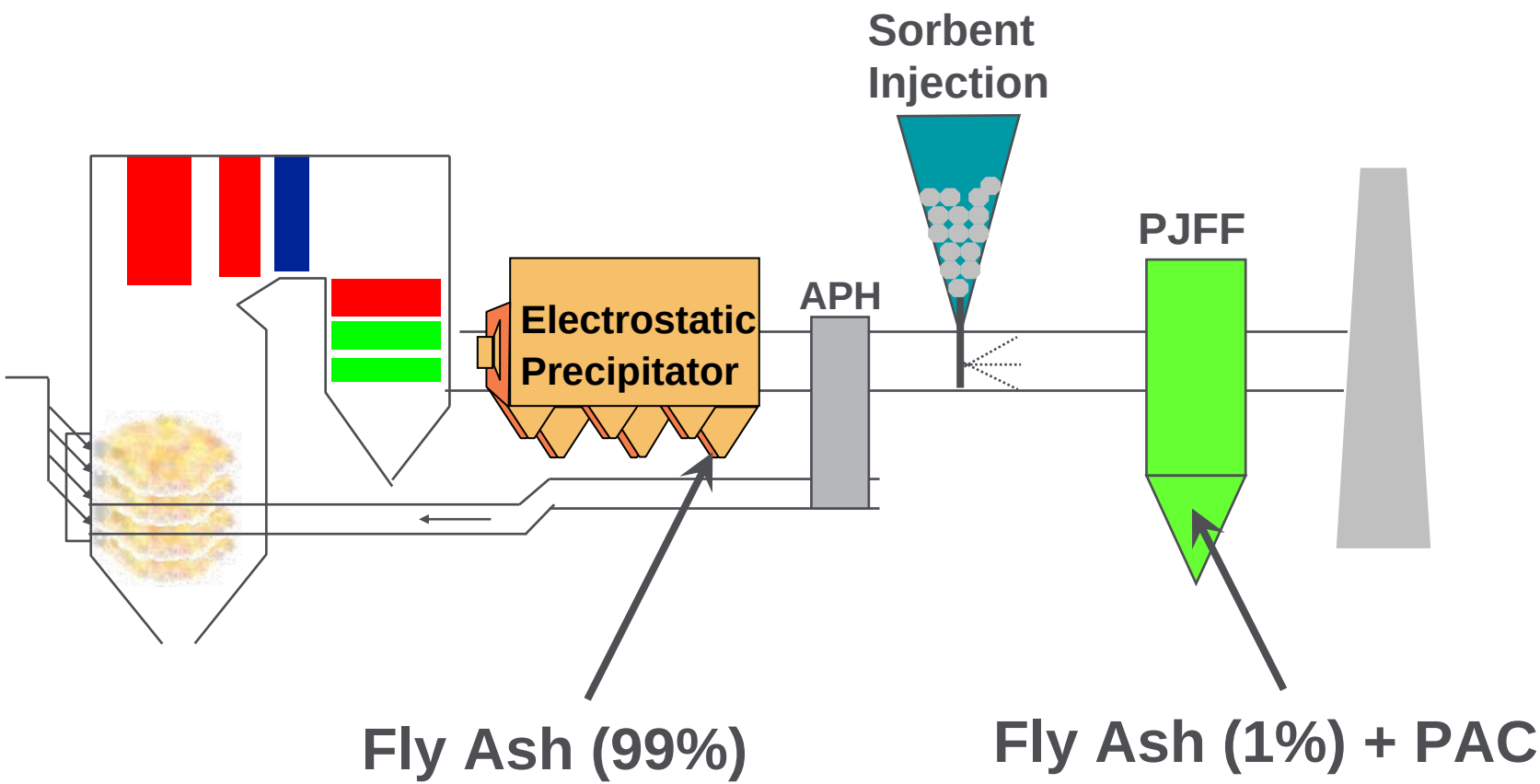


Illustration provided by EPRI

WE Energies TOXECON I®

- The TOXECON I process has been tested at pilot scale at a number of power plant facilities.
- One of the major full-scale applications of TOXECON I is located at WE Energies Presque Isle Power Plant located near Marquette, Michigan.
- Baghouses were installed downstream of the hot-side ESP and APH on three 90-MW units that fed to a common stack. The units burn PRB coal.
- The installation and testing program were part of a $54 million DOE Demonstration.
- Flue gas was rerouted through the baghouses in January 2006.
- Many parametric test programs have taken place.

WE Energies TOXECON I®

- Each baghouse has ten compartments. Each compartment has two 324-bag bundles.
- Each bag bundle is arranged in an 18 x 18 array. High pressure/low volume on-line cleaning is used.
- The total gas volume cleaned is 1.08 million acfm.
- The nominal air-to-cloth ratio is 5.5 ft per minute (gross).
- Preliminary performance data indicated excellent mercury removal.
- Parametric and long-term performance testing continued until 2009.

WE Energies TOXECON I®

- 90% mercury removal has been achieved with sorbent injection rates of 1.0 lb/h with Norit LH and 1.7 lb/h with Norit Hg.
- Bag cleaning rates range from 0.6 p/b/h with one unit in service to 0.2 p/b/h with all three units in service.
- Ash is pulled from the hoppers every four hours.
- Hopper wall temperatures are maintained below 300 degrees F.
- There have been several O&M issues that have been addressed since startup.
- These include spontaneous combustion, ash/PAC handling, duct corrosion, and bag life.

WE Energies TOXECON I®

Spontaneous Combustion

- Changes in operation have successfully prevented recurrence of problems
  - Complete emptying of hoppers
  - Minimizing residence time of ash/PAC in hoppers
  - Lower set point for hopper heaters
  - Minimize injection rate of sorbent
- CO monitors were tested in several hoppers
- The tests demonstrated that these types of monitors were not adequately sensitive to provide acceptable warning of combustion.

WE Energies TOXECON I®

Material Handling Issues

- The ash silo wet un-loader caused significant problems
  - There were excessive fugitive dust occurrences during startup periods
  - This required extensive modifications
  - This included adding an enclosure around the truck loading station to contain fugitive ash.

WE Energies TOXECON I®

Duct Corrosion

- Wall loss up to 19% in localized areas
- Expansion joint frames
- Diverter damper seals
- Possible causes include:
  - Increase of SO_3 concentrations across baghouses
  - Dead-ended ducting can create conditions below the acid dewpoint under certain operating conditions

WE Energies TOXECON I®

Bag Life

- Bag testing indicated that the original PPS bags had reached their end of life (3 years)
- The utility had expected considerably longer life
- A complete set of replacement bags were ordered
- There were no actual bag failures
- End of life was determined by Mullen Burst Strength Tests

Additional TOXECON I® Installations

- American Ref-Fuel, SEMASS Waste-to-Energy Combustors Units 1 & 2
    - 2 x 25MW Boilers
    - First Full-Scale TOXECON Demonstration
    - System captures Hg, Dioxins/Furans and other metals
- WE Energies, Presque Isle Units 7, 8 & 9
- PSEG Bridgeport Harbor Unit 3
- PSEG Mercer Station Units 1 & 2
- Dynegy Vermillion Station Units 1 & 2
- Georgia Power, Plant Scherer 1-4
- LG&E, Trimble County Unit 2

Information provided by ADA

EPRI TOXECON II™ Configuration

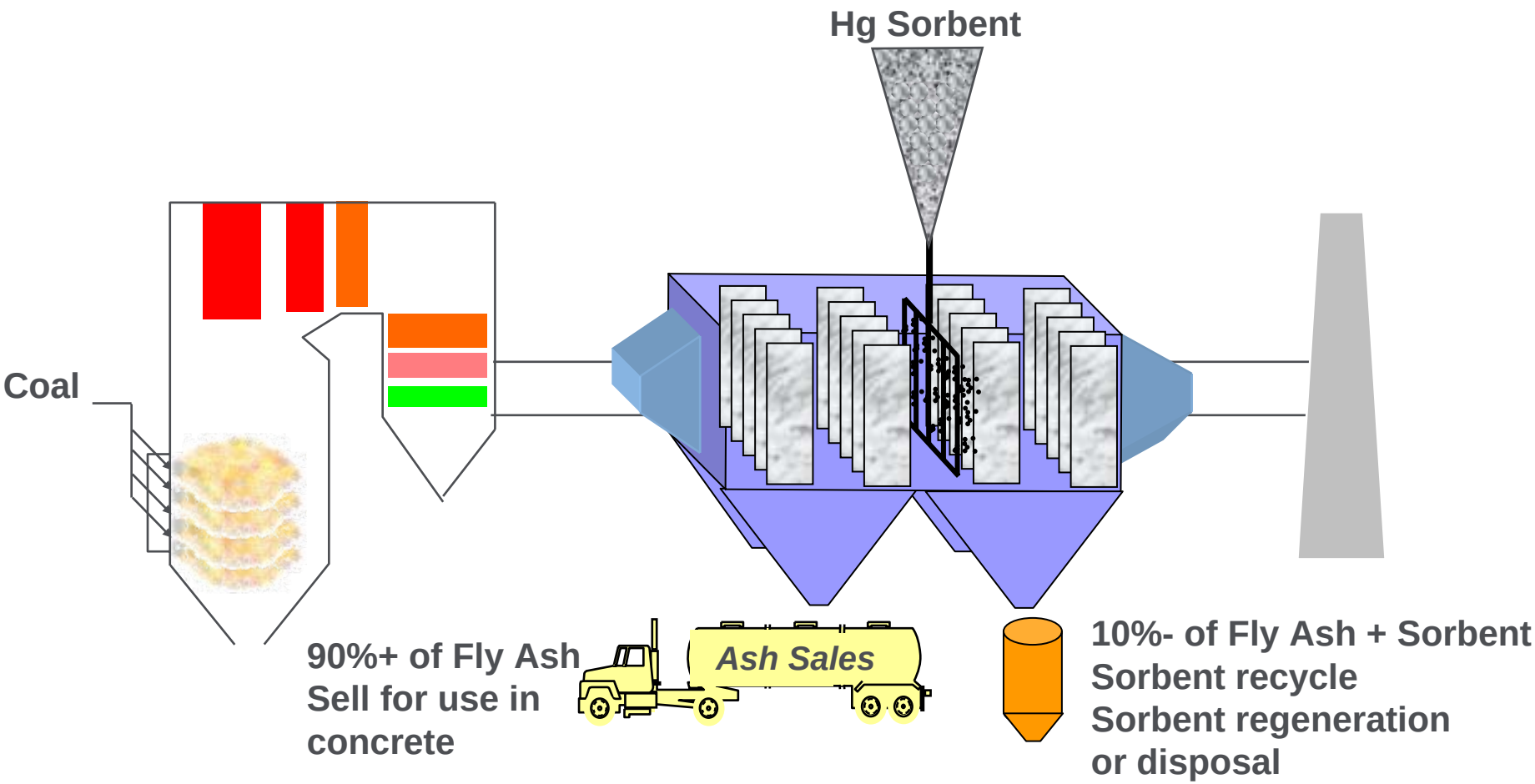


Illustration provided by EPRI

Questions?