

# **REINHOLD ENVIRONMENTAL Ltd.**



## **2011 APC Round Table & Expo Presentation**

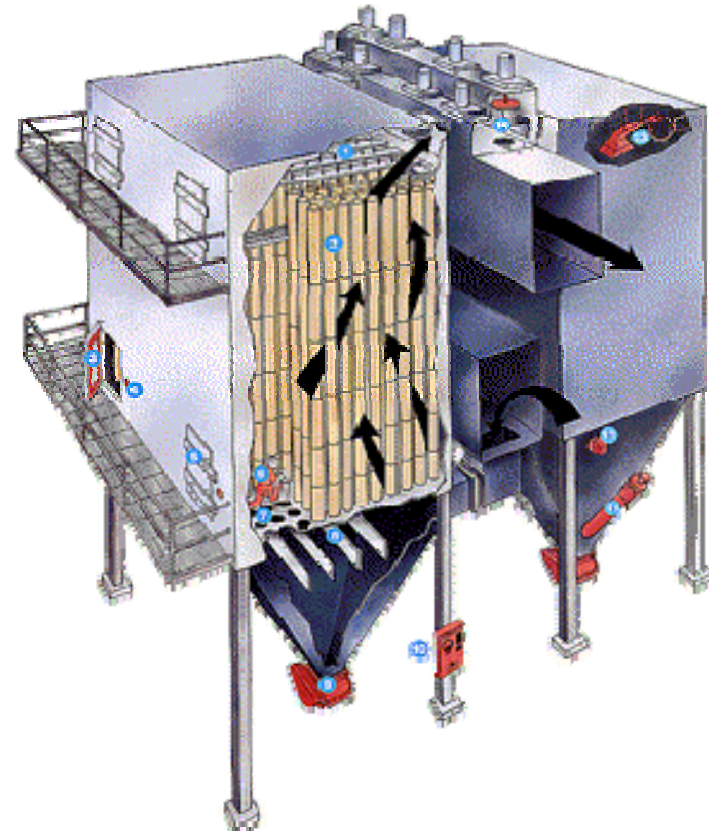
July 11-12, 2011, in Cleveland, OH / Hosted by FirstEnergy

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.

# Reinhold Environmental APC Roundtable and Expo

## Planning and Executing the Refurbishment of Coal-Fired Boiler Bag Houses

Bob Taylor and Tim Stark  
GE Energy



imagination at work

# Bag house refurbishment

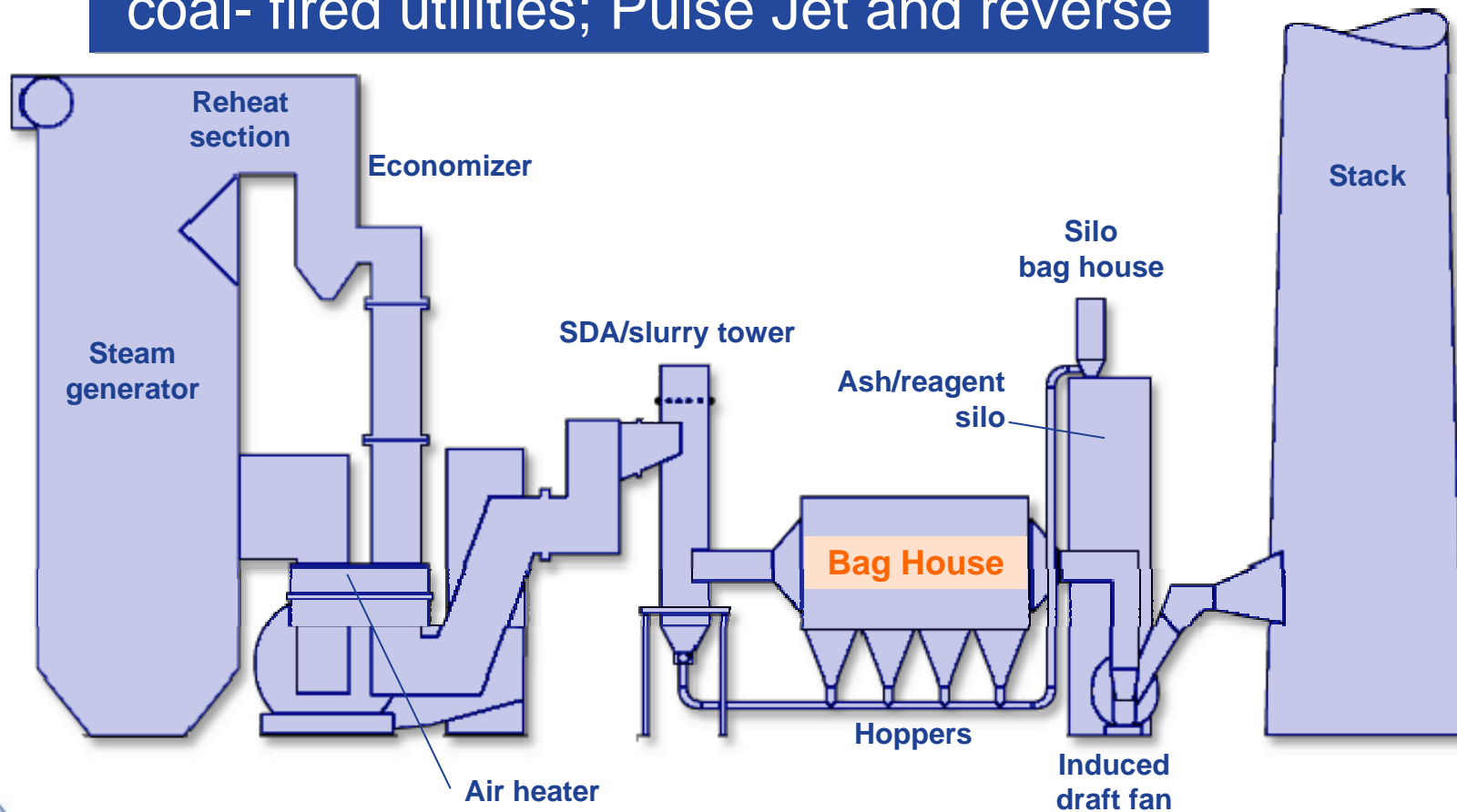
## Background

- Fabric filters are becoming more common as the primary particulate removal device serving a coal-fired utility
- Fabric filters are capable of achieving consistent high efficiency removal of fine particulate
- The filter bags, however, must be maintained to retain performance
- This presentation outlines the process of accomplishing a filter bag change out

# Bag house refurbishment

## Typical flow diagram

Two major types of bag houses serve coal-fired utilities; Pulse Jet and reverse



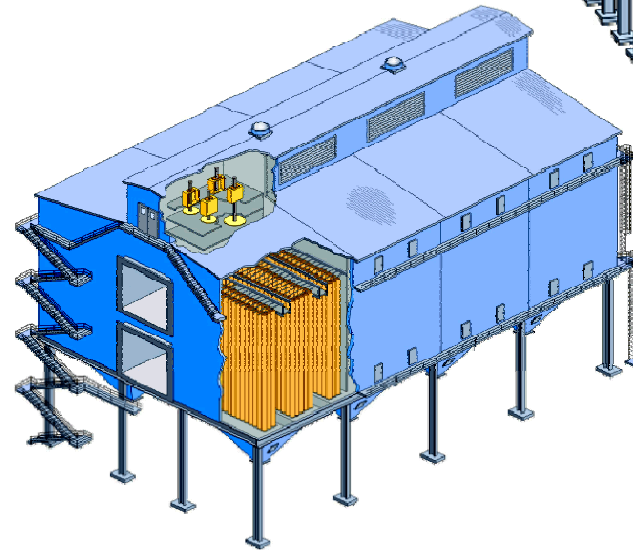
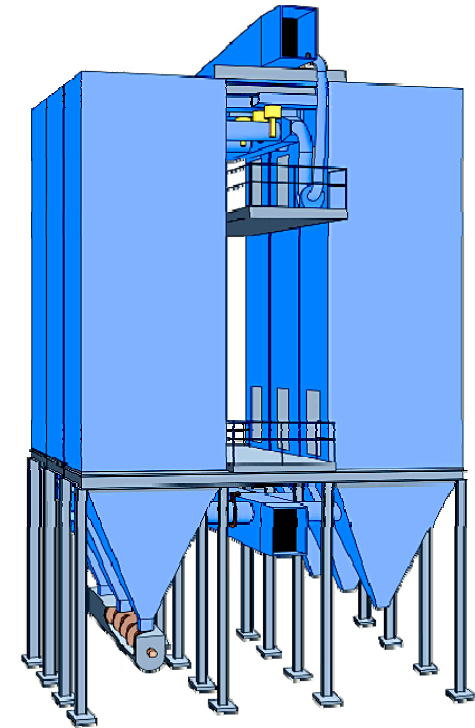
# Bag house refurbishment

## Reverse gas fabric filter

Historically, 95% of applications utilized reverse gas collector designs

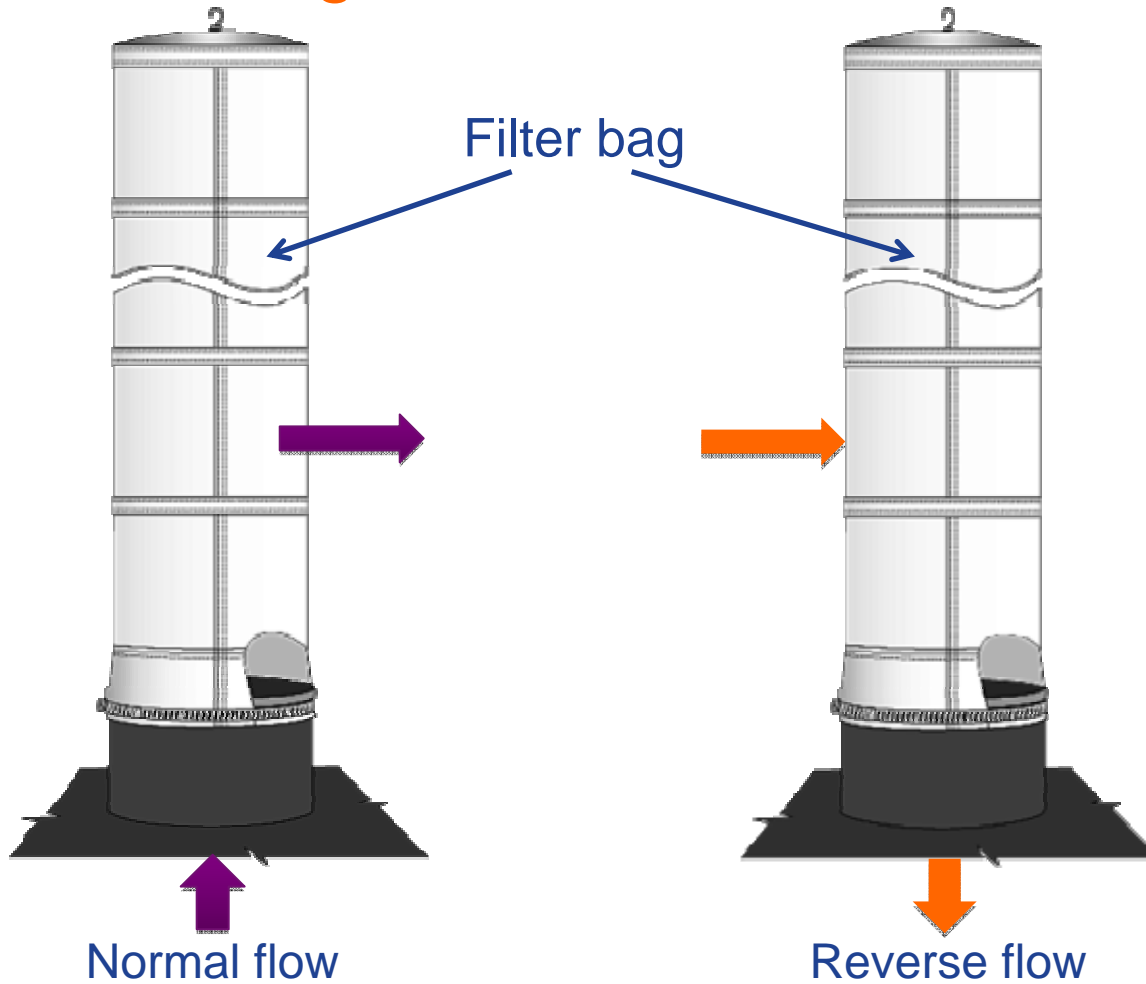
### Typical configuration:

- Woven fiberglass bags
- 2:1 (fpm) Air-to-Cloth Ratio (ACR)
- 11.5" x 30' filters (29 cm x 9 m)
- 4 – 10 year filter life
- Large footprint housing
- Off-line cleaning



# Bag house refurbishment

## Reverse gas fabric filter



Tension assembly

# Bag house refurbishment

## Pulse Jet fabric filter

**Most new installations use Pulse Jet technology**

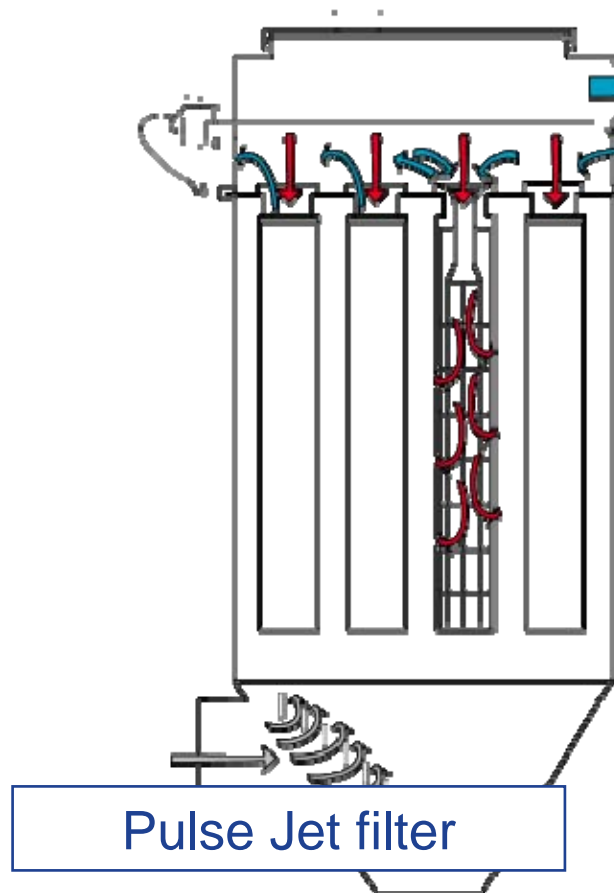
### **Typical configuration**

- Needle felts (acrylic, PPS, P-84), woven fiberglass and pleated filter elements
- 2.8 – 3.5 (fpm) Air-to-Cloth Ratio (ACR)
- 6" x 24'+ (15 cm x 730 cm)
- 3 – 5 year filter life
- Smaller housing footprint
- Typically on-line cleaning



# Bag house refurbishment

## Pulse Jet fabric filter



Pulse Jet filter

Cages



Pleated elements



Filter bags

# Bag house refurbishment

## What drives the need for a bag change?

**Ideally, filter bags should be changed at the end of their useful life**

### **Multiple factors impact bag life:**

- Gas temperature
- Dust loading
- Flow velocity and uniformity
- Cleaning cycles endured
- Bag-to-bag contact

Increasing rate of failure is an indication of bags reaching end of useful life

# Bag house refurbishment

## Outage planning decisions

**Multiple decisions must be made prior to initiating a bag change outage:**

- Will bag change occur on-line or off-line?
- What is start date and duration of outage?
- Will change out be contracted or handled in-house?
- Is configuration of bag, and if applicable, cage known?
- Does a purchasing specification for labor/materials exist?
- What receiving and staging areas can be dedicated?
- How does a bag change out integrate with other outage activities?
- Are existing confined space entry and LOTO procedures adequate?
- Is internal condition of bag house known?

**Answering the questions minimizes surprises**

# Bag house refurbishment

## Why is outage planning critical?

Estimated price off-line 500 MW boiler bag change out:

Pulse Jet:           \$1.2 to \$1.8 million installed

Reverse air:       \$1.0 to \$1.25 million installed

**Filter bag replacement is the highest bag house maintenance cost**

# Bag house refurbishment

## Change out approach

### Primary decision: **on-line or off-line change out?**

- The bag change out can occur while the boiler is shut down
- If sufficient compartmentalization and isolation exists, the change out can occur while the boiler is on-line
- If not then bags must be changed out off-line
- There are advantages and disadvantages of both approaches

# Bag house refurbishment

## Change out off-line

### Pros

- **Speed** – Access to all compartments at the same time
- **Safety** – No challenges with radiant temperature from other compartments or potential gas stream leaks
- **Thoroughness** – Simultaneous leak testing and pre-coat of entire system with ability to start-up and shut-down fans
- **Control** – Ability to control airflow through entire system at even loading during start-up
- **Predictability** – Improved bag life predictability with all filters having same start-up date
- **Uniformity** – Unit starts up at overall lower pressure drop, allowing less cleaning required to maintain pressure drop

### Cons

- **Time** – Outage sufficient for completion of entire unit; lost production

# Bag house refurbishment

## Change out on-line

### Pros

- **Time** – No boiler shut down required
- **Staging** – Minimize challenge associated with staging materials for several compartments

### Cons

- **Safety** – Potential issues with compartment isolation and heat
- **Non-Uniform** – Uneven loading to compartments with new filters leading to possible bleed-thru/blinding
- **Velocity** – Potential high velocity leading to abrasion issues in newly re-bagged compartments
- **Duration** – Slower schedule, takes longer to complete entire unit
- **Start-Up** – Challenge to properly leak test and pre-coat individual compartments

# Bag house refurbishment

## Change out mode decision

### Basis for decision

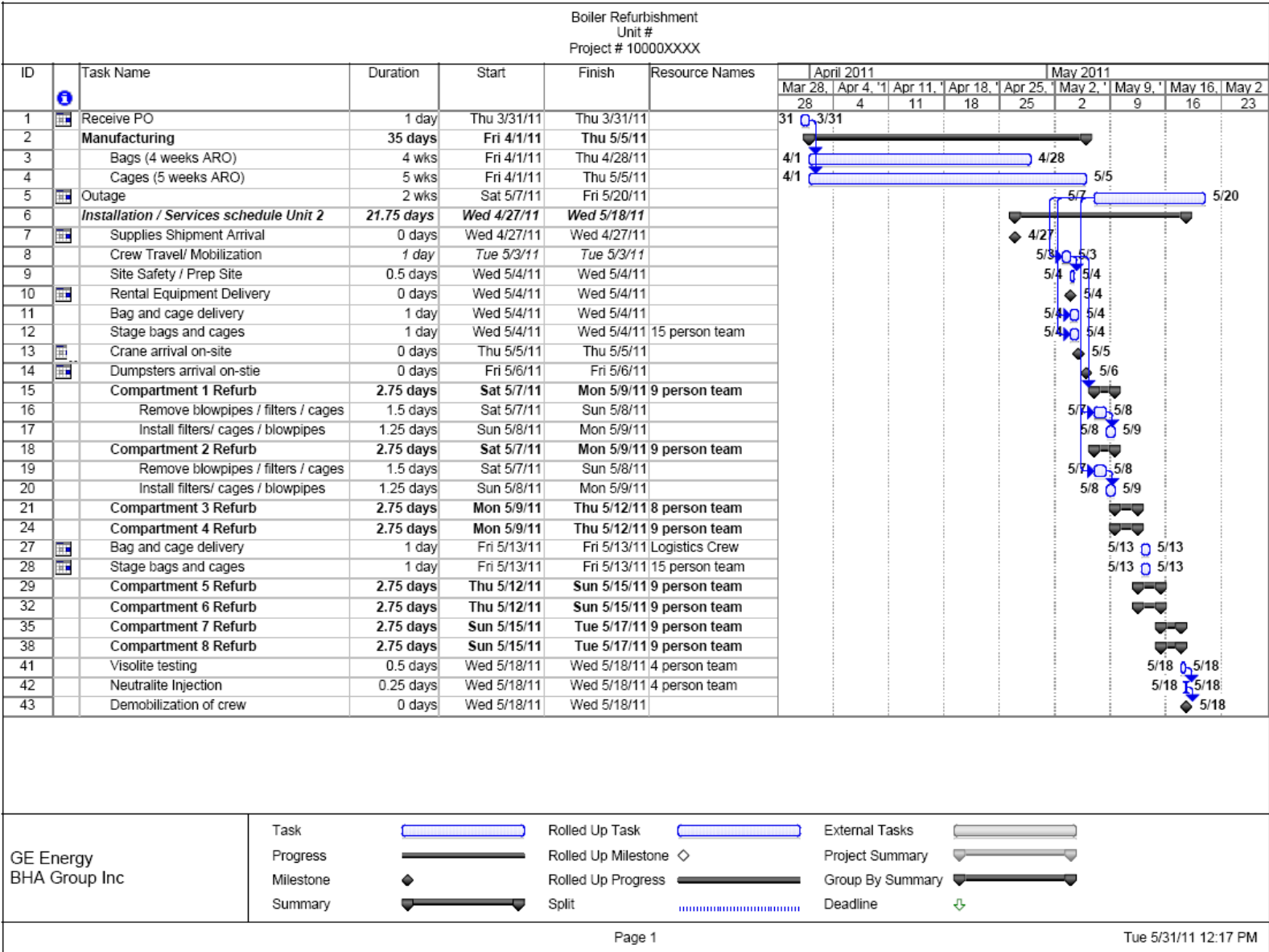
- Reverse gas versus Pulse Jet
- RA typically conducive to on-line change out
- Pulse Jet must have sufficient A/C to accommodate operation with one or more compartments off-line
- Compartments must be capable of being isolated from heat and process gas
- Relative cost of each option
- Time available for change out

# Bag house refurbishment

## Phases of change out



|          |            |          |
|----------|------------|----------|
| Inspect  | Clean      | Pre-coat |
| Plan     | Remove     | Start-up |
| Purchase | Position   | Monitor  |
| Schedule | Install    | Sample   |
| Receive  | Verify     | Test     |
| Stage    | Leak test  | Inspect  |
|          | Demobilize | Record   |



# Bag house refurbishment

Pre-change out activities



Pre-outage activities

# Bag house refurbishment

## Basic material procurement

| Pulse Jet                  | Reverse air                 |
|----------------------------|-----------------------------|
| Filters                    | Filter bags                 |
| Cages (100% or spares)     | Tensioning (100% or spares) |
| Door seal                  | Door seal                   |
| Labor                      | Labor                       |
| Pulse valve/solenoid parts | Clamps if required          |
| Leak detection materials   | Leak detection materials    |
| Pre-coat                   | Pre-coat                    |

- Depending on outage needs, additional equipment such as cranes, air compressors, welders, scaffolding, and ventilation may be required
- Lead time of purchased and rented material must meet outage schedule

# Bag house refurbishment

## Pre-outage Inspection

- Outage duration and staffing is based on assumed productivities
- Productivity is directly impacted by the internal condition of the equipment
- To minimize “surprises,” inspecting the bag house or at least a small number of compartments is recommended
- A pre-outage inspection can identify:
  - Filter bag “stuck” on cage
  - Corroded blow pipes connections
  - Accumulation of particulate
  - Damage to tube sheet
  - Corrosion damage to access doors
  - How many people fit into a compartment
  - Other issues that require lead time to address

# Bag house refurbishment

Clean air plenum access-space restrictions



Pre-outage inspection  
can identify access

restriction

# Bag house refurbishment

Clean air plenum access



What equipment is necessary to lift hatches and material?

# Bag house refurbishment

## Pulse valves and solenoids



Prior to outage, identify faulty diaphragm and solenoid valves

# Bag house refurbishment

## Ash accumulation



Look for ash buildup

# Bag house refurbishment

## Ash accumulation



Clean up before installation can  
begin

# Bag house refurbishment

## Blow pipe corrosion



Corrosion can cause blow pipe connections to seize

# Bag house refurbishment

## Door seal

Pre-outage inspection helps identify extra work scope and materials

Leakage at access doors causes corrosion

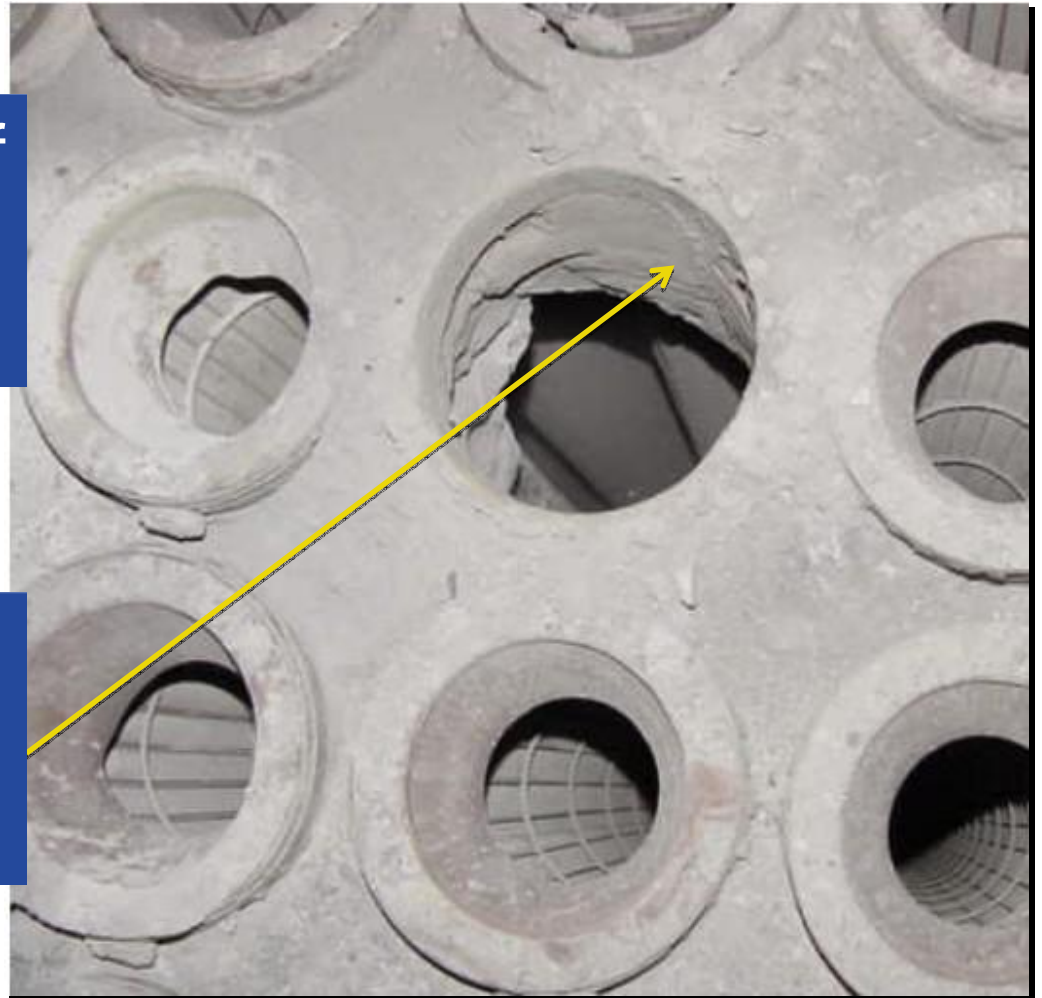


# Bag house refurbishment

Know what is in store for the crew

Deposits on bottom of  
tube sheet hamper  
bag removal

Unknown conditions  
can destroy outage  
schedules



# Bag house refurbishment

Have you considered the weight of the filter bag?

Dirty filter bags may weigh several times more than a clean filter bag

| Reverse gas fiberglass filter bag<br>12" diameter x 35' long | Filter Weight |
|--|---------------|
| New filter bag   | 16 lbs.       |
| Dirty Bag - SCR Offline                                      | 35-45 lbs.    |
| Dirty Bag - SCR Online                                       | 55-100 lbs.   |
| Dirty Membrane Bag - SCR On or Off                           | 20 lbs.       |

# Bag house refurbishment

## Pre-outage inspection

**Inspection findings should be documented to identify:**

- Repair work scopes
- Material necessary for repairs
- Need for “sucker” truck or other cleaning equipment
- Condition of tube sheet
- Available area for staging material near tube sheet
- Location of damaged bags
- Ease of access to platforms and doors

When documented, the inspection findings can be incorporated into the project scope of purchase specification

# Bag house refurbishment

## Outage activities



# Bag house refurbishment

## Hopper clean out



Hoppers should be cleaned out and the outlet plugged to exclude debris

# Bag house refurbishment

## Position material



# Bag house refurbishment

## Staging new materials



To expedite outage, stage material near work station

# Bag house refurbishment

## Filter/cage removal

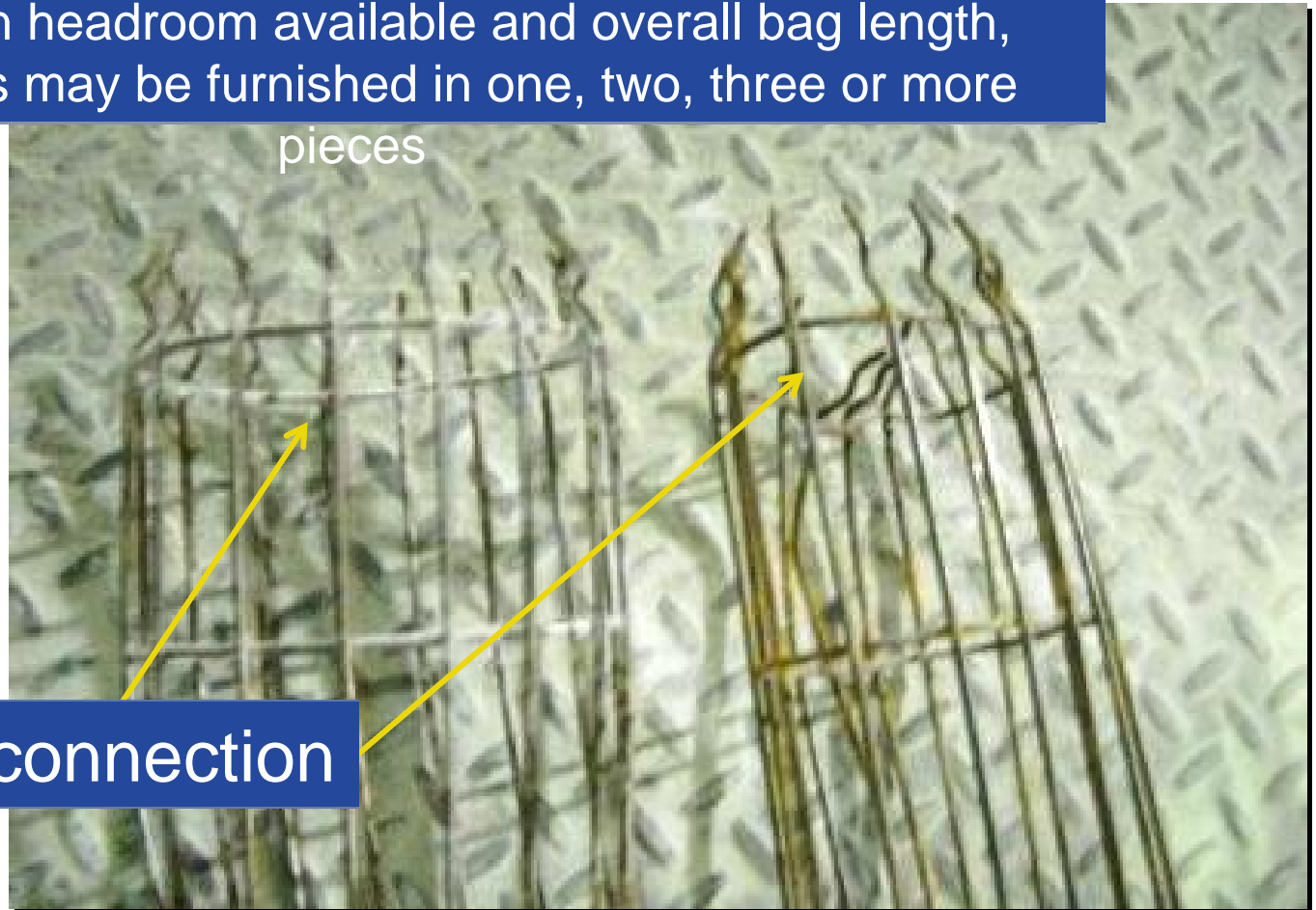


At the beginning of an outage, bags and cages are removed from the tube sheet

# Bag house refurbishment

## Two-and three-piece cages

Depending on headroom available and overall bag length, support cages may be furnished in one, two, three or more pieces



Used cage connection

# Bag house refurbishment

## Bag disposal



Used filters are placed in bags for disposal

# Bag house refurbishment

## Bag disposal chute

Chute emptying directly into  
 dumpster minimizes

handling



# Bag house refurbishment

## Installing new filters



Staging boxes of bags

# Bag house refurbishment

Lifting filter bags (reverse gas)



# Bag house refurbishment

## Fitting bag bottom and applying clamp



# Bag house refurbishment

## Tightening bottom clamp



# Bag house refurbishment

## Tensioning R/A filter bags



# Bag house refurbishment

## Tube sheet replacement



If extensive tube sheet damage is noted during inspection, it can be replaced during outage

# Bag house refurbishment

## Leak testing bag installation

**Prior to releasing a compartment, the filter bag installation shall be leak tested**

**A leak test will identify:**

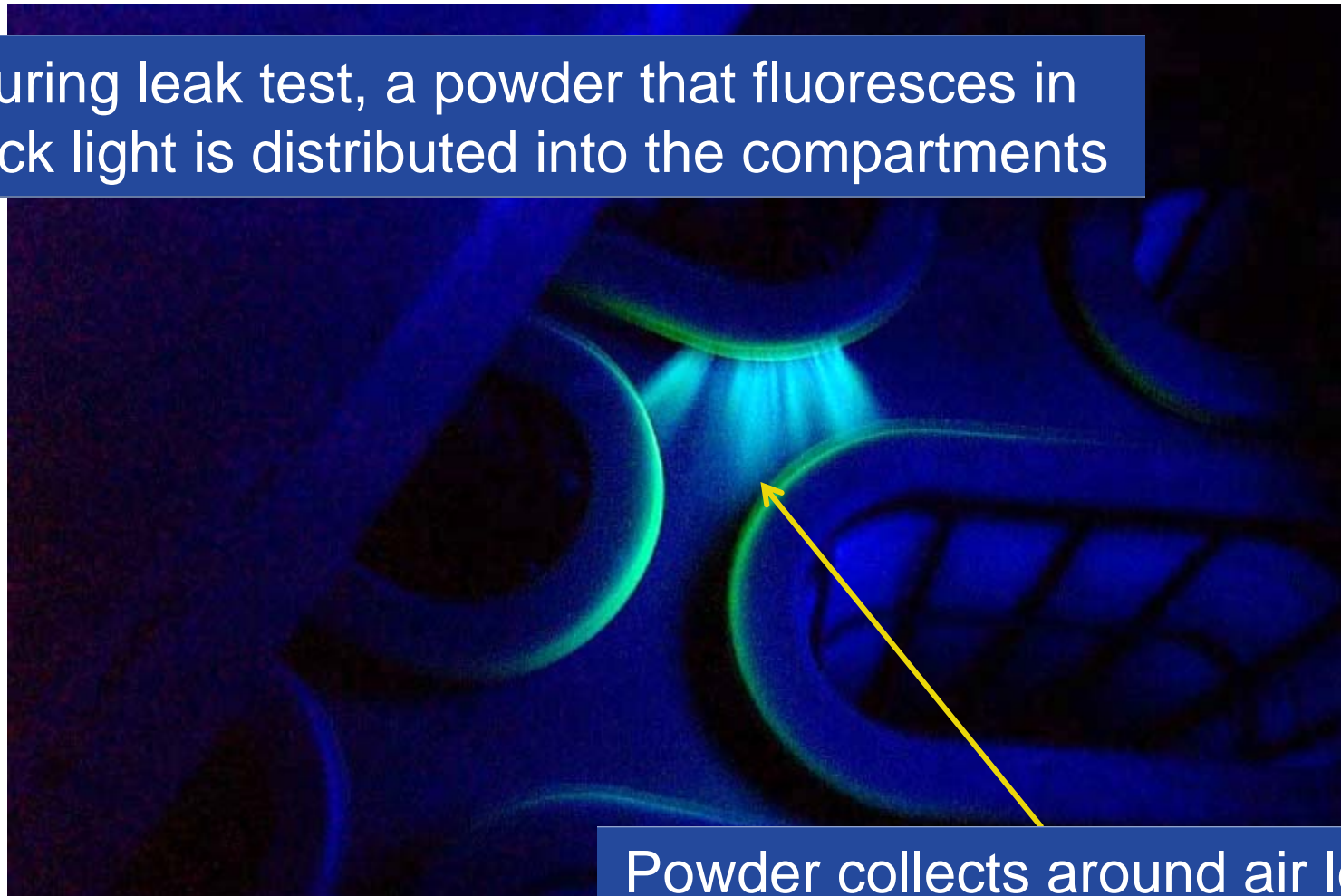
- Damaged bags
- Tube sheet leaks
- Loose clamps
- Improperly installed filter bags

Problems identified can be repaired before the compartment is turned back over to operations

# Bag house refurbishment

## Leak testing bag installation

During leak test, a powder that fluoresces in black light is distributed into the compartments



Powder collects around air leaks

# Bag house refurbishment

## Leak testing bag installation

- Shut off cleaning system
- Energize fan
- Inject leak test powder (~1lb. per 1000 sq. ft. of cloth)
- Shut off fan (after 45 – 60 seconds)
- Enter compartment and inspect with black light
- Mark and map defects observed
- Repair and repeat

# Bag house refurbishment

## Leak testing bag installation

GE Visolite® colors:

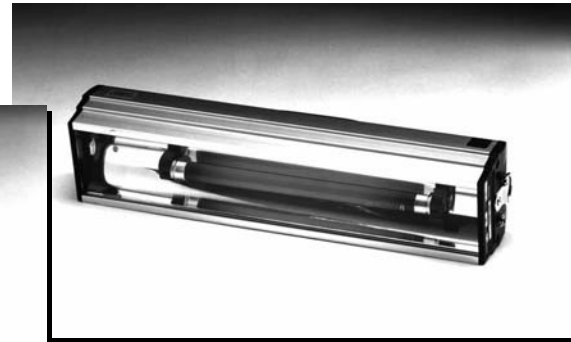
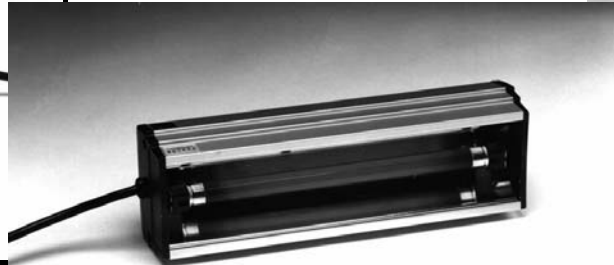
GREEN

ORANG

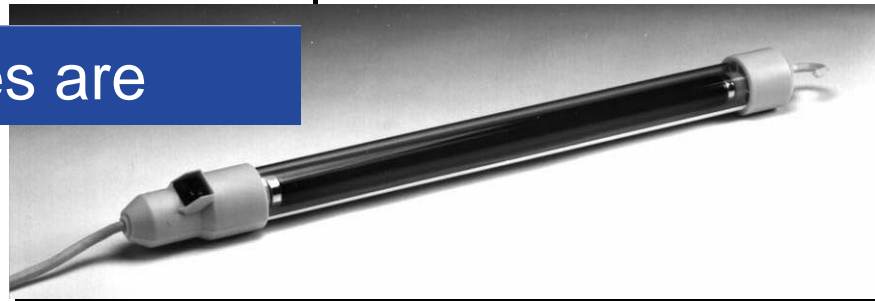
PINK

YELLO

Recommend purchase of at least two colors of leak test powder. <sup>W</sup>Re-testing can then be performed using a different color




A variety of light sources are



# Bag house refurbishment

## Start-up procedure



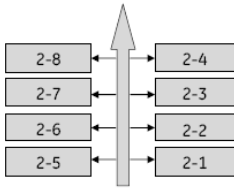
**GE Energy**

4800 East 63rd Street  
Kansas City, Missouri 64133  
USA

T 800 821 2222  
T 816 356 4400  
F 816 353 1873

*Brayton Point Station Dry Scrubber System/Operation Procedures document for "SYSTEM STARTUP procedures".  
This document describes the recommended startup procedure for Unit 2 PJFF only.*

**General Information**  
There is no alternative flue gas path from the boiler except through the pulse-jet fabric filter (PJFF). Flue gas from the SDA is ducted to the PJFF which evenly distributes flow to eight (8) compartments as shown in illustration 1 shown below:



*Flue gas path (Illustration 1)*

Each compartment contains 1,040 filter bags manufactured from polyphenylene sulfide (PPS) fabric laminated on the collection surface with GE Preveil™ ePTFE membrane. The filter bags are cleaned by using a reverse pulse of intermediate pressure (35 psig) compressed air at 150-200 ms on-time. To do so, compressed air is delivered to four (4) isolatable pulse air headers per compartment. Each header supplies air to 13, 3.0" double diaphragm pulse valves which are activated by a pilot solenoid valve and control air supply to a pulse manifold pipe. Each pipe delivers pulse air to twenty (20) filter bags within each compartment through holes in the bottom of the pipe. The reverse pulse of air dislodges the accumulated filter cake from the filter bags, and particulate falls to the hopper.

**Precoating and Re-Coating Procedures**

**Initial Precoating**  
Since the system will start-up with natural gas, the materials used for approved precoating are the dew point is crossed during startup, protecting the filters. Refer to the procedures for amount and various methods on injection. The amount of filtration media which will require a total of 13,117 lbs. of GE approved precoat material is introduced during the initial precoating. Once the approved precoat material is introduced, the dampers should not be turned off or compartments isolated in order to hold the precoat on the surface of the bags for a period of 24 hours.

After the initial startup, flyash is an acceptable coating of the filter bags. PJFF Unit 2 will require 65,584 lbs. (32.8 tons) of precoat material. Load out trucks should be utilized. The amount of precoat or re-coating is 50% of average operating gas flow rate (300,000 ACFM for Unit 2). The requirement for either the initial precoating or subsequent re-coating is 50% of average operating gas flow rate.

With only the Neutralite pre-coat is expected to be very low in the 1" range across the individual compartments. This is completely acceptable.

When bringing the PJFF unit online from a cold start, only 25% of the PJFF (2 compartments) should be brought online at a time. For example, compartments 2-4 and 2-8 can be used for startup. If an additional compartment needs to be added, please consult with the GE technical advisor. Startup utilizing natural gas firing typically take 12 - 16 hours. Because the gas flow rate is reduced, flue gas velocities through the PJFF unit are reduced. If all compartments were in service, it would take additional time for the startup. This would result in compartments operating a considerable amount of time at a lower temperature. Bringing several compartments online at different times and at different temperatures being brought up more quickly and subsequently bringing the remaining compartments online quickly. This minimizes the amount of condensation that occurs, which can damage the filter bags, support cages, and structural metal parts.

**Refurbished Compartments**  
The PJFF unit cleaning system should remain off for all compartments, including the inlet and outlet dampers. The cleaning system should remain off for all compartments, including the inlet and outlet dampers until the differential pressure ( $\Delta P$ ) across the compartment has reached the inlet and outlet dampers are fully open, and the  $\Delta P$  across the compartment tube sheets exceeds 4.0" w.g.

- The allowable volumetric flue gas flow rate, as measured at the stack, is limited based upon the number of compartments online (inlet & outlet dampers fully open). These limits are shown in Table 1. Unit load should be reduced as necessary to remain at or below these limits.
- Bring the pulse jet cleaning system online for each newly bagged compartment when the inlet and outlet dampers are fully open, and the  $\Delta P$  across the compartment tube sheets exceeds 4.0" w.g.

**Additional Guidelines**

If the differential pressure ( $\Delta P$ ) across the compartment tube sheets exceeds 4.0" w.g. across a newly bagged compartment, the inlet damper open times should be increased. If the  $\Delta P$  drops below 4.0" w.g. across all newly bagged compartments, the inlet damper to the compartment should be closed until the compartment  $\Delta P$  is at or below 4.0" w.g.

**Maximum Flue Gas Flow vs. No. Of Online Compartments**

| Number of Online Compartments (Dampers Full) | Maximum Allowable Flue Gas Flow Measured In The Stack (ACFM) |
|--|--|
| 1  | 1,100,000  |
| 2  | 962,000  |
| 3  | 825,000  |
| 4  | 687,500  |
| 5  | 550,000  |
| 6  | 412,500  |
| 7  | 275,000  |

**Additional information**  
The flue gas flow rate in any one newly bagged compartment is limited to the value established to keep the air-to-cloth ratio and at or below system design parameters. Refer to GE Energy's Performance Warranty.

The difference in differential pressure between the individual compartments and system (measured inlet to outlet across the PJFF) pressure should be controlled by pressure drop. Refer to the Pulse Jet Fabric Filter (PJFF) Operation/Pulse Air Cleaning System".

Document the start-up procedure to be applied

# Bag house refurbishment

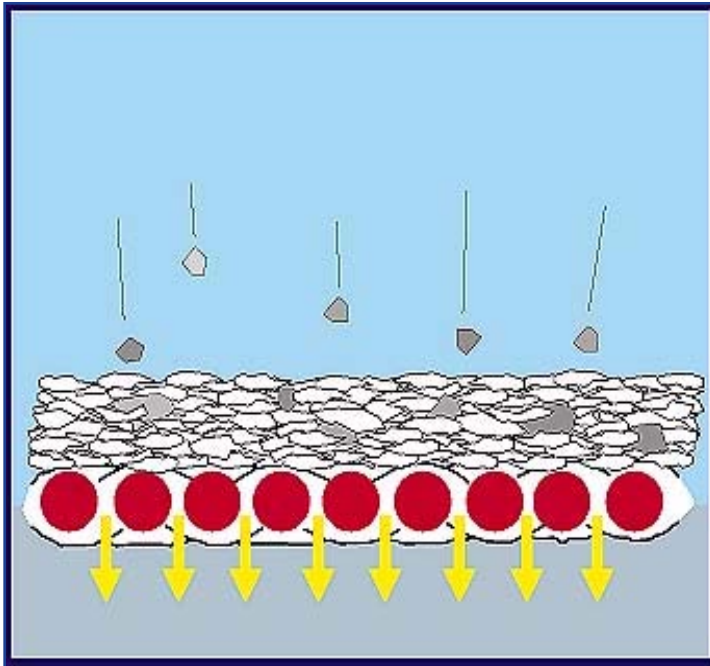
## Start-up procedure

### High level start-up guidelines:

- Build up initial dust cake (pre-coating)
- Preheat compartments
- Restrict airflows (balance dirty/clean compartments)
- Lockout cleaning cycle (initially)
- Stabilize process and release normal cleaning

# Bag house refurbishment

## Pre-coating filter bags



It is recommended to pre-coat new filter bags prior to introducing flue gas.

The pre-coat shall:

- Exhibit a wide range of particle sizes
- Contain a range of particle shapes
- Build to a uniform coat
- Present a neutral pH?
- Create a porous dust cake

**Effective pre-coat ensures acceptable gas flow, protects bags from moisture, hydrocarbons, and initial blinding**

# Bag house refurbishment

## Start-up procedure

### After pre-coating

- The cleaning system should be locked out to keep the initial dust cake in place until the desired differential pressure is achieved
- Monitor the DP at both flanges and tube sheet
- Cleaning prematurely will re-expose the new fabric to the gas flow, creating the potential for blinding and bag damage
- Cleaning system can be released when the desired pressure differential is achieved

# Bag house refurbishment

## Start-up procedure

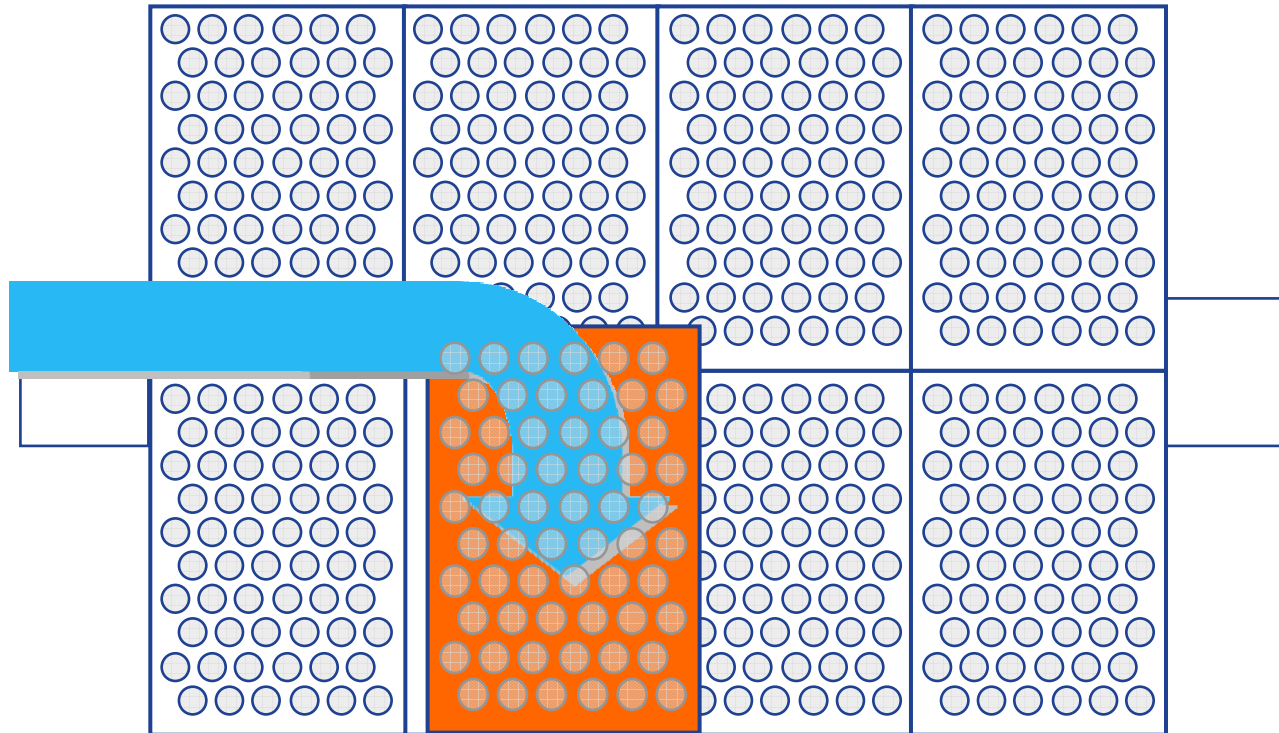
**If possible start up the boiler on natural gas**

Preheat the equipment on start-up fuel to minimize thermal shock to the mechanical and structural components of the system, and to ensure gas stream temperatures are above moisture and acid dew point prior to venting to the collector.

# Bag house refurbishment

Why balance flow?

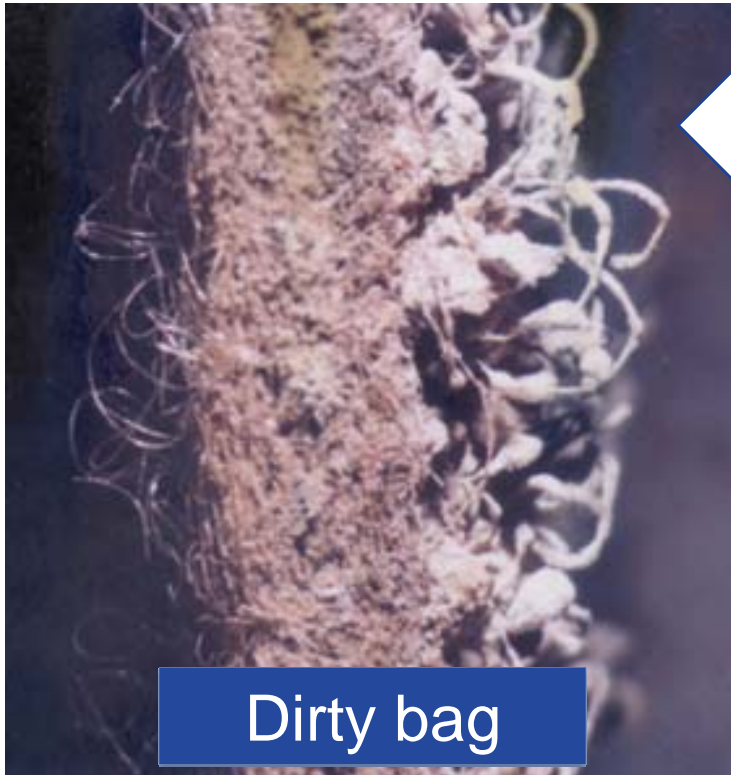
Compartment change out



**After bag change out, new filter bags offer less resistance to gas flow, compared to used bags**

# Bag house refurbishment

Why balance flow?



Dirty bag

Gas flow rates are higher through clean bags



Bag permeability degrades over time



Clean bag



# Bag house refurbishment

## Why balance flow?

- Field testing shows clean filter media accepts 20 to 50 cfm gas flow per square foot area
- Dirty filter media with dust cake accepts gas flow in the range of 5 to 10 cfm per square feet area
- Based on this difference, the clean filter bags will treat about three times more gas than dirty media
- Potential for **blinding** of bags, **scouring**, and bag to bag **abrasion** damage
- Increasing pressure loss to the clean compartments, or the entire bag house with clean media, will minimize potential for damage

# Bag house refurbishment

## Restrict initial gas flow

| Pulse Jet system |                  |
|------------------|------------------|
| Damper setting   | Operating period |
| 10%              | 12 hours         |
| 10%              | 6 hours          |
| 50%              | 6 hours          |

| Reverse gas system |                  |
|--------------------|------------------|
| Damper settings    | Operating period |
| 20%                | 12 hours         |
| 40%                | 6 hours          |
| 70%                | 6 hours          |

**Not critical how, just that flow is restricted to clean compartments on start-up**

# Bag house refurbishment

## Post-outage activities



Post-outage activities

# Bag house refurbishment

## Post-outage activities

**Post outage activities should be focused on preserving the bag change out investment**

**Some typical activities are:**

- Inspections
- Bag testing
- Monitoring
  - Emissions
  - Pressure drop
  - Cleaning interval

# Bag house refurbishment

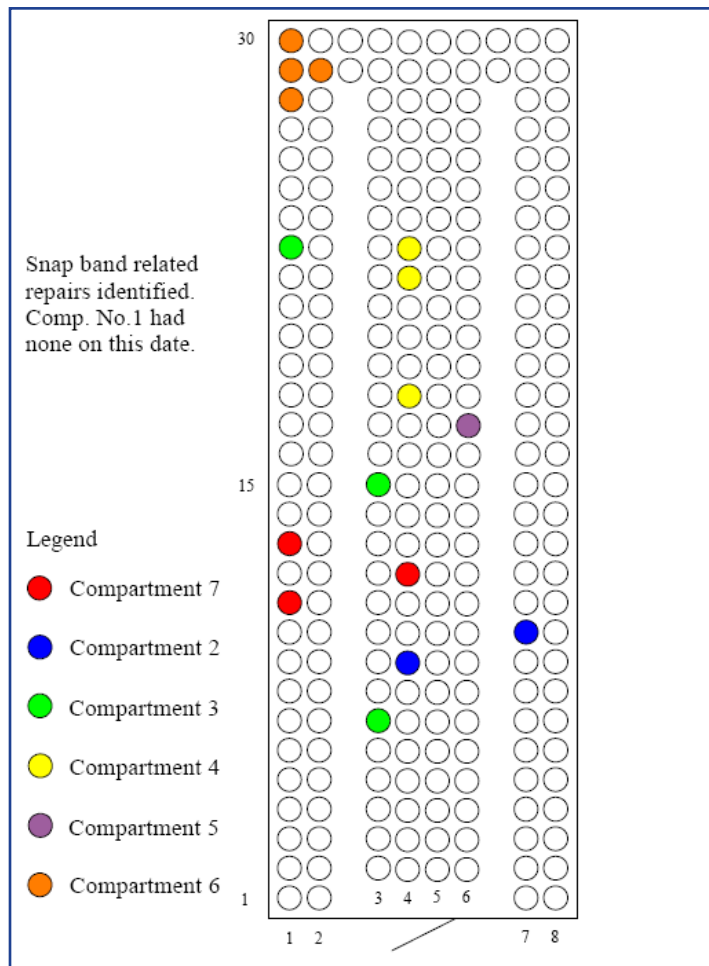
## Post-outage activities

### Inspections

- Each compartment should be inspected regularly to identify changes in condition
- Inspection shall reference bag installation date
- Establish tube sheet template for recording inspection observations
- Inspections should identify location of failed bags or components
- Location of defects can help characterize the nature of the problem

# Bag house refurbishment

## Post-outage activities



Tube sheet templates record location of defect and inspection findings for future reference

# Bag house refurbishment

## Post-outage activities

### Bag testing

- Filter bag testing can identify cause for failures and provide indication of remaining useful life
- Samples of damaged filter bags should be tested
- On an annual basis, it is recommended to test a sample of operating filters

### Typical properties tested are:

- Permeability
- Burst strength
- Flexural strength

# Bag house refurbishment

## Post-outage activities

### Bag testing

- Bag test results provide useful data when compared against baseline data
- Gathering bag test data for new filters and periodically thereafter provides an indication of the rate at which physical properties are degrading
- Test data obtained for failed bags provides insight into the failure mechanism
  - Chemical
  - Thermal
  - Mechanical

# Bag house refurbishment

## Post-outage activities

### Monitoring

- Overall emissions should be monitored, but individual compartment data may be more meaningful

### Overall emissions can be evaluated for:

- Absolute emission level
- Changes in emissions over time
- Variations in emission during cleaning
- Individual compartment emission data helps focus inspection and monitoring activities
- Problems associated with overall gas or temperature distribution can be identified using compartment specific data

# Bag house refurbishment

## Summary

- Filter bag replacement represents a major expense
- Proper planning minimizes surprises and extended outages
- Inspections performed prior to outages provide invaluable planning data
- Leak testing ensures that the installation was performed correctly
- Care must be exercised during start-up to avoid damage to clean filters
- Long-term management through inspections, bag testing, and monitoring will help extend the change out investment

# Bag house refurbishment

Q&A

Thank you for your time



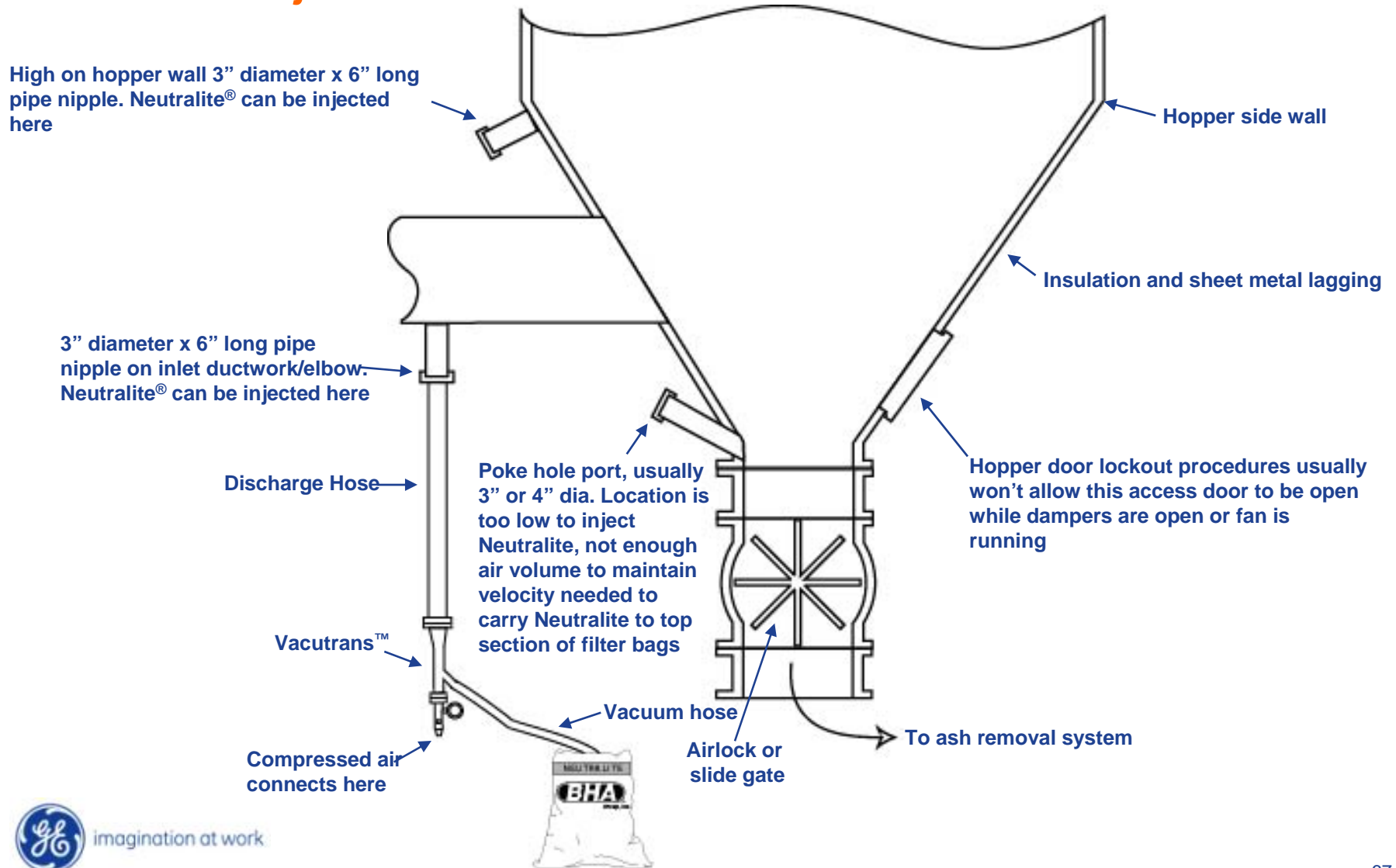
# Bag house refurbishment

## Protect against carryover

- **Moisture** – Can create agglomerated dust cake that destroys airflows; can create acid reaction, rust components
- **Hydrocarbons** – Create sticky dust cake difficult to clean; shorten bag life; high DP

# Bag house refurbishment

## Pre-coat injection



# Bag house refurbishment

## Fabric characteristics and suitability for power generation applications

|                                 | Polypropylene  | Polyester       | Acrylic         | Fiberglass      | Aramid          | PPS             | P84 ***         | Teflon® ***     |
|---------------------------------|----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Max. continuous operating temp. | 170° F (77° C) | 275° F (135° C) | 265° F (130° C) | 500° F (260° C) | 400° F (204° C) | 375° F (190° C) | 500° F (260° C) | 500° F (260° C) |
| Abrasion                        | Excellent      | Excellent       | Good            | Fair*           | Excellent       | Good            | Fair            | Good            |
| Energy absorption               | Good           | Excellent       | Good            | Fair            | Good            | Good            | Good*           | Good            |
| Filtration properties           | Good           | Excellent       | Good            | Fair            | Excellent       | Excellent       | Excellent       | Fair            |
| Moist heat                      | Excellent      | Poor            | Excellent       | Excellent       | Good            | Good            | Good            | Excellent       |
| Alkaline dust                   | Excellent      | Fair            | Fair            | Fair            | Good            | Excellent       | Fair            | Excellent       |
| Mineral acids                   | Excellent      | Fair            | Good            | Poor**          | Fair            | Excellent       | Good            | Excellent       |
| Oxygen (>15%)                   | Excellent      | Excellent       | Excellent       | Excellent       | Excellent       | Poor            | Excellent       | Excellent       |
| Relative cost                   | \$             | \$              | \$\$            | \$\$\$          | \$\$\$\$        | \$\$\$\$\$\$    | \$\$\$\$\$\$    | \$\$\$\$\$\$    |

\* Sensitive bag-to-cage fit

\*\* Fair with chemical or acid-resistant finishes

\*\*\* Must oversize bag for shrinkage for temperatures above 450°F (232°C)

# Bag House Refurbishment

Abrasion failure: Bottom of filter bags located directly in line with inlet gas stream

Excessive movement of filters causing bag-to-bag abrasion



