Reinhold Environmental Ltd.

2007 APC Round Table & Expo Presentation

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

PCUG Pre-Conference Workshop
July 2007

Bag House Basics

GE Energy – Member WPCA
(World Pollution Control Association)

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Bag House Basics

- Historically, coal fired boilers utilized electrostatic precipitators for particulate control.
- The dynamics governing particulate control technology are changing:
  - Particulate emission standards are becoming more stringent.
  - Fuel flexibility is putting an increased burden on electrostatic precipitator capabilities.
  - Technologies focused on mercury, sulfur dioxide, and acid gas reduction can increase dust burden entering an electrostatic precipitator.
- It is increasingly difficult to upgrade existing ESP's to accommodate current demands.
- As a result an increasing number of fabric filters are being installed on utility boilers.

Bag House Basics

- An electrostatic precipitator is a constant pressure drop, constant removal efficiency device.
- As inlet dust burden increases, so do outlet emissions.
- To increase dust removal efficiency, an electrostatic precipitator must be made larger.
- The fabric filter is a dynamic pressure drop, constant emission device.
- Low dust emissions levels are achieved regardless of the required limits.

Bag House Basics

- As a result, electrostatic precipitator capital costs increase as the emission requirement becomes more stringent.
- As emission limits decrease, the fabric filter becomes more economical compared to an electrostatic precipitator.
- The break point for capital costs is at an emission level of approximately 0.015 to 0.02 lb/mmBTU or 20 to 25 mg/Nm^3.

Bag House Basics

- Variety of filter medias can accommodate many process conditions.
- Pressure loss through the bag house is a function of the original design, media, dust size, and dust layer thickness.
- To maintain pressure drop within acceptable limits, all bag houses periodically “clean” the filters.
- Cleaning interval is controlled either by pressure limit or a timer.
- There are several fabric filter technologies available, two of which are regularly applied to coal fired boilers.

Bag House Basics

- The two major coal fired boiler fabric filter technologies are:
  - Reverse gas
  - Pulse Jet
- Within the pulse jet category there are three approaches:
  - Conventional pulse jet
  - COHPAC
  - Max-9

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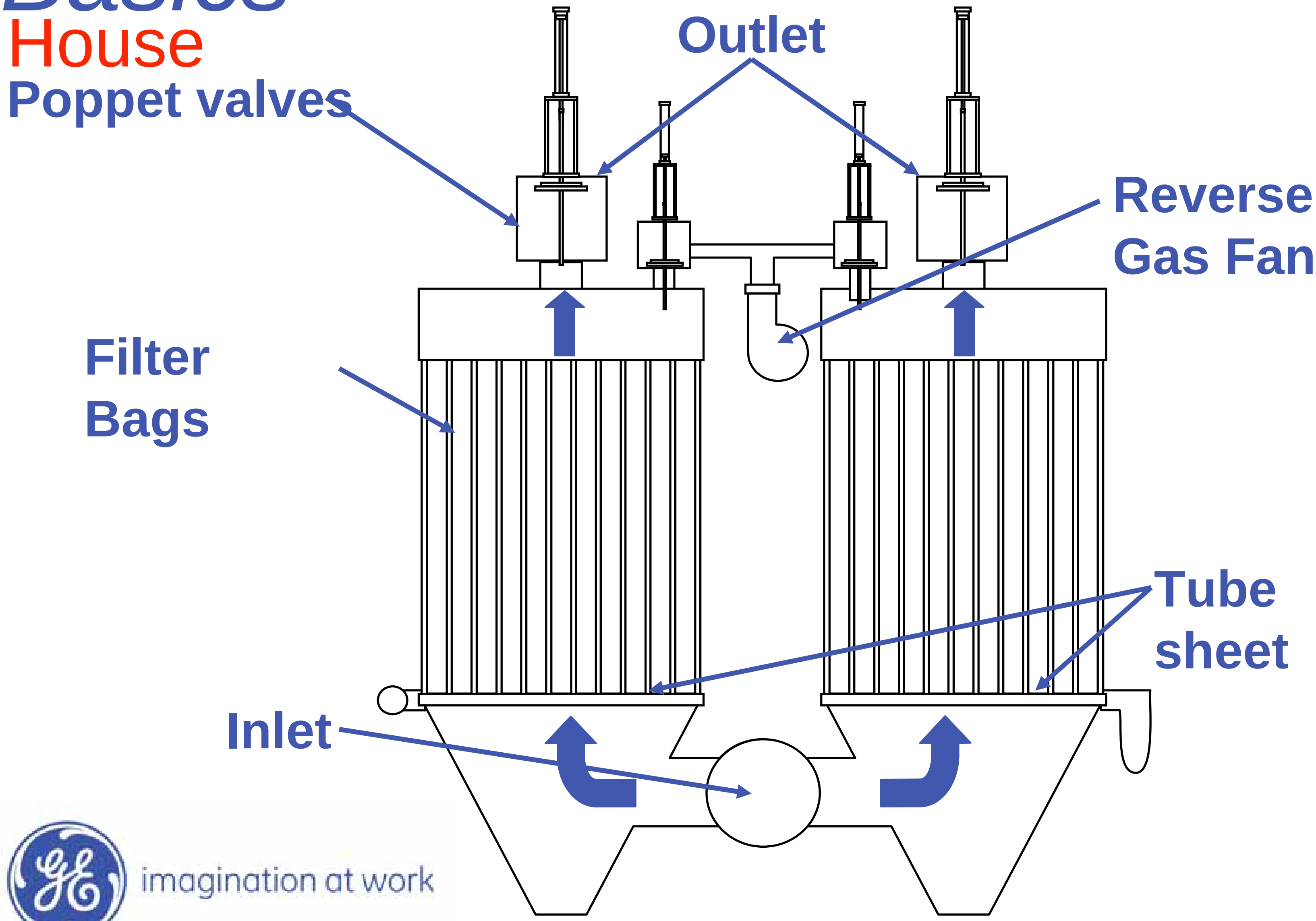
Bag House Basics

Reverse Gas Bag House



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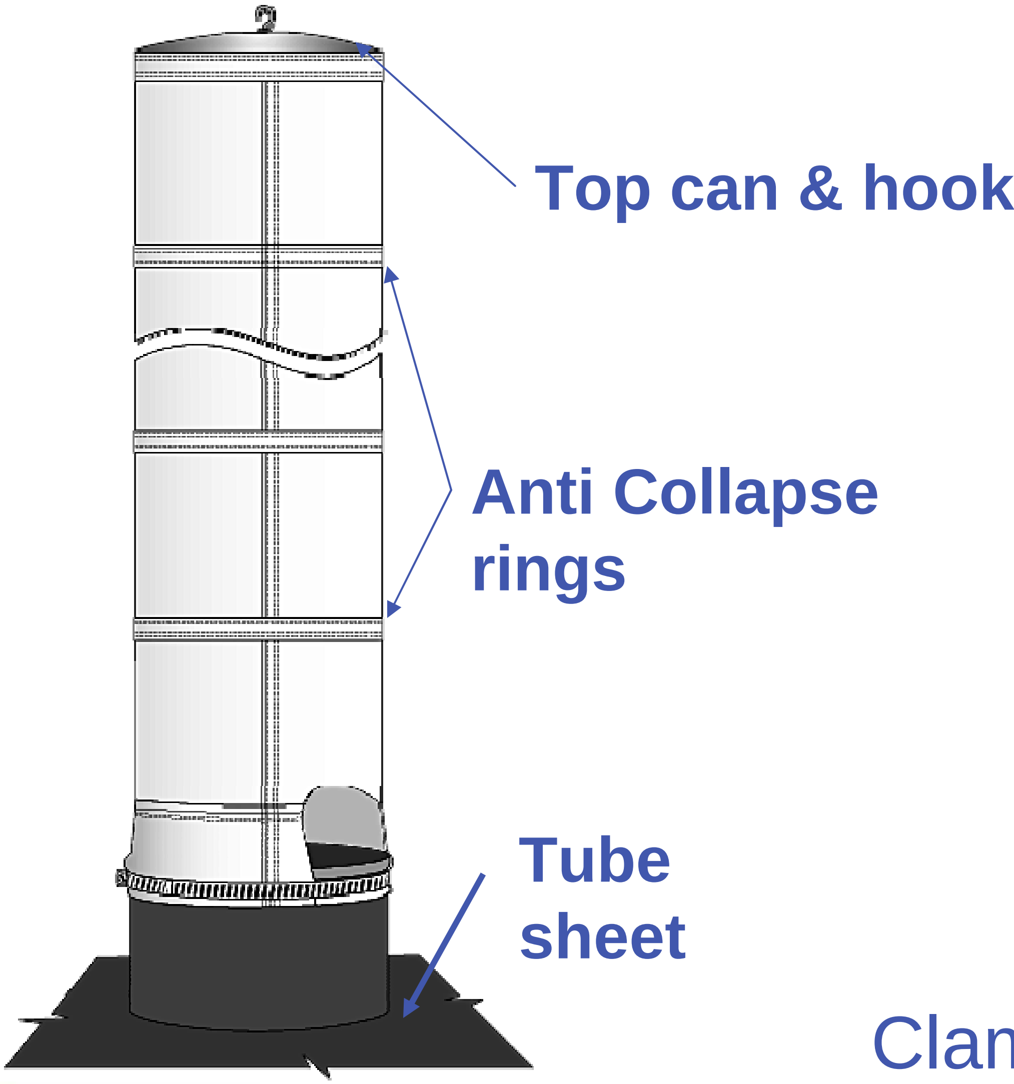
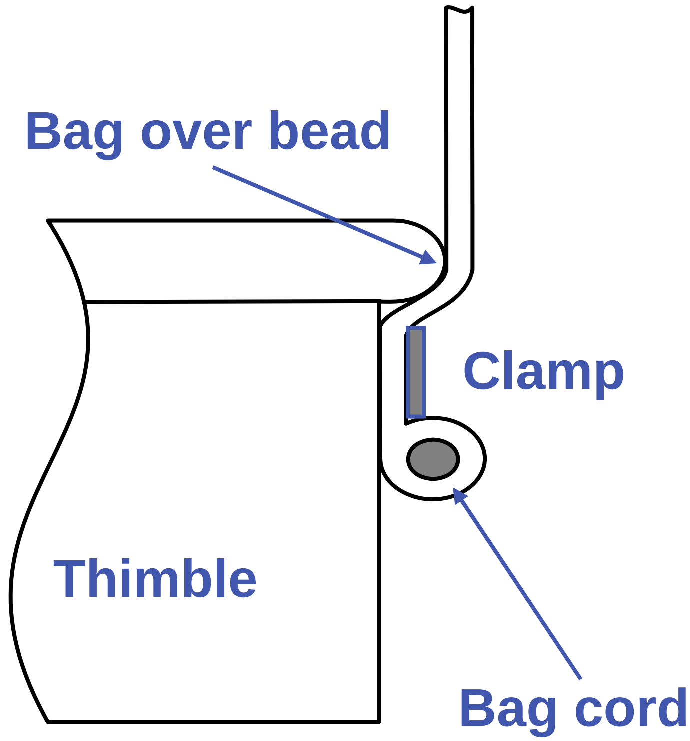
Bag House Basics

Typical reverse gas filter bag





Clamp-to-Bag Assembly

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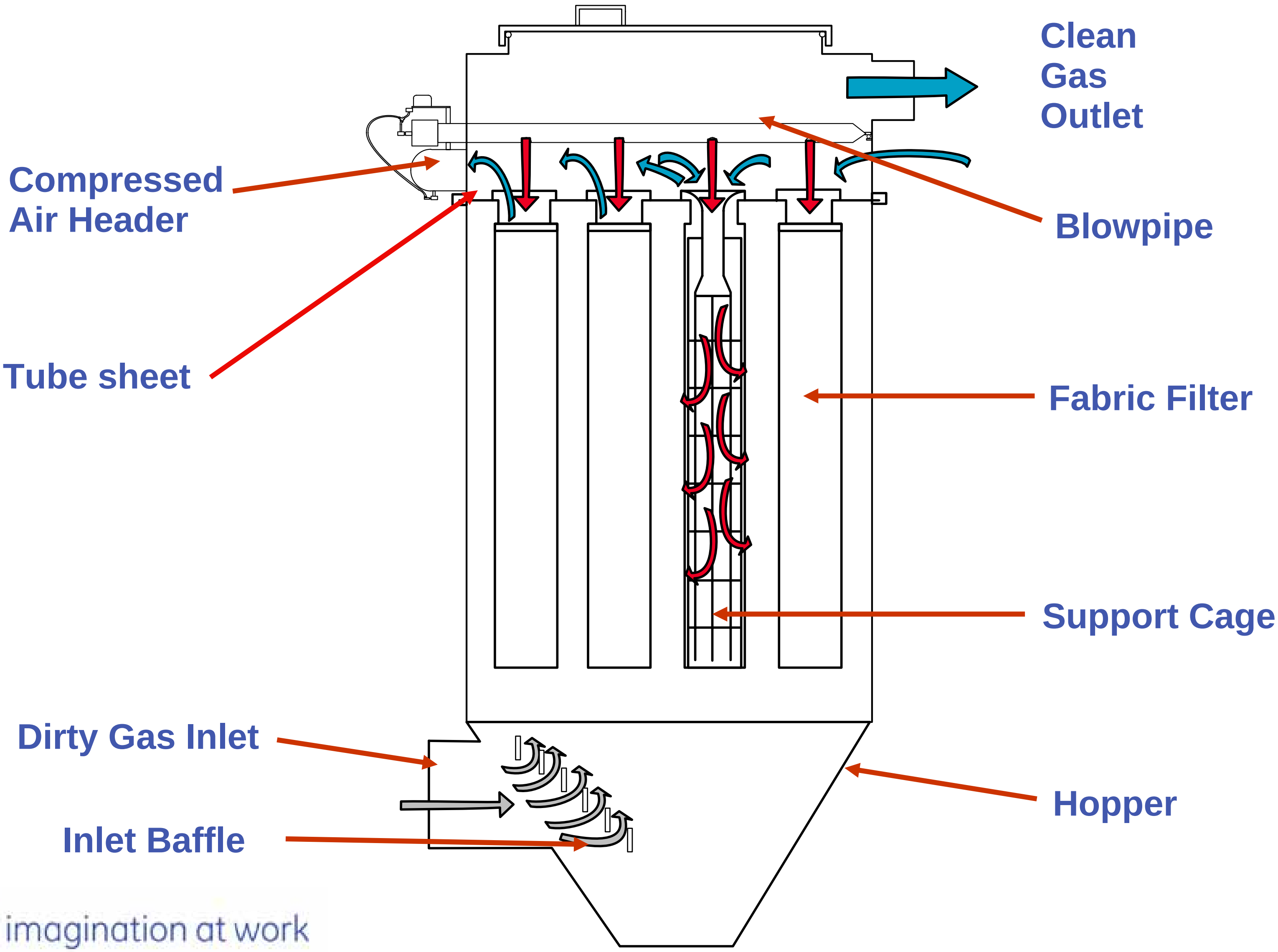
Bag House Basics

- Filter bags extend upward from the tube sheet.
- Dirty gas enters from the bottom of the tube sheet.
- Particulate is collected on the inside of the filter bag.
- Multiple compartments are used in a reverse gas design.
- Pressure drop is reduced by “reversing” flow of clean gas through the filter bag.
- “Rings” sewn into bag prevent collapse during cleaning.
- When cleaning occurs, the compartment is taken off-line.
- After cleaning is completed, the compartment is brought back on-line.

Bag House Basics

- Reverse Gas bag houses provide excellent bag life.
- Pressure losses are sensitive to the compartment cleaning cycle.
- Proper installation and tensioning are critical to bag life.
- Due to the low air to cloth ratio, foot print is nearly double that of a pulse jet.
- As a result, the capitol cost of the unit is high compared to pulse jet technology.

Bag House Basics
Pulse Jet Bag House



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Bag House Basics

- In a pulse jet bag house, filter bags extend downward from the tube sheet.
- Dirty gas flows from outside to inside of the filter bag.
- Particulate collects on the outside of the filter bag.
- A cage is required to prevent filter bag from collapsing during normal operation.

Bag House Basics

- When pressure losses in the bag house reach upper limit or timer elapses, a cleaning cycle is initiated.
- Blasts of air from a compressor or high pressure blower are introduced into the clean gas side of the filter bags.
- The air flow dislodges dust accumulated on the outside of the filter bag.
- In a pulse jet, cleaning normally occurs while the compartment is on-line.

Bag House Basics

- Pulse jet technology is being applied in most new coal fired boilers.
- Pressure losses can be controlled to acceptable limits.
- Compressed air pulse cleaning is efficient.
- When mounted externally, solenoids and diaphragms can be maintained while on-line.
- Total life cycle cost is generally lower for a pulse jet compared to a reverse gas bag house.

Bag House Basics

Design Considerations

Bag House Basics

- Selecting the correct filter media is critical to effective operation of the bag house.
- Filter media selection is a function of:
  - Gas chemistry
  - Gas temperature
  - Dust characteristics
  - Type of cleaning
- The filter media properties play a major role in bag life, removal efficiency, and pressure drop.

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Bag House Basics Filter Media Selection

Oper. Vari.	Polyester	Acrylic	Fiberglass	Aramid	PPS	P84
Max. Oper. Temperature	275°F (134°C)	265°F (130°C)	500°F (259°C)	400°F (204°C)	375°F (190°C)	500°F (259°C)
Abrasion	Excellent	Good	Fair	Excellent	Good	Fair
Filtration Properties	Excellent	Good	Fair	Excellent	Very Good	Excellent
Moist Heat	Poor	Excellent	Excellent	Good	Excellent	Good
Alkalines	Fair	Fair	Fair	Good	Excellent	Fair
Mineral Acids	Fair	Good	Poor**	Fair	Excellent	Good
Oxygen(15%+)	Excellent	Excellent	Excellent	Excellent	Poor	Excellent
Relative Cost	X	XX	XXX	XXXX	XXXXXX	XXXXXXX

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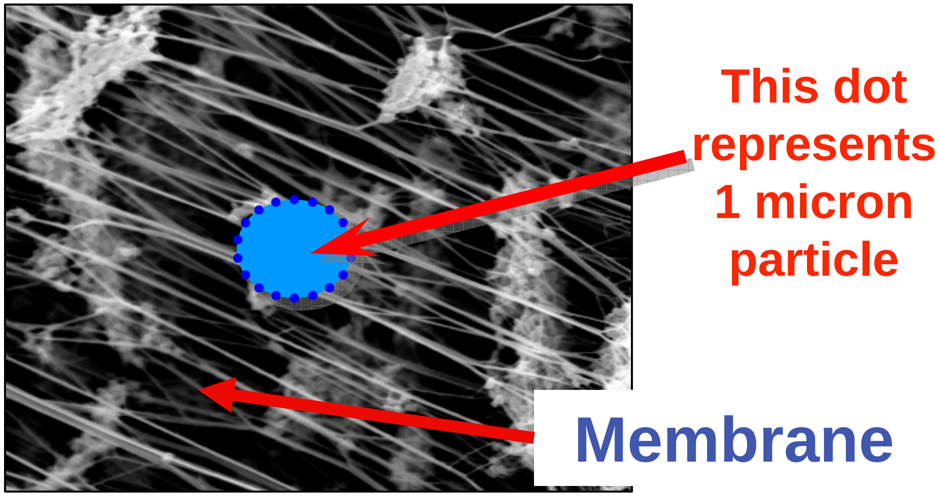
Bag House Basics

High Efficiency and Fine Particulate

- When the required emission level is very low or the incoming particulate is fine, a membrane lamination can be applied to the conventional filter media.
- The membrane is an expanded Teflon barrier containing millions of sub micron pores.



When the membrane is applied, dust particles are collected on the surface of the media, not in it.

Bag House Basics

Air-to-Cloth Ratio calculations

Air to cloth ratio defines the area of filter media available to treat a volume of gas.

Air-to-cloth ratio = Gas volume / total filter area

(Filter dia. X length x 3.14) = filter area

Total # filters x filter area = total filter area

Although typically referenced as a dimensionless value, the units for air to cloth ratio are:

feet/min or meters/min

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Bag House Basics

Air-to-Cloth ratio (filter rate)

Type of Filter Cleaning System	Maximum Recommended Air-to-Cloth Ratio	
	Imperial	Metric
Shaker	**3.0**	**0.91**
Reverse Air	**2.5**	**0.76**
Pulse-Jet:		
A. Cylindrical Filter Bags	**4.0**	**1.22**
B. Pleated Filters (Non-Paper Media)	**3.5**	**1.07**
C. Pleated Filters (Paper Media)	**2.0**	**0.67**

The air to cloth ratio defines the size of the collector and the minimum pressure loss.

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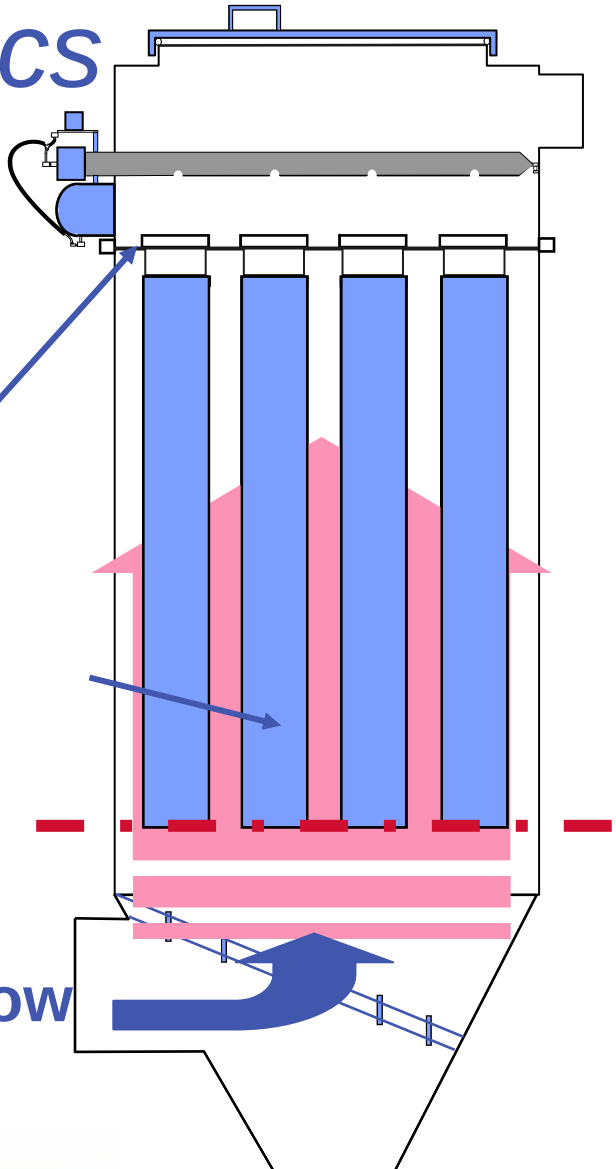
Bag House Basics



Can velocity

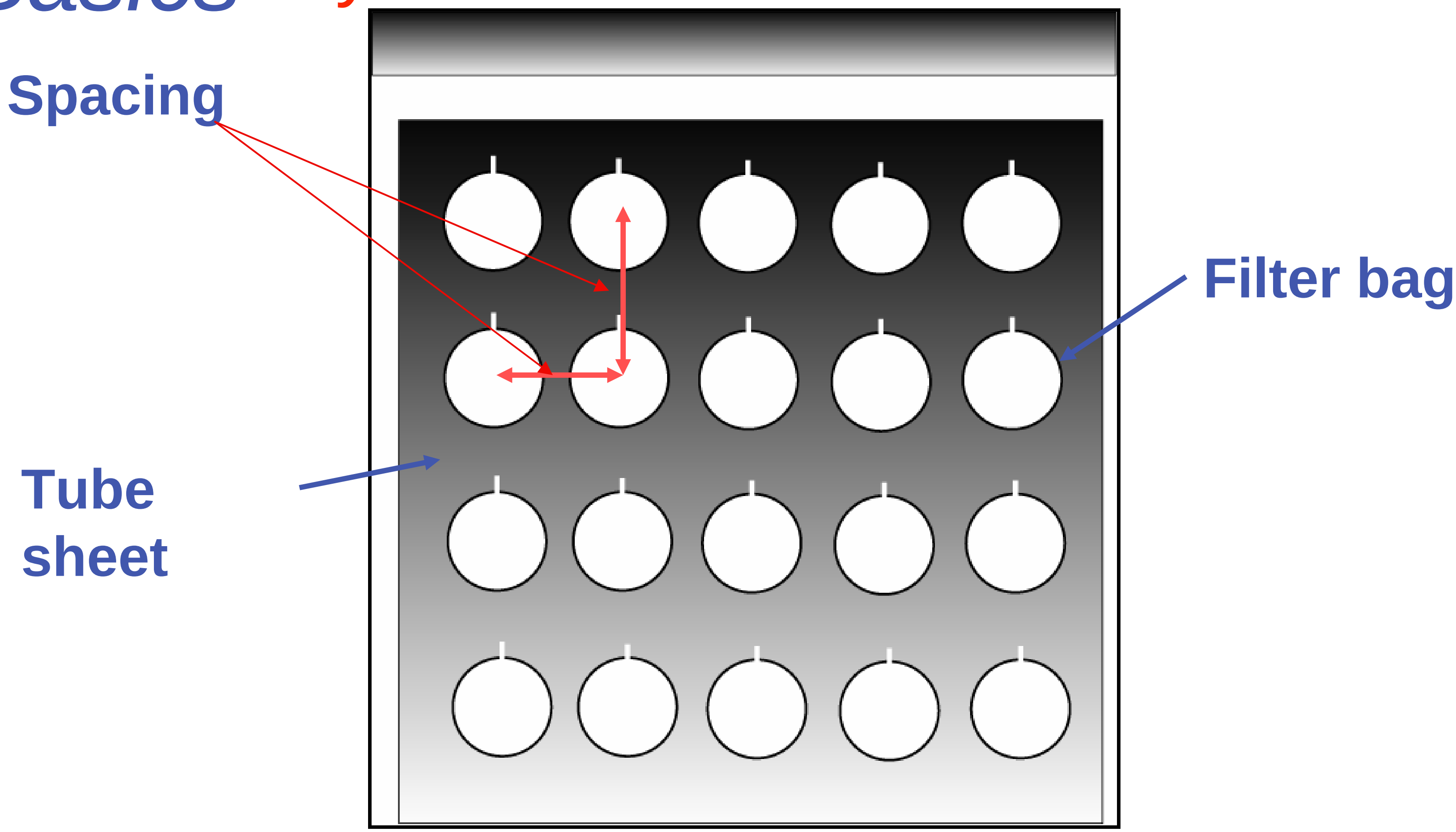
Can Velocity is the upward gas velocity passing between the filters.

Calculated in the horizontal cross-sectional plane of the collector housing at the bottom of the filters.

Can velocity should reflect particle size & density as well as bag house air to cloth ratio.

Bag House Basics

Can velocity



Center to center distance of filter bags defines can velocity

Bag House Basics

Can Velocity is equal to:

$$\frac{\text{Gas volume}}{((\text{Casing width} \times \text{length}) - (\#\ \text{Bags} * (D^2 * \pi)/4))}$$

- A typical design value for can velocity is 300 ft/min (91 m/min) or less.
- Low density or fine dust will require lower can velocity.

Bag House Basics

Maintenance Considerations

Bag House Basics
Maintenance Considerations

- A properly designed pulse jet fabric filter is a very reliable device.
- Maintenance can generally be planned based on observation of trends.
- Multiple compartments provide ability to “isolate” problems and perform maintenance online.

Bag House Basics

Maintenance Considerations

Typical fabric filter maintenance problems:

- Bag Abrasion – Excessive emissions and shortened bag life.
- Tube sheet leakage – Excessive emissions and shortened bag life.
- Over Cleaning – Shortened bag life, elevated operating costs
- Temperature Excursion – Shortened bag life.
- Blinding of filter bags – Excessive pressure drop, shortened bag life
- Chemical attack – Shortened bag life
- Hydrocarbons deposits – Excessive pressure drop and shortened bag life.

Bag House Basics
Maintenance Considerations

To control bag abrasion:

- Utilize a reasonable can velocity based on cleaning method and dust characteristics.
- Avoid introduction of gas directly onto surface of filter bags.
- Review alignment of filter bags, especially where multiple piece cages are used.
- Avoid over filled hoppers.
- Verify proper alignment of blow pipe relative to bag throat.

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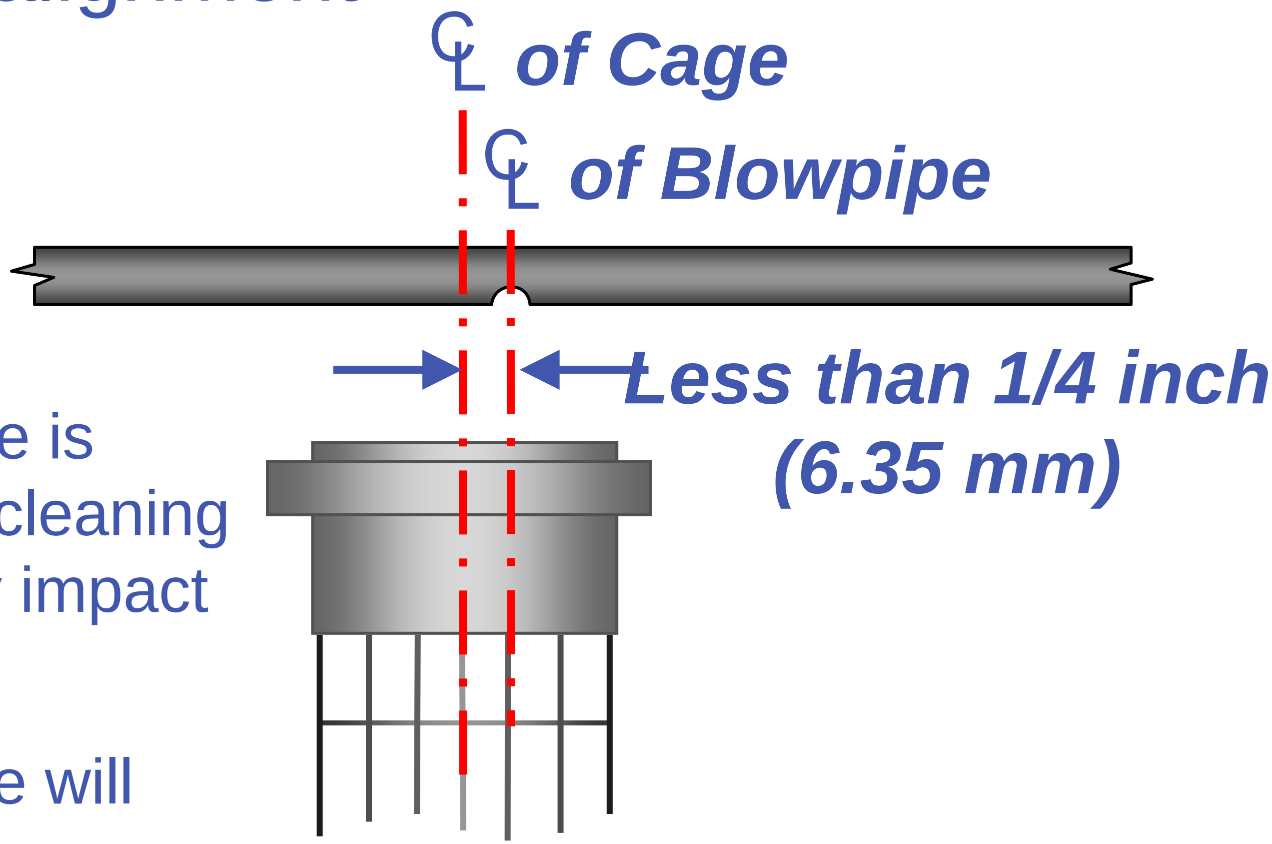
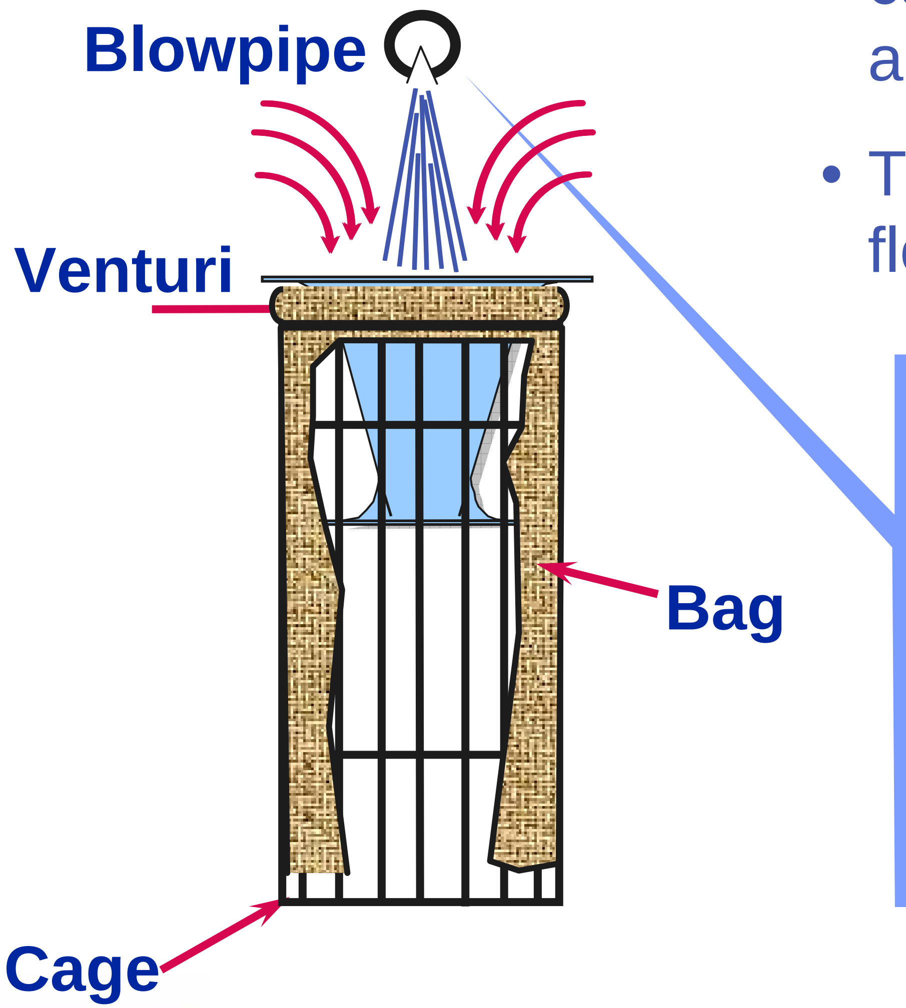
Bag House Basics

Blowpipe Misalignment

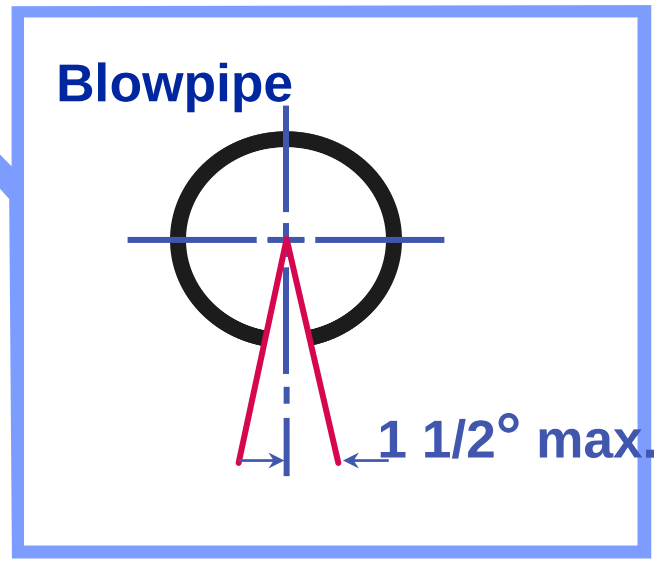


- When a blow pipe is mis-aligned, the cleaning pulse will directly impact the filter bag.
- Eventaully, a hole will wear in the bag.

Bag House Basics



- The potential for abrasion can be minimized by using a cage with venturi.
- The venturi will induce flow and protect filter bag.



Bag House Basics

Maintenance Considerations

To control leakage from dirty to clean side:

- Utilize a proven tube sheet seal arrangement integrated into cuff of filter bag.
- Utilize VisoLite or equivalent to check for leaks after installation.
- Verify filter bag fabrication quality control systems.
- Ensure tube sheet is seal welded to the casing.
- Replace damaged filter bags immediately upon increased emission indication.

Bag House Basics
Maintenance Considerations
Area of leakage

VisoLite indicates areas of leakage in filter bag and casing seals.

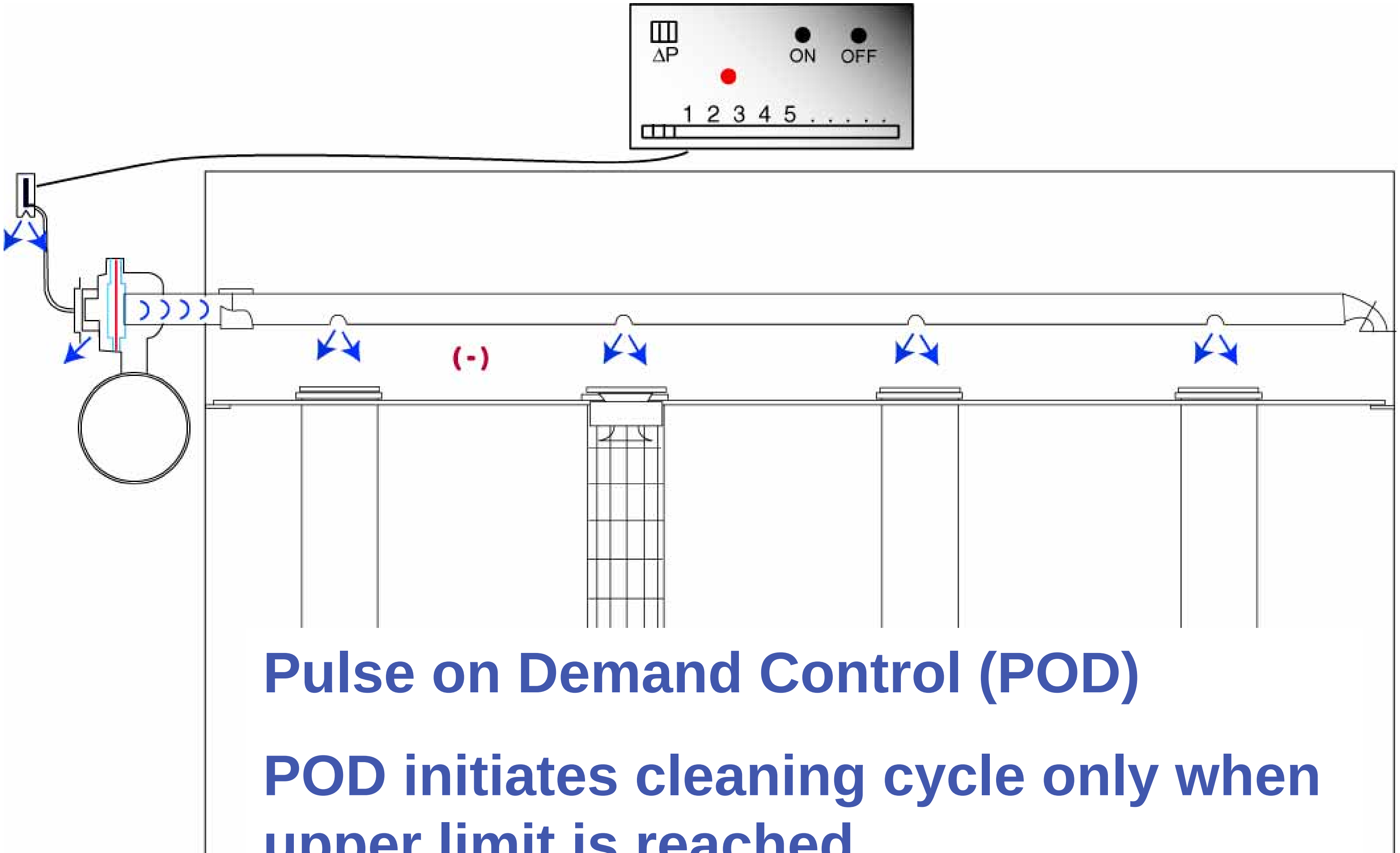
Bag House Basics
Maintenance Considerations

To control “over” cleaning:

- Ensure cleaning air supply is sufficient to provide adequate flow and pressure.
- Cleaning air supply should be clean and dry.
- Minimize fines reaching filter bags.
- Keep air to cloth ratio at acceptable levels.
- Keep can velocity at acceptable levels.
- Avoid condensation in bag house.
- Minimize hydro carbon introduction to bag house.
- Utilize pressure limits to initiate cleaning.

Bag House Basics

Maintenance Considerations



Pulse on Demand Control (POD)

POD initiates cleaning cycle only when upper limit is reached.

Bag House Basics
Maintenance Considerations

To control blinding temperature excursions:

- Define filter media on the basis of the expected range of operating temperatures.
- Monitor inlet gas temperature continuously.
- Utilize dilution air damper to modify inlet temperature.
- Avoid build up of high carbon content material in hoppers.
- Limit hopper “wattage” density on heaters.
- Minimize in-leakage in hopper doors, ports, and evacuation connections.

Bag House Basics

Impact of Oxygen Level & Temperature on Bag Life		
Data Based on PPS Material		
Gas Temperature	Oxygen, %	Service Life
400°F (204°C)	0 to 10%	>24 months
	11 to 15%	12 months
	16 to 20	9 months
>375°F (190°C)	<20%	>24 months
	>20%	>12 months
<350°F (176°C)	<20%	>24 months
	>20%	>18 months

Bag House Basics

Maintenance Considerations

To control blinding of the filter bags:

- Minimize introduction of dust with narrow particle size range.
- Avoid fine dust build up in fabric.
- Define a “start up” compartment to avoid hydrocarbon build up in all compartments.
- Address tube leaks quickly.
- Pre-condition the filter bags prior to start up.

Bag House Basics
Maintenance Considerations

To control chemical attack:

- Select fabric based on gas composition.
- Minimize excess air and in-leakage into gas stream.
- Minimize start up and shut down cycles.
- Keep operating temperature above acid dew point.
- Ensure pulse cleaning air is dry.
- Pre-condition the filter bags prior to start up.

Bag House Basics

Maintenance Considerations

To control hydrocarbons:

- Minimize start up cycles.
- Utilize natural gas for start up if possible.
- Pre-condition filter bags prior to start up.
- Assign one or more compartment as a "sacrificial" start up compartment.
- Avoid alternative fuels which could contribute to hydrocarbon levels.

Bag House Basics

Summary

- Properly designed, a fabric filter will provide continuous compliance within emission limits.
- Changes in dust burden or gas volume do not result in emission fluctuations.
- Start up can generally occur at dispatch rates without opacity spike concerns.
- Maintenance including bag changes can be accomplished on-line.
- The cost of bag changes is a major component of total cost of ownership.
- Maintaining gas temperature within media limits is critical.