Mercury and MACT Emissions Reductions via Total PM Control

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Presentation that introduces Flash Drying and present the approach to mercury control using that system.

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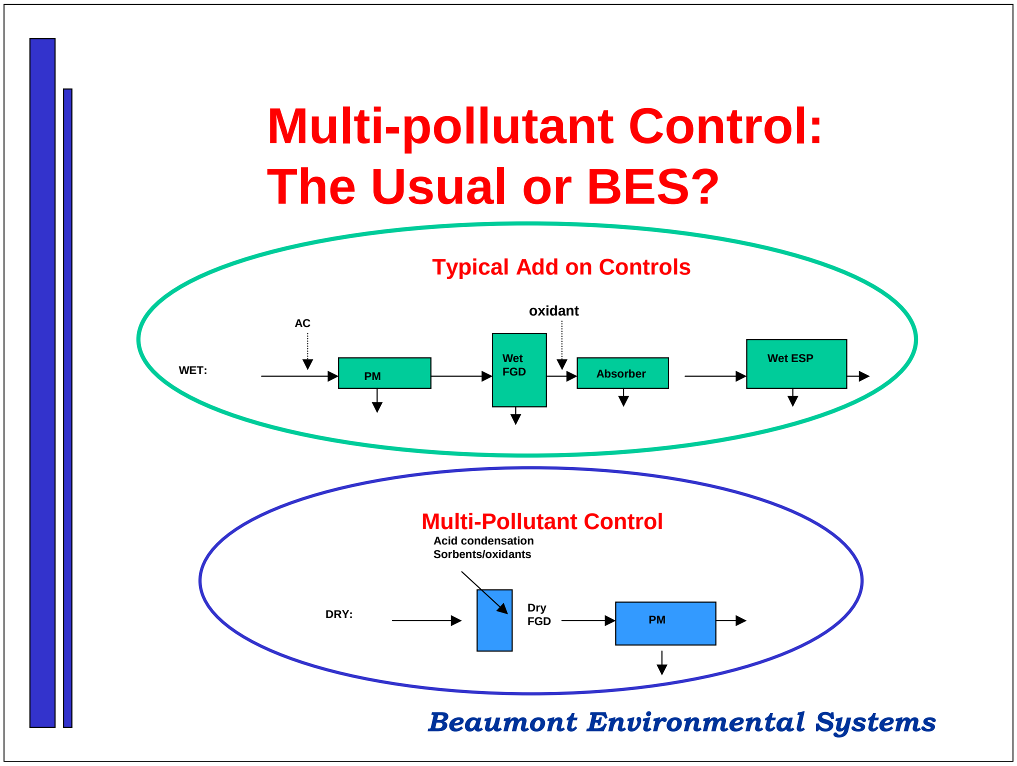

The chart has been prepared to demonstrate the typical control sequence currently used for Utility Boilers into compliance. Operating costs will run high due to the power requirements, cost of activated carbon, manpower to operate as well as the cost for conventional sorbents

The lower diagram shows a system utilizing gas conditioning, flash dryer and fabric filter.

Capital cost of this approach will be 20 to 30% of the current conventional approach.

Multi-Pollutant Control

- Traditional Approach
  - **SCR/ESP/FGD**
  - **Total PM (H2SO4) still a liability**
  - **Alkalinity “freezes” mercury capture**
  - **Mercury “re-emission” with wet FGD**
- RJM Approach
  - **Flash Drying (SO2 Control)**
  - **Gas Cooling/Conditioning before PM Control**
  - **Larger particles; mercury mostly oxidized**
  - **SCR and SO2 oxidation beneficial**
  - **Can be upgraded to semi-dry FGD or used upstream of wet FGD to boost overall mercury capture and eliminate need for wet ESP**
  - **Baghouse preferred for lowest MACT emissions**
  - **Electro-Pulse reduces emissions and increases bag life**

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From the previous chart we can compare the RJM – Beaumont approach to the older single pollutant approach.

The control of boilers has expanded over the years to include SO2, NOx, Mercury, H2SO4 and other Air Toxics in addition to closer attention to particulate. In addition the required removal efficiency of the pollutants has been rising, making it important to select control equipment that can be expanded or improved to accommodate future requirements.

Mercury and particulate control has become of more importance as part of the Multi-Pollutant control system.

Beaumont Environmental Systems offers a true multi-pollutant system using a flash dryer combined with a pulse type filter.and inlet gas conditioning.

Technology Summary

Mercury / Metals Controls

- Most cost-effective approach
  - **Improvement of PM control**
- Bituminous coal applications
  - **Gas cooling and Conditioning**
- Subbituminous and lignite coals
  - **staged acid addition cooling and conditioning**
  - **added sorbent for mercury polishing**
    - **oxidant preferred over activated carbon**
- Baghouse is preferred PM control
  - **Electropulse enhancement available for MACT reductions**

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The RAP/DAP approach is a cost effective approach to boiler control.

Using different conditioning methods, we can control both mercury and metals in the RAP/DAP approach. This is accomplished by the gaseous discharge to particulate.

Adding the fabric filter for final particulate control lets us meet most emission requirements.

Importance of Cooling and Conditioning Stage

(Patent Pending)

- Gas Conditioning
  - **Turbulence increases gas-solid interface and sorption rates**
  - **Additives increase acid sites for mercury oxidation/binding and particle agglomeration**
- Gas Cooling
  - **Increases agglomeration of ultrafine particles**
  - **Increases adsorption of H2SO4 to fly ash**
  - **Hydrates alkaline oxides and salts**
  - **Creates acid layer below acid dew point**
  - **Oxidizes mercury vapor**
- Particulate Control Improvement
  - **Lower gas velocities improve PM collection**
  - **Condensable gases become particles; reduces total PM**
  - **Entering ultrafine particles (MACT metals) are larger**

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In using the RAP (Flash Dying)to remove SO_2 we may need to condition the gases prior to the Final Filter.

We may require cooling prior to the introduction of lime for condensing and capture of mercury prior to the introduction of lime. The ability to remove Elemental Mercury captured by the Carbon (LOI) and SO_3 in the flue gas could be retarded by the introduction of lime.

By providing a cooling spray at the bottom of the reactor we can cool condense and agglomerate the particulate and gaseous materials in a treatment zone prior to the venturi section above which the lime and recycle material is added.

After conditioning, converting gaseous to particulate, the use of a fabric filter completes the system.

Application of Staged Cooling and Sorbent Addition

- For bituminous coal applications
  - **Increases mercury oxidation for capture in PM collector and/or wet FGD absorber**
  - **Maximizes condensable capture in PM collector**
  - **Maximizes particle growth**
- For sub-bituminous/lignite coal applications
  - **Allows increased number and longevity of acid sites for mercury oxidation and capture**
  - **Oxidant in sorbent can further boost NOx and mercury capture**

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The only time we want to stage cooling with lime addition is where LOI is low, and acids are present, i.e. with PC-fired bituminous coal.

Mercury capture is always improved by cooling; lime addition "freezes" mercury oxidation by acids but is a stronger bonding site than AC, especially with ESP; therefore lime addition where LOI is high can be implemented with or without cooling with impunity.

With subbituminous/lignite, we cool only if we either add carbon or acids or both, or use oxidants to make acids.

Conditioning Steps

- **Cooling of Gases**
  - **Upstream of the primary dust collector**
  - **Below the sulfuric acid dewpoint**
  - **With acid present**
- **Providing sufficient time and turbulence**
  - **For mercury oxidation**
  - **Binding on the particle surfaces**
- **Alkaline neutralization of acids**
- **Removal of Mercury as Particulate**
  - **In the dust collector**
- **Adding Oxidized Sorbent**
  - **Into the Fabric Filter**
  - **As Polishing Step**

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The conditioning steps employed are listed above in the order they take place in a RAP system with conditioning.

We can also use recycle with acid addition where SO2 removal is not required and we are dealing with very little ash available and very little SO2 present.

Mercury Control for PRB Coal

- **Gas Cooling must be supplemented with acid addition upstream of PM Collector**
- **For mercury reductions of >50% the primary collector must be a fabric filter**
- **For mercury reductions of>90% an oxidant-enhanced lime sorbent is injected between cooling section and baghouse**
- **Electropulse fabric filter will also improve mercury and fine PM collection**

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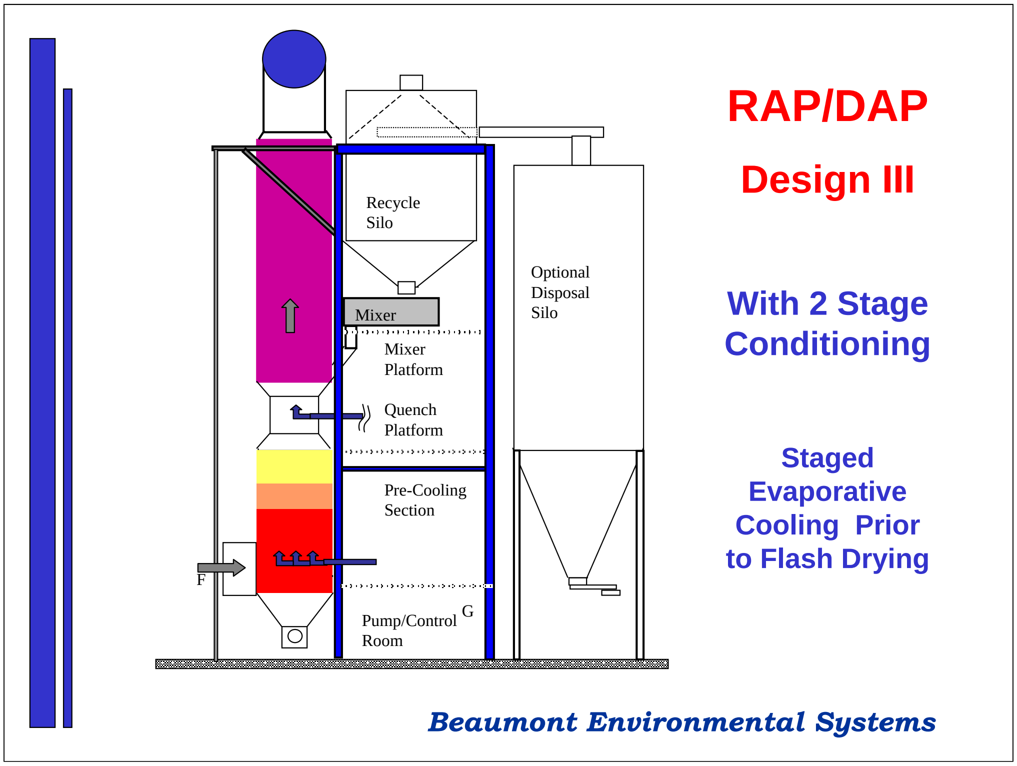
PRB coal is harder to control. The elemental mercury must be oxidized or absorbed prior to the final particulate collector. This is accomplished in the gas conditioning section of the RAP

A fabric filter is the best selection for particulate control. It will capture fine particulate and allow for building a cake on the fabric.

Sorbent addition such as an oxidized lime will form the cake and provide mercury polishing.



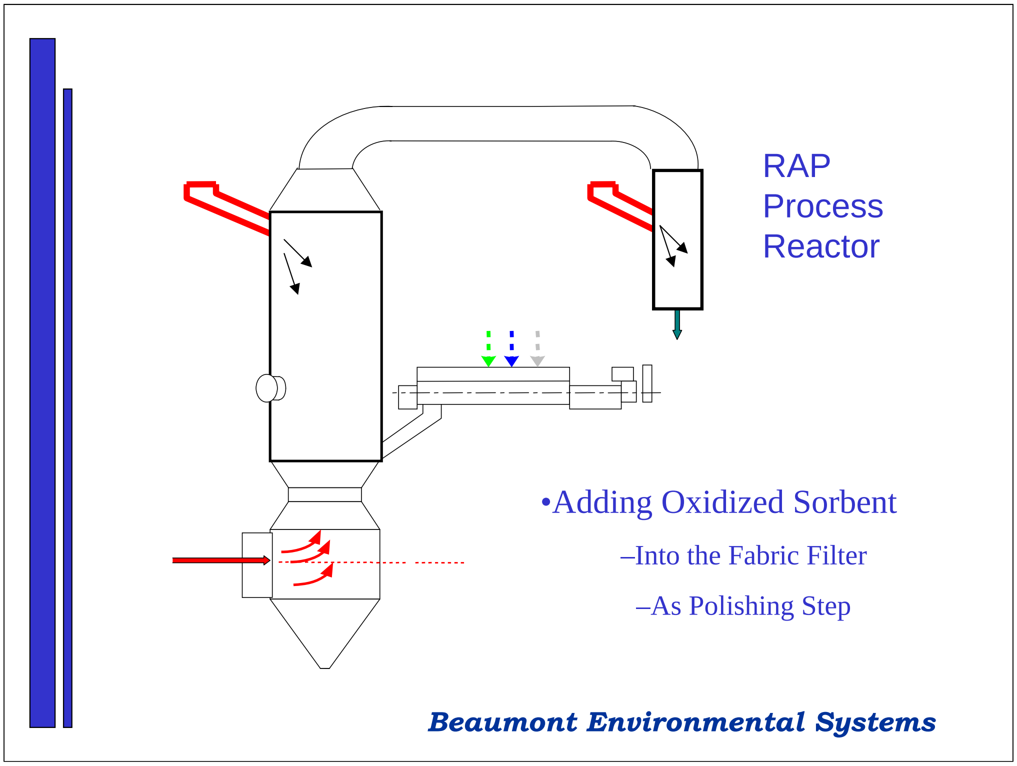
This RAP, Flash Drying **Control system replaces the older** series of controls, where each pollutant has it's own "box" where it is removed.

To enhance Mercury control with bituminous coals we can pre-condition the incoming flue gas and ash. We attempt to overcome the lack of acid (SO3) in the flue gas of lower-sulfur fuels for elemental mercury removal. Added acid can be absorbed on ash acts as a landing zone for elemental Mercury.

By combining **gas conditioning** (patent pending) in the reactor along with **Flash Drying** (patented) for SO_2 removal; we control most boiler flue gas contaminates. In most cases the NOx will be controlled at the boiler.

After cooling some of the **Acid gases will become solid particles** that can then be collected in the Final Filter.

The need to capture multi-pollutants and do it economically is accomplished by identifying the various pollutants; understanding their physical characteristics and understanding how the pollutants react under varying conditioning methods



In some cases we may require adding a sorbent to the baghouse to polish the mercury removal by the RAP Flash Dryer.

We do not anticipate needing the addition of a dry sorbent for mercury polishing except for removal rates above 90% for sub-bituminous coals.

Dry Sorbent may be added at top of the Reactor after Flash Drying has taken place or in the reactor down comer to the Fabric Filter.

An Oxidized Lime or Activated Carbon are additives that may be employed. The Oxidized Lime will cost about 40% vs. that of using carbon, is easier to handle and easier to convey to the system.

MACT Particulate Control

- Sub Micron Metallic Fume Cooling
  - **condensation**
  - **agglomeration**
- Conversion of PM - Condensable to Filterable
- Filterable + Condensable PM and MACT Metals Removal Rates:
  - **99.9% with Fabric Filter**
  - **99.99% with Electro-Pulse ™ Filter**

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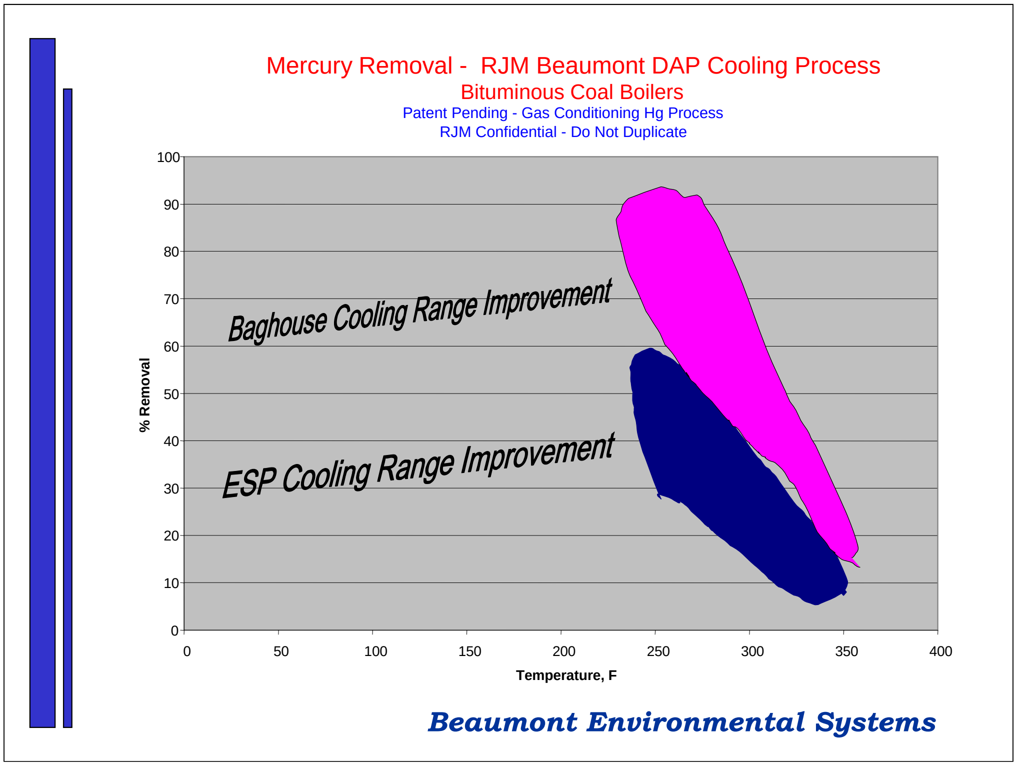
The final filter controls condensable fume. The cooling prior to the final filter becomes quite important in producing a filterable fume.

This is usually a simple cooling plus lime to meet MACT standards.



1. With high LOI ash, HCl and SO2 both drive mercury to oxidized state
2. With high LOI ash, temperature becomes very important (no surprise)
3. When LOI is low, temperature is not as important, but HCl and SO2 remains important..

Also, oxidized and particulate mercury vapor are indistinguishable,
therefore are include together in our discussions.

Here are estimates of mercury oxidation/capture (guarantees) we are looking at for stokers (LOI above 20%) burning bituminous coals (we're assuming both HCl and SO3 are present in the gas prior to lime addition):

ESP with lime injection to freeze reaction and bind mercury:

350F 20% oxidation/particulate x 50% capture or - **10% control**

300F 50% oxidation/particulate x 70% capture or - **35% control**

250F 75% oxidation/particulate x 80% capture or - **60% control**

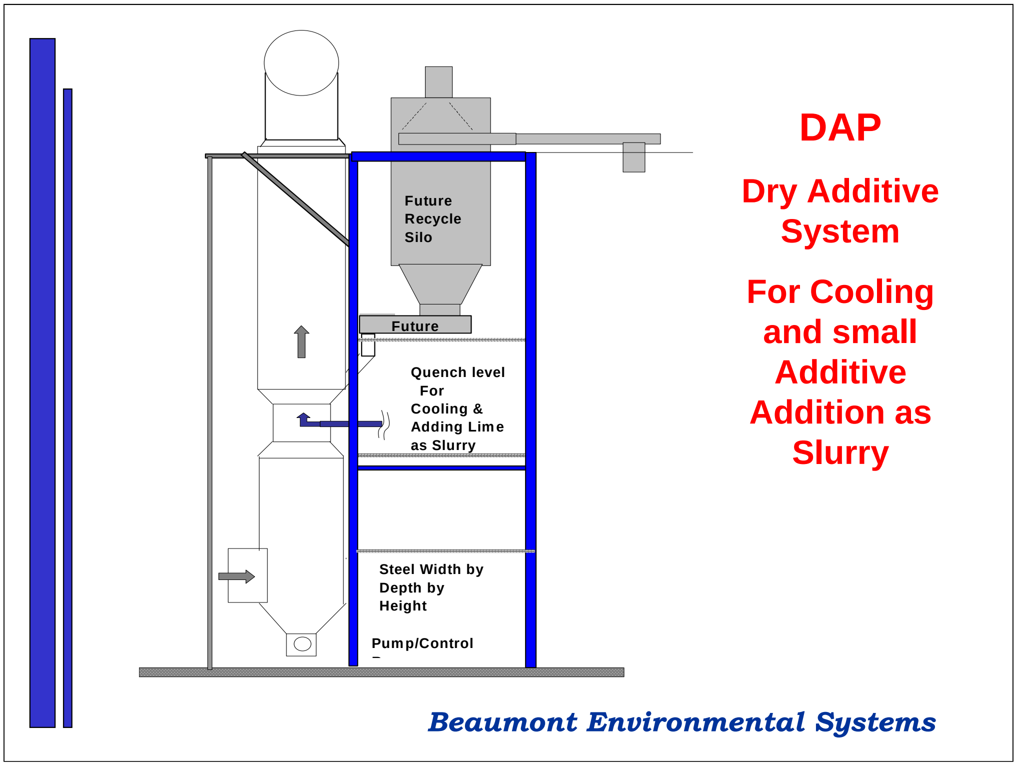
Baghouses with lime injection:

350F 20% oxidation/p x 80% capture or - **15 control**

300F 70% oxidation/p x 95% capture or - **65% control**

250F 91% oxidation/p x 99% capture or - - **90% control**

The capture of oxidized and particulate mercury with baghouse is near 100% below the acid dew point because of all the crystalline water from gypsum.



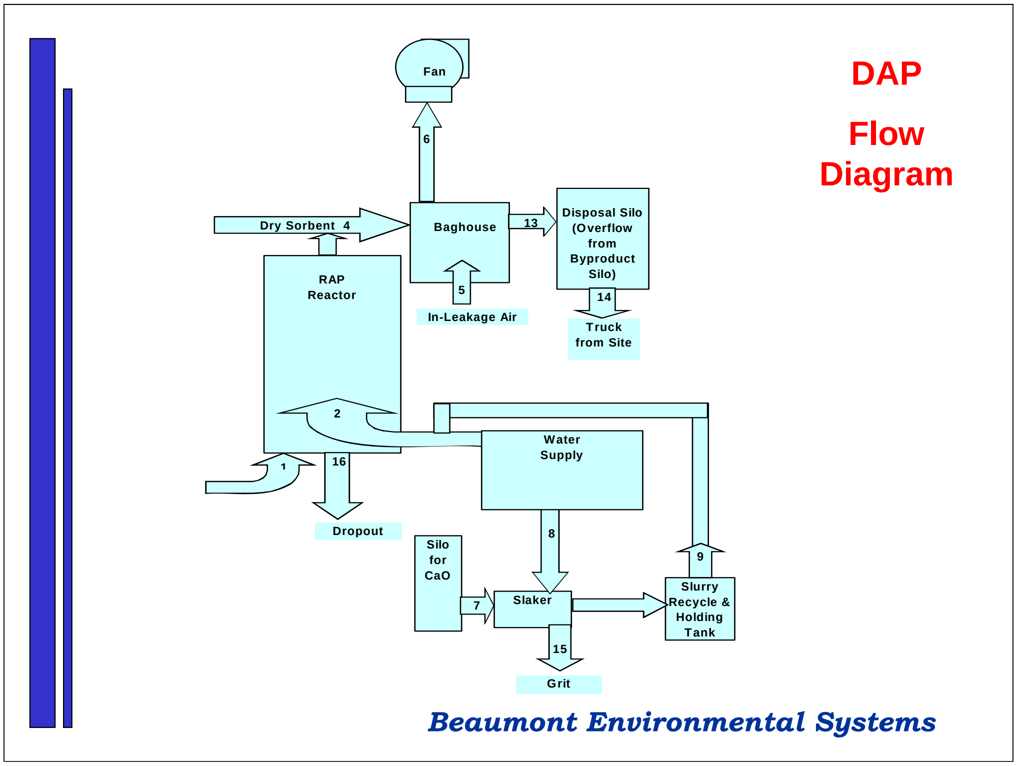
The DAP process uses the RAP flash drying design to provide cooling, conditioning and the addition of a dry sorbent.

Depending on the application the unit can be provided in various configurations.

For Stoker or CFB Boilers where MACT emission level control is the only consideration we could provide cooling only. The second level of control would be the addition of a sorbent to stabilize mercury removal.

Adding a small amount of lime slurry can be included in the cooling water in the lower conditioning zone.

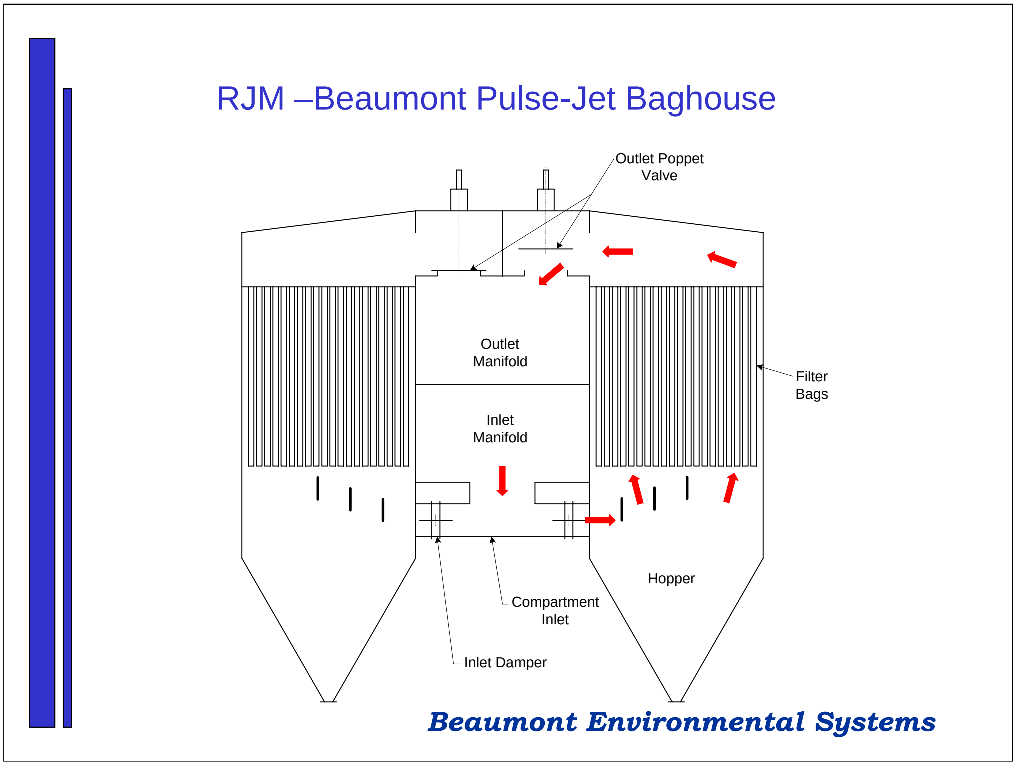
For a dry sorbent it can be best added at the future mixer level or in the down comer to the Fabric Filter.



The DAP flow diagram shown assumes cooling, the ability to add a small amount of $Ca(OH)_2$ at the bottom of the reactor.

In the reactor we are doing some cooling and adding lime for protection of the bags and mercury stabilization.

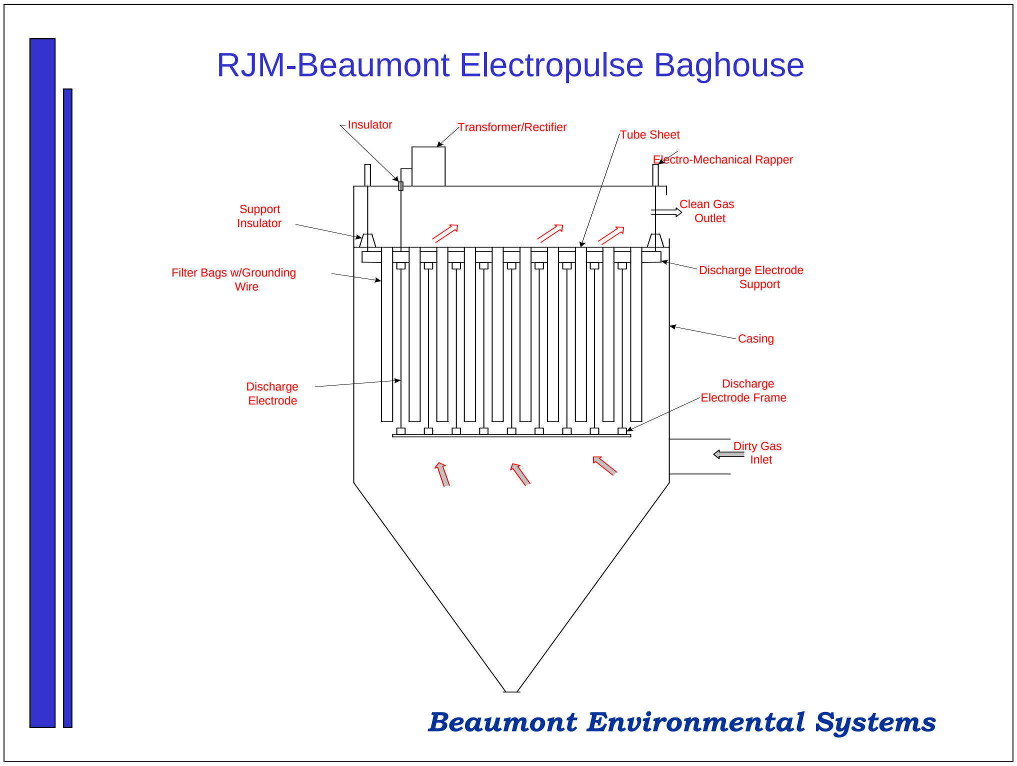
We can alternately add dry lime or an oxidized lime sorbent at point four. These form a cake on the bag surface.



In the RAP Flash Dryer or the DAP (Dry Absorption Process) the efficiency and sorbent utilization requires a high recycle rate that may vary from 40 to 120 grains per ACF. The recycle rate is determined by the amount of liquid added to the reactor through the external mixer**. The more SO_2 removal or cooling required increases the liquid added and the amount of recycle material being added**. The flash drying process works best **where** the feed to the reactor from the mixer is about 90% solids and 10% liquid.

Consequently the fabric filter (Pulse Type) should be designed to accommodate the high recycle rate. We must both build a cake for absorption and efficiently remove that cake to provide the necessary recycle material.

The pre-heater kiln, in cement applications, is the only common application that encounters high grain loading is. Most of these installations used electrostatic precipitators or reverse gas cleaning fabric filters that collect material on the inside of the bags. The grain loading encountered was up to 50 grains per ACF. These devices worked well but were not appropriate for use in flash drying due to their physical size.



In controlling particulate Beaumont can employ an electrostaticly enhanced Pulse type Fabric Filter.

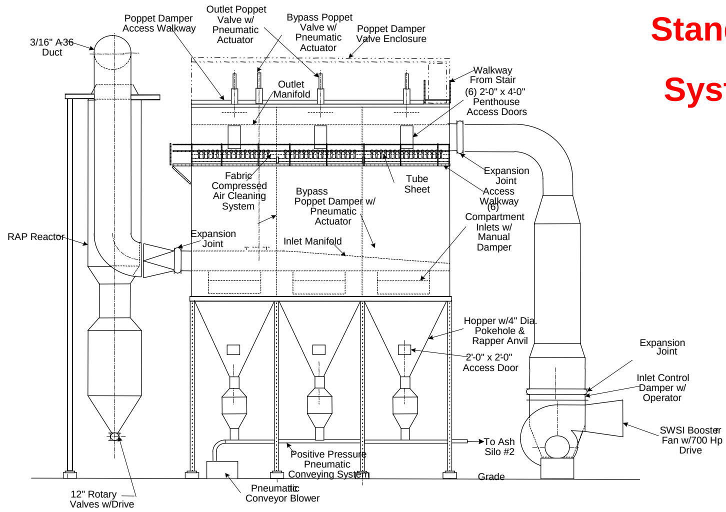
We can take advantage of the wider spacing inherent in the Electro-Pulse to provide lower can velocities and better sorbent operation.

The effort to improve fine-particle control has identified several options, one of the most advanced being Electrostatically Stimulated Fabric Filtration (ELECTRO-PULSE). The ELECTRO-PULSE concept charges particles, suspended in flue gas, with a corona discharge and collects the particles with a fabric filter under the influence of an electric field.

An attractive configuration for ELECTRO-PULSE is a design incorporating an array of discharge electrodes interspersed among the bags of a pulse-jet cleaned fabric filter. This design offers the compact size of pulse-jet cleaning with an improved efficiency.

The assembly of an ELECTRO-PULSE designed for pulse-jet cleaning uses commercially available bags and pulsejet cleaning systems with a high voltage frame and discharge electrodes added to the system.

RJM Standard System



Side Elevation

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A typical RAP or Dap system applied to a boiler.

Pneumatic transfer from the baghouse to the final silo from the DAP is illustrated. In the case of the RAP the material is recycled back to the reactor.