Multi-Pollutant Control Systems & Equipment

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What is **Multi-Pollutant** Control?

- Multi-pollutant Control may be a series of controls, typically practiced in the utility industry, where each pollutant has it's own "box" where it is removed
- With mercury and condensable PM2.5 added, serial control becomes unwieldy
- Our concept is to minimize the number of boxes and discharge points in addressing all regulated pollutants, current and future

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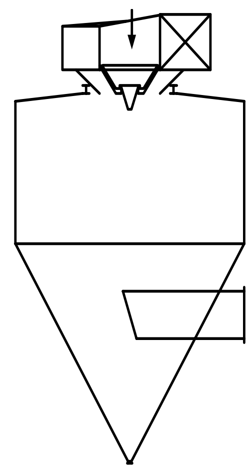
Reducing control devices while dealing with all the regulated pollutants.

Wheel Type Semi-Dry – Scrubber

(rotary atomized – spray slurry systems)



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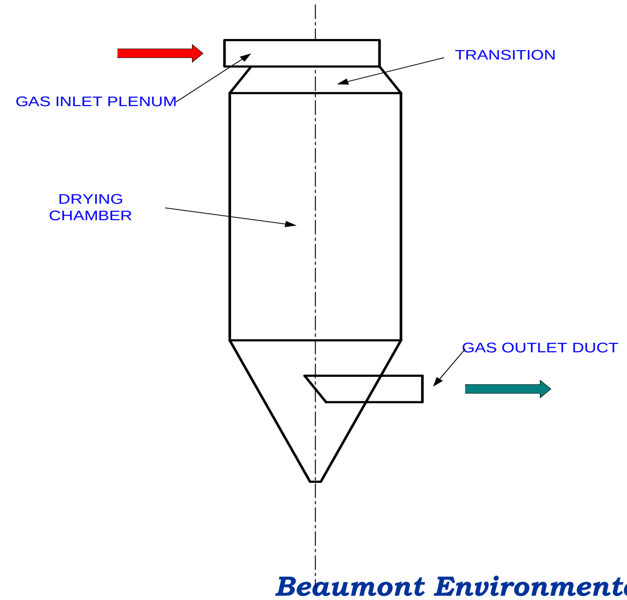
Disk Absorption Process – Older Technology

Rotating Wheel (5000 RPM) on which Slurry is introduced and atomized. Reacts to remove Slurry

Nozzle Type Semi-Dry Scrubber



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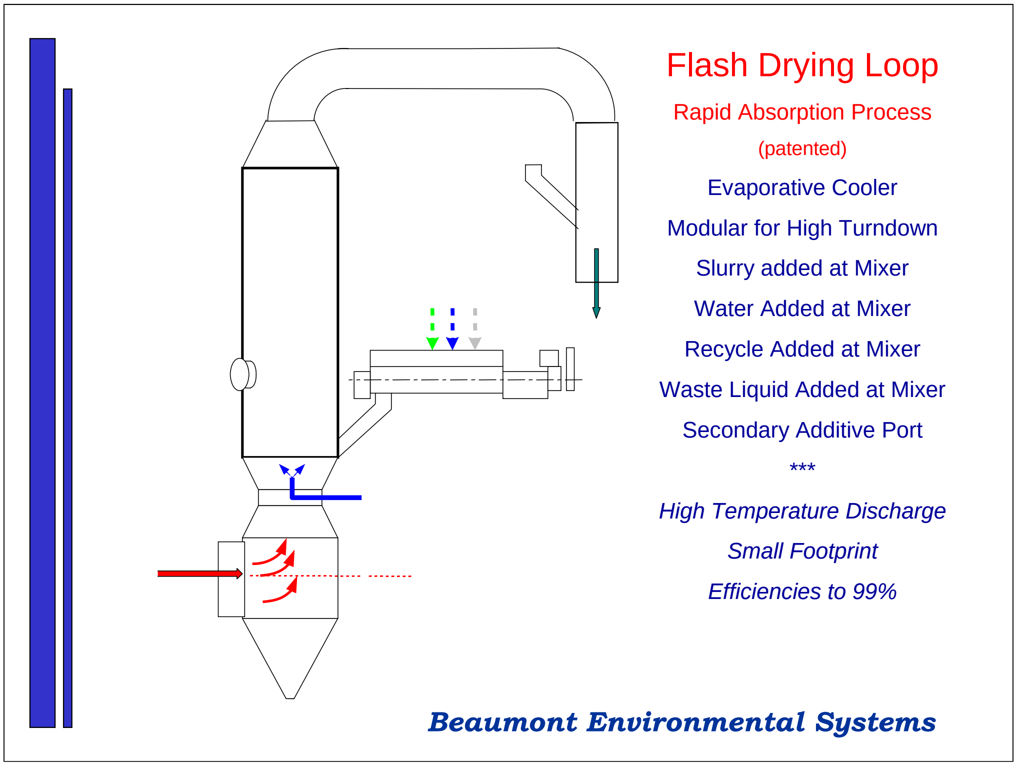
Spray Absorption Process – Second Emerging Technology

Slurry is sprayed into the gas stream to remove SO2



The latest in the evolution of dry/semi-dry systems uses the patented flash drying process.

The above features were added and patented to improve the older reactor type semi-dry system. In addition to the many improvements, the flash drying concept has improves efficiency, utilization of lime and allowed a higher outlet temperature.

What to Control?

- Temperature
- H_2SO_4
- HCl
- SO_3
- SO_2
- NO_x
- Mercury
- Other Toxic Metals (NESHAP)
- Ash
- Fine Particulate

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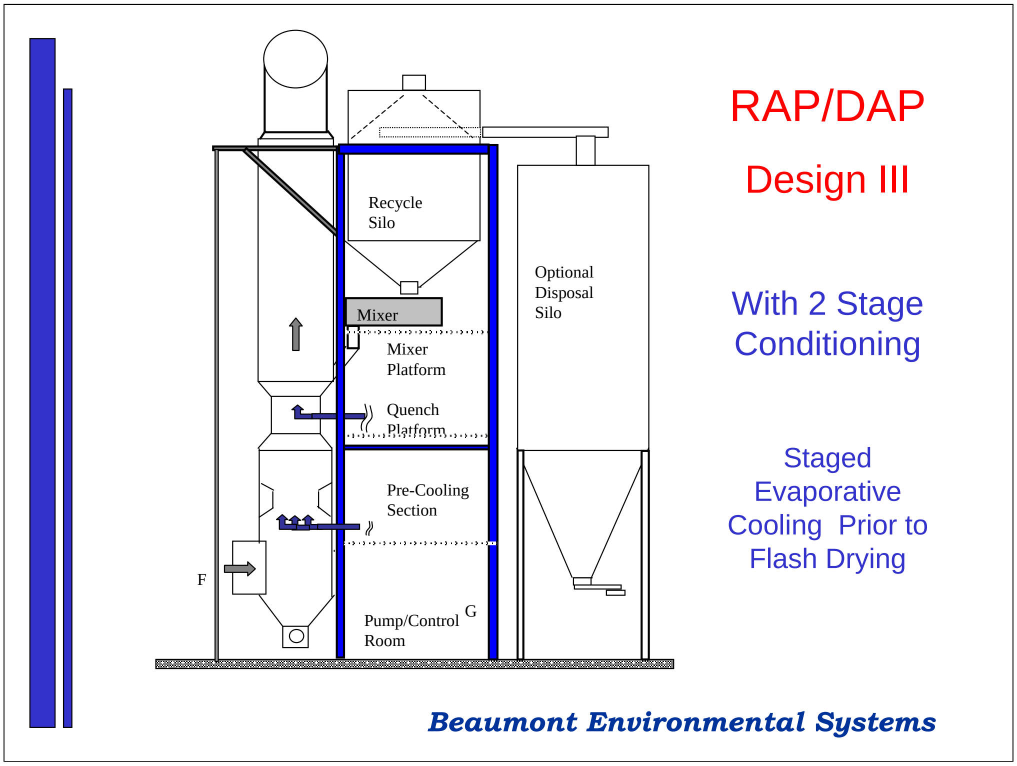
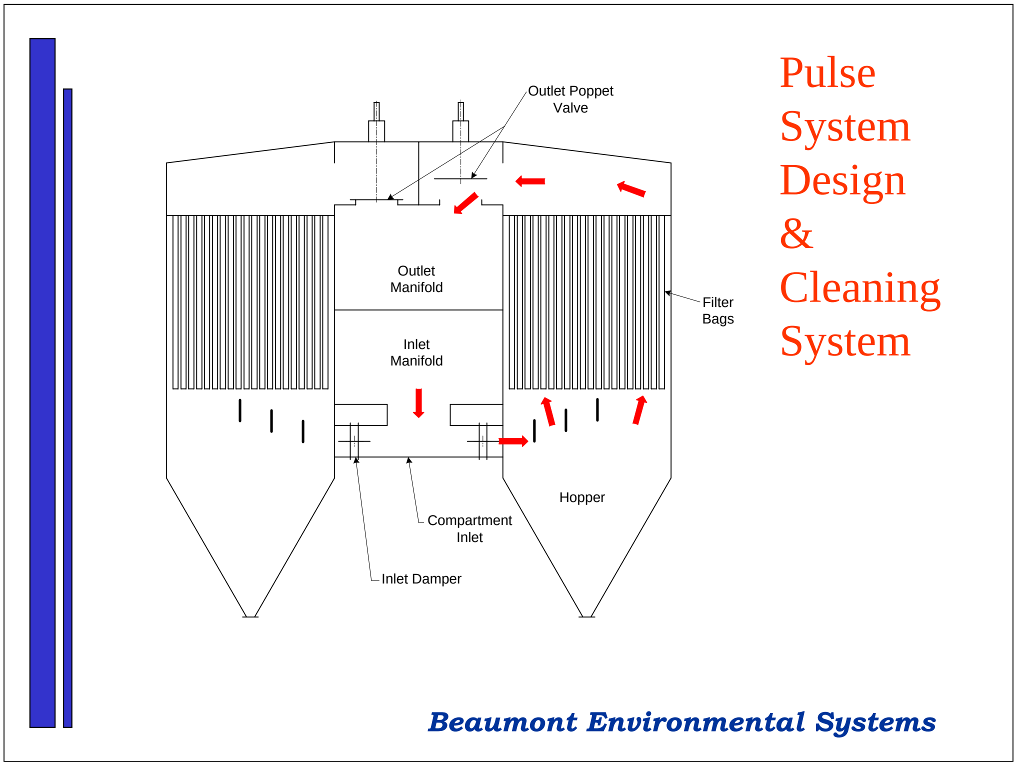
We are able to control all the regulated particulate, gases and metals following a NOx system for a coal fired boiler.

Indications are that some level of NOx polishing can be accomplished with additional oxidation added via oxidants or oxidized sorbents added upstream of the particulate collector.

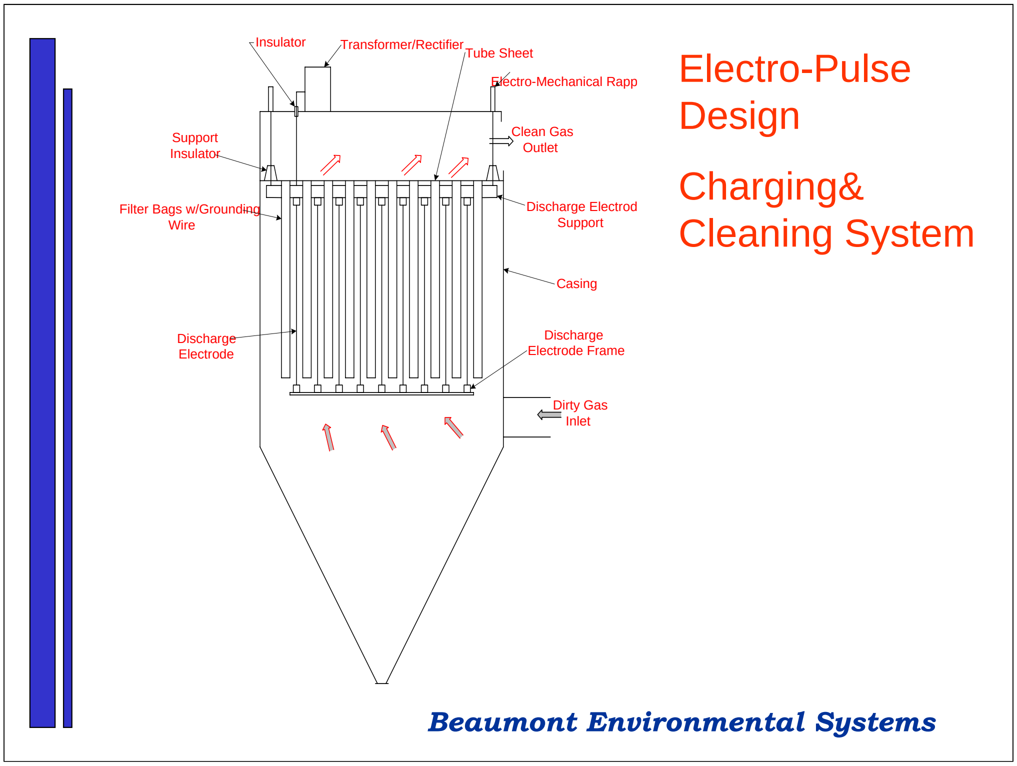


To enhance Mercury control with bituminous coals we pre-condition the incoming flue gas and ash. We attempt to overcome the lack of acid (SO_3) in the flue gas of lower-sulfur fuels for elemental mercury removal.



We prefer bottom bag entry for better dropout for the recycle system. The bag spacing is increased to lower the upward velocity.

The Cleaning System should be designed for both on-line and off-line cleaning.



We can take advantage of the wider spacing to include, or leave space for electrostatic charging design.

On 0.1 micron particles the removal efficiency increases by a factor of one or 90% reduction when using the charging system inside the Pulse Filter.

Mercury Control

- Mercury vapor must be oxidized before absorption on solids or in alkaline liquids
- HCl will promote oxidation in furnace; acids and fly ash surface continue oxidation in cooler regimes; higher LOI ash increases oxidation/capture; higher alkalinity reduces oxidation/capture
- Oxidation and capture greatly enhanced by fixed or circulating bed (fabric filter and/or semi-dry FGD)

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In the furnace heterogeneous (gas-phase) oxidation of mercury is driven by the chlorine content of coal. High gas temperatures generate free radical chlorine atoms which directly oxidize elemental mercury vapor to $HgCl_2$. After the airheater, heterogeneous (surface) reactions determine further mercury vapor oxidation and sorption. We know that carbon provides active surface sites and acids conjugate these sites for mercury oxidation, while alkaline fly ash inhibits mercury oxidation by sequestering HCl and H_2SO_4 from the flue gas.

Adding
Mercury Control

For Sub-Bituminous / PRB Coals

- Adding the Second Stage
- Adding Conditioning Acids
- Adding Special Oxidized Sorbents

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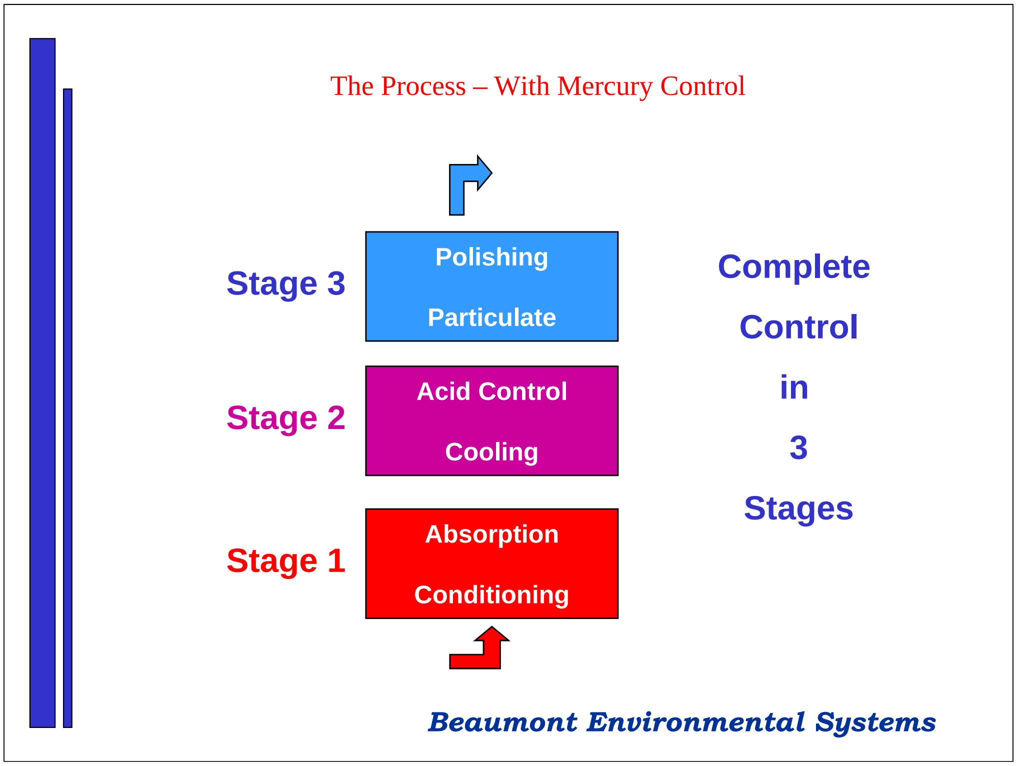
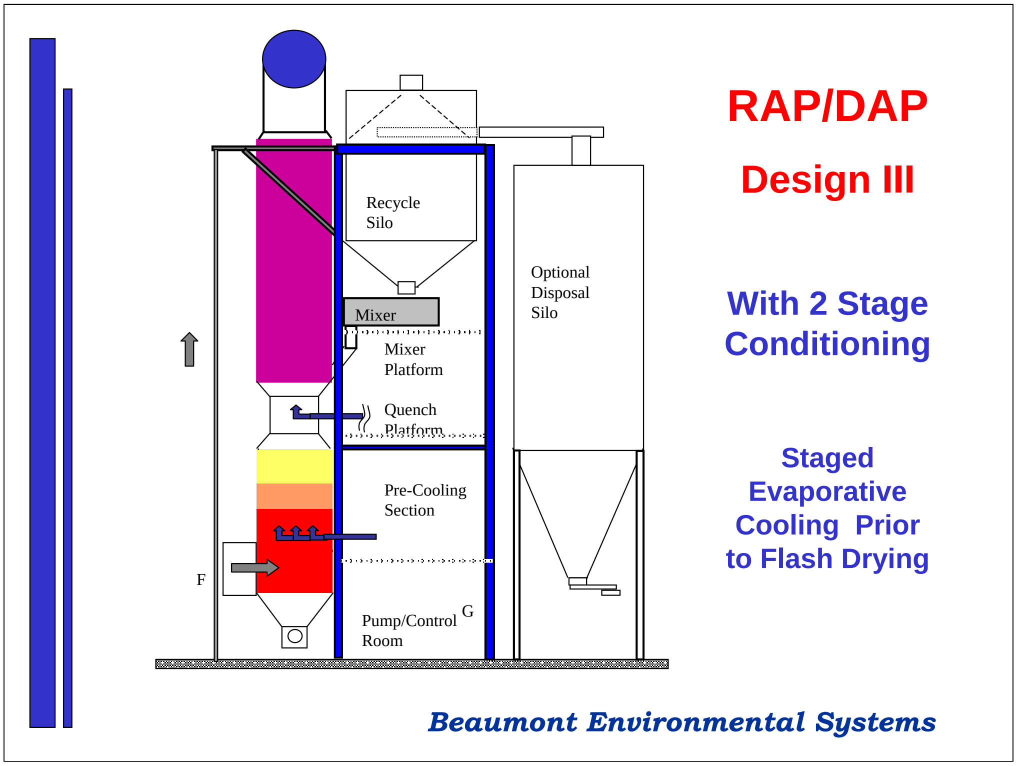
Using the RAP system as a starting point we can address mercury removal by adding a conditioning stage or adding a reactive sorbent at the final filter.



In the optional first stage, we cool and condition the ash for absorption of the elemental Mercury.

In stage two, where we normally provide SO2 removal by flash drying, we utilize the recycle of ash and sorbent to continue Mercury removal while also dealing with acids.

Finally the flue gas moves to stage three, the fabric filter, where particulate is removed and sorbent for Mercury polishing can be added if necessary.



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.

$PM_{2.5}$ Control

- $PM_{2.5}$ dominated by condensable PM
- Operation of PM control below acid dew point greatly reduces $PM_{2.5}$
- One comparison study shows $PM_{2.5}$ from semi-dry FGD/FF to be less than one-tenth that of ESP/wet FGD
- Same study shows electrostatic FF (Electro-Pulse) reduces $PM_{2.5}$ by another order of magnitude

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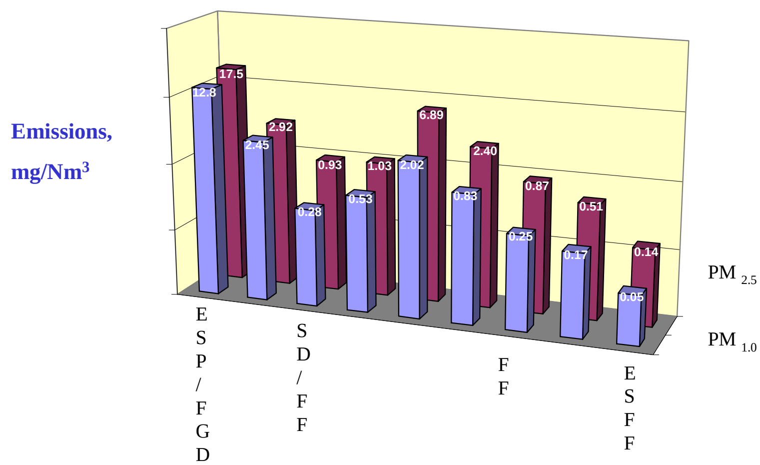
Study referenced is one by Southern Research first presented in June 2000 Pollution Engineering

$PM_{2.5}$ / $PM_{1.0}$ Emissions From Various Technologies



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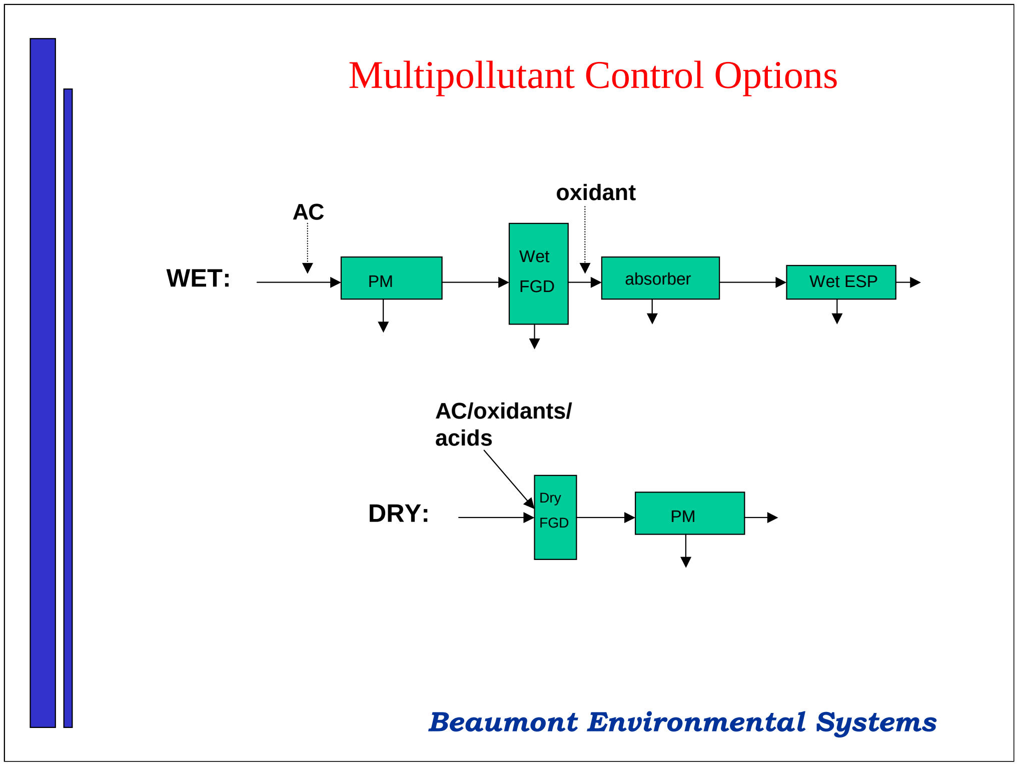
Database for PM stack emissions to date is based on cyclone samplers from studies performed by Southern Research Institute and published in Pollution Engineering, June, 2000

Data limited to one spray tower FGD, one spray dryer, and several baghouses and ESPs

Differing temperatures and situations make the above chart only an indicator of PM outlets.



Wet system has four boxes, three wet discharge points, and one dry discharge point. Semi-dry system has two boxes, one discharge point

Flash Dry Multipollutant Control

- Gas Cooling can be staged before Gas Absorption to allow optimal mercury oxidation by condensed acids and condensable fine particle growth
- Gas Absorption is rapid, allowing two separate gas cooling and absorption stages within a relatively small vessel
- PM control can be electrostatically enhanced for MACT metals control

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2 Stages of treatment. First conditioning then absorption prior to the particulate collector allows for Elemental Mercury collection.

Special Applications

- Lower-rank coals have special mercury, PM, and NOx considerations that can be more easily attacked with staged semi-dry absorption
- Stoker coals have inherently higher carbon ash and SO3/H2SO4 than PCs – tailor-made for semi-dry multi-pollutant emission control
- Industrial applications with MACT metals requirements will find semi-dry/ESFF to be LAER technology

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Recent field test shows mercury emissions from subbituminous coal increased when spray dry absorber turned on upstream of fabric filter. This can be addressed if gas cooling sufficiently precedes introduction of alkaline absorbent upstream of PM collector. PM collector will also perform better. Oxidant addition may assist in polishing mercury and NOx emissions.

Flash Drying Improvements

- Reduced Reactor Diameter and residence time
- Reduced Tower Steel and Access Required
- Reduced Material Handling Required
- Eliminated Sprays in Reactor & Build-Up
- Reduced Compressed Air Requirements
- Improved SO2 Removal
- Raised Outlet Temperature

- Lowered Operating Costs
  - 4 Inches Lower PD
  - 70% Less compressed Air
  - Lower MH Horsepower
  - Lowered Maintenance
  - Lowered Downtime
- Lower Capital Costs
  - Reduced Structural Steel
  - Reduced Access
  - Silo in Lieu of Cyclone
  - Simplified Controls

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This chart lists improvements and cost considerations. Flash drying has moved significantly ahead of the the previous semi-dry scrubbers.

Building a Simple MACT System

- Mercury
  - Need a Baghouse
  - Need some Cooling
  - Need a Simple Sorbent
- HCl
  - Need a Simple Sorbent
- Particulate
  - Baghouse
  - SO3 Control

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Cooling plus a Baghouse

Add future SO2 Control

Sorbent Properties and System $HgCl_2$ Capacities

Sorbent	pH	BET Surface Area (m^2/g)	Avg. pore diameter (D)	D_{50} (ìm)	Porosity	Surface Basicity (mmoles/m^2)	$HgCl_2$ Capacity (mg $HgCl_2$/g)		
							q_{60}	q_{100}	q_{140}
$Ca(OH)_2$	11.95	14.510	248	6.25	0.156	0.033	0.4469	0.2020	0.0800
CaO	11.95	4.525	5840	7.01	0.065	0.017	0.4471	0.0538	0.0153
$CaCO_3$	9.64	0.9042	4130	23.69	0.006	n/a	0.4594	0.0509	0.0111
$CaSO_4 \cdot xH_2O$	7.4	6.605	198	29.09	0.069	n/a	0.3595	0.1152	0.0039
$NaHCO_3$	8.35	14.305	500	53.9	0.161	n/a	0.2416	0.1467	0.0358
Na_2CO_3	10.98	0.9582	221	300	0.006	0.032	0.2814	0.0551	0.0188
NaOH	12.01	0.2546	252	300	0.001	2.530	0.0000	0.0978	0.0085
Na_2SO_4	6.65	0.2031	74.4	88.94	0.001	n/a	0.1847	0.0424	0.0090
K_2CO_3	10.98	0.5718	111	300	0.003	0.124	0.4102	0.0409	0.0090
K_2SO_4	7.37	0.4448	110	30.64	0.002	n/a	0.2047	0.0253	0.0028
$Mg(OH)_2$	10.21	10.91	315	9.61	0.152	0.002	0.2900	0.0370	0.0024

(n/a) means that there was no color change of the indicator, suggesting a weak, basic sorbent and that the indicator was unsuitable, so titration was not performed).

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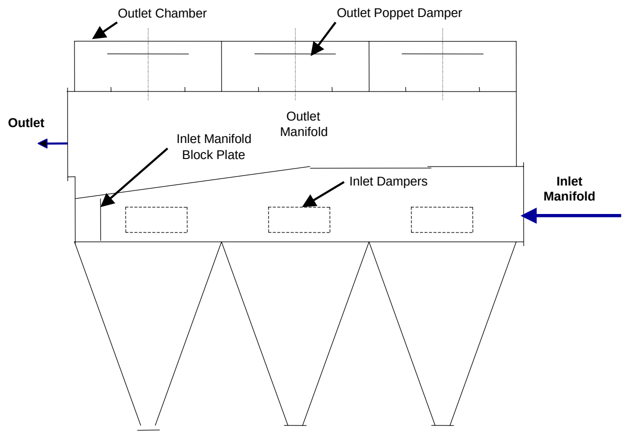
The physical and chemical characterization of sorbents are shown above along with the system's 24 h mercury capacity, q_T, for reaction temperatures, T, of 60 and 100 °C and the 17 h mercury capacity for 140 °C. The empty reactor capture is appreciable; at 60 and 100 ° C, these amounts are equal to 41% (0.1361 mg) and 66% 0.0523 mg), respectively, of the average gross sorbent capture.

The lime reactivity jumps dramatically between 212 and 140F due to water sorbed (hydration by flue gas moisture); hydrated lime shows less improvement because it already has hydrated water. This table is important in showing why you would use **hydrated lime** rather than pebble lime for dry injection, and **why lowering the temperature** is important for any lime sorbent to be effective on mercury. The table also shows, curiously, that limestone is as effective as lime for all temp ranges and hydrated gypsum actually better than lime at 212F. but not at 284F (where gypsum loses hydrated water).

Incoming Manifold



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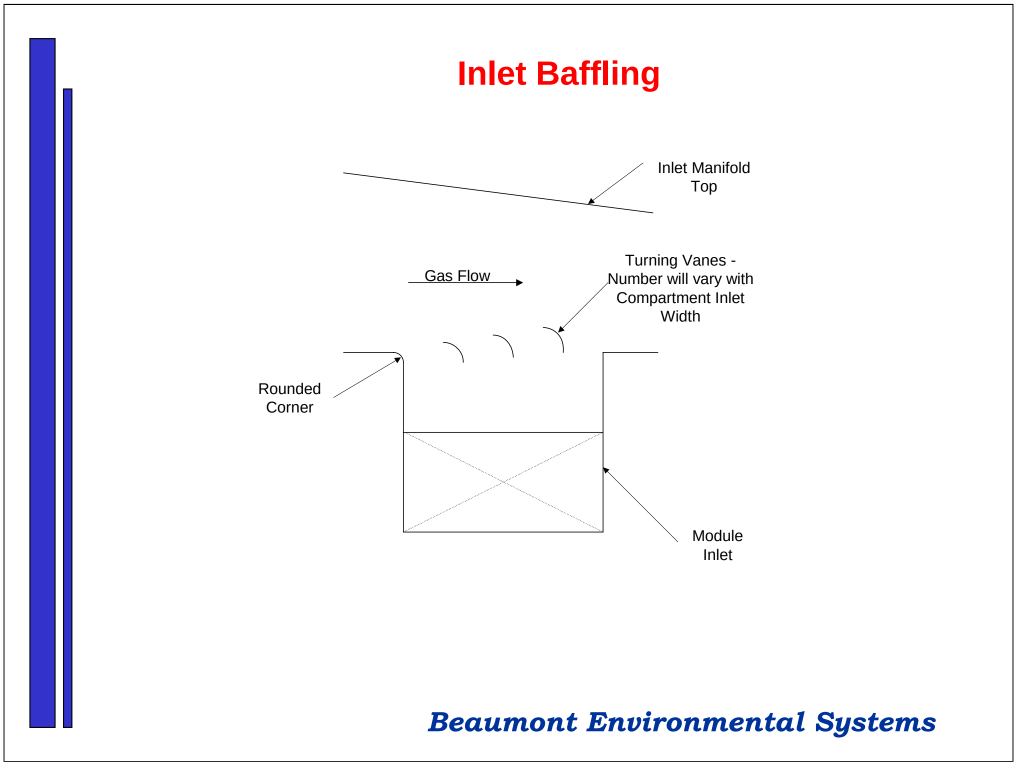
Beaumont has devised a design based on their years of experience that provides optimum distribution of both gas and dust within the fabric filter. We have found that if the gas/dust is closely controlled from the initial entrance into the fabric filter inlet manifold then optimum uniform distribution can be achieved to each compartment and each bag.

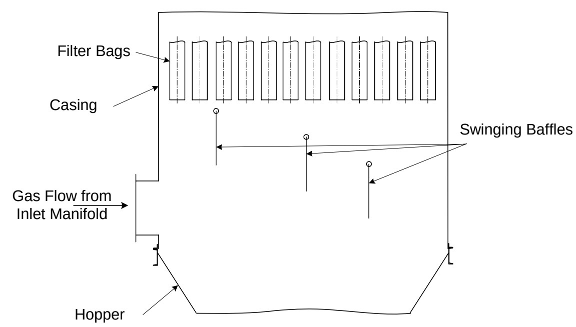
Dust tends to settle towards the bottom of the duct/manifold more than gas due to its greater density. Proper selection of gas velocity assists in maintaining the dust more uniformly disbursed in the gas stream. A tapered inlet manifold is utilized to maintain the proper gas velocity as a constant as gas/dust is distributed to compartments located along the manifold.



The constant gas velocity assists in maintaining a uniform dust/gas mixture. Curved baffles are utilized at the gas/dust entrance to the compartment from the inlet manifold. These baffles are located low in the inlet manifold, where dust particles tend to accumulate, and act as impingers to force the dust into the compartment inlet. Gas is also channeled into the compartment inlet. Without the impingers the dust particles will continue along the inlet manifold to the rear compartments due to their mass and inertia.

The upstream side of the compartment inlet is rounded to prevent gas separation as the gas/dust turns the 90° required to direct the mixture from the inlet manifold to the compartment. The gas and dust would create a circular, whirling motion as it enters the compartment if the impingers and rounded edge were not utilized. This condition would force the gas and dust to one side of the compartment inlet and create an uncontrollable distribution of the dust and gas. It would also create pockets of high gas velocity that can be very detrimental to bag life due to dust impingement and bag movement.

Dust Inlet & Distribution



End Elevation
Compartment Baffle Arrangement

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A large area is provided beneath the filter bags to reduce the gas and dust velocity to a low level and allow the gas/dust to expand over the compartment cross sectional area and to the filter bags. Several swinging baffles are provided below the filter bags to assist the gas/dust distribution and expansion process. The baffles can be easily adjusted, if necessary, in the field to optimize the gas/dust distribution to the filter bags. The bags are spaced wider than normal in both directions to provide channels for coating the bags and later cleaning on-line.

Fabric Filter Dust Cake

Distribution

Building Cake

Cleaning

Future

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The filter fabric, in itself, does not provide the efficient removal of particulates. It is necessary to establish and maintain a dust cake to attain high efficiency particulate removal rates and provide for extended fabric life. A portion of the dust cake is permanently attached to the filter fabric and is never removed. This permanent dust cake is established early in the life of filter fabric, therefore, care is required in the start-up and initial operation of the fabric filter. Diatomaceous earth, coal fired fly ash or other acceptable materials are utilized to pre-coat the filter fabric prior to the first introduction of gases as a preparatory step in establishing a good ash cake and also to protect the filter fabric from unburned hydrocarbons, sparks and other undesirable elements. Fabric cleaning is not initiated until a predetermined pressure drop is established across the filter fabric and dust cake. Once fabric cleaning is established most of the dust will be cleaned from the bags. Slowly, over time, a permanent dust cake is established. Filter bags that have established a permanent filter cake weigh 5 to 10 times the original unused filter fabric.

References

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- Singer & Ghorishi, Sedman“Simultaneous Control of Hg^o,SO2,and NOx”, presented at MEGA Symposium, Chicago, IL, August 21-23, 2001
- Singer & Ghorishi, Sedman“Lime based Multi-Pollutant Sorbents”, presented at MEGA Symposium, Atlanta,GA, 1999

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The above papers are the most recent that have been presented covering aspects of the multi-pollutant control system.

The third paper traces history of semi-dry scrubbing that has led to the development of flash drying san covers some advantages of flash drying.

The first paper covers the operating results at the Medical College of Ohio and furnishes more detail on that project.