WPCA NEWS

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WORLDWIDE POLLUTION CONTROL ASSOCIATION

Sulfur Trioxide (SO_3) Mist Formation

In an article published in the November issue of Power Engineering, Wayne P. Buckley and Dr. Boris Altshuler, of Croll-Reynolds Clean Air Technologies, Inc., describe the mechanisms of sulfur trioxide (SO_3) mist formation.

Depending upon the type of flue gas desulfurization (FGD) technology utilized, a considerable portion of ammonia salts and sulfuric acid may exit the stack (30-60 percent) as respirable submicron fine particle emissions. This presents an extremely difficult air pollution control problem. When SO_3 is hydrated with moisture in the gas stream or in the atmosphere, forms sulfuric acid (H_2SO_4), which if present in the flue gas, can violate local opacity regulations.

Figure 1
Wet ESP pilot at coal fired plant

Sulfuric acid emissions are problematic in both wet and dry (FGD) processes. In wet processes, where the flue gas leaving the absorber is saturated with moisture, sulfuric acid mist can form instantly after the flue gas is saturated. When this occurs it immediately creates a stack opacity problem. Dry processes, where the flue gas is not saturated with moisture, typically remove fine particles such as $(NH_4)_2SO_4$. However, the dry processes have low removal efficiency for SO_3 vapors. At stack conditions, these vapors convert to sulfuric acid mist and produce significant visible emissions.

Sulfuric acid formation takes place through the oxidation of sulfur dioxide (SO_2) to SO_3, followed by reaction with H_2O to form H_2SO_4. During the combustion process, the sulfur in the fossil fuel reacts to form about 95-97 percent SO_2 and the remainder SO_3. Most of the SO_3 in boiler flue gas likely forms during the several seconds when the combustion gas cools from 2900-3100 °F to about 1830° F. Selective catalytic reactor (SCR) technologies will generate an additional quantity of SO_3 through catalytic conversion of SO_2 to SO_3 even at low temperatures.

There are two primary mechanisms for sulfuric acid mist formation. The first mechanism is the reaction between H_2O vapors and SO_3 vapors that form liquid droplets. The second mechanism is sulfuric acid vapor condensation in the bulk gas phase when the gas stream temperature is

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INSIDE HIGHLIGHTS

SCR Retrofit Effects on Downstream Equipment

by Bob Crynack & Richard Gentile P.E. - EPSCO International

Retrofitting a Selective Catalytic Reduction (SCR) system for NOx control into an existing boiler unit designed 15 to 30 years ago presents many design challenges. The design engineers must also consider the effect that the SCR will have on the performance of the downstream equipment and its structural integrity. Most SCRs are being retrofit ahead of electrostatic precipitators. This article focuses on the structural integrity issues for the downstream electrostatic precipitator (ESP) and associated ducts.

Engineers need to analyze, assess and evaluate the ESP for the new higher suction loads and operating conditions it will be subjected to. Further, because of its extensive past use, often times abusive use, the material needs to be inspected and examined to determine its present and possible future strength.

Although an ESP is a piece of electromechanical equipment, it is constructed of, supported by and receives its throughput from structural elements. The ability of the ESP to remain gas tight and support the loads that it is subjected to is critical to the performance, compliance and overall cost of the system.

To evaluate the structural elements of an ESP, a three-phase procedure is recommended by EPSCO. These phases include (1) structural analysis, (2) physical inspection, and (3) metallurgical laboratory testing.

Phase 1: Structural Analysis

This phase requires the review and comparison of both the initial and proposed new design criteria. Particular attention needs to be directed to the added suction loads with the SCR. It is not enough to use the material specification and plate thickness of material shown on the design drawings. Although the material

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Electrostatic Precipitator Rebuild Strategies for Improved Particulate Emissions

by Robert Mastropietro - Hamon Research-Cottrell

Due to governmental legislation which reduced allowable particulate emission in the 1972-1978 time period, there were a great number of utility electrostatic precipitators (ESPs) installed in that era. This "aging fleet" of ESPs is now about 25-30 years old, and are often the highest emitting sources (in terms of particulate matter) within utility systems. These older units were designed (and are Grand-Fathered) to achieve 0.1 lb/MMBtu of particulate matter, instead of modern NSPS of 0.03 lb/MMBtu. Many of the units are experiencing problems with the internal electrodes corroding or sustaining rapper damage, to the point of failure. It is possible to rebuild, enlarge, and improve these existing ESPs, to get lower particulate emissions.

The sizing of ESPs for utility boilers has changed dramatically since the early 1970s. This to some extent, has been based upon a move to lower sulfur coals. However, the main reason for the increase in ESP size or treatment time, has been a reduction in required outlet emissions. Since the internal electrodes of an ESP are subjected to both acid corrosion and rapping damage, they are a long term replaceable component. On extreme high sulfur applications (high sulfuric acid), internals have been replaced on about a 20 year cycle. With lower sulfur coals, internals life approaches 30 years. In either case, many of the 1970s vintage ESPs are now being rebuilt. There are a number of ways to rebuild these installations and get larger treatment times and improved particulate emissions, even within a tight location.

These would include:

- Use of open area ahead or behind the ESP for added field(s)
- Use of area on the side of the ESP for added chambers
- Demolition of an upstream mechanical collector, and replacement with an ESP field
- Increased utilization of the ESP casing length as collecting zone length
- Increasing the collecting plate height

PERFORMANCE IMPACTS OF REBUILD/ENLARGEMENTS

If the existing ESP is small and achieving 0.1 lb/MMBtu, then the fly ash resistivity is typically being controlled by natural (high sulfur coal) or injected sulfur trioxide (SO_3) surface conditioning. If there is low sulfur coal achieving 0.1 lb/MMBtu without SO_3, then typically the ESP sizing is larger. Thus there is no one ESP size that does achieve 0.1 lb/MMBtu. It is possible to take any of these ESPs and rebuild them much larger, sometimes even within the existing footprint. This will result in reductions in particulate emissions and opacity.

Note however, that particulate emissions and opacity are not directly related. This is because the ESP will collect larger particles first, driving down on the penetrating particle size. The light scattering extinction coefficient of particulates has been found to be more severe as the particle size gets finer. Thus if the desire/requirement is to reduce opacity by half, then particulate emissions would have to be cut by about $^{2}/_{3}$. Thus a move from 0.1 lb/MM Btu down to 0.03 lb/MMBtu would ensure that opacity would roughly be cut in half.

For discussions purposes, the impacts of the above enlargements on ESP performance, in terms of particulate emissions, can be calculated using the modified Deutsch Equation. Using the above ESP enlargements as typical, outlet particulate emissions can be calculated for various combinations of rebuilds/enlargements. In the following table Hamon Research-Cottrell has referred to the existing ESP size as the "Base" case and assigned X to represent the treatment time, depending on fly ash resistivity. Then particulate emission calculations were performed for percentage enlargements to X.

See the following Figure 10.

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Optimizing Boiler Combustion Using Flow Models

by Rob Mudry - Airflow Sciences

The overall performance of a power plant depends significantly on how fuel and combustion air enter the furnace. Large fossil fuel boilers can have up to 100 individual burners that inject fuel and air. The proportion of flow through each of these plays an important role in the efficiency of the combustion process. By properly designing the combustion system, plant emissions of nitrogen oxide (NOx) and carbon monoxide (CO) can be minimized while boiler efficiency and equipment longevity are maximized.

Often the engineering design process for a combustion system involves a flow model of the air and/or fuel delivery equipment. Airflow Sciences Corporation of Livonia, Michigan, USA, performs analysis and design of power plant equipment using both scaled physical models and computational fluid dynamics (CFD) models. The figures show these two types of models applied to the design of a power plant windbox (the duct that feeds combustion air to the burners).

Figure 2

Figure 2 depicts a laboratory physical model, which is a $^{1}/_{18}$ scale replica of an actual windbox. A fan supplies air to the model, and laboratory experiments are performed to analyze the velocity, pressure, flow rate, and other fluid dynamic properties.

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Redundancy In Precipitator TR Controls Increases Precipitator Availability

by Paul Ford - RedKoh Megamation

Under today's pollution limitations the availability of the precipitator power supply is of the utmost importance.

A simple failure in a TR surge arrester can bring a high tech state of the art precipitator control to its knees.

Recently a Southern U.S. utility installation experienced these exact circumstances. The loss of the secondary current signal shut the TR down for a number of days. The problem manifested itself in the lack of spark and arc detection and a subsequent trip on overcurrent. Since this kind of problem is not often seen, the plant personnel recruited the services of an outside service engineer who took a number of days to arrive.

A TR control with redundant systems would have prevented this from happening. Since it is not only the current signal that is affected during sparking and arcing, a redundant spark and arc detection system should be part of any modern AVC.

Following the turn of events mentioned above, the utility investigated such a system from Redkoh Megamation and found that the control under evaluation looked for sparks on both the precipitator current and voltage signals.

With a failure of either one, or both, of the signals the unit would remain safely in service due to the arc detect which is based on the primary current and zero cross signals.

Such a system would have allowed them a tremendous amount of flexibility in that the service engineer, while still required to search out the bad surge arrester, would not have had to be on site until the unit came down for an outage.

The example of the bad surge arrester is just one of the 'difficult to find faults' associated with precipitator TR set feedback signals.

Another case where such a redundant system recently saved de-rating, was where a bad ground put severe noise on the feedback signals. The noise caused false triggering of the spark detector. Once the noisy signal was discovered, the field wire was disconnected from the AVC, and while it lost its meter readings the power rose to the spark over level and the TR was able to reach its expected operating levels.

This was extremely valuable since the problem turned out to be a badly routed cable that was not easily corrected.

In the next WPCA News, Redkoh will investigate further benefits to be gained from redundant AVC capabilities.

Croll-Reynolds Continued from page 1

lowered below the H_2SO_4 dew point.

If reduction of mass emissions, stack opacity, or both are required, it is necessary to use a technology that will simultaneously remove both sulfuric acid mist and solid particulate material from the flue gas. Wet electrostatic precipitation (WESP) technology can satisfy this requirement and, as proven in numerous industrial applications, has the added potential for abatement of heavy metals (including mercury), as well as water mist carryover from an FGD scrubber system, while minimizing both the capital and operating costs.

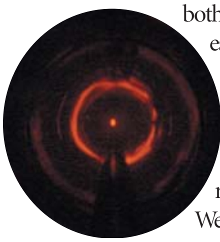

Figure 3
No power - dark tube

Test Results:

Test results from a slip-stream pilot WESP at a coal fired power plant have demonstrated the effectiveness of WESP technology to abate SO_3 mist and PM 2.5. To very high levels - over 95% since SO_3 mist and PM 2.5 are the primary causes of visible emissions, opacity is consequently reduced. A 19 foot long observation tube to replicate stack diameter was installed. For qualitative purpose figure 3 is a picture of the inside of the observation tube with minimum power. With no power on the tube was completely dark. Figure 4 shows the inside of the observation tube with full power. WESPs are an established, well known technology for capturing very fine SO_3 acid mist associated with blue plume.

Figure 4
Full power - clear tube

EPSCO Continued from 1

specification has not changed, the microstructure may have changed, particularly in units subjected to hot side operation or extensive corrosion in cold side units. The casing thickness may have changed, particularly in cold side units that have been subjected to corrosion. Consequently, to finalize the analysis, one needs to conduct a physical inspection and test the material.

Phase 2: Structural Inspection

The primary objectives of the structural inspection are to see and measure the critical elements and overall condition of the ESP. Additionally; samples are selected for metallurgical testing. Metal thickness readings of the platework are taken where accessible. Readings, cracks, buckling, excessive corrosion are recorded and photographed for documentation.

Phase 3: Metallurgical Laboratory Testing

Testing is for strength, chemistry and micro structural evaluation. Strength tests include tensile, impact and hardness. Chemistry tests are conducted to determine the chemical components, properties and specification of the steel. Microstructure examination is to determine changes in metalography that have taken place, within the material, during its lifetime in operation. The results of these tests provide a means of evaluating the existing material and offer a prognosis to estimate its future life.

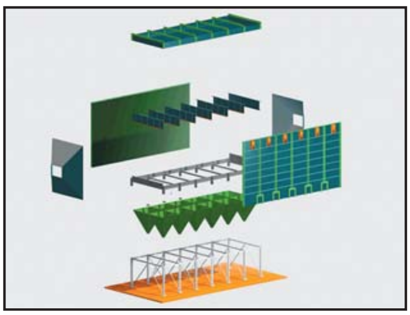

Figure 5
Structural breakdown of the ESP

Summary

This three phase structural evaluation could produce recommendations from “do nothing” to a major reinforcement of the ESP’s structural components, in order to obtain compatibility. Properly performing these three phases of the ESP evaluation will assure its structural integrity and continued performance levels.

Airflow Sciences Continued from page 2

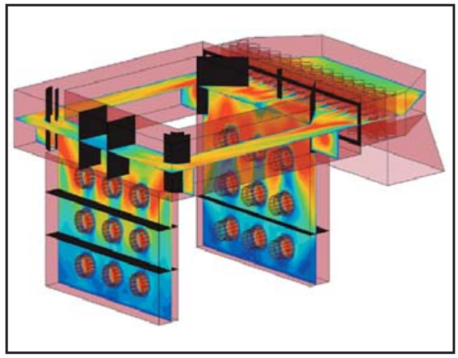

Figure 6

These models are usually built with clear materials to allow flow visualization using smoke streamlines.

Results from a CFD windbox model are shown in Figure 6 In a CFD model, the geometry is represented virtually using a computer. Sophisticated software calculates the air flow properties including velocity patterns, pressures, flow balance, temperatures, etc.

For this windbox, a flow model allowed deficiencies in the basic design to be pinpointed. Design of flow control devices such as turning vanes and baffle plates was optimized using the model before any actual construction occurred at the plant. The final design from the model was implemented to achieve optimal combustion of a low-NOx burner system.

Burner flow balancing can have a dramatic impact on plant performance for relatively low cost. After implementing design changes recommended by Airflow Sciences Corporation at Deseret Generation’s Bonanza Plant Unit 1, NOx emissions were reduced by 8%. Additionally, boiler efficiency improved, as the amount of unburned carbon was decreased by 40% and the boiler net heat rate improved by 0.7%.

Aluminum Oxide Rapper Shafts: High Alumina, Higher Strength

by Jim Foster - CoorsTek

Aluminum Oxide ceramic shafts have been manufactured for the magnetic impulse gravity impact rapper systems for many years. Alumina is recognized as the industry standard for the ceramic insulator shafts.Since the alumina ceramics are superior to porcelains, including so-called High Alumina porcelains. In late 1996, CoorsTek , formerly Coors Ceramics, began producing the tapered rapper shafts. Up to that time the available ceramic tapered shafts were inconsistent and of inferior quality with respect to material homogeneity and straightness. A high frequency of failures of the existing ceramic products led to the transition to their alumina shafts by the majority of the ESP equipment manufacturers and service companies.

Typically the alumina rapper shafts are produced from AD 85 material, 85% aluminum oxide ceramic. The manufacturing process for the alumina shafts has been engineered to ensure that the material properties meet rigid internal standards necessary in promoting good mechanical strength and electrical insulating properties. Special firing techniques and post-fired grinding of the tapered ends help maintain the straightness. Each part is measured for straightness by mounting on centers and rotating the shaft in contact with a dial gauge. Liquid dye penetrant inspection is carried out to detect any cracks or open porosity. The alumina shafts are fully dense so there is no opportunity for moisture to penetrate into the surface.

The 85% alumina has consistently proven to be perfectly sound for the magnetic impact rapper systems in the vast majority of applications. However, there are occasions when misalignment or overstressing the ceramic shafts can lead to mechanical failure due to the ceramic breaking or the tapered ends chipping and fracturing. In addition certain end users do have specifications in place that dictate the need for higher alumina content, for example 95% minimum aluminum oxide. To help address these problem issues CoorsTek is continuing to try to expand on the variety of ceramic materials available for the rapper shafts.

One such alternative formulation that has been successfully used is CoorsTek's FG995 Alumina. The typical material properties for FG995 and AD85 Aluminas are listed in Figure 7. The FG995 offers advantages in mechanical strength plus increased fracture toughness. The flexural strength for FG995 is 27% higher while the tensile strength is 60% higher. The greater strength and fracture toughness enhance the ability of the FG995 shafts to tolerate higher shear forces that occur as a result of misalignment of the rapper system when the precipitator unit heats up and expands. Increased toughness of the FG995 also relates to improved chip resistance.

In one particular case CoorsTek was approached by a service company whose customer was applying unusually high rapping force. The height of the rapping weights was up to 100% above the typical recommended lifting height for the equipment. The very heavy rapping was causing too high a percentage of the regular 85% alumina shafts in service to break; chunks of the ceramic were breaking off at the tapered ends plus shafts were breaking higher up the length.

The contractor preferred to initially try to substitute an alternative material rather than redesigning the existing rapper design, and were offered the FG995 material for trial. They were able to install the new shafts and avoid reengineering the rappers as the higher alumina shafts were installed with no equipment modifications.

The FG995 shafts have been in service for about two years and have performed exceptionally well. The customer is very pleased with the service life of the material so far. The FG995 shafts have not experienced the same breakage or chipping at the tapered ends that was occurring under the extra heavy rapping.

Figure 7

Comparison of Material Properties For AD85 and FG995 Aluminas

Properties	Units	Test	AD85	FG995
Density	g/cc	ASTM-C20	3.42	3.80
Water Absorption	%	ASTM-373	0	0
Flexural Strength	psi	ASTM-F417	43,000	54,000
Compressive Strength	psi	ASTM-C773	280,000	363,000
Tensile Strength	psi	ACMA Test #4	22,000	36,000
Fracture Toughness	Mpa m1/2	Notched Beam	3 to 4	4 to 5
Dielectric Strength	ac-kV/mm	ASTM-D116	9.4	8.7
Volume Resistivity 25C	ohm-cm	ASTM-D1829	$>10^{14}$	$>10^{14}$

Material Properties are typical and values are not to be construed as absolute engineering data. Actual values may vary with method of manufacture, size and shape of part. CoorsTek offers no guarantee or warranty based on material property data.

Putting More Juice in your Precipitator

by Jim Morgan - BHA Group

The JuiceCan is a high voltage filter for electrostatic precipitators. Developed by BHA Group, Inc., the product is designed to significantly increase secondary current and average voltage. This can lead to higher collection efficiency and lowered stack opacity. It is economically priced, easy to install, works with all types of precipitators, and requires no special controls.

Figure 8
Juice can compartment

The JuiceCan filters (smoothes out) the DC pulses from the transformer/rectifier to narrow the gap between peak and minimum voltage. In many cases, the DC voltage from a typical T/R set can be highly rippled, with peak voltage exceeding average voltage by 40% or more. The high peak voltage can lead to sparking in the precipitator field at a low average voltage, which robs the field of its collection efficiency. If the peak, average, and minimum voltage could be equalized, the precipitator field could operate at maximum power with minimum sparking.

Installed between the T/R set and the precipitator, the JuiceCan is basically a capacitor, but a very special type of capacitor. It is "spiral wound" which provides very high internal inductance. It therefore can be thought of as two components in one: a capacitor and an inductor. While the capacitance increases average voltage into the precipitator, the inductance limits high frequency spark currents so as not to increase spark intensity.

DC voltage filtering is not new. Filters are used on many types of DC power supply applications. There have been numerous attempts to put filters and snubbers on precipitators, with limited results. "Most filters could not withstand the precipitator's high voltage environment," says Terry Farmer, Manager-Electrical Products for BHA, "and eventually everyone gave up on the idea. But our engineers, who have expertise with high voltage applications and precipitator operations, made the breakthrough." Farmer says his company began researching ideas in late 2001, testing a variety of designs. "We discovered there is significant science and technology involved in making this type of filter. It is a difficult application, and we now know why others gave up trying. But we stayed focused and found the right way to make it work." The product is patent pending.

Developers claim that testing has gone well, and that the product has been installed in several applications in the U.S. and Europe. The company's website reports one test site in which the JuiceCan improved KV average by 20.5% and improved milliamps by 121.5%. The product comes in a small size that weighs about 75 lbs. and a larger size that weighs about 165 lbs. The product is typically installed in a bus duct or enclosure.

Farmer says initial customers are pleased, with some reporting "significant" reductions in stack opacity. "As we continue to install JuiceCans in various applications, we'll continue to learn about what it can do. But we think this is a breakthrough technology that has an incredible payback. We're having fun selling it, and we're hearing that customers are enjoying the benefits."

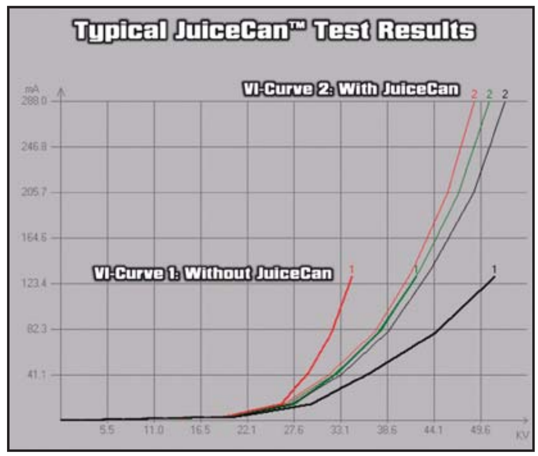

Figure 9

Chemithon SafeDeNOx™ Process

by Bill Hankins & Geoff Stensland - Chemithon

Chemithon is currently commissioning a full size urea to ammonia SafeDeNOx™ system at a major Midwest utility. The urea to ammonia system is designed to produce up to 800 lb/hr of ammonia for two new SCR's that have been installed on the generating station's two existing coal fired units. Each unit has 260 MW generating capacity.

Some specific technical features that the system includes are:

Material Handling

Prilled or granular urea is hydroscopic and will agglomerate if not kept very dry. To keep the urea from agglomerating an air dryer was supplied to provide adequate amounts of dry air for all urea handling and storage equipment. In addition solid urea is very fragile and easily crushed. Silo height was kept low to keep the static head minimal and prevent crushing the urea. Crushed urea inside the silos will cause build up leading to storage and handling problems.

Urea Processing

De-ionized water is not required for the SafeDeNOx™ process. The dry urea from the silos is fed directly to the melters, metered and finally pumped to the reactor. This eliminates the process of having to dissolve the urea with de-ionized water.

Reaction Kinetics

The reactors utilize a catalyst that increases the reaction rate up to 20 times faster over non-catalytic systems. Due to the faster reaction rates the SafeDeNOx™ reactor vessels are much smaller than other system's reactors. The smaller reactors greatly reduce the potential for a significant ammonia release since less free ammonia is inside the reactor vessel at any given time. The faster reaction rate also enables the process to quickly respond to changes in ammonia demand for more accurate ammonia supply to the SCR injection grid. This also benefits the end user by minimizing ammonia slip during a rapid decrease in ammonia demand since the SafeDeNOx™ unit can quickly ramp down its production rate of ammonia.

Urea Impurities

Extensive pilot testing has shown that urea impurities and urea process by-products can accumulate and foul the reactors over time. To minimize this problem the SafeDeNOx™ system is designed to remove the urea contaminants and by-products while the urea reactor is on line. Pilot testing has also shown that the SafeDeNOx™ technology does not release significant quantities of formaldehyde. This can be important as formaldehyde is on the EPA list of hazardous chemicals. Other urea to ammonia technologies can release significant or reportable levels of formaldehyde as the non-catalyzed hydrolysis process reverts chemically bound formaldehyde back to free formaldehyde.

The SafeDeNOx™ process should address many of the technical concerns regarding the Urea To Ammonia process. Following successful commissioning of this new generation of urea to ammonia process, the use of hydrolyzed urea as an alternative to Anhydrous ammonia looks to be a viable long-term solution to Utility Companies safety concerns around handling anhydrous ammonia.

Figure 10

Hamon Research-Cottrell Continued from page 2

Impact of ESP treatment time increase on predicted particulate emissions

Case	ESP Treatment Time	Particulate Emissions lb/MMBtu
Base	1.0 X	0.10
Optimize Existing Length	1.20 X	0.06
Increase Plate Height	1.30 X	0.06*
Optimize Length-Increase Height	1.60 X	0.03
Optimize Length-Add Field	1.55 X	0.03
Add One field	1.33 X	0.05
Add Two Fields	1.67 X	0.03
Add One Field, Increase Height	1.73 X	0.03
Add Parallel Chamber	1.30 X	0.05
Add Parallel Chamber, Increase Hut.	1.69 X	0.03
Add Parallel Chamber, Add Field	1.73 X	0.03

* Note less improvement than strict mathematical prediction, due to decrease in aspect ratio.

From this it can be seen that theoretically it is possible to take an existing 0.1 lb/MMBtu ESP and enlarge it in any of several ways to achieve 0.03 lb/MMBtu. In each case, it will be the existing site constraints which dictate available enlargement direction. There are many other possibilities for enhancements of ESP treatment time to allow coal switching to low sulfur coal or elimination of SO_3 injection. However, these would involve more major enlargements of the ESP and should be examined on a case by case basis.

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