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WORLDWIDE POLLUTION CONTROL ASSOCIATION

Tune in; Tune up

AIG Tuning – An Essential Part of SCR Management

By Hans Hartenstein, STEAG LLC

As part of every Selective Catalytic Reduction (SCR) management program, an ammonia injection grid (AIG) tuning should be conducted regularly in order to optimize the operation of the AIG, minimize ammonia slip (NH_3), and reduce O&M costs. We recommend that an AIG tuning be performed on all units, even those that feature static mixers and those AIGs with a smaller number of individually tunable valves.

AIG tuning should be performed by a team of experienced technicians and engineers. The ammonia distribution upstream of the SCR's first catalyst layer must be determined under actual full load operating conditions. Then, using the fixed installed sampling grid after the last catalyst layer, a series of tests must be conducted during tuning of the AIG for adjustment of the AIG tuning valves until the SCR is operating at peak performance. In general, it is recommended that an optimization of the flue gas distribution and tuning of the (AIG) be done at least once a year.

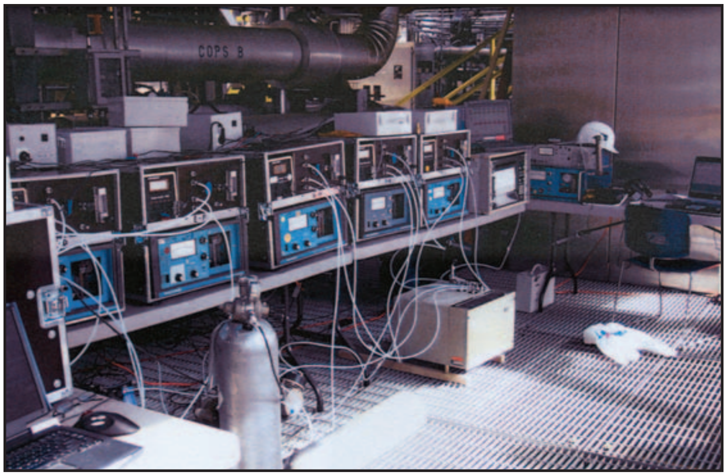

Figure 1: **AIG tuning using an ECOS setup with 7 NO/O_2 analyzers in parallel**

Figure 17 on page 9 shows the principle schematic of Steag's ECOS (Emission Control and Optimization System), which is used to measure the NO and O_2 distributions after the last catalyst layer.

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When the sky's NOT the limit

New Coal-Fired Power Plants Specifying Wet Electrostatic Precipitator Technology to Control PM2.5 and SO_3

By James "Buzz" Reynolds, Wheelabrator Air Pollution Control Inc.

The U.S. EPA has proposed more stringent New Source Performance Standards and National Ambient Air Quality Standards for particulate matter that require control of condensable particulate. The EPA estimates that current particulate test methodology measures only 29% of the particulate matter that is emitted into the air by omitting the condensable fraction collected in the back-half impingers of test apparatus. In addition, because installation of selective catalytic reduction equipment for NOx control oxidizes some fraction of SO_2 to SO_3 which increases visible plume, control of sulfuric acid mist (H_2SO_4) has become a pollutant of particular concern. Consequently, specifications for new coal-fired power plants are requiring limits not only on filterable particulate matter, but also on the condensable fraction. This is in addition to specific limits on SO_3.

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Stealing the limelight

Lime or Limestone for Your New FGD System

By Ron Richard, EPSCO International, LTD.

When one is considering building a new FGD system, which reagent is best? The two main reagents used are lime and limestone. Let's look briefly at each.

Lime

Lime is a manufactured product. It starts with limestone ($CaCO_3$) being quarried and crushed. This limestone is then passed through a rotary kiln. The heat of the kiln drives the carbon dioxide (CO_2) from the limestone in a process known as calcination and leaves what is referred to in the industry as quicklime (CaO). High calcium pebble quicklime is normally used in FGD systems. This means the lime was manufactured from a high calcium limestone.

To use lime in the FGD process, the quicklime is fed into a lime slaker where it is reacted with water. The reaction produces heat and a solution of calcium hydroxide ($Ca(OH)_2$). The calcium hydroxide is very reactive and readily reacts with the SO_2 in the flue gas. Because lime is so reactive, the absorber towers and slurry recirculation pumps can be smaller in a lime process. This can save in initial capital cost and lower pump power requirements and operating costs. However, since lime is manufactured from limestone, the delivered cost of lime to a site may be on the order of five times more expensive than limestone delivered to the same site.

Limestone

Limestone was formed when sections of the continent were covered with water. Because of this, the limestone formations occur in layers. The layers have different thicknesses and composition depending on the prevailing environment at the time that particular ledge was formed. Consequently, it is not unusual to find a three foot ledge of limestone with a 95% calcium carbonate ($CaCO_3$) content sitting on top of a seven foot ledge of limestone with a 65% calcium carbonate content.

If the limestone is to be used in an FGD process, this range of variation is unacceptable. One must think of the limestone as a source of calcium. The more limestone one must transport and grind to get one ton of calcium into the absorber tower, the more costly per ton of calcium that limestone will be. Because of that fact, an FGD operator would prefer to buy a limestone that has 95% or greater calcium carbonate composition. But in the real world, it can be difficult to consistently obtain such a high quality stone from a near-by quarry. The scrubber owner and the quarry operator must work together for the most cost effective solution. The quarry operator will need to map and analyze all the quarry ledges and then develop a quarry plan to obtain the highest quality stone at a reasonable cost.

With limestone scrubbing, calcium carbonate is entering the absorber tower. Calcium carbonate cannot react directly with the SO_2. For the limestone to react well, it must be ground very finely to expose a lot of surface area and the pH in the tower must not be too high. First the limestone must dissolve in the weak acid formed by the reaction of SO_2 and water. The resulting reaction will release the carbon dioxide (CO_2) from the limestone. Once the limestone has dissolved and the carbon dioxide has been released, the calcium can react with the SO_2 to form calcium sulfite ($CaSO_3$) and calcium sulfate ($CaSO_4$).

These reactions occur slowly, so limestone absorber towers must be large to give the required residence time and the slurry recirculation flows must be high to give the required contact between the limestone slurry and the flue gas. To obtain the needed residence time, the absorber towers must be larger than those in a lime system. This adds to the capital cost. To obtain the higher slurry recirculation flows, the recirculation pumps must be larger and more of them may be required. This adds to the capital cost and also to the operating cost since more pumping horsepower is connected to the electrical feed. These higher costs can be offset by the lower delivered cost of the limestone versus the delivered cost of lime.

Summary

The advantage of lime is its high reactivity which leads to smaller absorber towers, smaller slurry recirculation pumps, and less required pumping horsepower. The disadvantage of lime is its high delivered cost.

The advantage of limestone is its low delivered cost. The disadvantage of limestone is its low reactivity which leads to larger absorber towers, larger slurry recirculation pumps, and more required pumping horsepower.

The decision is a simple economic decision. On one side of the equation are the additional capital costs for the larger absorber towers, the larger and more numerous slurry recirculation pumps, and the additional operating costs for the additional electricity to run the pumps over the unit's life if one uses limestone. On the other side of the equation are the additional operating costs due to the price differential per delivered ton for lime vs. limestone times the number of tons of lime that will be used over the unit's life.

It is interesting to note that most of the new FGD systems already announced have chosen to use limestone.

This article is an excerpt from the RE SOx Training Manual. For more information on the training manual, contact Susan Reinhold at sreinhold@reinholdenvironmental.com

For more information on this article, contact Ron Richard at ron.richard@hughes.net

All in a day's work

ESKOM's "Operation Cleanup" an Award Winning Success

Excerpts from an ESKOM Citation by Deidre Herbst with additional notes from Rod Hansen, ESKOM

Every year at Eskom there is a tradition called the Chairmans Awards. This year the prestigious Environmental Award was given to Rod Hansen and his team for reducing particulate emissions and increasing capacity.

Figure 2. **The Air Quality Team Members. From left to right: Front row–Ivan Hartman, Rod Hansen, Robbie van Rensburg, Shaun Pershad. Middle row–John Begg, Don Gibson, Hendre Grobbelaar. Back row–Vali Moosa, Mike Beeselaar, Kammy Dhaver, Tony Stott**

Goal: The reduction of particulate emissions from Eskom's coal-fired powerstations is one of the most significant environmental challenges the organization has had to deal with.

The Air Quality Team: The Air Quality Team is comprised of individuals who have dedicated their careers and time to intensive research and strategic direction (Figure 2). They have developed policies and strategies, consistently striving for cleaner performance, which have resulted in the implementation of the most appropriate technologies. Team members include: **Ivan Hartman,** System Engineer from Arnot Power Station (6 x 350 MW), who struggled for many years with aging under designed ESP's and who introduced several innovations when fabric filters were ultimately retrofitted to all units. **Rod Hansen,** Corporate Consultant Air Pollution Control Technologies and Team Leader, (ISESP International Fellow, Frederick Cottrell Award and past Secretary and past President, WPCA Advisor). **Robbie van Rensburg,** System Engineer Duvha (6 x 600 MW), who coordinated the intensive research investigation into the premature bag failures on their units 1 to 3. **Shaun Pershad** (previous ISESP Harry White Award recipient) from the Research Department for his work on suspending ESP CE's from load cells. **John Begg,** Generation Engineering Department Manager who gave Rod Hansen the space and high level support to implement his strategy. **Don Gibson** from the Research Department, flow specialist and the first person to implement "skewed flow technology" on a large scale using CFD as a tool (ISESP International Fellow Award). **Hendre Grobbelaar,** System Engineer at Hendrina (10 x 200 MW), who oversaw the phased retrofitting of Pulse Jet Fabric Filters on all units and also introduced many innovations to improve the design. **Vali Moosa,** Eskom Chairman and previously Minister of Environmental Affairs and Tourism. He is understandably a keen environmentalist himself and is represented on several international environmental bodies. **Mike Beeselaar,** from the Research Department, who was instrumental in identifying the root cause chemistry that caused our premature bag failures at Duvha. **Kammy Dhaver,** from the Research Department, who currently leads the team in our fabric research seeking longer lasting fabrics and who is involved in the FGD program. **Tony Stott,** who was then Generation Environmental Manager and who provided the vision, high level strategies and support. Lastly, the present Environmental Manager, **Deidre Herbst,** who wrote and submitted the citation.

Results: The passion and dedication of this team have resulted in a significant average yearly reduction of 21.4% in particulate emissions from our power stations (Figure 3). The environmental performance recorded in the past financial year was the best ever achieved by Eskom, and these efforts have greatly contributed to our capacity to operate power stations at higher load factors. 🌎

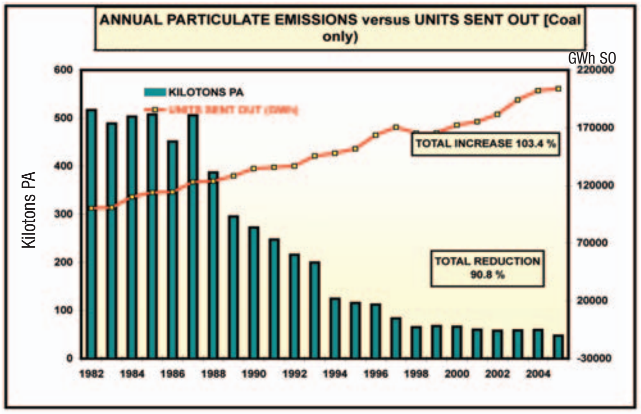

Figure 3: **Annual Particulate Emissions vs. Units Sent Out: This massive reduction in emissions is a result of a number of interventions at various power stations over a 20+ year period.**

For more information, contact Rod Hansen at hansenRS@eskom.co.za

Going to pieces

Parameters Impacting Limestone Dissolution in WFGD Systems

Excerpts from a paper presented by Michael L. Mengel, Marsulex Environmental Technologies, at the recent "Energy from Clean Coal in the Perspective of the Kyoto Accord" in Milan, Italy

An analysis of the parameters affecting limestone dissolution rate is presented. In general, the number of moles of SO_2 absorbed by the solution must be equal to the number of moles of calcium carbonate that should dissolve into the solution from the solid particles of limestone. The analysis shows that SO_2 removal efficiency is lower in a Wet Flue Gas Desulfurization (WFGD) system operating at 109.4°F (43°C) compared to a WFGD operating at 140°F (60°C). The efficiency is further reduced if, in addition to the low temperature, a low reactivity limestone is used.

Variables Affecting Limestone Dissolution Rate

The overall performance of the WFGD system and the removal efficiency of SO_2 are strongly dependent on the quality of the limestone and the rate it dissolves into the solution.

The overall reaction that takes place in the WFGD system is

$$CaCO_3 + SO_2 + 2H_2O + {}^1/_2O_2 \rightarrow CaSO_4 \bullet 2H_2O + CO_2$$

The implication is that for every one mole of SO_2 captured one mole of limestone has to dissolve. The dissolved calcium in ionic form precipitates with SO_2 (after oxidation) as gypsum while the carbonate ion, in the presence of acid, forms CO_2 gas which is stripped out of the solution.

The steps involved in the dissolution of limestone follow:

1. $CaCO_3 \rightarrow Ca^{++} + CO_3^{=}$
2. $CO_3^{=} + H^+ \rightarrow HCO_3^-$
3. $HCO_3^- + H^+ \rightarrow H_2CO_3$
4. $H_2CO_3 \rightarrow H_2O + CO_2$
5. $Ca^{++} + SO_4^{=} + 2H_2O \rightarrow CaSO_4 \bullet 2H_2O$

The dissolution rate of the limestone depends on the following parameters:

1. Slurry pH – The H^+ ion reacts with carbonate and bicarbonate ions (reactions 2 & 3 above) and enhances the dissolution of the limestone.
2. Surface area – larger surface area increases limestone dissolution rate. Surface area depends on grinding and typically 95%<325 mesh is used in WFGD systems and results in a high dissolution rate of the limestone. (Note: to achieve high dissolution rate, the surface area should be accessible to the solution. Surface blinding, caused by excess ash in the slurry or by sulfite precipitation, slows the dissolution rate significantly)
3. Temperature – Diffusion rate of H^+ towards the limestone particles and of the Ca^{++} and $CO_3^{=}$ away from the limestone particle are enhanced at higher temperature. Similarly, CO_2 stripping from the solution and the rate of the chemical reactions involved are increased at higher temperature.
4. Reactivity – Limestone dissolution rate depends on its crystalline structure and level and type of impurities. For example, limestone that contains $MgCO_3$ as dolomite is typically less reactive than limestone with less dolomite.
5. Chloride concentration – High concentration of Cl^- ions is electronically balanced by high concentration of Ca^{++} ions in the solution, which slows the limestone dissolution in reaction 1.
6. CO_2 stripping – Stripping of CO_2 occurs naturally and is enhanced by the oxidation air. The stripping of CO_2 reduces the concentration of H_2CO_3 in equation 3 and 4 and further promotes limestone dissolution.

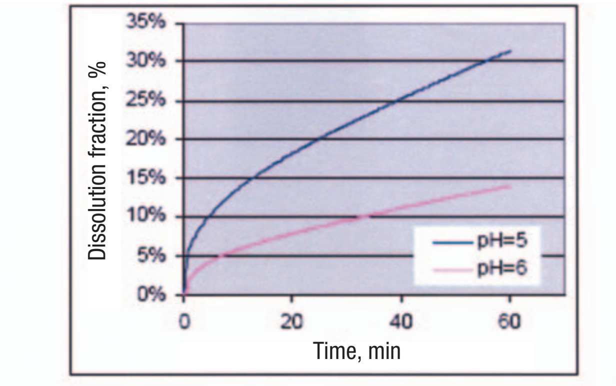

Figure 4: **Impact of pH on limestone dissolution rate at 50°C**

Impact of Selected Parameters on Limestone Dissolution

pH

The concentration of H^+ ions in the slurry, measured by the slurry pH, has a strong impact on the dissolution rate of limestone. In Figure 4 the dissolution rate, given as % of the limestone dissolved vs. time at constant pH and temperature, is shown. The dissolution rate at lower pH is more rapid than at higher pH. It takes approximately 32 minutes to dissolve 10% of the sample at pH=6.0 while it takes only approximately 5 minutes to dissolve the same 10% of the sample at pH=5.0, a faster rate by a factor of more than 6.

Typically, WFGD systems are designed to operate at optimal pH in the range of 5.0-6.0. At lower pH, limestone dissolution rate is considerably higher but SO_2 dissolution into the slurry and its removal efficiency is lower and vice versa.

Limestone Grind

The effect of limestone grinding on the dissolution rate of limestone is given in Figure 5 and it shows that a finer mesh sample dissolves a lot faster than coarser mesh. Typically, a

95% through 325 mesh is required for a high performance WFGD system, especially when a combination of high SO_2 removal efficiency and low limestone stoichiometry are required.

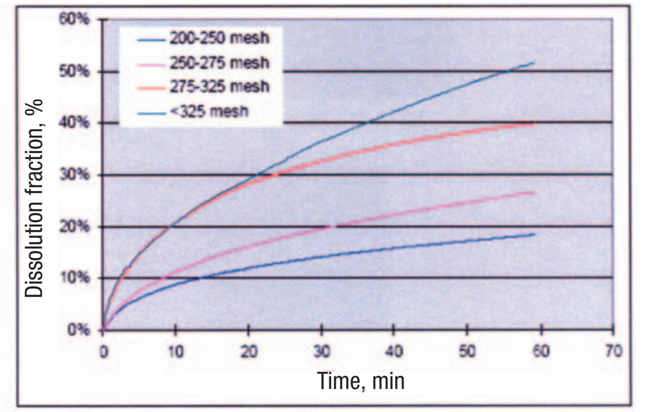

Figure 5: **Limestone dissolution rate as a function of time for various particle sizes at temperature of 50°C and pH=6.0**

Temperature

Typical WFGD absorber operates at 123.8-149°F (51-65°C) when no gas reheat is required and at 105.8-122°F (41-50°C) when gas reheat is accomplished by extracting heat from the flue gas upstream of the absorber. Lower absorber saturation temperature reduces limestone dissolution rate and as a result reduces its reactivity. For example, pH drops much faster at lower temperature when adding acid at constant rate. It takes 25 minutes, 35 minutes and 42.5 minutes for the pH to drop to a value of 5.0 at temperatures 109.4°F (43°C), 123.8°F (51°C) and 140°F (60°C) respectively.

Reactivity

The reactivity of limestone depends on its crystalline structure, density and impurities. A limestone of equivalent particle size distribution and at the same temperature, pH, chloride concentration and CO_2 stripping may dissolve at a significantly lower or higher rate than a standard limestone due to differences in crystalline structure and/or presence of impurities.

Impact of Chloride Slurry Concentration

Dissolution rate of standard limestone at pH=5.5, 140°F (60°C) and chlorides concentration in the range of 0-50,000 PPM was measured by MET (see US Patent 5,630,991 by Mengel and Gal) and is provided in Figure 6. It shows that dissolution rate drops with the increase in chlorides concentration.

Impact of Reactivity on SO_2 Removal Efficiency

The basic Marsulex model predicts removal efficiency of SO_2 as a function of gas velocity, liquid recycle rate, SO_2 concentration and absorber dimensions and is given in the form

Eff = 1- Exp [-Z] Where: Z= f (v, L, [SO2], V, Gm)

The model assumes 15% solids in slurry and 3% $CaCO_3$ in the dry gypsum cake. Under such conditions, there are approximately 4.5 grams of $CaCO_3$ in 1000 grams of slurry in the absorber. The model also assumes grinding with 95% passing through 325 mesh with limestone particle size P80=30.8 microns. For design and guarantee purposes, the reactivity of the limestone should be tested at the temperature at which the absorber is expected to operate.

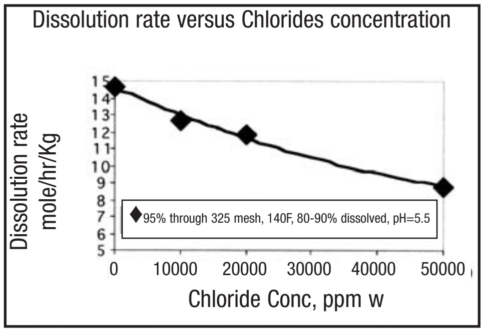

Figure 6: **Limestone dissolution rate vs. chlorides concentration**

Determination of Limestone Dissolution Rate

The value of the dissolution rate parameter, R, has to be determined experimentally using one of the following methods:

- ***Direct measurement procedure:***
  - Grinding a sample of the limestone to be used to the specified mesh size.
  - Controlling the temperature to the design absorber temperature.
  - Adding sulfuric acid at constant pH of 5.5
  - Measuring the average dissolution rate for 80-90% dissolved limestone.

The procedure is simple and low cost. The procedure can be used to measure the dissolution rate of fresh limestone as well as the dissolution rate of limestone in the slurry of an operating absorber.

- ***Indirect measurement procedure:***
  - Use Marsulex Environmental Technologies (MET) current reactivity tests with limestone sample at absorber designed temperature and measure the time to reach a pH of 5.0
  - Calculate R

    $R = \mathscr{R}*(\mathscr{t}/t)$

    Where:

    R = Dissolution rate of the sample limestone at the designed temperature.

    $\mathscr{R}$ = Dissolution rate of standard limestone at 140°F

    $\mathscr{t}$ = time to pH =5 for standard limestone under standare conditions

    t = test time to reach pH = 5.0

To address scrubber design issues arising from low temperature operation and low reactivity limestone, Marsulex is developing a data base to account for (1) dissolution rate as a function of temperature, and (2) dissolution rate for limestone with reactivity lower than that of standard limestone.

Summary

In cases where limestone dissolution is an issue due to inadequate surface area, low limestone reactivity due to impurities, high pH, high levels of chlorides (above 20,000 ppm) or low temperature due to in leakage or other factors, several solutions can be used to compensate. These include:

- ➔ Lower chlorides concentration
- ➔ Finer limestone grinding
- ➔ Higher purity limestone
- ➔ Lower system pH
- ➔ Higher L/G ratio

The solution that requires the least change in the system and therefore the lowest cost is to simply increase the solids concentration in the reaction tank; thereby having a higher concentration of limestone particles in the slurry.

Footnote: Authors include...
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It's in the bag

Ensuring Optimum Baghouse Performance

Robert G. Mudry, P.E, Airflow Sciences Corporation

Baghouses (also known as fabric filters) remove particulate from a gas stream and are a commonly-used pollution control device at industrial facilities. They are used extensively at electric power plants, steel mills, cement plants, and food processing facilities. If designed and installed correctly, a baghouse can be exceptionally effective, collecting over 99 percent of particulate before it reaches the stack. Incorrect design, on the other hand, can lead to performance or maintenance problems such as reduced capture efficiency, plant production decreases, premature wear of bags, high system pressure losses, or particulate buildup in the ductwork. A typical baghouse from an electric power plant is shown in Figure 7.

Building and testing a flow model is one of the most effective ways to ensure optimum baghouse design and performance. This is often done during the initial design of a baghouse, but can also be performed for an existing baghouse that is experiencing operational problems. **There are two types of flow models that are used in industry today: a physical laboratory model and a computer flow model.**

Physical Model: A physical model can help engineers visualize flow and flow distribution, predict velocity, temperature, pressure losses, and particulate buildup, and design flow control devices, such as vanes and baffles, that can optimize performance and avoid costly problems. A photograph of a typical baghouse model is shown in Figure 8. This particular model is $^1/_{12}$ scale. In this design, flow travels from a coal-fired boiler through a cylindrical cooling tower (where the gas temperature is reduced by water sprays) to a baghouse. The baghouse in this design has six separate compartments where bags collect the ash residue from the coal-burning process.

Figure 7: **Typical baghouse from an electric power plant**

Specific objectives of a baghouse physical model study usually include:

- ➤ Ensuring a uniform portion of the gas and particulate go to each compartment, with all compartments in service or with one out of service.
- ➤ Ensuring that flows entering each compartment are well-behaved and that all bags are utilized within a given compartment.
- ➤ Preventing gas velocities that are high enough to damage a bag via ash erosion.
- ➤ Minimizing pressure losses.

- Obtaining adequate mixing of any temperature or gas species imbalances to ensure uniform gas properties through each compartment.

Figure 8: **Typical baghouse model**

Models are usually constructed of clear acrylic at a $^{1}/_{12}$ scale and are designed based on original drawings, operating conditions, photos and inspection logs. Once designed and built, a baseline flow simulation is conducted for the system at full load. Velocity, pressure, dust and flow visualization tests are completed to quantify performance and determine baseline values. After baseline values are established, design modifications are made to the model, and the model is retested. These modifications can include the addition of new flow control devices or alterations of existing geometry elements. Once a final configuration is established, the model goes through a final round of testing. These tests determine:

- Traverses in each compartment inlet to evaluate gas flow split between chambers.
- Inlet duct re-entrainment tests for all chambers in service.
- Flange-to-flange pressure drop across the fabric filter for all chambers in service and one chamber out of service.

The photos presented in Figures 9 and 10 show smoke visualization and dust testing through such a model. Injecting smoke into the model allows observation of the flow patterns and is a useful technique to troubleshoot problem areas. Dust testing is typically performed using a simulated dust (such as sand, cork, salt, cement, or others) to represent the flow patterns of the actual particulate. The dust is injected into the model to observe areas where piles may build up on duct floors or other surfaces. The particulate will drop out in low velocity regions, especially when the system is operated at reduced flow rates. The goal of the modeling is to minimize any accumulation and to ensure that if any dust drops out under reduced operating conditions that it is swept back into the flow at full operation. Figure 10 shows minor dust deposits in the ductwork of a model while operating at a low load condition; these deposits were successfully re-entrained into the flow under full load conditions.

Figure 9: **Smoke Visualization**

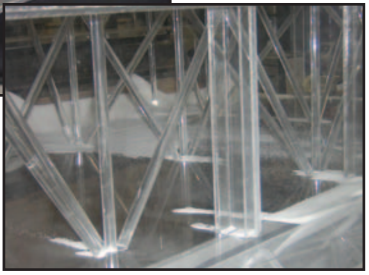
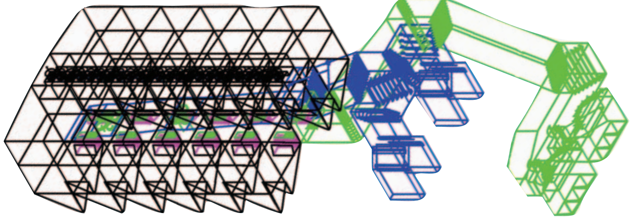


Figure 10: **Dust Testing**

Computer Flow Model: A second type of flow model utilizes Computational Fluid Dynamics (CFD) techniques. CFD is a method of simulating flow using a high-speed computer. CFD was developed in the aerospace industry in the 1970s to design airplanes and spacecraft, but has been applied to many other industries over the past 20 years.

Figure 11: **3D full scale model of a power plant baghouse**



The CFD process begins with a computerized representation of the geometry, as shown in Figure 11. This is a 3-D, full scale model of a power plant baghouse. By using sophisticated software and very high-end computers, the flow properties within the domain are calculated.

The software solves the equations of fluid motion (Conservation of Mass, Momentum, and Energy), and thus determines the velocity, pressure, temperature, gas species, and turbulence characteristics within the geometry. Results are generally plotted as color contours or particle streamlines, as Figures 12 and 13 provide. Figure 12 shows an overall baghouse model with velocity patterns indicated in the color contours (red = high velocity, blue = low velocity). Figure 13 is a detailed model of a single baghouse compartment; flow around and through the bags, which hang vertically, is depicted. Computer-animated movies can also be created that show the flow in motion.

Both types of models, physical and CFD, are used extensively in baghouse design and for other pollution control devices. There are advantages and disadvantages of each method, and the choice between the two techniques is made by the equipment supplier, the equipment owner, and the flow

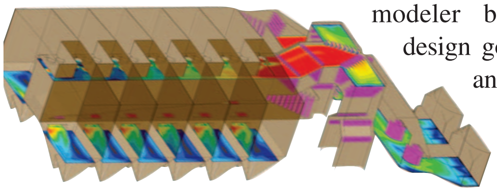


Figure 12: **Overall baghouse model with velocity patterns indicated in the color contours red=high; blue=low**

modeler based on the design goals, schedule, and other parameters. In some cases, both types of models are used in order to obtain the best overall engineering design of the system.

A baghouse can be a powerful pollution control device, but its performance hinges greatly on flow balance, velocity profiles, temperature patterns, and pressure losses. Ensuring that these factors are accounted for in the design is a worthwhile investment that can save much in maintenance, energy and labor costs.

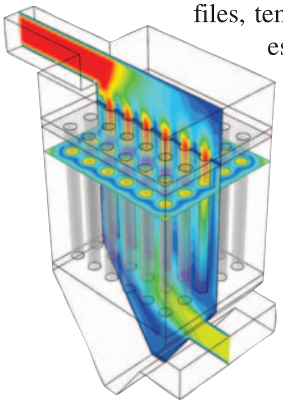


Figure 13: **Detailed model of a single baghouse compartment**

For more information,
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When good components go bad

Current Limiting Reactors: The Overlooked ESP Control Component

By Peter Aa and Paul Ford, Redkoh Industries

In Silicon Controlled Rectifier (SCR) type Transformer Rectifier (TR) control circuits, you will find a Current Limiting Reactor (CLR). The CLR is located in one of the legs feeding the primary of the TR. (Figures 14 & 15)

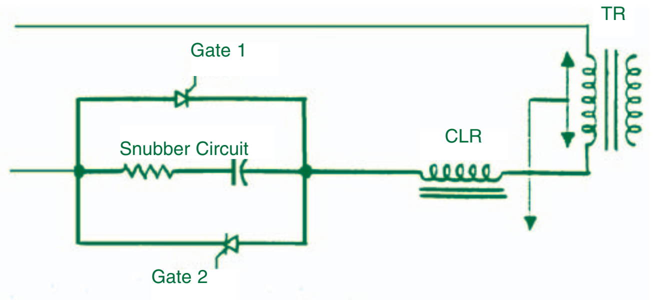

Figure 14: **Location of the CLR**

By definition, a CLR is an electrical choke that resists the instantaneous change in AC current in an electrical circuit. This is accomplished by a bucking Electromagnetic Field (EMF) that is generated by the magnetic field that builds up from the inrush current.

The purpose of the CLR in an electrostatic precipitator control circuit is twofold; one purpose is to reduce the instantaneous rise in current to the primary of the TR that occurs from the turn-on of an SCR, to a slower more sinusoidal shape; and the other purpose is to limit the instantaneous rise in current in the primary of the TR due to sparking and arcing within the precipitator (secondary load on the TR).

When sized properly (millihenry rating based on design current flow during precipitator operation and the desired percent impedance of the total circuit) the CLR permits the greatest SCR conduction duration when the precipitator is operating at design conditions. When no precipitator sparking or arcing occurs the control system will allow TR rated current to flow.

When a CLR goes bad, the TR rated design current may not be reached even in the absence of sparking or arcing. Some CLR failures are easy to detect. If the metal laminations that make up the core of the CLR become excessively loose, the CLR will make a very loud humming/vibrating noise. The loudness can reach levels where you can not hold a conversation if you are near the CLR. Other failures can manifest themselves as overheating of the CLR. Most CLRs are rated to operate up to 200°F (93.3°C) or so over ambient. Using an infrared thermometer, the temperature of a CLR can accurately be measured. Those running substantially hotter than design have either failed or are on their way to failing.

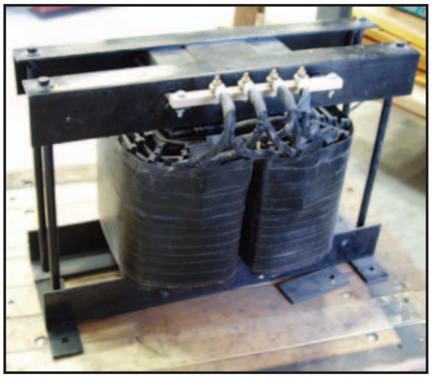

Figure 15: **Current Limiting Reactor**

Remember, a failure of a CLR (unless it is an open circuit failure) may not shut down a control cabinet, but it will result in less than desirable SCR conduction angles that will reduce power to the precipitator and result in lower collection and higher emissions.

Figure 16 shows some electrical readings that indicate a CLR has failed over time:

At Time 1: The control has driven the TR to its rating and the AVC is in control of the SCR's. Current limit is achieved.

At Time 2: The circumstances have changed little and the AVC remains in control of the SCR's. The unit continues to achieve current limit.

At Time 3: The reactor impedance has started to increase and voltage has reduced on the primary of the TR. The AVC has phased the SCR's forward to 162 degrees in an effort to raise the kV and to try and increase the current on the ESP.

At Time 4: The reactor impedance has further increased; the SCRs are full on (note – This AVC considers that 162 degrees is full conduction). Since more volts are dropped across the reactor, fewer volts appear on the TR primary and so the kV on the ESP falls further and current is reduced.

Times 5-8: The reactor deteriorates further and since there is nothing the AVC can do to get more power to the TR, the KV and mA fall to levels way below satisfactory and efficiencies are compromised.

Time	Primary Volts	Primary Amps	Secondary Voltage (KV)	Secondary Current (ma)	Conduction Angle (degrees)
1	399	238	45	1500	155
2	395	236	44	1507	158
3	392	234	43	1500	162
4	382	228	42	1460	162
5	376	224	41	1430	162
6	362	215	40	1367	162
7	358	213	39	1350	162
8	338	202	37	1274	162

Figure 16: **Electrical readings that indicate a CLR failure**

In conclusion: It can be seen from this discussion that the CLR is a critical element within the controls system. Certainly in non-sparking precipitator electrical fields and in the presence of certain flu gas condition agents, the AVC is able to maximize the power into the TR and hence the ESP. A faulty reactor would counter both the AVC's efforts as well as undermine the effects of the FGC agent.

For more information, contact Peter Aa at peteraa@redkoh.com or Paul Ford at paulford@redkoh.com

AIG Tuning

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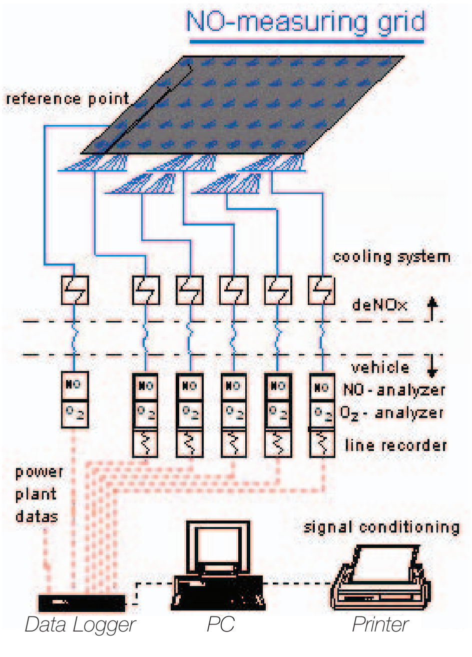

Figure 17: **Schematic of a typical ECOS setup for AIG tuning**

ECOS is used for fine tuning the ammonia injection grid, the investigation of load dependent NO operating points, and possibly the determination of the NOx reduction efficiency of a single catalyst layer. Providing quasi-simultaneous flue gas analysis over the SCR's entire cross-sectional area by operating up to seven (7) NO/O_2 analyzers in parallel, ECOS accurately determines the NO and O_2 concentrations in the flue gas at up to 100 measuring points within forty-five (45) minutes using the fixed sampling grid installed after the last catalyst layer. The results are directly converted online into a three dimensional concentration profile in order to allow a correct evaluation of the found distribution, which then can be optimized.

Figure 1 on page 1 shows an actual ECOS set up on a platform between the SCR reactors of two units for which Steag performed AIG tuning.

In order to ideally overlay the NH_3 profile over the NOx profile for combining maximum removal efficiency with minimum NH_3 slip, the NO profile after the last catalyst layer is measured. Subsequently, the NH_3 injection system is adjusted in such a way that the NO profile after the last catalyst layer is as uniform as possible at the lowest possible level. This ensures a minimum ammonia slip at a maximum NOx removal efficiency.

Unlike hand-held or other analyzers for NO, an ECOS multiple analyzer set up yields numerous significant advantageous, namely:

✔ Up to seven (7) sampling points can be measured in parallel thus providing a real time NO distribution along one axis of the SCR reactor at any time.

✓ Online correction of trends and fluctuations in the NO inlet concentration by generating a single NO reference point at all times.

✓ A 3-dimensional NO-profile can be generated in real-time allowing for easy and accurate balancing of the ammonia injection valves.

✓ All NO measurements are O_2-corrected allowing for fully comparable NO values by canceling out any dilution effects due to varying O_2-contents.

✓ An O_2-profile, which is generated in parallel, allows for the detection and identification of leaking or otherwise faulty sampling lines as well as for possible imbalances in the air distribution of the combustion system.

AIG tuning must be performed with the goal of achieving the best possible NO profile after the last catalyst layer. Efforts should not be stopped after achieving a certain targeted root-mean-square (RMS) of the NO distribution. Based on Steag's long term SCR operating experience, they have concluded that the RMS is an inadequate measure for characterizing the quality of the ammonia distribution upstream of the first catalyst layer and, therefore, not useful for AIG tuning.

Typically, a coal-fired boiler operated at steady full load conditions produces a reasonably steady NOx inlet profile at the inlet to the SCR. However, similar to the surface of a lake on a calm day, each point of the surface of this profile fluctuates by about +/- 5 ppm to +/- 10 ppm, which is considered a signal noise in the NO reading. The same NO signal noise is also found in the same absolute quantity after the last catalyst layer and cannot be tuned out. Based on our experience, a good AIG tuning result is obtained as soon as the NO profile after the last catalyst layer remains within +/- 2 times the NO signal noise. Thus, for example, in case the NO signal noise is +/- 5 ppm, a good AIG tuning result would be considered as achieved as soon as the NO profile after the last catalyst fluctuates with absolute NO values of less than +/- 10 ppm regardless of the absolute level of the NOx concentration at the stack.

Typically, good practice dictates utilizing five or six NO/O_2 analyzers in parallel for generating the NO-profile with one additional NO/O_2 analyzer providing the reference point needed for the correction of NO trends and fluctuations. This reference point measures only the relative changes in NO during the generating of the NO-profile, which will then be used for correcting the generated NO-profile in order to eliminate trends and changes in the NO concentration produced by the combustion system. This will allow the development of a full 3-dimensional, fully trend and O_2-corrected NO-profile after the last catalyst layer in 20 – 45 minutes with a sampling time of about 3 minutes at each point.

During actual AIG tuning, the unit must be operated at full load on a continuous basis, thus ensuring the maximum flue gas volume flow rate and maximum NOx mass flow rate through the SCR. Obviously, the unit's SCR reactor must be equipped with a fixed installed sampling grid after the last catalyst layer. It must also be ensured that all test ports are free of air in-leakage and are correctly labeled in order to clearly identify which test port corresponds to which point inside the SCR reactor. It is recommended to verify the labeling of the ports during a scheduled outage prior to AIG tuning and ensure also that none of sampling lines expose leaks at their connectors or due to corrosion. 🌎

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New Coal-Fired Power Plants Specifying WESP

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To meet these new stringent emission limits, consulting engineering firms are including in their specifications for the air pollution control system a wet electrostatic precipitator device. The wet electrostatic precipitator (WESP) acts as a final polishing device that removes from the flue gas those particles and condensable vapors that pass through the dry electrostatic precipitator (ESP), fabric filter and FGD either because of their sub-micron size or condensable nature. Dry ESPs and fabric filters operate in an unsaturated condition where the flue gas temperature is in the range of 300-400°F (148.9-204.4°C) and above the dew point of sulfuric acid mist. As the temperature of the flue gas drops as it passes through the FGD scrubber, any SO_3 present in the flue gas condenses into sub-micron mist and hydrolyzes with H_2O to form H_2SO_4, sulfuric acid mist. While the bulk of particulate mass is removed in the upstream APC equipment, only a small fraction of the actual number of particles in the flue gas are removed because of their sub-micron size. Due to light extinction, these sub-micron particles create the most visible plume. Wet ESP technology is a well-known technology for control of these sub-micron particles and aerosols with application in a wide variety of industries around the world that is now being recognized by the utility industry as a control option for abatement of $PM_{2.5}$ and SO_3. 🌎

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