WPCA NEWS

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WORLDWIDE POLLUTION CONTROL ASSOCIATION

Out with the Old, In with the New

Upgrading Your Wet FGD System

By Richard Staehle, Marsulex Environmental Technologies

Wet flue gas desulfurization (WFGD) technology has undergone numerous improvements and changes since first being introduced to electric utilities over 30 years ago. Many of these changes have been brought on by improvements in technology/equipment as well as by the lessons learned as WFGD experience in start-up and operation was gained over the decades. Improvements in reliability are evidenced by the fact that today, single FGD absorbers are typically installed for boilers up to 1000 megawatts and, in some cases, multiple smaller boilers are today serviced by single WFGD absorbers. The old design philosophy of supplying multiple absorbers with spares is rarely - if ever - seen anymore.


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Figure 1: Absorber Liquid Redistribution Devices (ALRD) in tile-lined FGD

Many utility WFGD systems in operation today were considered "state-of-the-art" when installed 20 or 30 years ago but face new hurdles as their age and design are being challenged by new and changing tasks. Examples of these drivers are the ratcheting-down of allowable emissions and switching to higher sulfur coal. New, lower emissions requirements can be dramatic when compared to original design levels. This may require the elimination of an existing partial bypass which will strain the system not only process-wise, but also create higher flow and pressure drop in the absorber and greater strain on the mechanical systems.

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Mercury: What comes in must go out!

Increasing Mercury Removal Efficiency of Wet FGD

By Philip Elliott and Hans Hartenstein, Evonik Energy Services LLC

Mercury Emission Reduction

As of late, mercury released to the environment has become a very important issue due to its effect in the aquatic environment and thus the food chain. Coal-fired power plants have been identified as one of the major sources of mercury emissions. As a result of the courts invalidating the Clean Air Mercury Rule (CAMR) ruling, regulations regarding mercury emissions can be expected to become even more stringent than proposed under CAMR. Several states have already implemented regulations that require coal-fired power plants to drastically reduce their mercury output.

Mercury enters the power plant process as a trace component of the coal combusted. There are only four paths for mercury to leave the power plant process, namely with the ash, with the flue gas cleaning byproducts (e.g. gypsum), with the waste water, and with the flue gas.

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What's right is what's right for you!

Does Electrostatic Precipitator Operating Frequency Matter?

By Peter Aa, Redkoh Industries

Back in the very early 1900's, when Frederic Cottrell was installing the first electrostatic precipitator, he had to use 60 Hertz (cycles back then) as the rectified DC frequency because he had no other choice. Devices for controlling the frequency to an ESP had not yet been invented. As a matter of fact, since the precipitator controls had no feedback/control in those days, double half wave was used so that an electrical frame actually only saw 30 Hertz. This lower frequency allowed some additional "off" time for a spark to extinguish on its own.

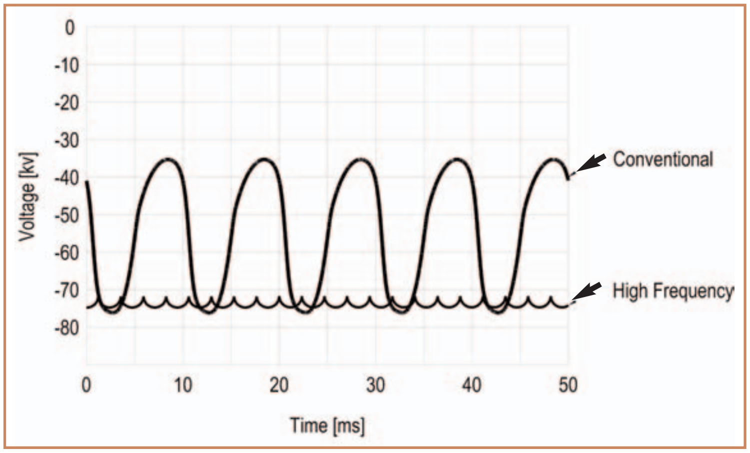

FIgure 2: Ripple Voltage

At the 60 Hertz frequency, and without feedback to control sparking, these early controls were both unstable and produced a significant DC ripple (difference between the peak and the minimum values) on the precipitator power. Because of this ripple, the average voltage applied to the precipitator was always considerably lower than the peak.

As electronic components, such as electron tubes and solid state devices advanced, TR controls were able to sense operating conditions and control spark and arc rates in a precipitator. This created a much more stable, and reliable, precipitator control. However, the operating frequency remained at 60 Hertz and the average voltage to the precipitator was still considerably lower than the peak.

With the invention and subsequent improvements in Switch Mode Power Supply technology, the frequency of the power supply to the precipitator is now controllable through the use of electronic Insulated Gate Bipolar Transistor (IGBT) devices. Since IGBT's allow the voltage to be turned on and off at any time in their waveform, almost any frequency can be produced by an appropriate power converter and then stepped up and supplied to the precipitator by a suitable transformer.

Operating at higher frequencies causes the voltage to be re-applied to the precipitator before it has had significant time to discharge following the previous half cycle of supply. In doing so, the amount of ripple is reduced and the ripple voltage minimum value approaches the peak value. See Figure 2.

The average voltage to the precipitator is thus at a higher level than with conventional 60 Hz controllers. Since voltage and current go hand in hand, higher voltages should translate into higher current and overall higher power into the precipitator. The higher power in turn should translate into higher collection efficiencies and lower outlet emissions.

A precipitator power supply that can switch with elevated frequencies as low as 400Hz can provide 800Hz to the precipitator while allowing existing transformer-rectifiers to be re-used.

As the switching frequency is elevated into the kilohertz range, a new more sophisticated step-up transformer-rectifier is required.

With the ability to use elevated frequencies, precipitator power supplies have become remarkably more flexible. Systems can now be put in place to deal with numerous applications issues, all with a view to improving overall performance and reducing cost.

Your plant will most likely respond favorably to one or more of the following approaches.

- Hybrid systems with a collection of conventional transformers mixed in with switch mode units.
- Splitting fields and increasing the number of transformers (switched or conventional).
- Mixing in mid frequency controls and using existing conventional transformers or new transformers.

Exactly which frequency and which scenario will produce the optimal increase in precipitator performance remains an ongoing discussion topic. Since this question will likely not be answered for years to come, the real question is, having all these tools at your fingertips, *what will work for you?*

For more information, contact Peter Aa, Redkoh Industries, at peter.aa@redkoh.com

When there's more than one answer

The Pros and Cons of CFD and Physical Flow Modeling

by Kevin W. Linfield, Ph.D., P.E. & Robert G. Mudry, P.E.

When it comes to flow modeling to optimize performance or to develop solutions for flow-related problems, a frequent question that industry engineers ask is "Which is better – a CFD or physical (scale) flow model?" The short answer is, "It Depends."

Background: Computational Fluid Dynamics (CFD) is a method of simulating fluid flow behavior using high speed computers. There are well-known mathematical equations that define how air and gases behave (Conservation of Mass, Momentum, and Energy). These equations are extremely complex (differential equations), and thus cannot be solved by hand calculations except for very simple geometries such as flow around a cylinder. As computer power increased in the 1970s, the aerospace industry led the way in developing software to approximate solutions to these equations for complicated flows around air and space craft. Over the past few decades, these software tools have advanced to a point where accurate solutions can be obtained for complex flows, including heat transfer, particle tracking, and chemical reactions. See Figure 3.

Figure 3: CFD was first developed for the aerospace industry

In a CFD model, the three-dimensional domain is built in the computer via a CAD model. A computational mesh is then inserted into the domain – this mesh divides the region where flow travels into many, many control volumes, or cells. It is not uncommon for a CFD model to contain millions of these cells. The software then solves the equations of fluid motion (Conservation of Mass, Momentum, and Energy) in every one of these cells. The results are plotted as color contours to depict the flow parameters at any location within the domain. Thus, it is possible to analyze millions of velocities, pressures, temperatures, species concentrations, and other values. Computer-generated animations can also be created that provide flow visualization to observe the "real-time" motion of the flows. See Figure 4.

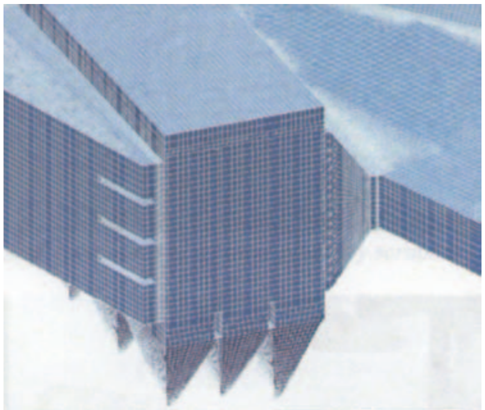

Figure 4: CFD mesh for an electrostatic precipitator

It is difficult to determine how long physical flow modeling has been used in engineering applications. Obviously, full-scale versions of land and sea vessels were tested via trial-and-error for centuries to optimize designs. In the early 1900s, the Wright Brothers tested a scaled version of an airfoil in a small wind tunnel that led to the age of flight. Since the 1960s, scale models have been used to assess flow patterns in power plant duct systems, pollution control equipment, and boilers. Today, many of these models are built to a scale of 1:8 to 1:16, with 1:12 being a common scale factor. See Figures 5 & 6.

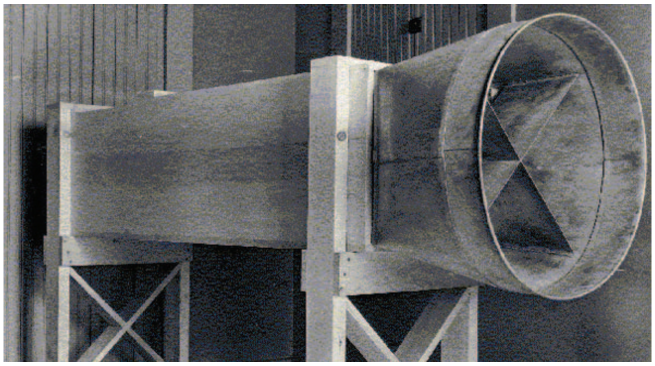

Figure 5: Wright Brothers wind tunnel

Figure 6: Physical flow model of a power plant dry scrubber and baghouse

Once the physical model is constructed, large fans are used to draw air through the model at a flow rate that provides similar fluid dynamic behavior to the full scale system. Flow characteristics are measured over a grid of traverse points with an inserted probe. Values for velocity and pressure at select locations are thus obtained. Dust can be injected into a model to simulate the behavior of particulate in a system (to assess ash deposition, for example). Of course, the model is constructed with clear walls or windows so that flow patterns can be observed via smoke flow, strings, or bubbles. Model results can be presented as color contours, histograms, or other plotting methods similar to field testing. See Figure 7.

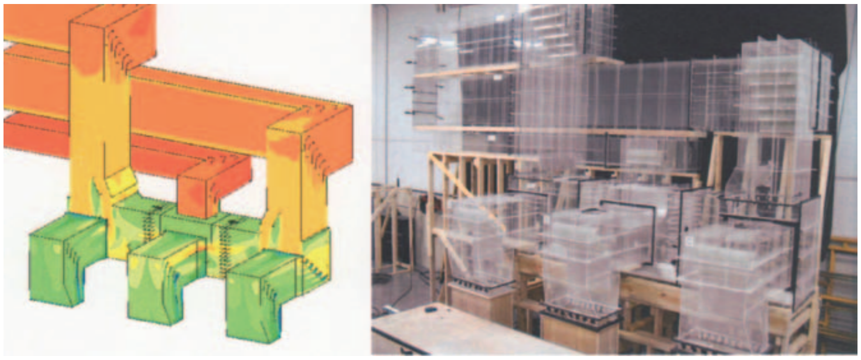

Figure 8: Comparison of CFD and physical model results for an FGD duct system where flow from 3 units (1,750 MW total) combine to feed 3 new booster fans (CFD pressure drop 1.19 “H20;Physical pressure drop 1.27 “H_20)

With either type of model, the flow patterns through the system are quantified and the model geometry is iteratively altered in order to optimize the flow. The location and shape of control devices such as turning vanes, mixers, baffles, and dampers are thus determined such that the design objectives are attained.

Figure 7: Smoke flow through an SCR physical model

Accuracy: With the proliferation of high speed computers, the resolution and cell size of CFD models has improved dramatically over the past few decades. Airflow Sciences Corporation, which has used both modeling methods since 1975, has made numerous comparisons between CFD modeling, physical modeling, and field testing. Results indicate that both types of models share the same accuracy when it comes to velocities and pressures. For more on this please visit ASC's web site (www.airflowsciences.com) for conference proceedings which make this comparison with respect to ESP and scrubber modeling. See Figure 8.

There are certain areas where CFD and physical model results differ and it is not clear which provides the best real-world results. For instance, in SCR modeling, CFD models tend to predict slightly worse ammonia uniformity at the catalyst compared to physical models. Industry comfort is with the physical model in this case, and it is possible that the underlying mesh is not fine enough to resolve all the details of the injection and mixing. That said, there is not a lot of specific data published that shows how well either model matches real-world test data.

Similarly, for wet FGD absorbers and stacks, physical models are often used with liquid water injected into the models. Though the droplet size is not scaled properly, and evaporation is not represented accurately, some industry designers find value in the results and utilize their experience to interpret the results of the wet modeling. Because this is such a complex flow phenomenon, CFD models have not yet proven to be better at predicting droplet movement and impingement. So both model types have drawbacks where industry experience in applying the results to the real world become important.

Schedule: CFD modeling is almost always faster than physical modeling. In many cases, design results from a CFD model are available several weeks before similar results from a scale model. And the more complicated or repetitive the model geometry is, the more advantage the CFD model has. This has to do with three factors:

❶ The CFD mesh can usually be built faster than a scale model can be fabricated,
❷ For repetitive or symmetric duct systems, portions of a CFD model can be copied and pasted while all pieces of the physical model need to be built separately, and
❸ Once a CFD model is built, it can be run simultaneously on separate computers.

Thus, several designs can be evaluated at the same time, while only one physical model exists to evaluate designs.

Modeling Cost: CFD model studies are generally 20-40% less than a comparable physical model effort. This is tied quite strongly to the labor difference in model construction that influences the schedule. Also, many CFD tasks can be automated with the computer, including the design optimization process, whereas these tasks are always manual with the physical model.

Scale: Most physical models are built to scale, typically 1:12 or 1:16 for power plant models. CFD models are almost always built full size (1:1 scale). Care must be taken in computer models to ensure the correct number, size, and shape of computational cells are used, and the level of detail to include must be considered in a scaled model to ensure geometric and dynamic similarity is maintained. In a CFD model, the Reynolds Number is often matched exactly, while in a physical model, industry tries to match the Reynolds Number regime (i.e., laminar or turbulent). Both are fine as long as the boundary layer is negligible. This is generally the case for large power plant duct systems. Note, however, that one must closely match the exact value of the Reynolds Number if the objective is to determine lift or drag characteristics, or any system where the boundary layer along a surface is important. For liquid sprays, since particle droplets don't scale and evaporation can't be simulated in a cold flow model, a CFD is often the best choice, but note that agglomeration is often ignored. See figure 9.

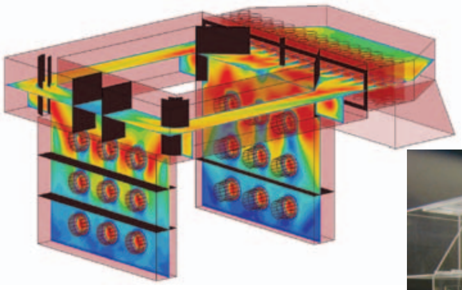

Figure 9: CFD and physical model of a windbox

Particulate: In general, particle drop-out or re-entrainment is more accurate in a physical model. These tests help assess whether particulate (such as coal flyash) will fall out of the gas stream at lower unit flow rates. It is important to run the physical model at comparable velocities to the actual system, taking into account particulate aerodynamic characteristics which can be determined via wind tunnel tests. CFD results can be used to assess potential areas for particulate drop out by examining low velocity regions near duct floors and other surfaces, but CFD cannot yet predict re-entrainment of particles as the system flow rate ramps up. This is because particulate build-up and re-entrainment are time-dependent phenomena. A physical model can be used to observe the particle behavior over time, but a CFD model is generally run as a steady-state simulation.

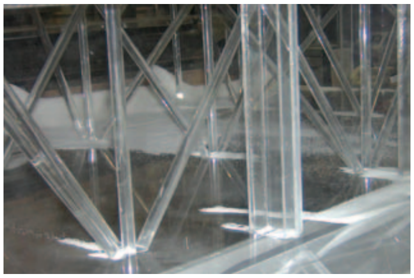

Figure 10: Physical model dust testing (dust accumulation simulated with fine white pow-

Particulate tracking is often desired to assess items such as large particle ash pluggage, activated carbon/sorbent injection, or flyash erosion issues. Particles "in flight" are better simulated in a CFD model. This is because the CFD model is run full scale and can thus match all the important factors for particle behavior simultaneously (gravity, particle drag, gas velocity, gas viscosity, particle Reynolds number, particle mass and size). Some qualitative assessments of particle behavior "in flight" can be performed with physical models, but because all the scale factors and fluid dynamic properties cannot be matched simultaneously, quantifiable results are more difficult to obtain. See Figures 10 & 11.

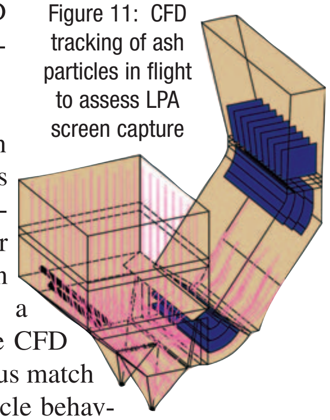

Figure 11: CFD tracking of ash particles in flight to assess LPA screen capture

Heat Transfer: For complex temperature problems (especially those involving conduction, convection, or radiation), CFD is really the only option. Physical models are often called "cold-flow models" since room-temperature air is drawn through the domain. Methods have been devised to simulate thermal mixing in a physical model (such as the merging of gas streams of differing temperature) via an injected tracer gas. These tracer gas methods can simulate thermal mixing and diffusion, but constant temperature physical models cannot simulate conductive heat transfer, thermal radiation, or similar phenomena. CFD models are run at the correct temperature, and take into account changes in density, viscosity, thermal conductivity, and the heat transfer coefficient. CFD models of boiler combustion processes, heat exchangers, and evaporative processes are thus possible. See Figures 12 & 13.

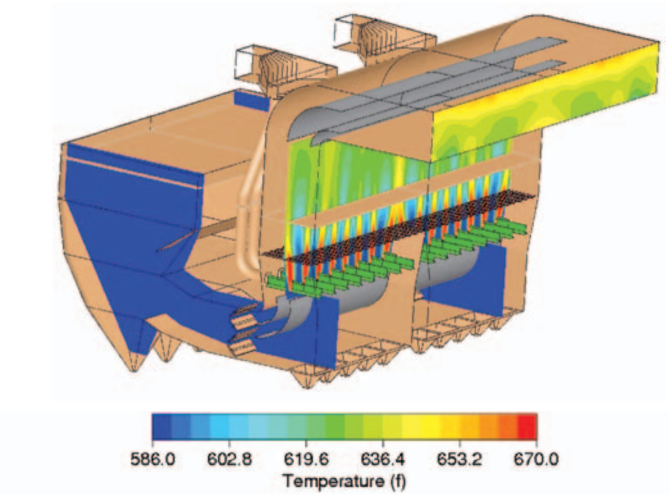

Figure 12: CFD modeling of thermal mixing (SCR economizer bypass flow)

Chemical Reaction: Simulation of a chemical reaction (such as combustion or change-of-state) can realistically only be done with a computational model or a laboratory test that includes the reactions. The latter would not really be referred to as a "physical flow model" as much as a lab test (such as a combustion test chamber). Short of such a lab test, computer flow modeling can be used to simulate complex processes, incorporating individual species and compounds via reaction equations. Furnace combustion models are done via CFD to assess items such as burner/OFA systems, NOx creation, gas temperature uniformity, SNCR performance, slagging, and corrosion. Also, evaporative processes can only be fully simulated in a CFD model due to the changes in temperature and the moisture transfer from one state to another.

Figure 13: Physical model testing of thermal mixing via tracer gas injection (SCR economizer bypass)

Results Visualization: Both types of models rely on color contour plots and flow statistics (uniformity, min/max values, etc.) to quantify results. Smoke injections and string tufts are also used to visualize the flow field inside a scale model. These are videotaped and photographed to document the flow patterns. Dust testing results are also videotaped so observations of particulate drop-out and re-entrainment can be documented. Flow animations from CFD results can provide similar views on the motion of the flow as a physical model smoke test. CFD animations can also present characteristics that are difficult to quantify in a physical model (i.e., a visual tracking of injected gas molecules, such as SO_3 or NH_3, through a duct). See Figures 14 & 15.

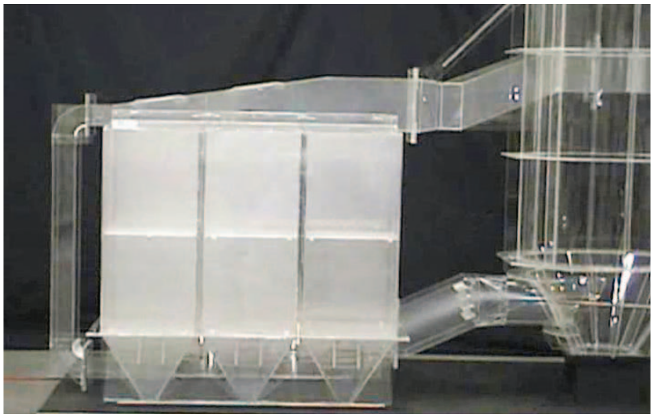

Figure 14: Smoke flow details in a physical model

Touch and Feel: Seeing and touching a laboratory model can be more satisfying than looking at color contour plots and animations of a virtual model. Many clients appreciate walking around a 3-D scale model and examining flow details around the vanes, through perforated plates, and near internal structure. What's best depends on personal preference.

Storage: CFD models are usually stored on tape, CD-ROMS or DVDs which typically have a much longer storage life and negligible space requirements. Physical models can take up considerable space in a warehouse. A benefit of the physical model after the design effort is that it can be used for other purposes, including as training tools for plant staff or as a display item for a plant lobby.

Concluding Thoughts: As noted above, there are certain flow characteristics that are best simulated with a particular type of model. Since there are advantages and disadvantages of both models, a number of new systems, particularly the more expensive pollution control devices such as SCR and FGD, utilizing both modeling methods are being used to get the optimal design. For ductwork systems, ESPs, or fabric filters, both methods have shown they offer similar results and acceptable designs; in these cases, the selection of the method often comes down to personal preference of the OEM or the end user.

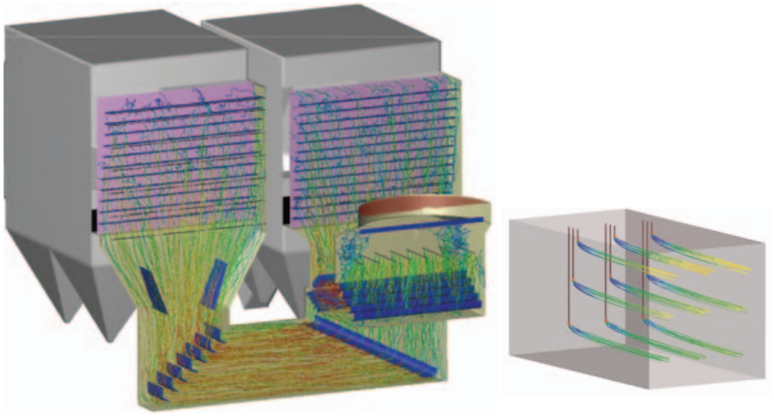

Figure 15: CFD injection of activated carbon upstream of an electrostatic precipitator

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Upgrading Your Wet FGD System

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Some utilities wish to burn alternative, lower cost coals with a higher sulfur content (well beyond that originally designed for) that promise to further compound the demands on older WFGDs. In some older plants, the modification of oxidation mode has been done in order to provide a more beneficial gypsum by-product or to eliminate a disposal issue. Various chronic maintenance chores can sometimes be eliminated or reduced greatly by modification of the problem area to a modern, higher reliability design.

Figure 16: Alloy ALRD

The application of current improvements in technology, equipment, process improvements and general know-how to provide better operation, maintenance and performance to existing WFGD systems (i.e. "Upgrades") are becoming more of a necessity as the older systems are asked to do more and more relative to their original functions.

SO_2 Removal Efficiency Upgrades

The need to remove more SO_2 due to more stringent regulations and/or fuel switching is a common need. This need can manifest with a requirement to boost SO_2 removal efficiency percentage from the high 80's or low 90's to upper 90's. Another reason can be due to the elimination of existing partial gas bypass. For plants with spare absorbers and/or spray levels, this can result in ongoing usage of spare spray levels and/or spare absorbers on a normal basis. In this case, the shortcomings of original design relating to reliability must be addressed as the backups will not be available. An additional approach is to boost the ability of the existing absorbers to capture SO_2. The typical upgrade approaches are to increase reagent slurry recycle flow (L/G), improve spray patterns/nozzle layout, and to install (in an open spray tower) Absorber Liquid Redistribution Devices (ALRDs) or perforated trays.

Marsulex Environmental Technologies, or MET) received a U.S. Patent in 2003 for ALRD technology which is incorporated in MET's OEM designs today. See Figures 1 & 16. ALRDs improve SO_2 efficiency by significantly reducing the gas sneakage in an open spray tower due to the tendency of gas to hug the walls of the absorber vessel. The ALRDs do this, as well as "kick-out" slurry run-down from the walls back into the gas stream, making better use of the L/G delivered to the spray banks. In a 3% sulfur fuel WFGD, past retrofits of ALRDs alone boosted removal efficiency equivalent to an L/G increase of 15-25% with a negligible (less than 0.1" w.c.) pressure drop penalty. *(ALRD technology is further discussed in an article in the "WPCA Newsletter No. 11" from 2007, found at www.wpca.info).*

Perforated trays can be another approach to attempt to boost SO_2 removal. The trays provide a bubbling bed of slurry froth in which mass transfer is enhanced. The back-pressure to the system imposed by the tray can also act to improve gas flow uniformity problems. Depending on the site-specific FGD unit and operating requirements, if the FGD is afterwards operated at a lower L/G ratio (i.e., less slurry recycled) the savings in recycle pump power will act as an offset to the penalty of increased absorber pressure drop (i.e., pump versus fan power).

Both the ALRD and tray approach have been used to upgrade absorbers of the 1970-1980's vintage. These absorbers were originally designed with banks of wetted-film contactor (i.e., packing) that were prone to scaling, buildups and plugging as well as wear and the need for cleaning & regular replacement. Elimination of packing in modern tower design (or by retrofit of ALRDs or trays in packed towers) adds a large measure of reliability and provides savings on plant costs. See Figure 17.

Figure 17: Packing in early FGD designs was prone to plugging. This can be eliminated with modern technology.

Upgrading the absorption chemistry is another fundamental means of boosting SO_2 performance. Usage of alternative reagents, modifying the type or grind fineness of limestone used and chemical additives (such as DBA), can be used to meaningfully improve capture of SO_2.

SO_2 Removal – FGD Upgrade Case Study

A mid-western plant firing 2.5 – 3.5% sulfur coal operated with a single, open spray tower limestone WFGD designed to use 4 operating (with 1 spare) spray levels. The baseline SO_2 efficiencies were approximately 95.7% with 4 operating spray levels and 93.8% with 3 operating levels. ALRDs were retrofitted at 2 elevations with a very negligible increase in system pressure drop. The ALRDs increased efficiency to 98.7% (3 points higher) with 4 operating levels and to 96.1% (2.3 points higher) with 3 levels on. Thus, this unit was then able to operate with one less spray level at a higher removal than before, or to operate at a significantly higher removal with the 4 levels on. Even higher levels of removal were demonstrated by modification to the operating pH of the slurry.

Ancillary Equipment/System Upgrades

Areas that also need to be examined during the upgrade planning include the reagent preparation, water make-up, dewatering and ductwork to insure compatibility with new factors relating to the future improved operation. Some areas may need to have materials of construction reviewed to make sure they are adequate to meet the new operating conditions. See Figure 18.


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Figure 18. Ball Mill

Other Problems Solved by FGD Upgrades

Common problems or situations with older FGDs include the need to modify the characteristics of by-product gypsum, optimize the use of limestone reagent, economize on the usage of water and power, and to address operating problems such as scaling, buildups and plugging of mist eliminators. See Figure 19. Engineered solutions can be sought as an alternative to spending the time, resources and money to merely live with the problems. Examples of such solutions include forced oxidation conversions, redesign and replacement of absorber spray headers and/or nozzles, recycle sump agitator revisions, modifications to instruments & FGD process control, and improved mist eliminator cleaning systems. Engineering studies, fluid dynamics models and chemical process reviews will many times identify effective means and measures to mitigate the various situations in a justifiable, cost-effective and long-term manner.


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Figure 19: Mist Eliminator Wash Headers.
Mist eliminator upgrades can improve FGD reliability and performance.

Conclusion

As U.S. utilities strive to economize in the operation and maintenance of existing FGD systems, they are also faced many times with the simultaneous need to have the FGD perform better and/or differently than originally designed. Aspects of design of current FGD technology are generally available and can be incorporated in the previous generations of operating units to provide better performance and solutions to problems or needs. All key areas of many older FGD systems – absorber, reagent preparation and dewatering – may benefit by the engineered retrofit of modern upgrades.

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Increasing Mercury Removal Efficiency of Wet FGD

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Figure 20: Four different ways for mercury to be emitted into the atmosphere

These paths are shown in Figure 20. To achieve a significant mercury emission reduction, several possibilities exist and have been explored. These include preventing the mercury from entering the process including:

- Cleaning the coal before it is combusted
- Adsorbing the mercury onto the flyash or an additional injected adsorbens, i.e. powdered activated carbon (PAC)
- Absorbing the mercury in a liquid, usually in a wet FGD system, and chemically binding it in a solid form, often in the gypsum.

The concern is that with these processes, it only shifts the mercury from the flue gas to another stream that still must be treated in order to fully remove the mercury from the biosphere.

Mercury captured in ash might leach out from the disposal area and is finally found in the water. Mercury in solid byproducts, such as gypsum, also has the potential to limit sales of these byproducts as it may be emitted back into the atmosphere, i.e. during calcination of the gypsum. Mercury washed out of the coal before burning will be found in the washing solutions, which must be treated in order to avoid discharge into the aquatic environment. Mercury dissolved in the FGD wastewater released from the power plant process without treatment will also enter the aquatic environment directly. Mercury emitted into the atmosphere with the flue gas will be washed out by rain and into the aquatic environment. Without any additional efforts, all these described pathways are undesirable and are likely to be prohibited in the future by new, more stringent regulations expected in the wake of CAMR. Therefore, it is key to find the most efficient and cost effective method that will not allow mercury to be released back into the aquatic environment.

Mercury Removal from Flue Gas

Assuming that mercury in the flue gas is nearly quantitatively oxidized – either through some type of halogen injection (i.e. bromine) or by the SCR catalyst, every power plant equipped with a wet FGD system is able to capture mercury because oxidized mercury is water soluble and therefore absorbed into the FGD slurry. In fact, many plants are relying on this technique as a co-benefit of the installation of an FGD system. However, there are two major concerns with this co-benefit concept. First, absorbed ionic mercury can, under certain circumstances, convert from the oxidized, water soluble form back to its insoluble elemental form (Hg0), which results in reemission from the slurry back into the flue gas. This effect has been observed frequently and measured as higher mercury concentrations downstream of the FGD absorber than upstream of it. The second concern is that mercury captured in the FGD slurry must be prevented from being accumulated in the solid byproducts (i.e. gypsum) or discharged to the aquatic environment with the FGD wastewater. Thus, a FGD wastewater treatment system is required to effectively remove the dissolved mercury from the FGD wastewater prior to its discharge.

Prevention of Reemission of Mercury from Absorber

Several processes have been tried attempting to prevent the reemission of dissolved ionic mercury from the FGD absorber slurry into the flue gas. Unfortunately, the equilibrium point where the mercury is completely saturated in the FGD slurry is reached rather quickly. Therefore, either the solution's equilibrium point must be shifted to allow more mercury to be retained in the solution, which is rather difficult, or the mercury must be continuously removed from the solution. Evonik has developed and implemented a patented process that continuously removes the dissolved mercury from the FGD absorber slurry. The addition of PAC to the FGD absorber slurry results in the effective adsorption of the dissolved mercury onto the PAC, thus removing it from the solution and allowing more mercury to dissolve into the FGD absorber slurry.

Once adsorbed on the PAC, the captured mercury must be removed from the absorber slurry. This is accomplished by removing the PAC including the adsorbed mercury with the FGD wastewater and discharging it to the FGDs wastewater treatment system. Using the correct particle size PAC along with the very significant difference in molecular weight allows the PAC to pass through the primary and secondary hydrocyclones in case of gypsum being the FGD byproduct. This allows for the removal of the PAC along with the adsorbed mercury to the FGD wastewater system.

Figure 21 shows data, collected in one of our 500 MW bituminous coal-fired units, which indicates an oxidized mercury reduction to well below 1µg/Nm^3 at the outlet of the wet FGD absorber. Adding PAC to the FGD absorber slurry immediately decreased the dissolved mercury as can be seen in Figure 22, confirming that reemission is very unlikely to occur.

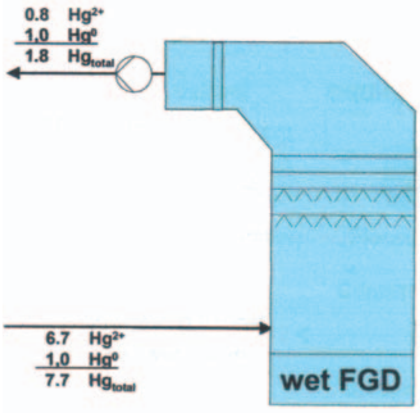

Figure 21: Actual Hg test data

FGD Wastewater Treatment Process

Once the mercury is captured and removed from the FGD absorber slurry with the PAC to the FGD wastewater, it must be treated so that the mercury is removed and cannot enter the environment with the wastewater discharge. In a conventional FGD wastewater treatment system, the PAC carrying mercury is precipitated along with other particles, i.e. gypsum, inerts, flyash, etc. and dewatered to a filter cake that is then landfilled. The economic concern with this conventional process is that the vast majority of the filter cake consists of compounds such as sulfates, fluorides, silicates, etc., which are environmentally uncritical. Yet, because of the comparatively small amount of mercury contained in the filter cake, it cannot be recycled and should be disposed as hazardous waste.

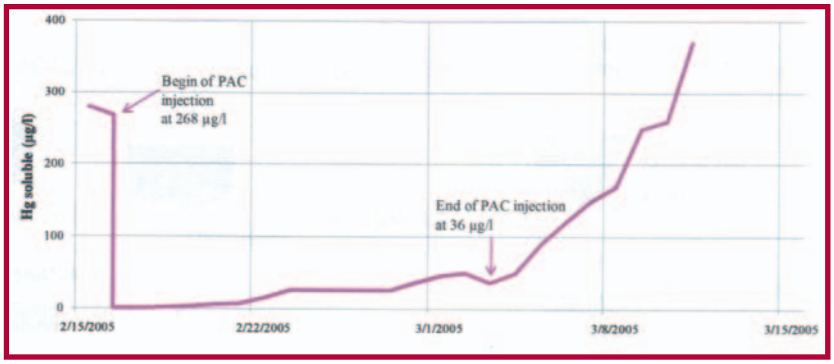

Figure 22: Results of PAC addition to th FGD absorber

Evonik's patented FGD wastewater treatment allows for a selective separation of mercury from the remaining wastewater filter cake by effectively splitting the filter cake into two fractions – a large fraction (~97%), which is largely heavy metal free (less than 3 ppm Hg) and a very small fraction (~3%), in which the heavy metals are highly concentrated (approx. 2,000 ppm Hg). The advantage to this patented process is that the large, harmless fraction of the filter cake can be recycled within the plant internally by putting it back on the coal pile. Only the very small fraction containing the concentrated heavy metals must be disposed in a special landfill. The resulting savings in landfill disposal costs are very significant since the volume of filter cake to be disposed is only approximately 3% of that of a conventional FGD wastewater treatment system.

In 2000, Evonik began to retrofit our fleet of bituminous coal-fired electric generating units equipped with wet FGDs with this wastewater treatment process for selective mercury removal. A schematic of Evonik's FGD wastewater treatment process is shown in Figure 23.

In the first stage of the FGD wastewater treatment system, all the non-heavy metal containing particles are removed while keeping the heavy metals in solution. During this process, more than 85% of the adsorbed mercury is chemically desorbed from the PAC and brought back in solution while the now "mercury free" PAC is precipitated out with the other harmless particles. The mercury desorbed from the PAC is kept in solution and moved with the largely solids free wastewater treated in the first stage to the second stage. In the second stage, the heavy metals and remaining very fine inerts are precipitated out in an environmentally inert form (i.e. as HgS) and are dewatered to the very small fraction of the filter cake that is disposed in a special landfill.

The effective control of the complete fate of the mercury contained in the coal is becoming more and more important and will have a significant impact on the operation of coal-fired power plants. The key to effective mercury control is not only to remove the mercury from the flue gas, but to control its fate after the removal from the flue gas in order to prevent its discharge to the environment through another pathway. Evonik has developed a process that ensures controlled mercury removal utilizing already existing equipment, and thus significantly reducing capital and O&M costs. By injecting PAC into the FGD absorber, absorbed mercury can be effectively removed from the scrubbing slurry. Selective FGD wastewater treatment allows concentrating the removed mercury into a very small amount of residue to be disposed in an environmentally inert form. By controlling the complete pathway of the mercury from the flue gas to the concentrated filter cake, it is removed from the biosphere in an effective and environmentally friendly manner.

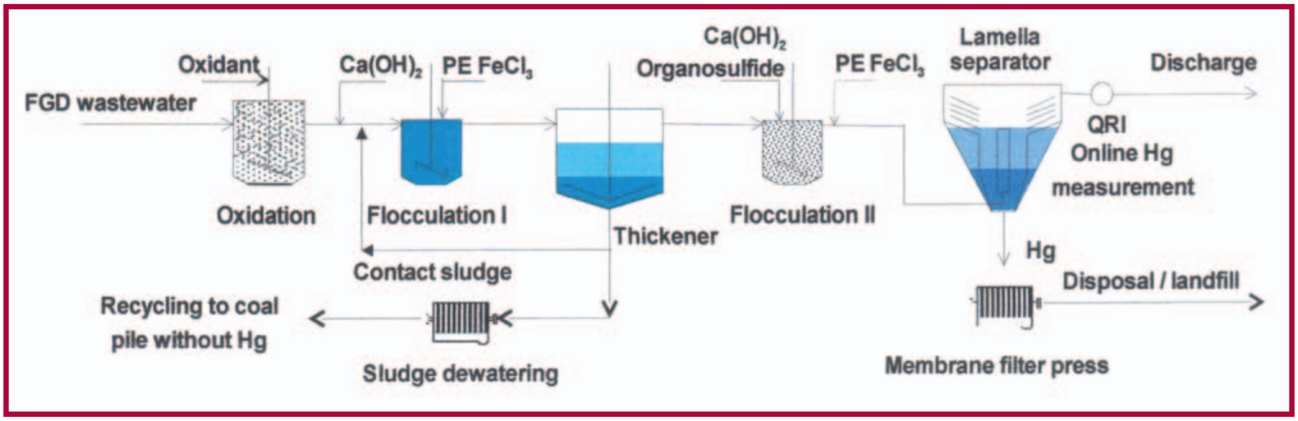

Figure 23: Evonik's patented FGD wastewater treatment process

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WPCA Wet FGD Technical Seminar

Competitive Power College Curriculum at Power-Gen 2008, Monday, December 1

–8-Hour course registration fees include workshop materials, certificate of completion, lunch and coffee breaks–

CPC 101 - WPCA WET FGD TRAINING SEMINAR

Date: Monday, December 1, 2008 ✦ **Time:** 8:00 am - 5:00 pm ✦ **Room:** S320D ✦ **Cost:** $500.00

Instructors

Richard C. Staehle, Vice President, Business Dev. & Technology, Marsulex Environmental Technologies; Michael Walsh, VP Engineering, Marsulex Environmental Technologies; Anthony Licata, Vice President, Babcock Power Environmental Inc.; Gregory T. Bielawski, Manager, Environmental Aftermarket Services, The Babcock & Wilcox Company Power Generation Group; Gordon Maller, Project Manager, URS Corporation; N. Scott Williams, P.E., Senior Engineer, Duke Energy; Philip Rader, Business Sales Manager, Alstom Environmental Control System

Discussion Panelists

Ron Richard, Consultant, RE Consulting; Steve Wolsiffer, Consultant, RE Consulting

Who Should Attend

- Actual plant operators of wet FGD equipment
- Corporate personnel who are involved with the purchase, operation and/or maintenance of wet FGD
- New employees of utilities and/or suppliers that need a broad knowledge of wet FGD systems

Course Overview and Objective

Wet FGD Training - learn all about it, from the basics to what you need to know to live with one. The speakers are seasoned veterans with more than 100 years of combined FGD experience. The Discussion Panelists are or were actual users of the equipment. We promise to keep the session lively!!! The topics covered will be: see the bullets below.

Course Highlights

- Wet FGD Types and Fundamentals: Wet vs. dry, semi-dry, CDS selection factors; reagent types & by products; absorber configurations; basic chemistry
- Wet FGD System Overview & Operation: Absorber island, reagent prep island, dewatering island – equipment, instruments, piping, electrical, controls and interconnections
- Panel Discussion by Users – FGD Design Issues & Improvements
- Wet FGD Materials of Construction
- WFGD Maintenance
- Wet FGD Chemistry & Performance Factors
- Panel Discussion by Users – WFGD Problems & Solutions

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