the **Conduit**
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In this Issue

EPRI Corrosion of Wet Flue Gas Desulfurization Systems

By Max Moskal
Principal Engineer

During January, 2011, M&M Engineering attended an Electric Power Research Institute (EPRI) interest group meeting on corrosion problems with utility stainless steel wet flue gas desulfurization (FGD) systems. The purpose of the meeting was to help collect industry experience on corrosion problems to develop solutions to corrosion issues in scrubber absorbers. The current issue has been corrosion in Type 2205 duplex stainless steel (DSS) absorber systems, which has been the material of choice for scrubber systems since 2004. Approximately 360 FGD units have been installed, with about one-third of the systems being constructed from stainless steel, and 19% from Type 2205 DSS. Approximately 35 organizations were present at the meeting, representing users, producers of materials and consulting services to the industry.

Overall, the problem of Type 2205 DDS corrosion is gigantic because the capital cost for installation of new systems represents up to 35-40% of the total capital of the utility. Many new systems and retrofits are just coming on line. Experience of some users during 2010 has shown vessel through-wall penetration due to corrosion pitting within one year. Some users have installed and run equipment for as long as three years until first inspections, only to find severe corrosion and/or wall penetration of absorber tanks. Problems have also developed with internal corrosion of recirculation piping made from DSS.

Figure 1. Corrosion of 2205 stainless steel absorber at welds and base metal.

Selection of Type 2205 DSS for FGD systems was driven largely by cost, and the fact that laboratory and early field studies of the alloy showed excellent corrosion resistance to the scrubber environmental conditions (up to 10,000 ppm chloride, pH of 5.5-6.5 and temperatures of 130°F). Apparently, not all conditions affecting corrosion were considered in the material selection.

Potential solutions to the corrosion problem will be studied in the next two years by EPRI and the seven or so project funders. The scope of the research includes identification of the root cause for corrosion, fabrication guidelines for DSS alloys, vessel repair guidelines and corrosion behavior with other stainless steel and specialty alloys.

M&M Engineering has studied the absorber problem and found that microbiological influenced corrosion may be an important factor in aggressive pitting corrosion of DSS. Microbiological DNA tests for one utility found that several species of bacteria that are corrosive to DSS are present in the limestone absorber slurries. Sources of the bacteria can be from limestone and makeup water. The microbiological activity was severe in the absorber slurry of one facility experiencing severe corrosion, but only minimal microbiological presence was found in a second facility experiencing no corrosion on 2205 stainless steel. It is believed that the most severe corrosion is experienced in the vessel with sulfate reducing bacteria

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slimes forming under tenacious gypsum deposits, and that the conditions that promote bacteria colonization may be related to the grade of coal burned. So far, it appears that units handling high-sulfur coal may more susceptible to MIC than units burning low sulfur coal.

Stress-Assisted Corrosion in Pulp & Paper Recovery Boilers

By Max Moskal
Principal Engineer

Stress-assisted corrosion (SAC) has been a known corrosion problem in recovery boiler tubes for more than 25 years, yet attempts to eliminate or control the condition have been largely unsuccessful. SAC is probably the least recognized form of corrosion in boiler tubes because it begins on the inside of the tube surface and works through to the outside (Figure 1). Deterioration by corrosion may proceed undiscovered until a leak develops. Unless a careful metallurgical examination is made, the problem is often interpreted as simply a leak at a weld flaw. Power boilers are also subject to SAC damage but do not experience the potentially severe consequences of a smelt-water explosion. In the electric utility industry, SAC is referred to as [waterside] corrosion fatigue, and the terminology stems from original work on the problem by the Electric Power Research Institute (EPRI) during the 1980s. The basic terms (corrosion fatigue and SAC) have stuck with their respective industries, but the damage mechanism is identical.

The SAC mechanism is based on the premise that the highest stressed zone will selectively corrode in boiler feedwater. Studies by EPRI and elsewhere have shown that SAC occurs if the local strain on the internal surface of the tube is high enough to fissure the protective magnetite scale. This condition leads to corrosion of the steel at the bottom of the fissure and also weakens the magnetite scale that eventually reforms at the fissure. Thus, the cycle is repeated until a crack-like crevice grows into the tube wall.

Studies have shown that up to 50% of older recovery boilers have SAC at some locations. Further, that SAC tends to be a relatively slow process and is most commonly found in boilers that have been operating for at least ten years. SAC is almost always found near weld attachments to the tubes, which contribute to local stresses in the tubes as the boiler cycles in temperature and

Table 1. Level of SAC Severity Assessed by Radiographic Testing

Level	Crack Description	Depth	Disposition
0	Single or multiple indications, not closely grouped, and not exceeding 1/8 "in length	Very faint (less than 10% wall thickness)	No action required.
1	Single indication not exceeding ½" in length; multiple indications not exceeding ¾"	Less than 10%	This is a level of concern. Replacement of tubes is not required. Expanding radiographic testing should be considered.
2	Single indication not exceeding 1" in length; multiple indications not exceeding 3/4"	10% or greater; less than 25%	An attempt should be made to radiograph all tubes in the section of the boiler showing Level 2 severity. Replacement is not required.
3	Single indication exceeding 1" in length; multiple indications exceeding 3/4"	25% or greater; less than MAWT	Consideration should be made to replace tube at current or future shutdown.
4	Single and multiple indications	MAWT or greater	Remove tube within current shutdown.

The above table is just one criterion that has been used by owner-operators. It is important to recognize that the risk of water leaks due to SAC damage in recovery boilers should be evaluated on many factors, including prior tube leak experience, age of the tubes, extent of SAC testing performed (RT or UT), and location within the furnace. Likewise, the level of confidence on crack depth measurement should be verified by laboratory examination of SAC damaged tubes.

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Upcoming Events

On March 9 and 10 M&M Engineering sponsored a 2 day conference on equipment failures in electrical generating facilities. At the end of the first day, the participants were taken to M&M Engineering's offices and metallurgical laboratory for a tour and additional training. There were presentations on boiler and steam tube failures, turbine failures and high energy piping, NDE, and water chemistry. The conference was attended by 19 which was a great size for good discussion and interaction. Participants were a mix of M&M Engineering clients, including plant engineering and operating personnel and insurance adjusters. The diverse background of the attendees made for very good discussion of the presentations. Watch the Conduit for announcement of the 2012 Conference.

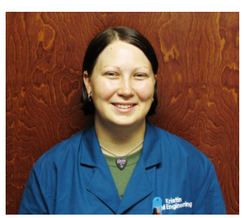
Catherine Noble attended the CORRISION 2011 conference in Houston, TX on March 14-16. She wrote and presented two papers for the conference with the following titles: Glossary of Boiler Tube Microstructures and Its Use to Verify Oxide Thickness Temperature Estimations Damage Mechanisms in Creep Strength Enhanced Ferritic (CSEF) Steels (T91 and T23). These can both be obtained on the NACE website (www.nace.org) under Publications-Conference Papers.

Spencer Rex will be attending the South Texas ASNT vendor exhibition on April 20, 2011 from 6:00-8:00 PM at CPS Energy in San Antonio, TX (Tuttle Learning Center). He will be manning a booth and discussing M&M Engineering's Nondestructive Testing capabilities.

Ron Munson will be attending the International Gas Turbine Institute Conference in Vancouver, Canada June 6-10, 2011.

New Employees Join M&M Engineering

Greg Sutter joined M&M Engineering Associates, Inc. in January 2011 as a Metallurgical Laboratory Technician. Greg has always been interested in metals and comes to M&M Engineering with a welding and blacksmithing background. Greg recently graduated from Austin Community College with an Associates Degree in Welding Technology. He also holds a license as a QC1 Welding Inspector. Prior to joining our team, Greg served in United States Navy as a Navy Corpsman. While serving in the U.S. Navy, Greg was fortunate to have been stationed in Florida, Okinawa, Japan and Hawaii. In his spare time, Greg enjoys instructing martial arts, making metal sculptures, building custom furniture, blacksmithing, motorcycle touring, hiking, camping, fishing and surfing.



Kristin Cockrum joined M&M Engineering Associates, Inc. in March 2011 as a Metallurgical Laboratory Technician. Kristin has been in the welding industry since 2005. She is currently attending Austin Community College to obtain her Associates degree in Code Welding with a focus on welding inspection and NDE testing. She is a Certified Associate Welding Inspector as well as a certified welder. Prior to joining M&M Engineering, Kristin worked as a structural welder for Fluor Corporation doing plant shutdowns. She says the majority of her structural knowledge and experience came from working for APC Metalworks building super structures from the baseplates on the slab up. Kristin is also an experienced Gas Tungsten Arc Welder on exotic metals. In her free time she enjoys welding at home, camping, fishing, hunting and raising cattle with her husband Alan.

Figure 1. Stress-assisted corrosion cracking in the tube ID at the smelt box attachment.

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pressure. The most likely locations for SAC in recovery boilers are the corners of spout openings and wind box attachments, and along floor to sidewall seal scallop bars. These locations, being lower in the furnace, represent a particular hazard should cracks penetrate to allow water to leak into the smelt bed.

While early detection of SAC in boiler tubes is crucial to avoid later surprises, the real challenges are to effectively measure the severity of the problem and then to decide on effective action based on the level of deterioration found. The most common nondestructive test method to detect SAC in recovery boilers today is by the radiographic test method (RT). Ultrasonic testing (UT) has also proved successful in locating SAC cracks, but is used to a lesser extent than RT. Whichever test method is used, there are problems in quantifying the severity (length and depth) of cracks. Crack length is usually easy to quantify, but to assist in quantifying crack depth, both the UT and RT methods require standards or crack examples for comparison of the depth of crack penetration. From a practical standpoint, the depth of penetration as viewed by either UT or RT is dependent of factors such as crack orientation and sometimes the proximity of adjacent weld attachments. Cases of quantifying depth of cracking have been most successful when the indications were consistently oriented (aligned).

When crack orientation is favorable to viewing by RT film, determination of crack depth can be compared with standard cracked tubes. An image densitometer may be used to compare the density of known crack depth on the standard to the unknown crack density in the boiler tube. When the depth of crack penetration is approximated, a standard method of severity can be assessed. One such method of assessing SAC severity is described in the following table, and has been used by several owner-operators of recovery boilers. Suggested actions for different levels of severity are provided in the table, and users who examine their boilers for SAC should be prepared to take action, often within the current shutdown.

The Chemistry of SAC (aka Corrosion Fatigue)

By David Daniels
Principal Scientist

While most stress assisted corrosion or corrosion fatigue is stress-driven, there are also boiler water chemistry factors that can increase the rate of the corrosion. In order to affect the rate of SAC, the chemistry must be corrosive during high stress periods, such as startup. Dissolved oxygen was considered a factor in the rate of SAC, but in most cases the dissolved oxygen is at very low levels during the high stress-portion of startup because of the low solubility of oxygen in hot water. The pH of the boiler water however does have an effect. Treating the boiler water to an alkaline pH when it is being filled after a shutdown will help minimize SAC. In boilers where phosphate hideout is a problem, the return of phosphate as the boiler cools can drop the pH of the boiler water and make for corrosive conditions on startup. In these cases, steps should be taken to reduce the hideout condition and prevent the problem.

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CONGRATULATIONS

Mark Tanner has reached a career milestone; his 25 year anniversary with M&M Engineering. After graduating from Texas A&M University with a Bachelor of Science degree in Mechanical Engineering and a Master's degree in Mechanical Engineering with Materials emphasis, Mark started his engineering career with the Mechanical and Materials Engineering Department at Radian Corporation in Austin, Texas on March 17, 1986. Mark worked on a variety of failure analysis projects ranging from boiler tubes to steam turbines and generators. In 1998, the owner's of Radian Corporation, The Hartford Steam Boiler Inspection and Insurance Company (HSB), sold Radian Corporation but retained the Mechanical and Materials Engineering Department, making it part of HSB. Because of his failure analysis experience with steam turbines and generators, Mark headed the development of a steam turbine risk assessment program (STRAP) for HSB. Mark worked with representatives of utilities, equipment manufacturers, insurance, and maintenance/repair firms to develop STRAP. Mark is the head of the STRAP program, now commercially available, updating, maintaining and performing evaluations. He has traveled to Mexico, Australia, Spain, Dominican Republic, England, Aruba, Canada, Oman, Indonesia, and most recently Turkey with the STRAP program.

Mark has been involved in many projects over the years, but the project he will remember most is the Columbia space shuttle failure investigation. Mark was selected as one of two On-site Failure Analysts at the Kennedy Space Center. Mark spent four months on the investigation and temporarily relocated his family to Coco Beach, Florida during the project. Not only was this project technically challenging, but rewarding in that determining the cause of the failure ensured that future shuttle flights would be done safely at minimal risk to astronauts. He was honored for his contribution to the project by NASA with a tile removed from a shuttle.

In 2008, employees of M&M Engineering purchased the business from HSB forming M&M Engineering Associates, Inc. Mark is currently a Vice President and Senior Principal Engineer with the company. He continues performing STRAP evaluations and failure investigations. The employees of M&M Engineering, Mark's wife, Erin and his four children, Amelia, Audrey, Lara and Ross congratulate Mark on his 25th anniversary and we all wish him another 25 years!

Ron Munson awarded the 2011 ASME Central Texas Chapter Engineer of the Year Award

On February 24, 2011, Ron Munson was presented the ASME Central Texas Chapter Engineer of the Year at The Texas Society of Professional Engineers, Travis Chapter's Engineers Week Banquet in Austin, TX.

Engineering's First Principal- The Ability to Think and Reason

When I began my engineering career training in 1968 our "technology" was a plastic covered, Bamboo Post slide rule. You wore it on your belt and along with your white shirt and pocket protector marked you as "an engineer". During the short tenure of my formal training the technology quickly progressed to HP calculators, punch cards and tapes to transmit FORTRAN code to a compiler for a main frame computer, separate work stations hard wired to a main frame, and eventually laptop computers and beyond. While the technology has certainly advanced, I have seen one area into which we have digressed- that is the ability to think and reason using first principals.

During my thirty-one years in my current position (all be it under four different company "names"), I have had the opportunity and pleasure to work with, mentor, and train numerous young engineers. What I have experienced during this tenure is their general lack of their ability to estimate answers- to bound or approximate the expected answer. They rely too much on computer and deterministic calculations. I have always stressed to them that Engineering is mostly the controlled practice of estimation and approximation. We seldom have "exact" input data and knowledge of the true facts. We must use our brains to estimate and reason, then calculate and then critically review our answer for a sanity check. We will then iterate and improve our answer based upon experience.

In my particular field, Forensic Metallurgy, I always say "The Metal Does Not Lie". However, we need to be sure we understand the language and interpret the inferences of the metal's monologue. In a failure analysis, I always stress to remember the basics; the laws of physics, chemistry, and thermodynamics must be obeyed. We cannot ever forget the first principals.

I want to thank ASME for this honor- and it is an honor to be selected out of this community of great engineers and recognized. The keys to my success are quite obvious to me:

- First of all, the support of my wife Leslie, who has always been there to make sure the little things got handled- socks match, shirt is pressed etc.
- My co-workers, who have provided me with a work environment that made it FUN to come to work everyday
- My customers, who allowed me to network and learn from them
- The nature of my work- I love what I do!