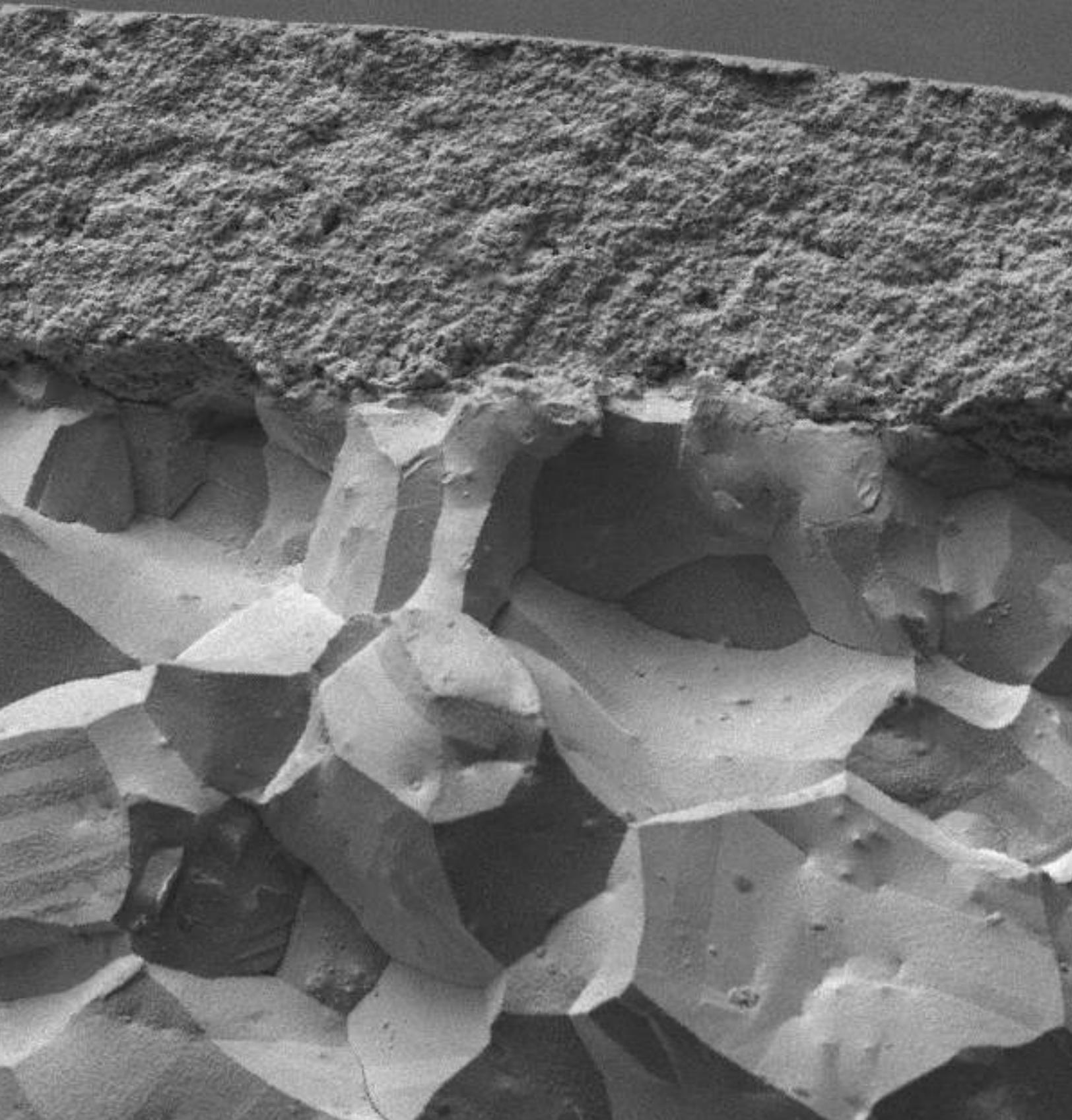


SPRING 2016

The Metal Never Lies

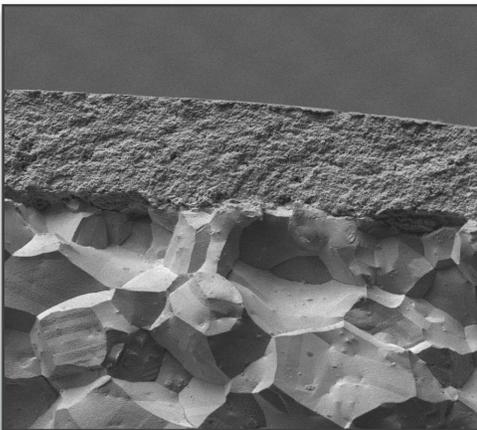


INSIDE THIS ISSUE

VOL 16, NO 1

3	Calling All Cooling Towers: Legionella—what’s the risk and where should we look for it	David G. Daniels, Sr. Principal Scientist
5	Batch Digester Stainless Steel Overlay “New” Thickness Measuring Technique	Ron Lansing, P.E., Consulting Engineer
6	Aerosol Cans and Their Failures—Part 2: We continue our look into failures of aerosol cans	Catherine A. Noble, P.E., Consulting Engineer
10	Recognizing our Staff	
11	New ASHRAE Standard in Effect What does it mean for you?	Karen T. Fuentes, P.E., Sr. Principal Engineer
12	2016 Fall Edition Workshop “Preventing Failures in Steam Generating Equipment”	Seating Limited—Register Today!
13	Welcome: Sig Hannesson, Sarah McGregor and Raymond Stonitsch, P.E.	
14	Flow Accelerated Corrosion Damage in Deaerators	Max Moskal, Principal Engineer
17	Contacts and Credits	

COVER PHOTO



This SEM photograph shows the coating/blade interface on a gas turbine blade near the leading edge. The mode of fracture of the blade airfoil is intergranular. Magnification: 150X

Examination of the fracture surfaces identified blades with pre-existing fatigue cracks. The largest crack grew until it became critical and the blade failed. The cracking most likely occurred during startups and shutdowns when certain blade harmonics were excited. Furthermore, the blade was embrittled as evidenced by significant reduction in room temperature ductility (% elongation) and intergranular failure mode. An embrittled microstructure will lower the fracture toughness and as such, reduce the size a crack has to grow before it becomes critical. The blades also contained coating cracks in the regions of the pre-existing cracks. These coating cracks could have acted as stress raisers to help fatigue crack initiation in the airfoil.

ABOUT the CONDUIT

For technical information please contact:

David Daniels
(512) 407-3752
david_daniels@mmengineering.com

Mark Tanner, P.E.
(512) 407-3777
mark_tanner@mmengineering.com

Karen Fuentes, P.E.
(512) 407-3778
karen_fuentes@mmengineering.com

We hope you enjoy reading **the Conduit**, our quarterly newsletter offering technical information, insight, and case studies.

the Conduit is distributed free of charge by M&M Engineering Associates, Inc. We welcome your comments, questions, and suggestions, and we encourage you to submit articles for publication. We grant limited permission to photocopy all or part of this publication for nonprofit use and distribution.

the **CONDUIT**

Calling All Cooling Towers

David G. Daniels, Senior Principal Scientist
david_daniels@mmengineering.com

If you own or operate a cooling tower, or insure companies that have cooling towers, you are probably aware that Legionella testing in cooling water has been a hotly debated topic for a number of years.

In summer 2015, another outbreak of Legionella in the South Bronx neighborhood of New York City prompted the New York City Council to pass new regulations. These required any facility in the city that had a potential source of Legionella to prepare a risk management plan identifying the sources of Legionella, as well as how they are monitoring for and controlling Legionella.

The regulation references a recently produced ASHRAE standard entitled “Legionellosis: Risk Management for Building Water Systems” (ANSI/ASHRAE Standard 188-2015). It lists not only cooling towers, but also a number of other sources of water that a facility should include as part of their risk assessment. These include:

- potable water systems
- evaporative condensers
- whirlpool spas
- ornamental fountains and other water features
- aerosol-generating misters, atomizers, air washers and humidifiers



Legionella

The ASHRAE Risk Assessment is just that—an overview of what is present and what the site is doing about it. It seeks to identify all the potential sources of Legionella. (photo courtesy: <https://wwwn.cdc.gov/elite/public/elitehome.aspx>)

The ASHRAE Standard covers both new and existing structures.

While the regulation requires that the ASHRAE risk assessment be performed, it only applies to facilities in New York City. However, the formal adoption of this ASHRAE standard means that there is now a recognized practice for assessing the risk of Legionella. In our litigious society, the presence of this standard makes it incumbent on any facility

that has potential Legionella sources to become compliant with the standard, or face difficult questions should someone contract Legionella and it can be traced back to equipment on your property, or the property of your insured. Particularly emphasized in the Standard is that risk assessments be performed for any hospital, health care facility, site that cares for the elderly, or

(Continued on page 4)

(Continued from page 3)

routinely deals with people with compromised immune systems. This includes universities that have teaching hospitals associated with them.

The ASHRAE Risk Assessment is just that—an overview of what risks are present and what the site is doing about it. It seeks to identify all the potential sources of Legionella on a particular site, makes an analysis of each of those systems for the potential to breed Legionella, considers control measures that might be implemented, details any monitoring or corrective actions that the site needs to take, and then documents confirmation that these things have indeed been done. This is all wrapped up in a single risk assessment document. It does not necessarily specify testing frequency, nor define an acceptable or unacceptable level of Legionella in the system.

It is obvious that the direction of this standard is to have all Legionella sources examined. If a facility survey finds a source of stagnant water that is being improperly treated or ignored, it should be readily obvious that something needs to be done. But, they will only find the sources if someone is tasked to look with the intent to discover all potential sources. Companies that sell water treatment chemicals and biocides to large industrial clients for their cooling towers have been active in preparing these risk assessments for their clients. Obviously, they should already be aware of the larger equipment such as cooling towers, and well aware of the treatment that is being used.

Control of Legionella in a cooling tower, or any water-containing system, requires proper and routine treatment with biocides to control the growth of biofilms, in which the Legionella bacteria multiply. The most commonly used oxidizing biocide in industrial settings is commercial bleach (generally 12.5%). However, there are many other biocides and chemicals which can be used in conjunction with the oxidizing biocides that increase their effectiveness. There are also many things that facility owners can do to ensure that the biocide program that they have is actually effective at controlling biofilms.

To learn more about the new ASHRAE Standard, see the article on Page 11.



If you would like an independent analysis of your cooling water system and the chemical treatment that you are currently using, or if you feel that your facility would be better served by having someone independent of your current chemical supplier perform the ASHRAE Legionella Risk Assessment, please contact [M&M Engineering](http://www.mmengineering.com) for assistance.

Batch Digester Stainless Steel Overlay “New” Thickness Testing Technique

Ron Lansing, P.E., Consulting Engineer
ron_lansing@mmengineering.com

For the last couple of years, we have been using a “new” technique to measure remaining weld overlay on batch digesters. “New”, unless you remember the old blacksmith method of watching grinder sparks to identify a metal.

THE PROBLEM

When doing internal visual inspection of a batch digester, the thickness of the remaining stainless steel is not evident unless it is bleeding rust-brown all the way down your wall. Ultrasound and eddy current test methods have been tried, and neither are very reliable at finding the welded interface of the stainless and the carbon steel beneath (plus an inspection crew is expensive!). Thickness of the remaining good stainless steel protective overlay is what you need to know for planning the next re-welding campaign.

WELDING CONTRACTOR SOLUTION

When preparing to do the re-welding, the contractor will generally need to know how thick the stainless layer is. They will air-arc cut a shallow gouge into the wall, stain the area with copper sulphate and then physically measure the unstained stainless steel layer with a machinist scale (Figure 1).

MAINTENANCE INSPECTION (A CHEAPER) SOLUTION

Instead of using the air-arc and stain method, which is expensive and technical, carefully cut into the stainless using a plunge cut with a grinder (Figure 2). Watch the sparks of the stainless (shorter white and fewer than carbon steel sparks) as the plunge proceeds. When the sparks change, stop. Measure the plunge cut depth.

This thickness value is a conservative measure of the remaining stainless steel overlay weld thickness. The spark appearance will change when more carbon is present, usually in the diffusion zone of the weld which is present just before the “actual” weld interface. Use this value to estimate the remaining overlay thickness and overlay life reduction rate for the stainless weld and the aggressiveness of your batch digester load and process parameters.



Figure 1. Air-Arc cut gouge for thickness measurement of the overlay by staining with copper sulfate.



Figure 2. Plunge cut with a grinder that goes until the sparks change, and then the depth is measured.

RON LANSING, P.E.

CONSULTING ENGINEER

503.706.8124 direct

Ron_Lansing@mmengineering.com



Aerosol Cans and Their Failures

Part 2—Failures in Aerosol Cans

Catherine A. Noble, P.E., Consulting Engineer
catherine_noble@mmengineering.com

In Part 1 of this article ([Conduit Vol. 15, No. 3](#)), we discussed the different types of aerosol cans, how they are made, and how they work. As a brief review, there are four main types of aerosol cans: 3-piece tin-plated steel, 2-piece laminate steel, 1-piece aluminum, and 1-piece plastic. While they are all manufactured differently out of different materials, they all have a standard 1-inch opening at the top for the dispenser to be attached during filling.

Aerosol cans are small pressure vessels that can hold up to 180 psi before deforming, depending on the pressure rating of the can. The pressure inside is a function of the mixture of propellant and product. Propellants are typically liquefied gases such as DME (dimethyl ether), but can also be compressed gases such as nitrous oxide.

TYPES OF FAILURES

Annual production of aerosol cans is about 13 billion units worldwide. While failures do occur, the percentage of failures is very low. Failures can be serious, leading to personal injuries, even death, but given the pressure contained in this type of vessel, most failures are not so severe that they result in burst cans.

There are four basic causes for aerosol can failures:

1. External/Internal Corrosion
2. Over pressurization
3. Mechanical damage
4. Manufacturing/material defects

in the base material, coating, or weld

Most of what is discussed in this article will apply more specifically to metal aerosol cans, but the same principles apply to plastic aerosols. The main exception is corrosion, where plastic is typically not susceptible to this mechanism. Material degradation would be the correlated reason for plastic aerosol failures.

CORROSION

Corrosion can occur on the external surface or the internal surface of the can due to a variety of factors. Corrosion may only affect the appearance of the can or the product, or it may actually lead to a failure if the corrosion perforates the can. The reasons for corrosion on either surface of an aerosol can are explored below.

EXTERNAL CORROSION

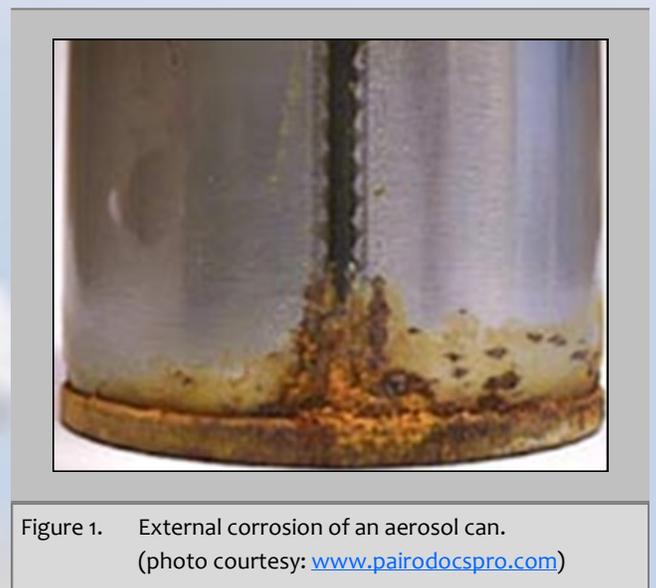
Corrosion typically occurs on the outside of the can due to environmental exposure, such as moisture or a marine environment (Figure 1). An example of this would be finding a rust ring on the bottom of a shave gel can after it sits in your shower for a while. Coatings are applied to can components to prevent or slow down this process, but long term exposure to wet environments can overcome these

measures. Another way that external corrosion can occur is if the external coating of the can is damaged, providing a weak point in the protective coating. This creates a small anode/large cathode scenario where the exposed area corrodes at a much faster rate than it would if the entire coating were missing.

External corrosion is more likely to adversely affect the appearance of the packaging rather than lead to perforation/failure. The environment would need to be extreme and constant to pose a significant risk for failure.

INTERNAL CORROSION

Corrosion on the inside of an aerosol can is also an issue and is a function of the product and propellant inside, as well as the construction of the can. Corrosion may simply lead to



(Continued on page 7)

(Continued from page 6)

discoloration of the product, or it can affect the usability of the product. For example, rust inside a spray starch can would ruin your clothes and would therefore make the product unusable. Internal corrosion is more likely to lead to failure than external corrosion, as any corrosive environment would be constantly present and can be more unique chemically than what is present outside the can. More specifically, internal corrosion can occur in four different scenarios (Figure 2):

1. Liquid Phase Corrosion
2. Vapor Phase Corrosion
3. Liquid-Vapor Interface Corrosion
4. Crevice Corrosion

The first two types of internal corrosion are fairly straight forward. Corrosion either occurs within the liquid phase of the can where the product sits (the lower portion), or it occurs in the vapor space above the liquid (the upper portion). The vapor space will contain the propellant (if it is a compressed gas), a small amount of the product in gas form, as well as any air and moisture that was not removed from the can during filling. Vacuum sealing the can is crucial to some applications, because water vapor in the air that stays in the can may lead to vapor phase corrosion, or liquid phase corrosion if it condenses.

Liquid-vapor interface corrosion occurs at the line between the liquid phase and the vapor phase due to the unique chemical mixture present where the two phases interact. If a liquid propellant is used, then there will likely be two interfaces – one between the product and propellant, and one between the propellant and the vapor phase.

Liquid-vapor interface corrosion can be difficult to predict. Long term

corrosion testing is often conducted in part to see if this type of corrosion will come about with a particular formulation. Test packs of the product are filled as they would be during production and stored at room and elevated temperatures for up to a year. One or more cans at each temperature are opened every three months to examine the internal surface of the can for corrosion in any of the locations mentioned above.

If one of these three corrosion scenarios results in a failure, it will typically occur on the can body because it is made of thinner material than the end components.

Crevice corrosion is more a function of the geometry of the can. If the can is of two or three piece construction, there is a crevice created where the bottom is double-seamed onto the body. This crevice creates a unique chemical environment where one of the product ingredients or a contaminant can concentrate and accelerate corrosion. Crevice corrosion can also happen at the top of the can if there is a top double seam, or at the valve cup due to vapor phase corrosion, but this is less common. Crevice corrosion testing is typically conducted on new formulations to see if they are prone to this type of corrosion.

Internal corrosion is typically preventable. First, can material construction and coating selection are used to provide the most resistant package for the product formulation.

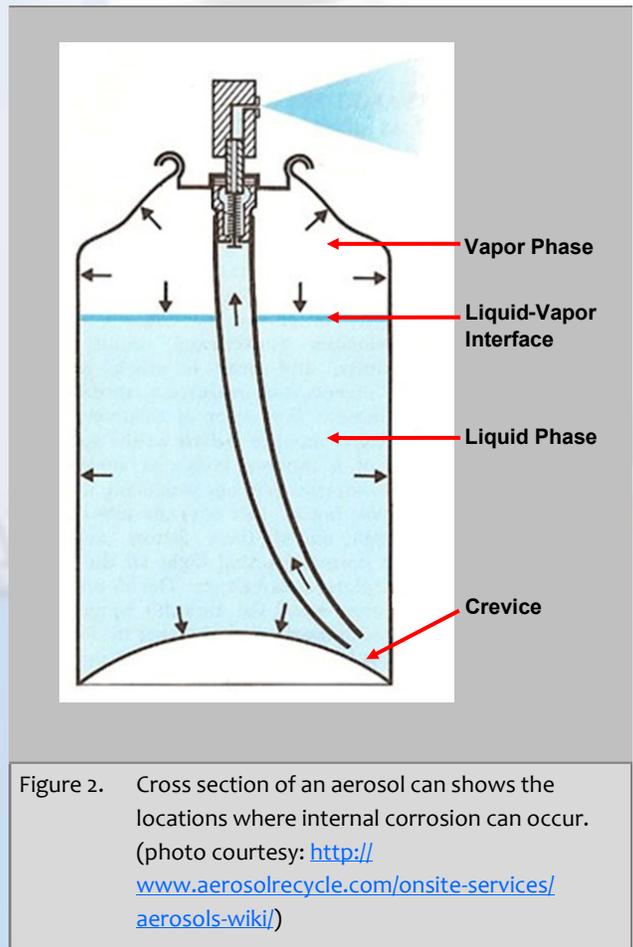


Figure 2. Cross section of an aerosol can shows the locations where internal corrosion can occur. (photo courtesy: <http://www.aerosolrecycle.com/onsite-services/aerosols-wiki/>)

Various types of testing of new formulations, such as test packs and crevice corrosion testing mentioned above, are conducted to look for potential problems. If inappropriate materials are used, then most of the cans will have corrosion inside. Cans are also inspected thoroughly during manufacturing to ensure that no material defects arise that would create a weak point for corrosion (e.g. holidays in the internal coating).

However, some aerosol products are still corrosive enough that material selection alone is not sufficient to prevent corrosion. In this case, corrosion inhibitors are added to product formulations in order to minimize internal corrosion. Inhibitors can be general for the entire package, or specific to the type of corrosion of concern, i.e. there are vapor-phase

(Continued on page 8)

(Continued from page 7)

corrosion inhibitors and liquid-phase corrosion inhibitors. Most inhibitors are proprietary formulations that work in concert with the product. However, some examples of basic corrosion inhibitors are sodium nitrite, morpholine, and ammonia.

Finally, contamination in the product and the can should to be minimized to prevent internal corrosion. Internal coatings and inhibitors can only do so much when, for example, contaminated water is used to make a product that puts corrosive species into the can.

Over Pressurization/Overheating

Another way that aerosols may fail is if the rated pressure is exceeded and the can deforms or opens up (Figure 3). Aerosol cans are rated to withstand certain pressures during the filling process, storage, and use. Table 1 from Part 1 is repeated here to show the pressures that a can must withstand before buckling (deforming) and

Table 1. Aerosol Can Ratings and Required Buckle/Burst Pressures

Rating	Buckle Pressure (psi)	Burst Pressure (psi)
Standard	140	210
DOT 2P	160	240
DOT 2Q	180	270

bursting (opening and releasing pressure).

If the pressure in the can exceeds the rating, the container can burst, allowing the product and propellant to come out of the can. Depending on the circumstances and contents, this burst can simply make a mess, turn the can into a projectile, or even lead to an explosion and/or fire. These more serious scenarios are rare, but have happened.

Over-pressurization is possible during the filling operation. If the propellant is at too high of a pressure, or comes in

too fast, it can deform one of the ends. Some formulations require mixing of product and propellant to obtain the desired pressure, and over pressurization may take place if they don't mix fast enough.

This failure mechanism more often happens during use or storage of the can due to abuse or misuse of the packaging. In this case, the pressure is usually raised in the can due to overheating. Cans are often stored in hot places, such as garages or cars or next to a furnace, even though this is warned against on the product label. If heated enough, the pressure can



Figure 3. Left: Bulged bottom of an aerosol can (www.coolminiornot.com/forums/showthread.php?50293). Right: Burst can that split at the weld seam (metroforensics.blogspot.com/2014/11/safety-reminder-when-aerosol-cans-are.html).

(Continued from page 8)

exceed the rating and buckle or burst the package. Care should be taken when storing and using aerosols to keep them away from heat and electrical sources.

All cans are proof tested in a hot water bath at 130°F after filling to raise the pressure inside and ensure that they meet pressure ratings. In addition, it is strongly recommended to not store aerosol packaging above 120°F. Finally, there is typically a safety factor built in to most designs so that a can will withstand slightly higher pressures than the minimum required. There must be a significant increase in pressure due to heat for a can to burst. With the safety precautions in place, this type of failure remains a rare event.

A material defect in the can, such as too thin or too soft a metal, can reduce the strength of the can, making it possible that it could fail at a pressure below its rating. Also, mechanical damage to the can after it is manufactured will reduce the strength of the vessel. These types of defects are discussed more below.

Mechanical Damage

Mechanical damage to an aerosol can typically occurs due to physical abuse, such as dropping. Sometimes containers suffer from abrasion or scratching, or even puncture from sharp objects. Mishandling of the can may cause dents, abrasions, or even holes in the container, all of which can lead to failure. The integrity of the can is dependent of the shape of all the parts, especially the shapes of the ends. An aerosol may fail immediately due to the mechanical damage itself. Alternatively, the damage may weaken the vessel so that it cannot withstand the rated pressure.

More minor damage such as abrasion can weaken or remove the protective coating and lead to external corrosion. Over time, the corrosion may penetrate through the material and lead to failure, as discussed above.

Manufacturing or Material Defects

While can manufacturers exercise quality control measures to minimize the number of defective cans that are produced, defects, though rare, may still occur. Without proper maintenance of production lines, issues can arise. Even if equipment is maintained, constant adjustment is still needed to produce quality parts. There are many testing steps along the way, but a stray defect can occasionally make it through the process. This is why in any failure analysis, it is always good practice to confirm that the correct materials were used and to inspect for manufacturing defects. Most of the time, everything will be fine, but a pre-existing defect is occasionally found that contributed to the failure.

Some examples of aerosol can manufacturing defects are described here and shown in Figure 4. Parts may sustain mechanical damage in the manufacturing process, such as a burr getting stuck in a piece of equipment and scratching any

parts that come by. If the can is three-piece, there can be weld defects if the welding machine isn't operating at peak performance. Coating defects can occur if the paint isn't applied uniformly, or if the curing oven is at the wrong temperature. Wall thickness variations can be present either due to press operations or as supplied by the mill. Material defects could be present from the metal or coating supplier, e.g. the wrong temper of the metal. In addition, mistakes in the formulation of product can also be considered a defect that could lead to corrosion.

CONCLUSIONS

While failures in aerosol cans are rare, especially given how many units have been produced in their history, they do occur. Care is taken in the manufacturing process, filling, storage,



Figure 4. Examples of can manufacturing defects: top – coating skip, middle – coating drip, and bottom – double bottom (www.inspection.gc.ca/food/fish-and-seafood/manuals/metal-can-defects).

(Continued from page 9)

and handling in order to minimize the occurrence of these failures.

SUPPORTING DOCUMENTS:

1. "How Aluminum Aerosol Cans Are Made," Metal Packaging Manufacturers Association
2. www.aerosol.org
3. www.cclcontainer.com
4. Southernaerosol.com
5. Packagingalliance.us
6. www.dscontainers.com
7. "An Introduction to Aerosol Propellants," Diversified CPC International, Inc.
8. www.exal.com
9. Smith, Scott. "Expanding the Aerosol Marketplace through Plastic Innovation." SPRAY Technology & Marketing, December 2013.
10. Daehn, R.C. and Blum, J.J. "Failure Analysis of Three-Piece Aerosol Cans." Journal of Failure Analysis and Prevention, ASM International, August 2004.
11. Woodford, Chris. "How do Aerosol Cans and Misters Work?" www.explainthatstuff.com, July 24, 2014.
12. www.nationalaerosol.com
13. "How does an Aerosol Spray Work?" www.scienceinspiration.blogspot.com
14. www.rexam.com
15. <http://agresearchmag.ars.usda.gov/2005/sep/vector>
16. www.inspection/gc/ca - Metal Can Defects
17. "Aerosol Formulation Considerations", Robert D. Geer (www.southernaerosol.com)
18. Howard, D.M., "Principles of Corrosion of Metal Containers by Cosmetic Products." Journal of the Society of Cosmetic Chemists, Volume 20, pg. 17-29, 1969.

CATHERINE A. NOBLE, P.E.
CONSULTING ENGINEER

512.407.3771 direct
Catherine.Noble@mmengineering.com



M&M Engineering Associates has the privilege of employing some of the brightest and most experienced professionals in our industry.

The success of our clients is a direct reflection of their consistent dedication and hard work.

Join us as we recognize all of our team members who have celebrated anniversaries thus far in 2016.

Congratulations to you all, and thank you for your contributions!



DAVID DANIELS
28 years

CATHERINE NOBLE
7 years

JON MCFARLEN
14 years

JOHN MOLLOY
10 years

KEN LAYTON
6 years

DAVID STONE
2 years

DEE WALL
37 years

MARK TANNER
30 years

BOB BRUSCATO
12 years

ANNA GENTRY
5 years



New ASHRAE Standard in Effect

Karen T. Fuentes, P.E., Senior Principal Engineer

karen_fuentes@mmengineering.com

ASHRAE has issued a new standard: ANSI/ASHRAE Standard 188-2015 entitled “Legionellosis: Risk Management for Building Water Systems.” The purpose of the standard is to minimize the exposure of building occupants to legionella bacteria which can cause Legionnaires disease (a form of pneumonia) or a less severe illness known as Pontiac fever.

The standard identifies the minimum risk management program requirements for water systems (potable and non-potable) in new and existing buildings. The new standard is applicable to commercial, institutional, industrial, and multiunit residential buildings. It does not apply to single-family residential buildings. The standard includes requirements for new building design and construction, as well as operation and maintenance of water systems in new and existing buildings.

The risk management program begins with a building survey to determine if the building has water systems covered under this standard. The covered water systems include any water systems that produce or could produce water droplets or mist. The types of equipment specifically identified in the standard are:

- potable water systems
- cooling towers and evaporative condensers
- whirlpool spas
- ornamental fountains and other water features
- aerosol-generating misters, atomizers, air washers and humidifiers

The survey will also determine whether the building has one or more of the following occupancy factors.

- multiple housing units with a centralized potable water-heater system
- more than 10 stories high
- a health care facility where patients stay more than 24 hours
- contains area(s) for occupants receiving treatment for burns, chemotherapy, organ or bone marrow transplants
- contains area(s) for occupants that are immune-compromised, at-risk, taking drugs that weaken the immune system or have renal disease, diabetes, or chronic lung disease
- houses occupants over the age of 65 years

If any of the systems in the first list are identified, a building water systems risk management program must be put into place for those specific water systems. If any of the conditions in the second list apply, then the standards are more stringent and require a program be developed for *all* potable building water systems and *all* building water systems.

The general elements of a water system management program include the following.

- Program Team – persons responsible for program development and implementation
- Water System Description – description of the water system which can include flow diagrams, piping diagrams and other schematics
- Analysis of Water System – identification of where hazardous

conditions could occur in the water systems

- Control Measures – identification of control measures to mitigate the hazardous conditions and where they can be applied
- Monitoring and Corrective Actions – procedures for monitoring and corrective actions if monitored values are out of established control limits
- Confirmation – procedures to confirm that the program is being implemented and effectively controls the hazardous conditions
- Documentation – establish documentation and communication procedures

To assist those developing a risk assessment program, Section 7 of the standard provides requirements for procedures such as start-up and shut-down procedures, equipment siting, maintenance, water treatment, response plans, and testing. Section 8 provides the requirements for designing these systems. The standard also contains an annex for additional requirements specific to water systems in health care facilities.

If we can be of assistance to you as you apply this new standard to your facility, please contact [David G. Daniels, Senior Principal Scientist](mailto:David.G.Daniels@mmengineering.com).

KAREN T. FUENTES, P.E.
SENIOR PRINCIPAL ENGINEER

512.407.3778 direct

Karen_Fuentes@mmengineering.com



PREVENTING FAILURES IN STEAM GENERATING EQUIPMENT

OCTOBER 4-5, 2016

LEANDER, TEXAS

It's that time again and we are excited to open registration for the 2016 Fall Edition of our workshop
"Preventing Failures in Steam Generating Equipment"

M&M Engineering Associates will host their 5th annual workshop for producers of steam, be it used in power or process applications. The two day workshop focuses on the issues most common in steam generating systems, and is applicable to many industries including pulp and paper, refining, petro-chemical, and power generation.

Seating is limited—[Click the ticket](#) and **REGISTER TODAY!**



DAY 1

- Equipment Associated with Steam Generation—A Primer
- Utility Feedwater Heaters and Damage Mechanisms
- Water Touched Boiler Tube Failure Mechanisms
- Steam Touched Boiler Tube Failure Mechanisms
- Introduction to Nondestructive Testing & Inspection Contracting
- High Energy Piping Damage Mechanisms and Corrections

DAY 2

- Introduction to Failure Analysis
- Failure Investigation Principles for Combustion Turbines
- Basic Steam Turbine Failures
- Condenser and Cooling Water Failures
- Damage Mechanisms in Deaerators
- Water and Steam Chemistry-Influenced Failures in the Steam Cycle
- Discussion and Wrap-up

Registration for this two-day event is \$800 (continental breakfast and lunch included).

The registration deadline is September 16th, 2016.

This event is being held at M&M Engineering Associates' headquarters located at 1815 S. Highway 183 in Leander, Texas (78641), just North of Austin.

[Click photo](#) for a map of our location.

For Information including class schedules and hotel room blocks, contact Lalena Kelly at Lalena_Kelly@mmengineering.com, or (512) 407-3775. Detailed information will follow confirmed registrations. Seating is limited and is first come, first served.



SAY HELLO TO NEW MEMBERS OF OUR TEAM

Sig Hannesson

Sig joined M&M Engineering as a Laboratory Metallurgical Technician in January 2016.

He has received two Associate degrees, one in Computer Maintenance, and the other in Cisco Networking. Looking for something more blue collar that he would enjoy as a career, Sig enrolled in Austin Community College where he is currently enrolled in the Welding Certification Associate Degree Program, and has plans to obtain his license as a Certified Welding Inspector.

Sig was born in Iceland and moved to Texas at the age of seven. While living in a small farm town in South Texas, he found himself

spending most of his free time in his Grandfather's barn woodworking.

A few years ago, he got into steel working and fell in love with its power and strength. As he learned more, Sig found metallurgical study very interesting and useful to his steel working. Sig's metal working interests include general fabrication, blacksmithing, bladesmithing and casting. His other hobbies are fishing, hunting, making stained glass lamps, leather working, wood carving, and fixing up his 46 year Chevy CST-10 truck.

Sig has said that tools have always been, and will always be a large part of his life. He appreciates the works of art that come from

studying and mastering the tools of the trade, whichever those may be.

Sig is also the proud father of two boys, seventeen and twelve, and says that although it can be challenging at times juggling all of their activities, he finds it very rewarding. He aims to encourage his kids to embrace the "DIY" approach and keeping them grounded in the basics of life in an ever changing world.

Contact Sig Hannesson:

Sig_Hannesson@mmengineering.com



Sarah McGregor

Sarah McGregor joined M&M Engineering in January 2016 as a Metallurgical Consulting Engineer.

Sarah holds a Bachelor of Science in Metallurgical Engineering from the Missouri University of Science and Technology and a Master of Business Administration from the University of Texas at Arlington.

Biography and Experience:

Sarah brings a combined fifteen years of metallurgical, manufacturing, and quality experience in the steel and aerospace industry.

She began her career as a Process Metallurgist for Mittal Steel (formerly Ispat Inland Steel) in Indiana before moving to Texas where she continued her career at Gerdau Steel. During her career in the steel industry she gained a

vast knowledge and experience in steel cleanliness and inclusion morphology, casting and rolling anomalies, destructive and nondestructive testing, and product development.

In 2011, she joined the aerospace industry at Bell Helicopter supporting and leading internal and external technical investigations. She evaluated and optimized heat treatment for transmission gears utilizing metallographic examination and mechanical testing. She gained a broad knowledge of aerospace SAE standards, AS9100, ISO17025, ASTM standards, and OEM specifications. Sarah continued expanding her knowledge in heat treating and mechanical testing at a local heat treating company where she worked prior to joining M&M Engineering.

Throughout her career she has lead and supported metallurgical investigations related to internal and external customer claims.

In her free time, Sarah enjoys spending time with her husband, exploring and hiking in Austin, dining, and listening to live music.

Areas of Specialization:

- Metallurgical Engineering
- Failure Analysis
- Laboratory Testing
- Quality Assurance Auditing – Specifications, Standards, and Document Review

Contact Sarah McGregor:

Sarah_McGregor@mmengineering.com



Ray Stonitsch, P.E.

Ray Stonitsch joined M&M Engineering in January 2016 as a Corporate Engineer.

Ray graduated with a BS degree in Metallurgical Engineering from the University of Missouri – Rolla in 1974.

After graduation, Ray worked at Armco Steel Corp in Houston, Texas as a melt metallurgist for the blast and electric arc furnaces. Later, he transferred to Kansas City to start up a new metallurgical facility with continuous casting and an integral breakdown mill. While in Kansas City, his other duties included working with merchant mills, the continuous cooling rod mill, high carbon wire drawing, designing wire rope, and technical customer support engineering for wire rope products. He then transferred to Middletown, OH as a scrap buyer. He bid and negotiated scrap buys for all of Armco's facilities. In addition, he negotiated

all the scrap reclamation contracts for Armco.

In 1984, Ray joined GE Aviation in Cincinnati, OH. While at GEAE, he held roles as a product metallurgist, technical lead engineer, sourcing contract administrator, and quality manager. All of these roles centered on wrought products, specifically nickel, titanium, and iron-based materials used in aircraft engines. For nickel and iron-based alloys, he was the engineer for forgings. For titanium-based alloys, he was the engineer responsible for the entire process – raw material, sponge, melting, and forging of critical rotating parts.

While at GEAE, he introduced cold hearth melting to aviation products, as well as multizone ultrasonic inspection of all titanium products.

Ray left GE in 1998 and joined Allvac as the titanium product metallurgist. He was

responsible for the profit/loss and processing of rotating titanium billet.

Ray came back to GE in 2000 in the Power Generation business. While at Power Systems, he performed alloy development on both nickel and titanium-based alloys. As part of his work, Ray developed the largest vacuum arc remelting (VAR) ingot in Inconel 718. He also produced the largest conventionally forged nickel powder turbine part. In addition, he developed a ferritic iron-based powder that competes with Inconels 706 and 718 at a considerably reduced cost.

Ray retired from GE in October 2015 and joined M&M Engineering shortly after.

Contact Ray Stonitsch:

Ray_Stonitsch@mmengineering.com



Flow-Accelerated Corrosion Damage in Deaerators

Max Moskal, Principal Engineer
max_moskal@mmengineering.com

In a previous *Conduit* article ([Vol. 15, No. 2](#))¹, we discussed *corrosion fatigue* (CF) cracking, which is a dangerous and insidious damage mechanism that was first revealed in deaerators (DAs) in about 1973. This article discusses the second-most common type of damage to DAs, *flow-accelerated corrosion* (FAC), a type of damage that can rapidly thin the vessel shell.

To recap from the previous article, corrosion fatigue is the most common damage mechanism to be encountered in DA heaters, and is equally a problem in the DA storage vessel. Cyclic stresses that contribute to CF are usually from the operation or service of the equipment. The presence of a residual stress, such as residual tensile stress from welding, further increases the susceptibility to cracking by this mechanism. The corrosion factor in this damage mechanism can vary from only slight corrosion (essentially no material loss), to very severe, where material thinning also contributes to increased stresses. Corrosion fatigue is detected by performing periodic nondestructive testing, typically magnetic particle

testing. Since the introduction and implementation of the NACE practices twenty-five years ago, the incidence of deaerator cracking appears to have significantly decreased. Additionally, the importance of modifying certain in-service operation practices to

reduce operation stresses was recognized, such as minimizing water/steam hammer, and cyclic fluctuations. Thus, better operation helped to reduce the incidence of cracking.

The second most likely damage mechanism in deaerators, and equally dangerous if not detected, is *flow-accelerated corrosion*. FAC damage occurs in areas of higher water-steam media velocity, such as in deaerator heaters and associated feedwater piping, especially horizontal units; the mechanism is not found in DA storage vessels where flow rates are almost nil. Also, FAC is limited to deterioration of low-carbon

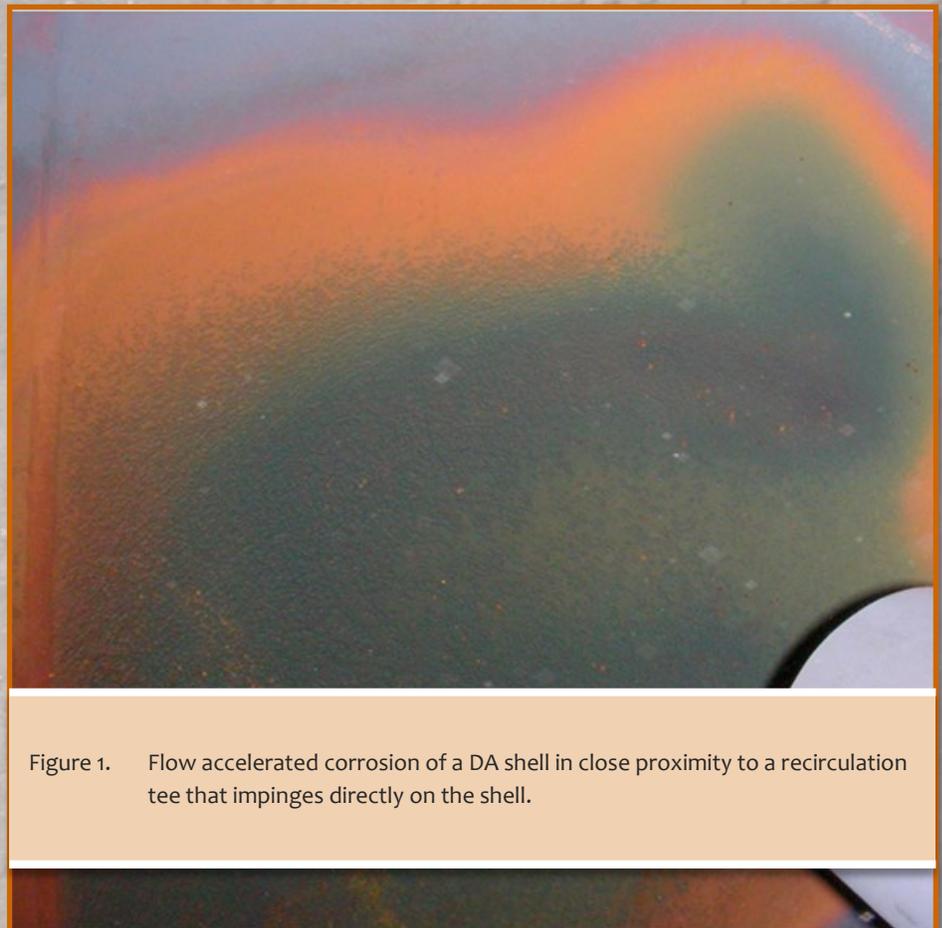


Figure 1. Flow accelerated corrosion of a DA shell in close proximity to a recirculation tee that impinges directly on the shell.

(Continued on page 15)

(Continued from page 14)

steel, not low-alloy or stainless steel.

FAC may be defined as metal loss that occurs when the normally protective magnetite (Fe_3O_4) layer is dissolved into a flowing stream of water or water-steam combination. The action is such that the oxide is cyclically loosened and dissolved in the water and/or steam, followed by repeated regeneration of oxide, with a resulting steady loss of metal thickness. Conditions that have been identified for FAC to be present are:

- Water chemistry: demineralized with pH less than 9.6.
- High water and/or steam flow rates.
- Temperatures must be above 212°F (The rate of FAC peaks in the temperature range of the DA.)
- The carbon steel must have low chromium, molybdenum and copper, as is normally specified for DA vessels.

FAC can occur when the liquid water phase is present (single-phase FAC), or when a combination of both water and steam are present (two-phase FAC). While the result of both single and two-phase FAC is the same (metal thinning), the visual appearance of the damage is different. Single-phase FAC will have a scalloped (orange peel) appearance while two-phase will have a horse-shoe shaped gouging or tiger-striping.

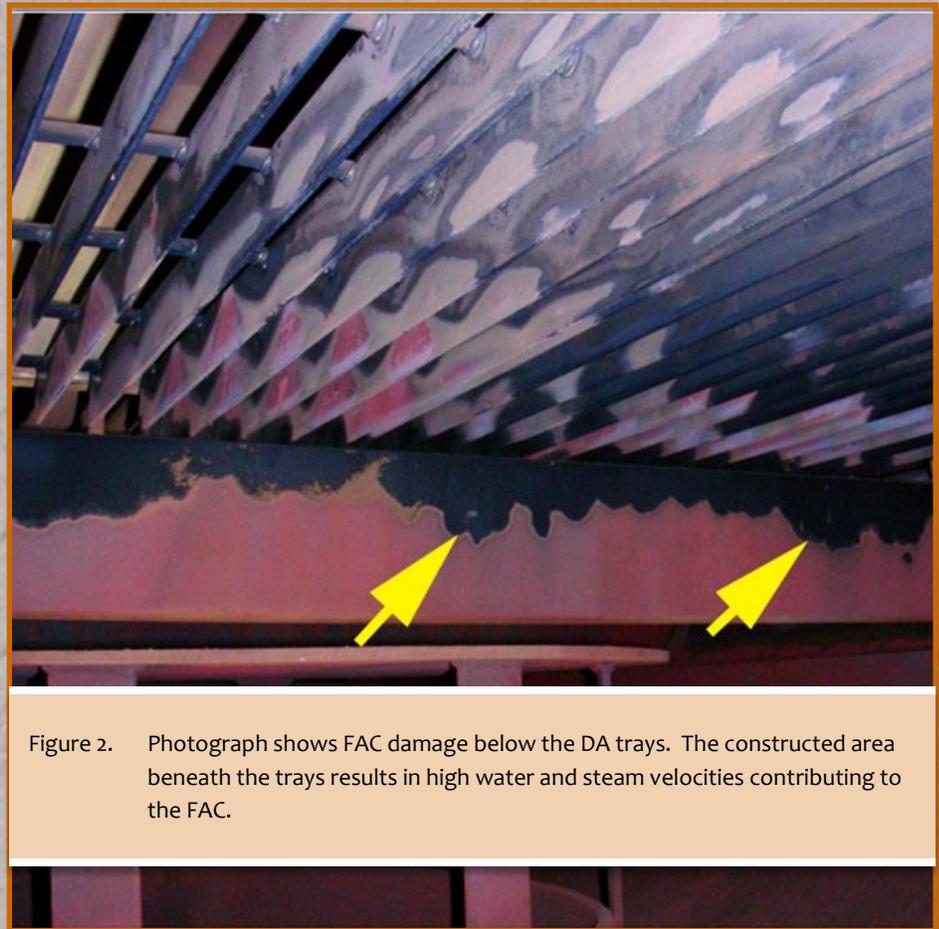


Figure 2. Photograph shows FAC damage below the DA trays. The constructed area beneath the trays results in high water and steam velocities contributing to the FAC.

Visual inspection of the interior of the deaerator is the best means of detecting FAC, and when found, the remaining metal thickness can be measured using ultrasonic thickness testing. During the inspection, look for metal gouging, pitting or thinning where the metal has a polished appearance and/or a gray or black color, contrasting from the normal reddish-brown color of the deaerator interior. Areas in the deaerator most susceptible are the steam inlet where steam enters the end of the vessel, where steam/water flows under the trays, and where water exits through bottom outlet pipes that connect to the DA storage tank. Examples of typical FAC damage are shown in Figures 1-4.

Changes in operation of the DA can trigger FAC degradation. For instance, a unit that has been modified to produce lower oxygen content water may become susceptible to FAC. Likewise, changing the load in the DA can result in a FAC problem. Changes to chemical feed systems, or the addition of nozzles also can create flow conditions that suddenly support damage by FAC.

A common method of repair of FAC damaged equipment is to build up the carbon steel by welding, followed by weld overlaying with stainless steel. Another method is to replace shell sections with carbon steel containing a higher

(Continued on page 16)

(Continued from page 15)

chromium content. It has been shown, for example, that even minimal chromium content in the alloy

significantly reduces the incidence of FAC. When deciding on repair strategy, one must keep the National Board Inspection Code rules in mind. For example, application of a stainless steel overlay does not constitute a design change, but a change of the shell material from plain carbon steel to low-alloy chromium-molybdenum steel does constitute an alteration. Repairs and weld overlays can also induce residual stresses in the applied welds, which in turn can increase the propensity for corrosion fatigue cracking. Weld repair of the affected area often only moves the FAC to where the weld bead stops. It is better if design changes (pointing nozzles away from the wall of the DA) or operating conditions (e.g., adjust the pH of the water or steam, temperature, velocity, etc.) are improved at the same time.

Finally, keep in mind that a first order of business in keeping deaerators safe is to inspect for both cracking and metal loss using periodic internal visual and nondestructive examination techniques by those familiar with these issues. When FAC or CF degradation are found, it is essential to review operation service conditions contributing to the damage, and correct these, if possible. The best methods for repair often requires a careful evaluation of original construction, past repair, and service history.

¹ Moskal, M., "40 Years of Deaerator Corrosion Fatigue," *Conduit*, Vol. 15, No. 2 (2015).

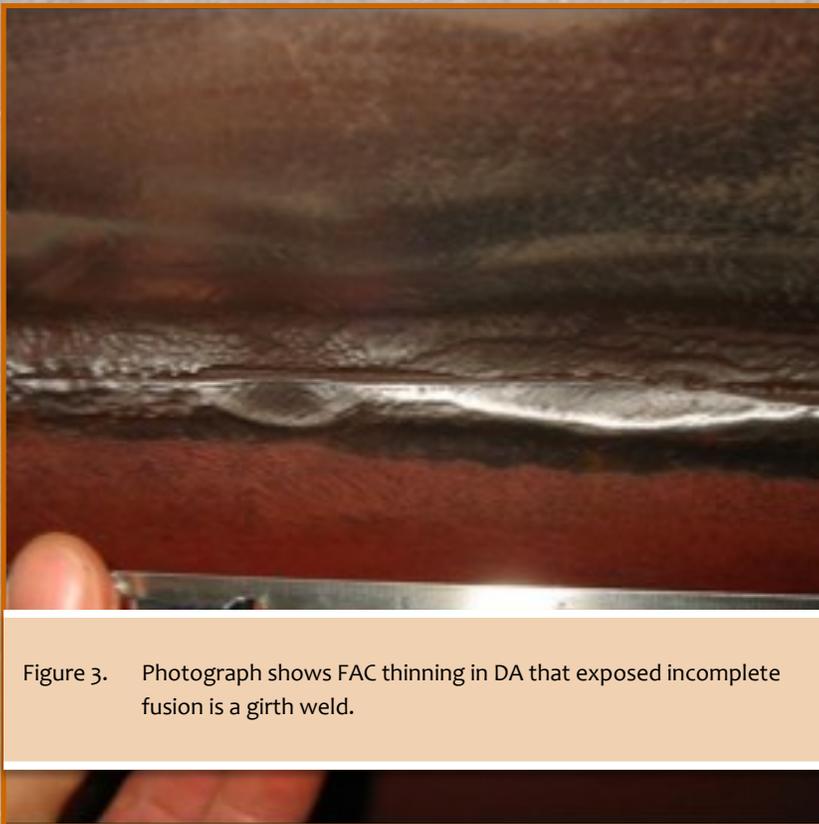


Figure 3. Photograph shows FAC thinning in DA that exposed incomplete fusion in a girth weld.

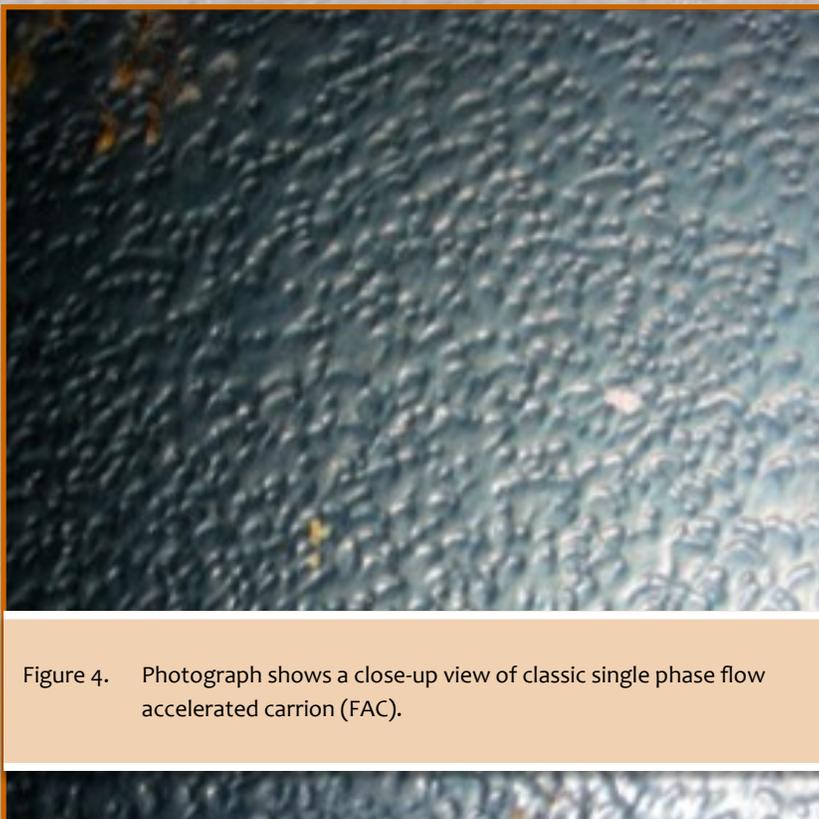


Figure 4. Photograph shows a close-up view of classic single phase flow accelerated corrosion (FAC).

MAX MOSKAL

CONSULTING ENGINEER

512.407.3755 direct

Max_Moskal@mmengineering.com



CONTACTS

1815 S. Highway 183
Suite 100
Leander, Texas 78641
[MAP](#)

info@mmengineering.com
Main: 512.407.8598
Toll-free: 800.421.9185
Fax: 512.407.3766

Our Business

Our History: <http://mmengineering.com/about-us/>

Facilities: <http://mmengineering.com/about-us/facilities/>

Our Team

Credentials: <http://mmengineering.com/about-us/our-credentials/>

People: <http://mmengineering.com/about-us/people/>

Our Services

<http://mmengineering.com/services/>

[Accident Investigation](#)

[Boiler Tube Assessment](#)

[Failure Analysis](#)

[Finite Element Analysis and Computational Mechanics](#)

[High Energy Piping Assessment](#)

[HRSG Condition Assessment](#)

[Independent Third-Party Laboratory](#)

[Materials Science Laboratory](#)

[Metallurgical Condition Assessment](#)

[Smart Non-Destructive Testing](#)

[Steam Cycle Chemistry Services](#)

[STRAP – Steam Turbine Risk Assessment Program](#)

[Support for Industrial Insurers and Independent Adjusters](#)

[Water Treatment Technologies Services](#)

Publications

By Author: <http://mmengineering.com/publications-reports/publications-author/>

Boiler Tube Failure Handbook: <http://mmengineering.com/boiler-tube-failure/>

the Conduit: <http://mmengineering.com/conduit/>

Sign-up to receive the Conduit: <http://mmengineering.com/conduit/conduit-updatesremovals/>

CREDITS

Image, Page 3, “Risk”: <http://www.forbes.com/sites/glennlopis/2011/04/04/why-risk-must-be-your-best-friend-in-todays-business-climate/#79f4a44e12dc>

Background image, Page 6: <http://aerosollarevista.com/wp-content/uploads/2013-07-A-La-Pulverizacion-del-Aerosol.jpg>

Background image, Page 7: http://i01.i.aliimg.com/img/pb/347/888/863/863888347_802.jpg

Background image, Page 8: <https://encrypted-tbno.gstatic.com/images?>

[q=tbn:ANd9GcQvqu9GDzBpA2E8aljIVoQjbo1sBfNkZhNGyBRRQTYRDjSg787YrA](https://encrypted-tbno.gstatic.com/images?q=tbn:ANd9GcQvqu9GDzBpA2E8aljIVoQjbo1sBfNkZhNGyBRRQTYRDjSg787YrA)

Background image, Page 9: https://www.linhardt.com/wp-content/uploads/2014/01/aerosoldosen_schultern_internet.png

Graphic, water droplet, Page 11: <http://www.clker.com/cliparts/2/2/3/7/1320352173735008201water%20droplet-hi.png>

