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COVER PHOTO

This issue’s cover photo shows a 300 series stainless steel that was sensitized during operation, and was subsequently affected by intergranular attack (IGA) that led to cracking. Intergranular attack can be mitigated by proper heat treatment, operation outside of the sensitization range, or using a stabilized grade of stainless steel, such as Type 321 or Type 347.

ABOUT the CONDUIT

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

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The old workhorse alloys used in corrosive environments, especially chloride containing environments, are 316L and 317L austenitic stainless steels. Although these alloys have good chloride pitting resistance, they are not impervious to chloride attack as chloride and temperature levels increase. A commonly used upgrade alloy when the environment is more corrosive (e.g., chloride content is high) is 2205 duplex stainless steel. In addition to increased chloride resistance, 2205 has greater mechanical strength than austenitic stainless steels.

The microstructure of 2205, as shown below in Figure 1, consists of a duplex structure of austenite and δ-ferrite. Thus, it gets its name “duplex stainless steel” from its structure.

2205 acquires its corrosion resistance from the alloying elements dispersed in a duplex structure. However, this good corrosion resistance can be removed by improper heat treating (too slow of a cool from the annealing temperature of 1950°F) or from welding with too much time above 1100°F (red zone). The weld must be completed with minimum time in the red zone, which is not usually a problem if stringer welds are applied. The time in the red zone is cumulative. Thus, a combination of poor heat treatment and large weld beads (i.e. longer time at elevated temperature) during construction can lead to problems. If improper heat treating has occurred, or there is a combination of poor heat treating and too high a welding temperature, the microstructure will change. Intermetallic precipitates will form and leave regions with minimal corrosion resistance.

A client of M&M Engineering’s recently sent in samples from their piping system with a unique problem. They had a subset of new piping flanges in their system that were rapidly corroding, resulting in leaks. After a metallurgical investigation was performed, it was found that some flanges had not
been properly heat treated resulting in intermetallic precipitates in the flange’s microstructure (Figure 2). Other flanges only corroded in the heat affected zone of the pipe to the flange weld (Figure 3). This location also showed intermetallic precipitates. In these cases, the flange’s general microstructure remote from the weld showed some areas of incipient intermetallic precipitates (Figure 4), but generally looked acceptable. This indicated that the combination of heat treatment and welding created localized areas of significant intermetallic precipitates and, in turn, areas for localized corrosion. Examination with a scanning electron microscope (SEM) showed chlorides concentrated at the precipitates, further illustrating the damage mechanism (Figure 5).

In summary, 2205 is great for many corrosive environments. However, its good corrosion resistance comes from its microstructure, which can be affected by poor heat treatment and/or improper welding.
Ultrasonic testing (UT) has been an accepted practice of inspection in industrial environments for decades. Our new textbook, titled Industrial Ultrasonic Inspection Levels 1 & 2, is designed to meet and exceed ISO 9712 training requirements for Level 1 and 2 certification. The material presented in this book will provide readers with all the basic knowledge of the theory behind elastic wave propagation and its uses through easy to read text and clear pictorial descriptors.

Discussed UT concepts include:

- General engineering, materials, and components theory
- Theory of sound waves and their propagation
- The general uses of ultrasonic waves
- Methods of ultrasonic wave generation
- Different ultrasonic inspection techniques
- Ultrasonic flaw detectors, scanning systems, and probes
- Calibration fundamentals
- General scanning techniques
- Flaw sizing techniques
- Basic analysis principles for ultrasonic, phased array ultrasonic, and time of flight diffraction inspection techniques
- Codes and standards
- Principles of technical documentation and reporting

It is the author’s intention that this book is used for general training purposes and is the ideal classroom textbook.

For more information visit the Eclipse Scientific textbooks page at www.eclipsescientific.com/books.html

Hardcover: $118.99 USD
Softcover: $94.99 USD
When sending a sample to the laboratory for failure analysis, it is important that parts are removed and packaged in a way to preserve the failure and protect it during shipping. Occasionally, we receive samples that are not ideal for conducting a failure analysis. Our intent with publishing this article is to inform our clients of best practices, to ensure the most accurate analysis possible. We acknowledge that sometimes a failed part is removed purely for replacement purposes to get equipment back up and running quickly, and failure analysis is an afterthought. In other cases, it is difficult to remove a sample without partially destroying it (e.g., boiler tubes where they go into the mud drum, Figure 1). But if you know ahead of time that you want to look at a failure more closely to determine the mechanism or root cause, it is important to minimize the damage to the failed area during removal and shipping. Preserving the sample as close as possible to its post-failure condition is imperative to an accurate and successful failure analysis.

In this article, we have collected some examples of parts that we have received that illustrate what not to do and the importance of this first step in a failure analysis. Client names have not been divulged in order to protect the innocent (or guilty as the case may be).

Sample Removal

It is tempting to think that since the part is already failed, that there is little you can do to cause more damage. However, there are several actions during sample removal that can further damage the part or remove "information" from the sample. In most cases, we are able to work with the sample condition as it is received, but it is optimal to avoid these practices to get the best sample possible for analysis. This can also help avoid a misdiagnosis of the problem. The following figures show examples of things to avoid during sample removal.

For the first example, this tube was received with a saw cut through the middle of the rupture (Figure 2). It appeared that this was done in order to fit the tube into a shorter box. In this case, we were still able to determine the failure mechanism (short-term overheating), but cutting through the failure area runs the risk of removing or damaging an artifact of the failure that would indicate the mechanism or more importantly in some cases, the initiation site. Sometimes we want to look at the middle of the failure, but might also want to look at the edges of the...
failure or adjacent to the failure to gain more information.

While saw cuts will remove a thin section of the part, they are much preferred to torch cuts. In addition to producing more metal loss, torch cutting causes significant heat damage to the part several inches around the cut (as shown earlier in Figure 1). This can obscure whether the part was overheated prior to or as a result of the failure. If torching is used, it is best to cut 12 to 18 inches away from either side of the area of interest to avoid damaging the microstructure in that area.

There have also been instances when a sample was cleaned before it was sent in. Some samples are required to be decontaminated before shipping, which is appropriate and appreciated. But, if a sample is washed or cleaned just to make it “nicer” for shipping, it can remove valuable information. We will often analyze deposits to determine what corrodents are present that led to corrosion damage. We can also examine deposits/oxides to ensure that they have a normal composition or if the makeup indicates an issue with water treatment, for example. It is best to avoid cleaning off deposit unless the part is hazardous without doing so.

Another cleaning method that can cause even more damage is grit blasting. Figure 3 shows a sample we received that had been grit blasted, including the fracture surface, to remove deposits. At first, it just appeared that the fracture was very smooth and flat. Examination at high magnification showed particles imbedded in the fracture from cleaning and dulled fracture features. This made it difficult to confirm the failure mechanism. Any grit or bead blasting of or around the fracture should be avoided to keep the damage morphology intact. Fracture surfaces should be carefully masked from any exposure to grit/bead blasting. Chemical cleaning methods can also cause similar damage if the part is exposed to the chemical for too long or without corrosion inhibitors.

Figure 4 shows a failed shaft that was received for analysis. The customer indicated that they machined around the circumference of the part to smooth the sharp edges for safety purposes. While this was considerate, it also removed the likely origin of the...
Employee Spotlight

David G. Daniels, Senior Principal Scientist

David Daniels has worked in the area of water and steam chemistry for more than 36 years. He was one of the founding members of M&M Engineering Associates when it formed in 2008. David has a BS in Chemistry from the University of Utah. After graduation, he worked for Pacificorp (then Utah Power and Light) for seven years, first as a lab technician, then plant environmental engineer, and finally as the plant chemist at the Hunter Station.

Since joining M&M Engineering Associates, David has provided consultations across the country, as well as internationally, with a number of industries regarding water and steam chemistry corrosion issues. David regularly performs audits of plant water and steam chemistry, inspects boilers, provides consultation on water/steam chemistry related corrosion failures, provides training for plant personnel, writes monitoring program specifications, monitors boiler chemical cleans, and is a prolific writer. David has a knack for making complicated water/steam equipment and issues understandable to the rest of us.

David has written numerous papers and has given presentations on various aspects of water and steam chemistry. From 1999 to 2016, he was a contributing editor on water and steam chemistry issues for Power magazine. He also has written articles in other publications such as Journal of Power Plant Chemistry, and Ultrapure Water. David has authored and presented numerous papers at the International Water Conference, and regularly provides a post-conference training course on boiler water chemistry for high pressure boilers at the conference. David is the lead presenter for M&M Engineering’s annual workshop “Preventing Failures in Steam Generating Equipment,” which is in its sixth year. David is currently serving as chairman of the ASME Research and Technology Committee on Water and Steam in Thermal Power Systems.

With more than three decades of experience, David has found that many corrosion problems can be prevented by paying attention to water/steam chemistry and taking the appropriate actions to prevent chemically-caused damage, and has dedicated his career to taking this message to various industries.

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fracture, as these tend to be along the surface of the shaft. It is best to avoid any machining, smoothing, or beveling of parts.

**Shipping**

Once a sample is successfully removed, it must be packaged for shipping to the lab. Many of the parts we receive are too large or heavy to fit in cardboard boxes. In this case, a wooden box can be built (or reused) or the parts can be strapped to a pallet to accommodate the heavier part. Regardless of the container used, the parts should be carefully packed, protected, and secured so that they survive the rigors of shipping. Relying on the carefulness of the shipping company can be a risky business.

When shipping samples in a cardboard box, they should be packed in an appropriately sized box with cushioning packing material inside. Some plants use old rags or newspaper – it doesn’t have to be brand new bubble wrap. When no packing material is used, the parts bang around in the box during shipping and can shake loose deposits and cause additional damage (Figure 5). This makes it difficult to discern whether the damage was due to the failure or shipping.

On the opposite end of the spectrum, going overboard with packing material can also affect the sample. Several years ago we received multiple boiler tubes from a customer that filled them with packing peanuts. This is undesirable for two reasons. First, pushing material into a tube or pipe can remove and/or contaminate deposits that are present that help determine the failure mechanism. Second, packing peanuts will do little to protect a metal tube or pipe on the inside – the material is much stronger than the peanuts, and if it does get crushed, then you have bigger problems on your hands (like someone ran over the package). For tubes or pipe sections, it is best to simply tape the ends closed to avoid anything going in or out.

In addition to padding the samples inside the box, the failure itself should be well protected (Figure 6). Wrapping the failure can also prevent damage during shipping, even if loose packing material is used around it. For example, if a fatigue fracture is impacted, it can damage the fracture and make it difficult or impossible to find the crack origin, or determine if it was high.
cycle or low cycle fatigue. This can easily happen post-failure, before the part is even removed from the equipment, so it is crucial to protect a “good” fracture surface that survived the failure to tell its story.

One item specific to fracture surfaces is to not put the mating fracture surfaces in contact. It is natural to want to fit the mating halves back together to see how well they match. However, even lightly fitting the halves back together can cause rubbing damage to the fine fracture features, particularly in the origin area. Avoid the natural tendency to put the pieces back together. We recently received a fractured shaft that was placed in a nice, custom-made wooden box for shipping (Figure 7). Everything was done really well, except that the mating fracture surfaces were secured into the box touching each other. This means that they impacted against each other during the entire shipping process, over 1000 miles, until we removed them from the box. This sample was actually the inspiration for putting together this article. If it is necessary to secure a fracture surface for shipping, place the fracture against a wooden support. The fracture halves shown in Figure 7 could have been successfully shipped if a wooden piece (2x4, piece of plywood, or even a stack of popsicle sticks) had been placed between the two fracture surfaces to prevent them from contacting one another during shipment.

Sometimes parts are welded together for removal or shipping. In some cases, this is good because it maintains a space between the mating fracture surfaces (Figure 8) to avoid the situation described above. In other cases, a handle might be welded onto the part that happens to be welded onto the failure area. When welding on parts to aid in sample removal or shipping, be mindful of keeping space between the fractures and avoiding welding too close to the failure and causing unwanted heat damage.

While we will accept samples in almost any condition, we appreciate when care is taken to remove and pack samples in a way that preserves the failure features. This way we can provide you with the most meaningful and accurate failure analysis possible.

Conveniently, we have a sample removal guideline for handy reference which is included on the following page. If you aren’t sure about something specific when removing or packing a sample, please don’t hesitate to contact us. We will be glad to answer any questions.

Figure 7. Fractured shaft that was packaged with the mating fracture surfaces touching.

Figure 8. Fractured fork lift boom, where a plate was tack welded (arrows) to maintain a space between the fracture surfaces.
Metal Sample Preparation Guidelines

Sampling Methods for Laboratory Analysis

The recommended sampling methods are saw and torch cutting, metal nippers, drilling and filings, and scraping. The table on the following page shows the type of sampling method we suggest for different suspected problems or information gathering tasks that you may need. Also shown are the sample sizes needed to perform laboratory tests and analyses.

- Saw cutting is usually the best method for general sample removal. Always make saw cuts away from area of interest or concern; 6 inches on either side of the area of interest.
- Torch cutting (flame or air arc), when necessary, must be done far enough away from the area of interest or concern to avoid over-heating damage; 12 to 18 inches or more from the area of interest.
- Metal nippers, drill bits, files or scrapers used for small sample removal should be clean (alcohol wipe is best) before using.
- IMPORTANT: Fractured Sample pieces should never be “matched” back up, rubbed together or cleaned before shipping. Carefully protect “fracture faces” and the surrounding edges for lab analysis.

Identification and Information for Samples

- Use a clear and logical numbering or naming label on the sample or a tag/bag with the sample to assure that the information you later receive from the lab is correctly connected with the sample.
- When writing on the sample avoid covering the area of concern (crack, corrosion products, stampings, etc.)
- Also, if appropriate, use arrows or direction words to orient the sample with the equipment/component it represents. Use terms such as “top”, “flow direction”, “plant north” or “fire side” to do this.
- Use a lead-free, indelible marker such as a “Sharpie®” for marking samples.
- For bagged or bottled small samples apply identification to the container directly. If labels are used, try to cover the label with clear tape to prevent smearing of the information during shipment.

Packaging Samples for Shipping

- Cap openings (such as tube ends) with tape or cardboard/plastic plugs.
- Wrap the sample securely so loose deposits or pieces stay intact if possible. Make sure that sharp edges are padded from cutting the packaging.
- Bag or bottle small samples (Snips, Drillings/Filings or Scrapings) in tightly sealed bags/containers.

Shipping

- Include written description of the sample identification and problem of concern with a sketch for orientation if possible. Also, send photos and descriptions via email, or include our Incoming Sample Form located on our website.
- Contaminated samples may need special packaging and paperwork; contact your shipper.
- Large samples are usually shipped by truck.
- Samples less than 75 lbs. can usually be shipped by a package service.
- Small samples can be shipped overnight by envelope.

Note: On a routine basis, M&M Engineering is able to safely receive and handle samples 1 ton and under when received on a pallet or in an appropriate shipping container. We are also able to receive items eight (8) feet in length, height, width and/or diameter. If you anticipate shipping a sample over 1 ton or with a dimension over eight (8) feet, please contact us prior to shipping the sample so the appropriate arrangements can be made to receive the item.
## Metal Sample Preparation Guidelines

### Sampling Methods for Laboratory Analysis

<table>
<thead>
<tr>
<th>SAMPLE TYPE</th>
<th>SUSPECTED PROBLEM</th>
<th>SIZE</th>
<th>CUTTING METHOD</th>
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</thead>
<tbody>
<tr>
<td>Whole</td>
<td>All Types (Particularly Fractures and Cracking)</td>
<td>1 ton and/or 8 feet in diameter, height, or width</td>
<td>___</td>
</tr>
<tr>
<td>Partial</td>
<td>All types</td>
<td>50 lbs. (Express delivery limit)</td>
<td>Saw or Torch Cut</td>
</tr>
<tr>
<td>Cores</td>
<td>Cracks, Corrosion, Damage, Heat Treatment, Subsurface Material Identification</td>
<td>1/4 inch diameter and above</td>
<td>Hole Saw</td>
</tr>
<tr>
<td>“Boats”</td>
<td>Shallow Surface Features: Alloy ID, Weld ID/defects, Corrosion Damage, Heat Treatment</td>
<td>Approximately 1/2 x 3/4 x 3 inches</td>
<td>Carbide Cut-off Saw Angled Hole Saw</td>
</tr>
<tr>
<td>Plate</td>
<td>Cracks Fractures, Alloy ID, Weld ID/defects, Corrosion Damage, Heat Treatment, Tensile or Bend Testing</td>
<td>6 inch and greater from area of interest 12 inch and greater from area of interest</td>
<td>Saw or nipper cut</td>
</tr>
<tr>
<td>Snips</td>
<td>Alloy ID</td>
<td>½” x ½” or as small as available</td>
<td>Saw or nipper cut</td>
</tr>
<tr>
<td>Drillings or Fillings</td>
<td>Alloy ID</td>
<td>1 ounces or more</td>
<td>Clean drill or file</td>
</tr>
<tr>
<td>Scrapings</td>
<td>Corrosion Damage Products</td>
<td>From 2 square inches or more area</td>
<td>Clean metal scraper</td>
</tr>
</tbody>
</table>
Press Release—January 1, 2017

Acuren Inspection, Inc., the global provider of nondestructive testing (NDT), inspection and related services, is pleased to announce the acquisition of M&M Engineering Associates, Inc., a leading U.S. provider of field and lab engineering services to the power generation, pulp and paper, chemical, and manufacturing segments. Through its state-of-the-art integrity management, condition assessment and failure analysis capabilities, M&M Engineering helps clients manage operational risk while reducing their overall cost of operation. This exciting combination enables Acuren, an established leader in NDT for over 40 years, to bring integrated assessment and inspection solutions to its valued customers across the U.S. Acuren, a wholly owned subsidiary of Rockwood Service Corporation, also provides a range of inspection and engineering services in Canada.

“We are delighted to welcome the M&M Engineering team to the Acuren family,” said Peter Scannell, Rockwood’s Founder and President. “M&M shares Acuren’s commitment to developing customized engineering and inspection programs that enable plants to optimize the life cycle of their critical assets. We are excited about bringing more value to our collective customers through combining Acuren’s best-in-class inspection, condition monitoring and rope access capabilities with M&M Engineering’s deep expertise in metallurgical condition assessment, risk-based evaluation and failure analysis.”

Karen Fuentes will continue to oversee the M&M organization and its experienced team of engineers and technical experts. Mrs. Fuentes commented: “We are highly enthusiastic about this new partnership and the broader set of capabilities that we can provide. Having worked together with Acuren in the past, we know that Acuren shares our commitment to quality, safety and continuous improvement.”

For more information, please contact Karen Fuentes at 512-407-3778 or Karen.Fuentes@acuren.com, or visit www.mmengineering.com.

ABOUT ACUREN

Acuren is an organization dedicated to the ongoing development of state-of-the-art inspection, testing, engineering and rope access enabled services delivered through over 80 locations across North America and the United Kingdom. Committed to delivering A Higher Level of Reliability, Acuren provides an unrivaled spectrum of capabilities worldwide. Acuren employs over 3,500 dedicated professionals, supporting the mechanical integrity and inspection programs of the world’s largest industrial segments including petroleum refinery, pipeline, power generation, pulp & paper, pharmaceutical, aerospace, and automotive. To learn more, please visit www.acuren.com.
M&M Engineering Associates would like to thank those that joined us for our 2017 annual workshop on August 15-16, 2017.

Ascend Performance Materials • Associated Electric Cooperative • Baker Hughes, a GE Company
Brazos Electric Cooperative • City of Grand Island • Cokenergy LLC • Entergy • Hartford Steam Boiler
ICU Medical • Independence Power & Light • San Miguel Electric Cooperative • Tenaska

We will host our 7th annual workshop in late summer 2018 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 PRE-REGISTER TODAY!

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<td>• Equipment Associated with Steam Generation—A Primer</td>
<td>• Failure Investigation Principles for Combustion Turbines</td>
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<td>• Steam Touched Boiler Tube Failure Mechanisms</td>
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<td>• Introduction to Nondestructive Testing &amp; Inspection</td>
<td>• Water and Steam Chemistry-Influenced Failures in the Steam Cycle</td>
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<td>• High Energy Piping Damage Mechanisms and Corrections</td>
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<td>• Introduction to Failure Analysis</td>
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Registration for this two-day event is $800 (continental breakfast and lunch included). Pre-registration is open for the 2018 event.

This event will be 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 contact Lalena Kelly at Lalena_Kelly@mmengineering.com, or (512) 407-3775.
The ASNT Annual Conference is the largest, dedicated gathering of industry professionals, equipment and technology suppliers, engineers and researchers working in the field of nondestructive testing and evaluation of materials. Registration will open soon, so check back with ASNT for updates. Be sure to stop by and visit with Acuren and Eclipse Scientific personnel who will be in Booth 1122, as well as learn what’s new in the world of online training by visiting Hellier just across the aisle in Booth 1123.

David Daniels, Senior Principal Scientist with M&M Engineering Associates, will be in attendance at the 2017 International Water Conference in Orlando, Florida on November 12-16, 2017.

David will be presenting again this year on W13: HRSG and High Pressure (>900 PSIG/60 BAR) Boiler Water Treatment and Operation. This workshop will cover the water quality required for high pressure (>900 psig/60 bar) steam boilers including the various treatments being used and new developments relative to protection from scale and corrosion. The workshop will also cover treatment issues related to pre-boiler systems and the condensate systems and a discussion of controls and troubleshooting techniques. Operators, utility plant supervisors, managers, and engineers can all benefit greatly from the practical information provided in this course.

Click to learn more about IWC and to register for this event International Water Conference (IWC).

M&M Engineering will host their 7th annual workshop in late summer 2018 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.

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Click the ticket and PRE-REGISTER TODAY!
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