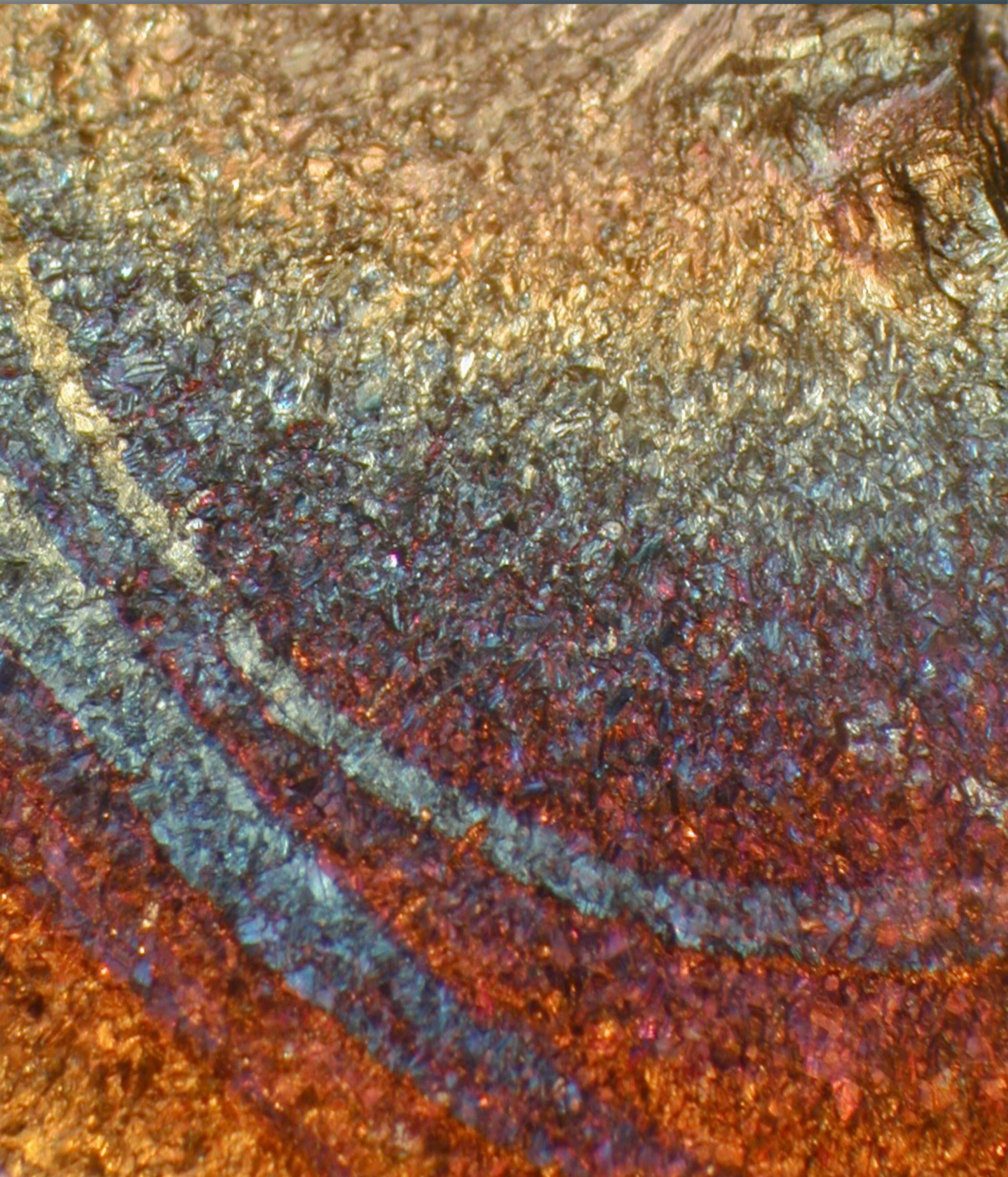
Winter 2018

The Metal Never Lies

the CONDUIT



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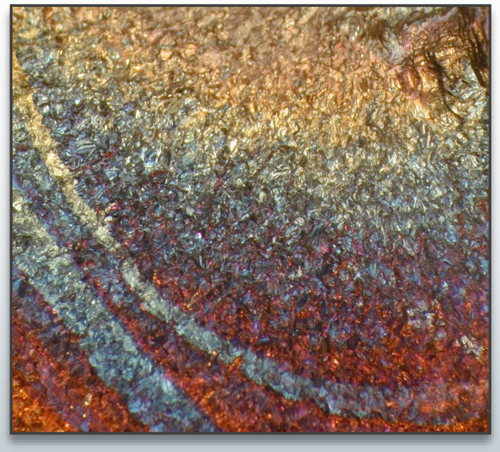
VOL 18, NO 1

COVER PHOTO



Our cover photo for this issue shows heat tinting of a fatigue crack on a gas turbine compressor blade.

Heat tinting can be an indication of the level of temperature exposure; alloying will also affect the colors developed.

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 CONDUIT

Industrial Ultrasonic Inspection Levels 1 & 2 — First Edition

Author: Ryan Chaplin
ISBN: 978-1-4602-9567-0 *(Hardcover)*
ISBN: 978-1-4602-9568-7 *(Softcover)*
Hardcover and Softcover, Full Color, 277 Pages

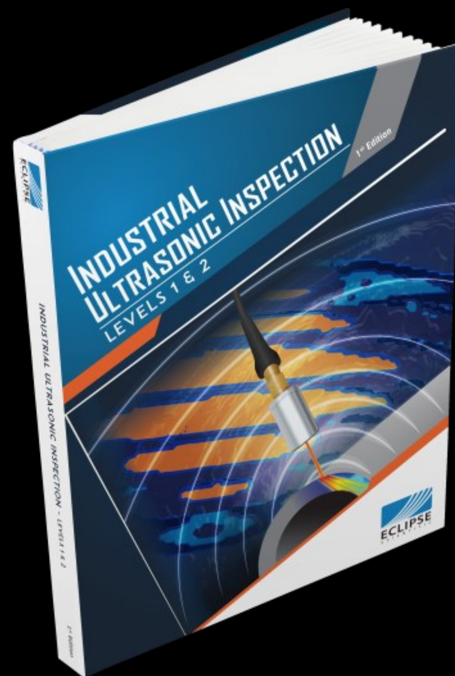
Ultrasonic testing (UT) has been an accepted practice of inspection in industrial environments for decades. Our new textbook, titled Industrial Ultrasonic Inspection Levels 1 & 2, is designed to meet and exceed ISO 9712 training requirements for Level 1 and 2 certification. The material presented in 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.

<u>Discussed UT concepts include:</u>

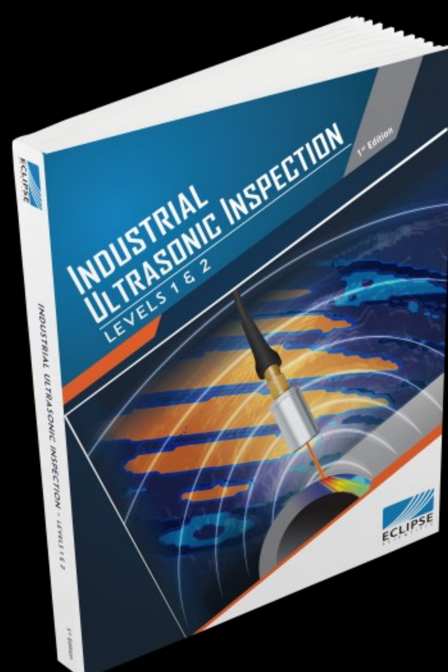
- General engineering, materials, and components theory
- Theory of sound waves and their propagation
- The general uses of ultrasonic waves
- Methods of ultrasonic wave generation
- Different ultrasonic inspection techniques
- Ultrasonic flaw detectors, scanning systems, and probes
- Calibration fundamentals
- 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

The Metal Doesn't Lie

Part 1 of 3: Fractography

G. Mark Tanner, P.E., *Senior Principal Engineer*

At M&M Engineering, we often tell clients that the metal doesn't lie. If we can metallurgically examine the part, it will provide us a wealth of information. It will tell us what the mode of failure was as well as what happened in the past (manufacturing and operation) that could have affected it. There have been countless times that a client sends us something that has been failing and where the self-diagnosis was not correct. What was thought to have been causing the failure was not correct and, as such, the solutions were solving the wrong problem. The metallurgical analysis determined a different mode and subsequent root cause of the failure.

There are numerous parts to a metallurgical investigation, but it can be divided into three primary categories: fractographic, metallographic, and mechanical/chemical. For the first part in this three part series, we will discuss the fractographic category.

Fractography is the examination of a fracture surface. This is done visually by an engineer, as well as with the aid of various laboratory tools. When a metal component finally fractures, there are three modes of failure. They are ductile overload, brittle overload, and fatigue. They each leave a distinctive "fingerprint" or fractographic features on the fracture surface that can be identified.

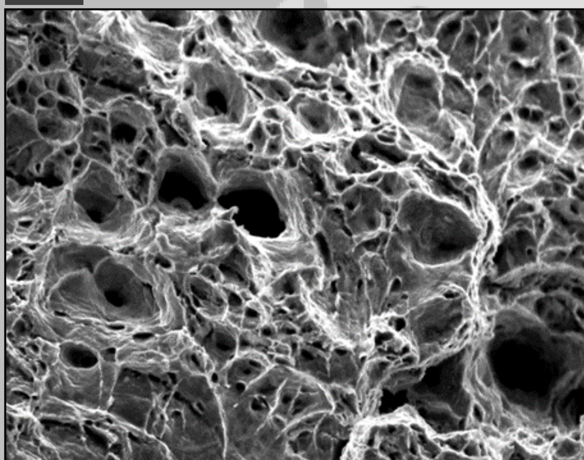
When a metal component cracks, there are five primary cracking mechanisms. They are fatigue (including corrosion fatigue), stress corrosion cracking, hydrogen cracking, creep cracking, and liquid metal embrittlement. For welds, there are several other cracking mechanisms that occur during manufacturing, including solidification cracks, hydrogen cracks, and chevron cracks. Just like modes of failure, cracking mechanisms also produce distinctive fractographic features. These fractographic features allow an engineer to identify the origin of the cracking as well as the crack propagation mechanism.

Along with the failure modes and cracking mechanisms, fractography also allows the engineer, in many circumstances, to determine the type of loading (stress) that was applied to the metal component at the time of failure. For example, an engineer can often times determine if the loading on the metal component was bending, tension, compressive, shear, torsional, or cyclic.

Based on the metal alloy (e.g., low alloy steel, stainless steel, nickel, aluminum, copper, titanium, etc.), the fine fractographic features can have subtle differences in the modes of failure, but significant differences in features for the failure mechanisms. For example, fatigue striations can easily be observed in austenitic stainless steel fatigue failures, while they are very difficult to see in martensitic stainless steels. Thus, the experience of the engineer, as well as their access to fractographic literature (books and articles), is very important. Now that we have explained some fractography basics, let's examine some photographs taken with a scanning electron microscope (SEM) at high magnifications that allow us to see the fine fractographic features ("fingerprints") of various metal failures.

Here are six examples of fracture surfaces. Can you determine the modes of fracture? Your choices are fatigue, ductile overload, corrosion fatigue, and brittle overload. Check your answers on page 17.

1



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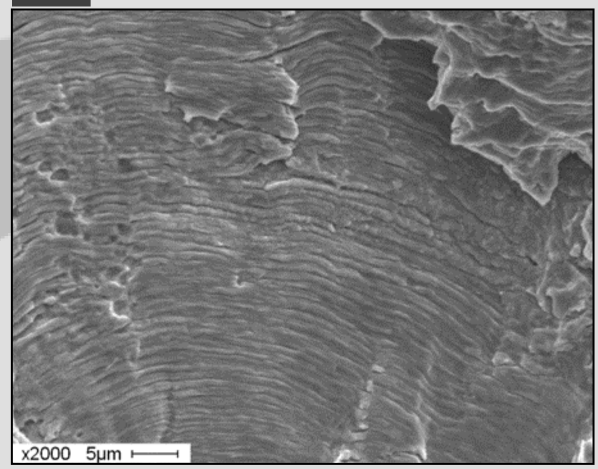

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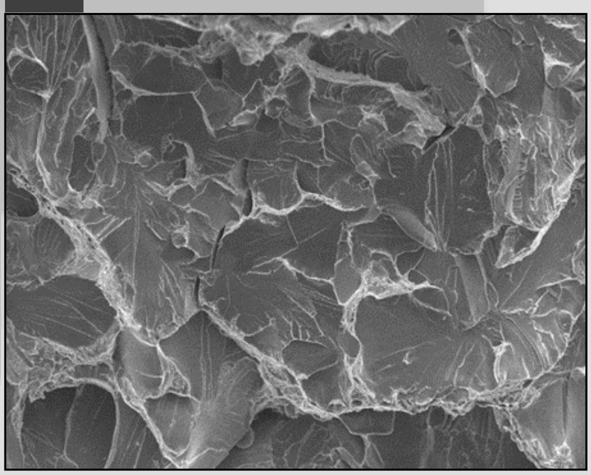

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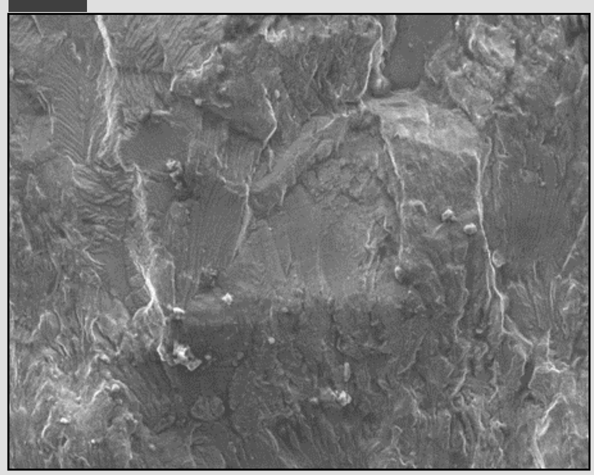

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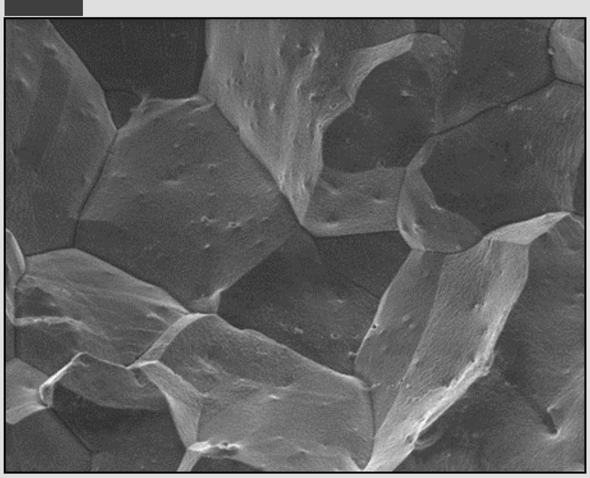

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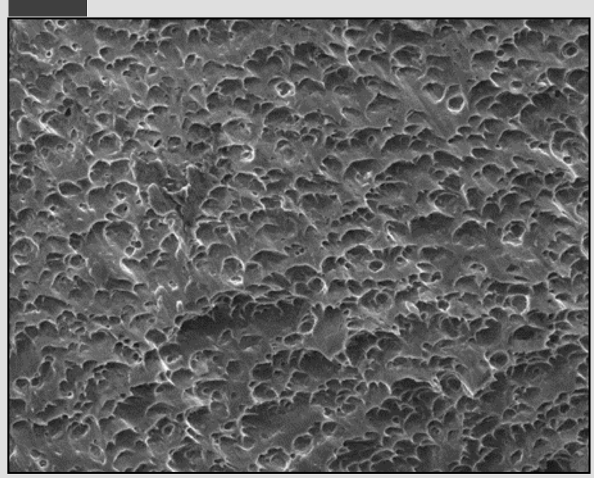

Employee Spotlight

David K. Fuhrmann, Principal Engineer

Dave Fuhrmann has worked in the pulp and paper industry for more than 44 years. He began his career as a laborer and fork truck driver in a sulfite pulp mill with Nekoosa Papers. He earned his BS in Pulp and Paper Engineering in 1987 while working shift work as a Recovery Operator and pulp mill supervisor. After graduation, he went to work for Weyerhaeuser in Valliant, Oklahoma as a Senior Process Engineer, then Powerhouse Technical Assistant. In 1999, he relocated to Loveland, Ohio to work from the Corporate Technology Center with International Paper. He retired from International Paper in 2017 as a Technology Fellow, and then formed his own company (Precision Reliability) before becoming an employee of M&M Engineering Associates, a Division of Acuren Inspection, Inc.

Throughout Dave's career, he has served to provide internal consultations on both short- and long-term reliability improvements for steam generating equipment, first within the US and internationally as well.

Dave worked to improve performance throughout his many positions, using planning and tracking tools to streamline and effectively execute boiler overhauls, as well as to successfully justify capital improvements and implementation. He was involved in coordinating and participating in powerhouse policy compliance audits and also in powerhouse performance assessments. He has been involved in developing and revising boiler equipment specifications and in dealing with vendor supply partnerships to standardize materials, equipment repairs, and inspections. Dave has a patent for Superheater Overheat Prevention, and has served on the Black Liquor Recovery Boiler Advisory Committee as an owner/operator representative for the Executive Committee, and as Chairman on the Materials and Welding Subcommittee.

With more than four decades of experience, Dave has found that reliability improvements can be made by using proper inspection methods, analyzing the data, and applying the right mix of training, maintenance, and capital to avoid failures and increase annual capacity of equipment.

Dave has been to 48 of the 50 United States (missing New Mexico and Delaware), and numerous countries outside the US including: Brazil, Canada, Mexico, France, Poland, Japan, Russia, New Zealand, Italy, Netherlands, Denmark, Finland, and Sweden. Hunting, fishing, gardening, travelling, and grandchildren are his biggest hobbies.

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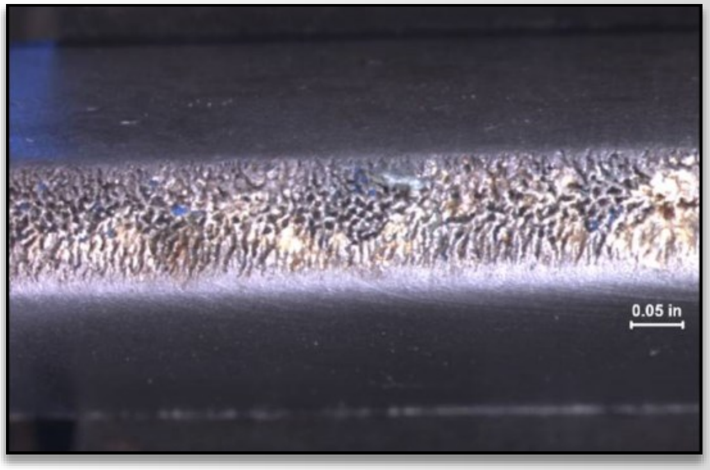
Combustion Turbine Forward Compressor Condition Assessment

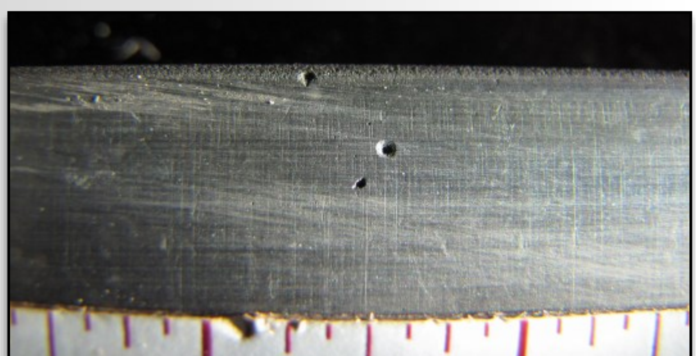
- Erosion Channeling Assessment
- Corrosion Pitting Assessment
- Deposit Analysis



Determining the condition of compressor components, with knowledge of fleet issues and risks, can provide valuable information on the suitability for continued service in its current condition. Typical mechanisms of degradation are erosion channeling and corrosion pitting, resulting in corrosion fatigue, and/or high cycle fatigue. Any of these conditions can progress to cause catastrophic failure. A tailored combination of appropriate replication, NDE, and visual examination can define the condition of the component and allow a planned approach to repair or replacement to avoid forced outages.

Mold Replication

GE TIL 1603, requires leading-edge dental molds for F-class R0 non-enhanced parts; however, dental molds are typically not required for enhanced R0s. Mold replication by a suitable NDE group, followed by the mold assessment, will provide an estimation of erosion channeling depth. Erosion channeling, if deep enough, can be a risk for fatigue crack initiation.



Mold replications are also performed on other OEM compressor blades and vanes that operate in environments with water droplet impingement.

Corrosion Pitting Assessment

Corrosion pitting creates localized blade and vane stress concentrations that can initiate cracking due to corrosion fatigue, particularly if the pitting occurs near a nodal point of known blade excitation. Corrosion pit depth can be estimated by the width off the pit and an assumed aspect ratio; however, accurate replication does not work with corrosion pits due to imbedded, tenacious deposits.

On compressors with erosion channeling or corrosion pitting, Fluorescent Penetrant Inspection (FPI) is also recommended for crack detection, if present.

Scale and Deposit Analysis

Scaling and deposit buildup can reduce efficiency by acting as barriers to heat transfer, promote corrosion by acting as concentration sites for corrosive species, or can result from corrosive attack. Samples are collected during on-site inspections and taken back to our laboratory for analysis. We employ energy dispersive X-ray spectroscopy and powder X-ray diffraction to identify constituents in a sample. Scale and deposit analysis can determine the nature, sources, and effects of deposits. We then suggest steps you can take to mitigate their formation.

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M&M ENGINEERING

Revisited—
Recovery Boiler Lower Furnace Problems

Ron Lansing, P.E., Consulting Engineer and Max Moskal, Principal Engineer

The lower furnace area has been a critical area in recovery boilers since the beginning of the recovery process. Furnace operators are well aware that a water leak into the molten smelt bed in the lower furnace is cause for them to rapidly shut down the boiler to avoid the worst possible situation—a boiler explosion. Many damage mechanisms can come into play in the lower furnace. These can range from normal tube thinning to stress assisted corrosion (SAC) cold side cracking.

Figure 1. Photograph shows how lower furnace studded tubes can become thin and difficult to test with UT between studs. Thinned tubes can be seen in the orange area.

The first high-pressure recovery boilers were introduced during the 1950s. B&W used studded tubes, even for low-pressure boilers. Studded tubes were also used on the earliest high-pressure boilers. C-E never used studs for new boilers, even when they built high-pressure boilers. Their initial approach was to use tri-coat metalizing for the lower furnace. Bare carbon steel tubes were used in the lower furnace because pressures (and tube surface temperatures) were low. Bare tubes are still acceptable in these old boilers with pressures up to 600 psi. Metal spray coatings proved to be largely unsuccessful for the long-term.

When studded tubes were used in the lower firebox (for better transfer of heat to the water carrying tubes), the tube and stud materials were plain carbon steel. The studs would corrode away by sulfidation at rates dependent on the liquor and/or smelt chemistry and temperatures. The tube wall thickness would also become thinner (Figure 1). Many lower-pressure boilers still operate and experience long life with studded carbon steel tube panels. Evidently, their process variables (the tube life and inspection and/or maintenance costs) are acceptable.

Two problems did arise with studded walls—finding and monitoring the areas of tube thinning, and new stud welds cracking due to sulfide contamination. The key to monitoring the tube thickness in order to determine the safe inspection interval is to determine the corrosion rate over several shutdowns. The stud weld contamination could be solved by carefully cleaning the area before welding.

The next generation lower furnace tubes were carbon steel with 304L stainless steel cladding made by the co-extrusion process. The stainless steel did not experience sulfidation corrosion. The first stainless steel composite tubes in North America were used in new, high pressure C-E and B&W boilers during 1981. It was generally believed that composite tubes should be used for boilers above 900 psi, but some users wanted

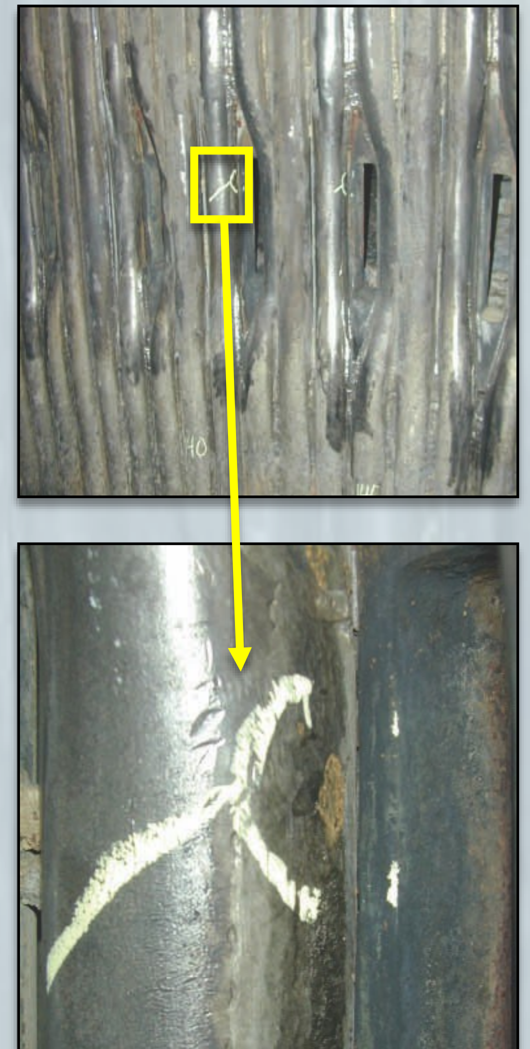


Figure 2. Photographs show a primary air port “balding” (rusty steel exposed).

composite tubes for lower pressure boilers.

Two separate problem areas have been found in 304L stainless steel composite tube designed furnaces. The first is air port area thinning called “balding,” and adjacent weld cracking. (Most air port cracking in composite tubes has been due to thermal fatigue.) The second problem area has been the floor where clad areas and membranes cracked.

At the air ports, inspections and metallurgical studies have shown that the thinning mostly occurred in the stainless steel. Small bald spots (Figure 2) thin much slower and could be more easily monitored and repaired by welding as necessary. Many mills used Type 309L stainless steel to weld bald spots at air ports. Experience has shown that the overlay corroded as fast as the original cladding, if not quicker. Nickel-based alloys were also satisfactory in repairing bald areas.

Repeated weld overlay invited cracking of air port tubes. Some boilers have been rebuilt with "modern" air distribution systems and automatic port rodders for better efficiency. However, some of these air port designs have resulted in wide temperature fluctuations at the air port tubes with thermal fatigue cracking as the consequence. Removing fin and crotch plate welds has limited air port crack sites. Alloy 625 weld overlays at air ports were found to have less thermal cracking than the original 304L stainless steel.

Floor tube stress corrosion cracking (see Figure 3) under the smelt bed was found to be due to contact with hydrated smelt in the critical tube temperature range of 300°F to 400°F. Most of these cracking problems occurred when boilers were reheated above 300°F for dryout while the tubes were in contact with the smelt. The cracking that had been identified using penetrant dye testing seemed to be present mostly within the stainless clad metal and self-arrested areas at the carbon steel interface. If cracking in 304L composite floor tubes occurs, it is often best to wait until cracking becomes more widespread to replace the tubes, and then use the Alloy 825 (high nickel

Figure 3. Photograph shows how SCC on a stainless steel clad floor tube can lead to spalling (circled).

UPCOMING EVENTS

ACUREN | ECLIPSE | WORLDSPEC | M&M ENGINEERING | HELLIER

HRSG User's Group Conference & Expo

February 12-14, 2018

Hilton-Americas—Houston, TX

Jonathan McFarlen, Consulting Engineer with M&M Engineering, will be visiting staff from Acuren Inspection, Inc. in BOOTH 304, 306, and 308. Don't miss the rope access demonstration.

Also, David Daniels, Sr. Principal Scientist with M&M Engineering, has the honor of being the conference emcee for this year's event, as well as presenting a paper at the Steam Chemistry Basics workshop on Monday.

2018 IPEIA Conference

22ND ANNUAL IPEIA CONFERENCE

INTERNATIONAL PRESSURE EQUIPMENT INTEGRITY ASSOCIATION

March 7-9, 2018

The Banff Center—Banff, Alberta, Canada

Acuren Inspection, Inc. is a proud sponsor of the 2018 IPEIA Conference & Exhibition.

iiar 2018 Natural Refrigeration Conference & Expo

March 18-21, 2018

The Broadmoor Hotel—Colorado Springs, CO

Visit with team members from Acuren Inspection, Inc. in BOOTH 119 at The Annual IIAR Natural Refrigeration Conference & Expo, the largest exposition dedicated to the ammonia and natural refrigeration industry.

20th Anniversary Electric Power Conference + Exhibition

Presented by POWER magazine

March 19-22, 2018

Gaylord Opryland Convention Center—Nashville, TN

Acuren Inspection, Inc. will be in BOOTH 402 at this year's Electric Power Conference & Expo. Be sure to stop by to see what's new.

BLRB

April 9-11, 2018

Crowne Plaza Atlanta-Airport—Atlanta, GA

Acuren Inspection, Inc. and M&M Engineering will be in attendance for BLRBAC 2018 Advisory Committee Meeting.

CORROSION 2018 Conference & Expo

Phoenix Convention Center
Phoenix, AZ

April 15-19, 2018

Catherine A. Noble, P.E., Consulting Engineer with M&M Engineering, will be presenting case studies for the following at this year's CORROSION Conference & Expo:

Boiler Waterside Failure Analysis (TEG 163X)
Wednesday, April 18th, 1:00 pm – 4:00 pm, Room 101.

Process Industry - Pulp, Paper, and Biomass Conversion (STG 38)
Tuesday, April 17th, 3:00 pm – 5:00 pm, Room 230

She is also Vice Chair for the following symposium:

Corrosion Issues in the Pulp, Paper, Biomass, and Biofuel Industries
Thursday, April 19th, 8:00 am – 12:00 pm, Room 226 B-C

The Fifth Meeting of the EHF

(European HRSG Forum)

May 15-17, 2018

Meliã Hotel—Bilbao, Spain

David G. Daniels, Sr. Principal Scientist with M&M Engineering Associates, will present his paper *Signs of Recovery from Closed Loop Contamination of HRSGs on Wednesday, May 16th.*

Electric Utility Chemistry Workshop

June 5-7, 2018

Phoenix Convention Center—Phoenix, AZ

David G. Daniels, Sr. Principal Scientist with M&M Engineering Associates, will be presenting a paper at the 38th Electric Utility Chemistry Workshop, June 5-7, 2018. Registration for this event will be opening soon, so please check back.

NDT in Canada — NDTC 2018 Canada's NDT Conference

June 19-21, 2018

Halifax Convention Centre—Halifax, Nova Scotia, Canada

Staff members of Acuren Inspection, Inc. will be in attendance at The NDT in Canada 2018 Conference.

UNDERSTANDING AND PREVENTING FAILURES IN INDUSTRIAL POWER & STEAM GENERATING EQUIPMENT

AUGUST 14-15, 2018

Now in our seventh year, the M&M Engineering workshop previously known as "Preventing Failures in Steam Generating Equipment" is geared towards producers of steam, be it used in power or process applications. This two day workshop focuses on the issues most common in steam generating systems and is applicable to many industries including: power generation, refining, petro-chemical, pulp and paper, and industrial insurers.
Our workshop covers the following topics:

- Equipment Associated with Steam Generation – A Primer
- Utility Feedwater Heaters and Damage Mechanisms
- Steam-Touched Boiler Tube Failure Mechanisms
- Water-Touched Boiler Tube Failure Mechanisms
- Introduction to Failure Analysis
- Introduction to Nondestructive Testing & Inspection Contracting
- Damage Mechanisms in Deaerators
- High Energy Piping: Damage Mechanisms and Corrections
- Failure Investigation Principles for Combustion Turbines
- Basic Steam Turbine Failures
- Condenser and Cooling Water Failures
- Water and Steam Chemistry-Influenced Failures in the Steam Cycle

Seating is limited—Click the ticket and REGISTER TODAY!

Registration for this two-day event is $800 (continental breakfast and lunch included). The deadline for registration is August 1, 2018.

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 the photo of our facility for a map of our location.

For more information, contact Lalena Kelly at Lalena_Kelly@mmengineering.com, or (512) 407-3775.

Figure 4. Photograph shows a floor tube leak at a weld. The low flow of the horizontal tube combined with weld drop-through initiated DNB tube overheating/thinning.

Figure 5. Photograph shows a decanting floor, a low area which inhibits water circulation, with the smelt bed removed.

stainless) weld overlay on the floor.

The floor tube cracking has been regularly monitored in some boilers in lieu of wide spread cladding replacement.

Floors have had other problems as well. Some second-generation retrofits were not as sloped as the original horizontal floor designs were. The horizontal floor tubes can be prone to low-flow problems, sometimes leading to localized tube overheating (Figure 4). In addition, sagging can cause low areas in the floor, which may further inhibit flow (Figure 5).

Waterside cracking is a problem that has begun to plague some older boilers. Stress assisted corrosion (SAC)—sometimes called corrosion fatigue in other industries—occurs internally throughout the boiler on the water side of tubes with highly restrained welded attachments. Since there are many such attachments in the lower furnace, SAC is definitely a damage mechanism that has disastrous potentials when adjacent to the smelt bed. SAC works its way through the protective oxide inside the restrained tube, gradually forming a crack-like corrosion groove, and then finally an actual crack that leaks. Special procedure radiography and phased-array UT have been the most effective test methods for finding SAC. A regular inspection is critical to catching this progressive problem, and determining the inspection interval requires repeated testing. There have been little or no reports on SAC susceptibility of boilers with stainless steel clad/composite tubes. However, research modeling shows that stainless steel is likely not susceptible to SAC compared to its plain carbon steel counterpart. The compressive stresses and thermal coefficient of expansion difference between stainless steel cladding and the carbon steel base metal diminishes the chance of SAC in clad tubes. SAC rarely occurs in boilers less than fifteen years old.

Careful monitoring with both nondestructive testing, and engineering evaluation of lower boiler conditions and test results will help owner/operators catch these damage mechanisms before serious failures can occur.

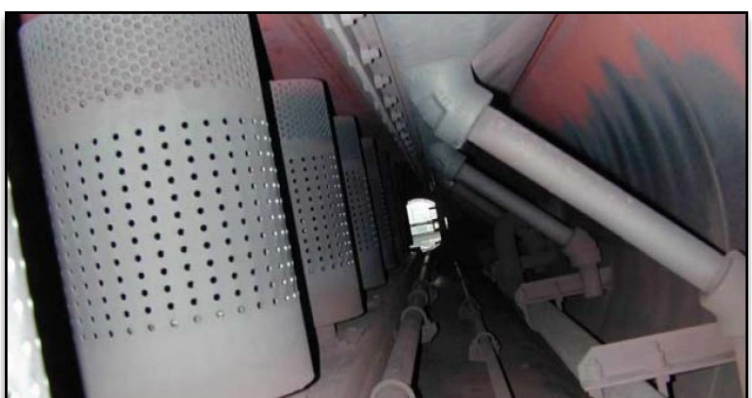
Author's note: This is an update to an article published in our [Summer 2008 issue of the Conduit](#).

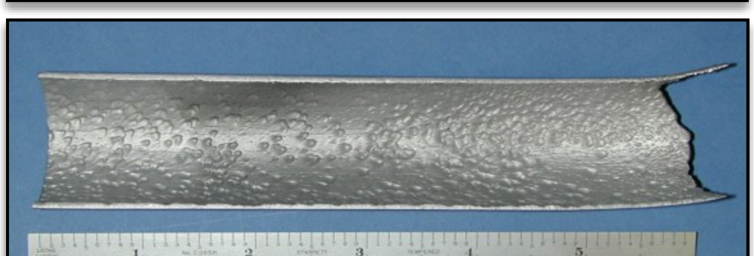
HRSG CONDITION ASSESSMENT

- **Gas Side and Water Side Inspections**
- **Visual Inspections, NDE and Metallurgical Analysis**
- **Rope Access for Inspections**
- **Water/Steam Chemistry Review and Troubleshooting**
- **Failure Investigations**

M&M Engineering Associates provides an experienced set of eyes to examine the health of the gas side and water side of your Heat Recovery Steam Generator (HRSG). We provide you with an independent assessment of the HRSG condition to assure you of reliable future operation whether you are an owner, operator, or insurer.

- We examine the gas side of duct burners, ductwork, tube banks, headers, the ammonia injection grid, and the support structure for signs of deterioration from corrosion, cracking, and wear.
- We examine the water side headers, steam drums, and risers for corrosion, cracking, FAC, or other damage mechanisms.
- We provide skilled nondestructive examination (NDE) technicians to provide a full condition assessment of your HRSG using the most advanced equipment and methods., including the use of Rope Access* (remote access technology) instead of scaffolding.
- When problems or failures occur, we provide on-site or in-laboratory metallurgical testing and engineering to get the unit back on line fast.





We Take a Closer Look

Gas path inspections from the floor are incomplete and using scaffolding or sky climbers to access upper components is costly both time-wise and financially. Utilizing rope access, we can inspect all of the gas path components up close , in person, for a fraction of the typical inspection cost. Don't assume that the lower burners look the same as the upper burners.

During the outage, our engineers, water chemists, and technicians provide recommendations for immediate repair, as well as focused testing and inspection strategies. Following our inspection, a detailed report of our findings will be provided electronically, in hard copy, or both. We can also recommend water treatment programs that will prevent waterside corrosion problems and provide recommendations for future repair, replacement, and inspection.

Water Chemistry is Critical

While HRSGs typically lack the heat flux of a standard fossil-fired unit, they are by no means problem-free when it comes to chemistry-related corrosion. In fact, experience has shown that these units seem to have more tube failures than their fossil-fired counterparts. Common causes include flow accelerated corrosion (FAC), under-deposit corrosion (hydrogen damage, gouging, and pitting), and corrosion fatigue. The complex flow patterns, quick starts and stops, and extended lay-up periods all combine to make proper chemical treatment of HRSGs different than the equivalent pressure fossil-fired boiler.

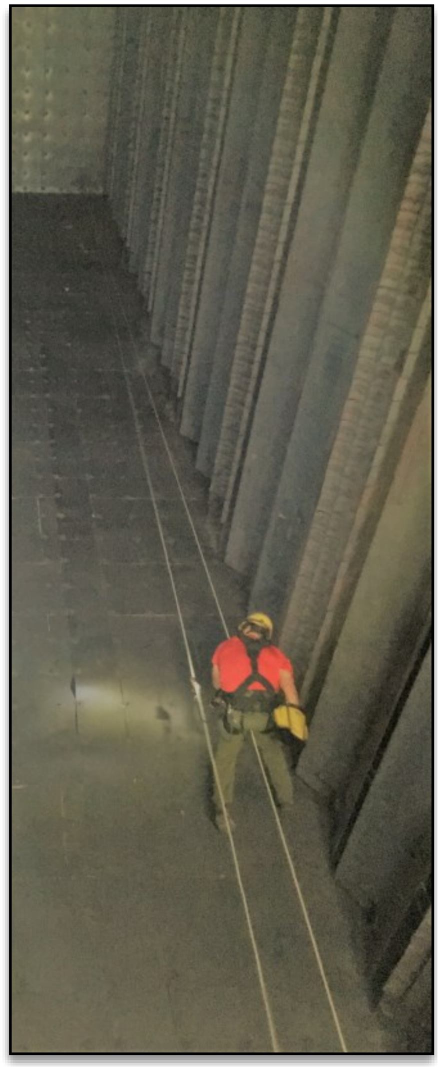
Don't Patch It — Fix It

When failures do occur, it is tempting to plug the tube and move on, but understanding the failure mechanism (the "why") is critical to understanding the potential for additional failures. A true root cause analysis of the failure is essential to solve the problem completely.

M&M Engineering has over 30 years of experience in failure analysis for all types of power and industrial boilers, as well as steam and gas turbines. We are experts in the analysis of steam and combustion turbine blade failures. We also understand the process, materials, and operational conditions in combined cycle plants and can work with you to find a way to eliminate failures in the future.

Training

Personnel at many combined cycle plants wear many hats. They operate, maintain, troubleshoot , and treat their units. To do it right, they need to know more than just what to do. They need to know the "why to do it." M&M Engineering can provide on-site training, tuned to your personnel and plant, for a number of areas including water and steam chemistry, nondestructive testing, materials and corrosion issues, and damage repair options.



In December 2017 our 300MW combined cycle unit at Stanton Energy Center started its Fall outage. Acuren's scope was to inspect burners, SCR lances, HP Superheat #4, and the Economizer # 4. This traditionally has been done from scaffold which requires time and sometimes very limited access. With the expertise of Remote Access Technology (RAT) they were able to perform the inspection in a timely manner with minimal support. When comparing the inspection via traditional scaffold there was both a significant time and money savings realized. It would have required approximately two days to erect scaffold for the inspection in which RAT performed, as well as at least a day to demo. Estimated cost for the scaffolding would have been approximately double of what RAT was to perform the same work.*

Acuren/RAT was able to handle dimensional checks, looking for abnormal wear or corrosion, etc. We were able to confirm that the burners, SCR lances, and HP Superheat #4, and Economizer # 4 were all in acceptable condition. Using RAT is a highly effective supplement to a traditional boiler inspector. In short, we will continue to look for other cost savings opportunities with Acuren/RAT in the future.

Wade Gillingham of Orlando Utilities

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Metal Sample Preparation Guidelines

Sampling Methods for Laboratory Analysis

The recommended sampling methods for metal parts being submitted for analysis 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 the area of interest or concern; 6 inches on either side of the area of interest is sufficient.

⇒ 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 analysis 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; please contact your shipper for more information.

⇒ Large samples are usually shipped by truck.

⇒ Samples less than 75 lbs. can usually be shipped by a package service (e.g., FedEx, UPS, DHL, etc.).

⇒ 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.

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Sampling Methods for Laboratory Analysis

SAMPLE TYPE	SUSPECTED PROBLEM	SIZE	CUTTING METHOD
Whole	All Types (Particularly Fractures and Cracking)	1 ton and/or 8 feet in diameter, height, or width	—
Partial	All types	50 lbs. (express delivery limit)	Saw or Torch Cut
Cores	Cracks, Corrosion, Damage, Heat Treatment, Subsurface Material Identification	1/4 inch diameter and above	Hole Saw
"Boats"	Shallow Surface Features: Alloy ID, Weld ID/defects, Corrosion Damage, Heat Treatment	Approximately 1/2 x 3/4 x 3 inches	Carbide Cut-off Saw Angled Hole Saw
Plate	Cracks Fractures, Alloy ID, Weld ID/defects, Corrosion Damage, Heat Treatment, Tensile or Bend Testing	6 inch and greater from area of interest 12 inch and greater from area of interest	Saw or nipper cut (NO Torch Cutting) Torch cut
Snips	Alloy ID	½" x ½" or as small as available	Saw or nipper cut
Drillings or Fillings	Alloy ID	1 ounce or more	Clean drill or file
Scrapings	Corrosion Damage Products	From a 2 square inch area, or more	Clean metal scraper

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Our Business

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

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

Acuren: https://www.acuren.com/about/

Our Team

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

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

Our Services

http://mmengineering.com/services/

https://www.acuren.com/

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/Answers

Background image, Pages 3: https://www.psffirm.com/blog/are-lie-detector-tests-accurate-and-can-they-be-used-in-court/

Background image, Pages 3-4: http://suppersleuths.com/resources/sleuth-school/

Answers from page 5: Photograph 1 - ductile overload – tensile loads, Photograph 2 - fatigue, Photograph 3 - brittle overload – transgranular cleavage, Photograph 4 - corrosion fatigue, Photograph 5 - brittle overload – intergranular cleavage, Photograph 6 – ductile overload – shear loads