



# *the* Conduit

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## Thickness Measurement of Digester Stainless Steel Overlays

By: Max Moskal,  
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Paper mill batch digesters are fabricated from either carbon steel or duplex stainless steel because of process-side corrosion. Duplex stainless steel (DSS) construction is the material of choice, but today several thousand batch digesters made from carbon steel are in service, some of which were built in the 1950s and before. Many new batch digesters are still fabricated from carbon steel because the initial cost is significantly lower than for solid DSS digesters. A new carbon steel batch digester may have up to one-inch corrosion allowance to resist corrosion from hot liquor; corrosion rates of up to 0.1 inch per year, or more, may be experienced in aggressive liquor systems.

When a carbon steel batch digester shell is thinned by corrosion to a thickness approaching the ASME minimum allowable wall thickness

(MAWT), stainless steel weld overlays may be applied to lengthen the vessel life. Weld overlays are usually applied to a thickness of about 0.20 inches, either by automatic SAW or GMAW weld methods or by manual welding. Type 309L and 312 stainless steel weld overlays are the most common today. The life of the overlays may be from eight to fifteen years, depending on factors such as application quality and liquor corrosivity.

As the initial digester overlay becomes thinned by corrosion, it is possible to re-overlay at least once without removal of the old overlay, provided the remaining carbon steel thickness is still above the MAWT (about 1 inch or more). Since the life of batch digesters can be extended for decades with stainless steel weld overlay, records of past overlays are often lost or unavailable. Lost records lead to problems because application of multiple or non-uniform overlays increases the chance of producing unacceptable distortion in the vessel. Also, the remaining overlay thickness is useful in planning the next overlay welding campaign.

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### Measurement of Old Overlay Thickness

The thickness of old overlays is difficult to determine. Specialized ultrasonic testing has been used, but the method is problematic and operator dependent. There have been cases of using magnetic lift-off (MLO) testing to determine the thickness of existing overlays, but accurate measurements are not possible due to the presence of the magnetic constituent, ferrite, in the overlay. Ferrite content in stainless steel overlay welds can vary substantially, and attempts to produce thickness standards for MLO measurement have been unsuccessful. For this reason, MLO testing should never be used to assess the remaining thickness of the overlay.

### Overlay Thickness by Semi-destructive Testing

One method that has been very successful has been to systematically measure the thickness by grinding slots into the digester overlay. M&M Engineering has found that circumferential thickness tests at 2-foot elevation increments provide a good overall record of

the remaining overlay thickness in the vessel. Testing is performed by careful plunge grinding with a grinding wheel through the stainless overlay. The image of sparks during plunge grinding the stainless steel varies markedly when the underlying carbon steel is reached, Figure 1.

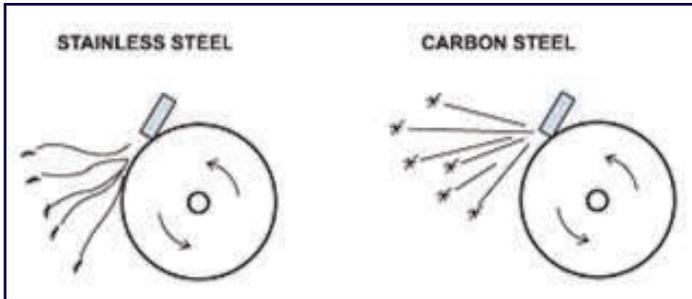


Figure 1. Spark differences by abrasive wheel cutting, stainless steel and carbon steel.

The depth of grinding is then measured to the nearest 0.01 inch with a scale. Application of copper sulfate solution may be applied to visually confirm the thickness of the overlay. Repair of the small grind area is necessary by welding with a matching overlay consumable. The total time for grinding and re-welding thickness test slots is less than one or two work shifts, depending on the number of tests. However, compared to tens of thousands of dollars for new overlay that is not needed, the cost for this testing is very small. An image of a test slot in a digester wall overlay weld is shown in Figure 2.



Figure 2. Plunge cut with abrasive wheel into stainless steel weld overlay to measure remaining thickness.

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### ***Recycling reduces waste, increases material utility, and is used to protect the environment. Below is a list of facts about recycling.***

- Iron and steel are the world's most recycled materials and among the easiest materials to reprocess.
- 42% of crude steel is made from recycled material.
- The aluminum "can" is the most recycled consumer product in the United States.
- Roughly 70% of all metal is used only once and then thrown away. The remaining 30% is recycled. After 5 cycles, only 0.25% (one quarter of one percent) of the original metal remains in circulation.
- When you throw away an aluminum can you are wasting the equivalent amount of energy of filling up that same can with gasoline and pouring it on the ground.
- In as little as 60 days a recycled aluminum can is able to be back on the supermarket shelf.
- In the United States over 100 million tin and steel cans are used every day.
- Mining wastes, air pollution, and water pollution are reduced by about 70% when a steel mill uses recycled metal scraps.
- Over 60% of all cans in a supermarket are made of steel.

Source: [americanmetalrecycling.net](http://americanmetalrecycling.net)

# Seminars & Workshops

## Spring BLRBAC Meeting

Max Moskal attended the Spring meeting of BLRBAC (Black Liquor Recovery Boiler Advisory Committee) during April, 2014. BLRBAC is a trade organization that exists for the purpose of generating safety procedures and guidelines that govern the operation of black liquor recovery boilers. Twenty-two boiler leak incidents and one explosion were reported, including the catastrophic smelt-water explosion incident at Lincoln Paper & Tissue in Lincoln, ME. This was the first smelt-water boiler explosion in North America reported by BLRBAC since 2012. Additionally, two international lower furnace explosions were reported, one in Skoghall, Sweden and another in Pols, Austria. The number of smelt-water explosions per 100 operating years for North American recovery boilers stands at about 0.5. The boiler explosion rate in recent years is down significantly. Only two smelt-water recovery boiler explosions have occurred in the past 15 years. This contrasts with almost fifty such explosions in the fifteen years prior to 1980.



### John Molloy, P.E. presented at the 23rd GE 9FA/FB User's Conference

John Molloy, Principal Engineer and Vice President with M&M Engineering Associates, Inc., participated in a presentation titled *Keratea – Lavrion S109FA+E, an R0 Compressor Blade Failure Analysis* at the 23rd GE 9FA/FB Users Conference which was held in Paris, France. For more details on this event: <http://paris2014-ge9fa-usersconference.com/>

David Daniels, Senior Principal Scientist with M&M Engineering will be presenting:

### *HRSB and High Pressure Boiler Water Treatment 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 course 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.



*Early Registration for the International Water Conference will be opening soon.*

# Rogue Metallurgy on Safety Devices Endangers Plant Personnel: Failed Clevis in Fall Support Device

By: John Molloy, Principal Engineer

## Introduction

M&M Engineering Associates, Inc. led an investigation into two stainless steel fall support devices used in a paper mill (Figure 1). One of the two clevises was fractured in two places and exhibited localized corrosion. The other clevis was intact and did not exhibit any signs of corrosion. Both clevis samples are reported to have come from the same fall protection devices and had been in service in the same environment for the same amount of time. The fall support devices remained in moderate tension while in storage, thus by fracturing in a static state, the plant personnel were able to notice the problem and avoid unfortunate usage. An additional, new clevis sample in original packaging was also received for reference (Figure 2). M&M Engineering was asked to determine the cause and failure mode of the failed clevis, and compare it to the un-failed clevis and new clevis sample.

## Visual Examination

The clevis stampings/markings indicated that the three clevis samples were supplied by the same vendor and fabricated from the same material, Type 316 stainless steel. Visually, it can be noted that the failed clevis was slightly thicker in cross section than the un-failed clevis. The failed clevis was significantly thicker and also had coarser, larger stampings, indicating that it was sourced either from a different manufacturing process or, more likely, a different foundry.

There were two fracture surfaces observed on the failed clevis. Both fractures exhibited a rough, irregular surface with a brown patina. After cleaning with an Alconox® solution, the selected fracture surface was documented at higher magnification, and an intergranular surface morphology was observed, indicating a likely environmental contribution. A crack was observed



Figure 1. Photograph shows the two clevis samples as-received. The Failed Clevis (right) was received along with an exemplar, Un-failed Clevis (left).



Figure 2. Photograph shows the new clevis as-received.

on the failed clevis near one of the fractures. The crack displayed an irregular morphology and was surrounded by corrosion products, again suggesting an environmental contribution.

## SEM and EDS Analyses

The fracture surface of the failed clevis was examined in the M&M Engineering Associates, Inc.

scanning electron microscope (SEM). In addition to fractography, EDS was performed *in situ* on the fracture surface before cleaning.

### EDS Analysis

EDS analysis was performed on the primary fracture surface of the failed clevis. This testing was performed prior to the cleaning mentioned in the visual examination above. Two sample areas were selected on the fracture surface for EDS analysis and the resulting spectrum can be seen in Figure 3. Carbon, oxygen, calcium, chromium, iron, and nickel were detected. In addition, small amounts of sodium, silicon, magnesium, sulfur, and chlorine (as chlorides), as well as trace amounts of manganese and aluminum were detected. Many of these elements are constituents of the base metal and native oxide (iron, chromium, nickel, silicon, and manganese). The other elements are likely from the local environment, of which sulfur and chlorine (as chlorides) are corrosives. Table 1 shows the EDS/SQ results.

### SEM Analysis

After completion of the fracture deposit EDS analysis, the fracture surface was ultrasonically cleaned in an Alconox® solution. The fracture was then analyzed in the SEM with a focus on the finer fractographic features. The fracture surface revealed a completely intergranular morphology, inferring that the fracture mode was

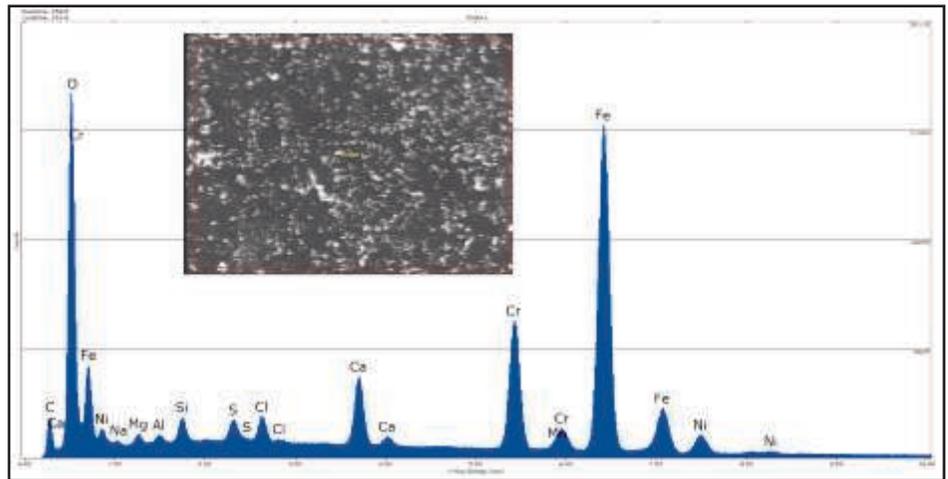


Figure 3. EDS spectrum for fracture deposit observed on the Failed Clevis. Sulfur (as sulfides) and chlorine (as chlorides) were noted.

environmentally assisted (Figure 4). A nonexistent overload area suggests that the nominal stress state was very low.

### Metallographic Examination

Longitudinal sections through the fractures of the failed clevis, as well as transverse sections of both of the clevis samples were prepared for metallographic examination. In addition, the new clevis was also transversely sectioned and prepared for metallographic examination. The sections were prepared using standard laboratory procedures for evaluation using a metallurgical microscope.

### Failed Clevis Fracture

A stereomicroscope image of the primary fracture cross section can be seen in Figure 5, where intergranular attack (IGA) was observed to penetrate deep into the bulk material. Higher magnification images of select regions of the fracture on the metallographic cross section can be

**Table 1. EDS/SQ Elemental Analysis Results (weight %)**

Primary Fracture	C	O	Na	Mg	Al	Si	S	Cl	Ca	Cr	Mn	Fe	Ni
Probe	3.9	18.9	1.5	1.3	0.6	1.3	1.2	1.4	3.5	11.2	0.6	50.6	4.2

<sup>1</sup>EDS provides qualitative elemental analysis of materials under SEM examination based on the characteristic energies of X-rays produced by the electron beam striking the sample. Using a light element detector, EDS can detect elements with atomic number 5 (boron) and above. Elements with atomic number 13 (aluminum) and above can be detected at concentrations as low as 0.2 weight percent; lighter elements are detectable at somewhat higher concentrations. As performed in this examination, EDS cannot detect the elements with atomic numbers less than 5 (i.e., beryllium, lithium, helium, or hydrogen). The relative concentrations of the identified elements were determined using semi-quantitative, standard less quantification (SQ) software. SQ electronically analyzed the EDS data, thereby lowering the detection limit to about 0.1 weight percent.

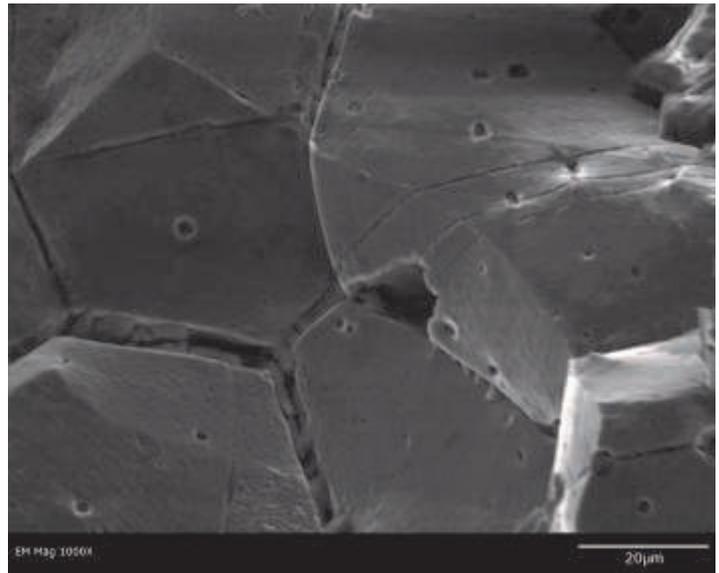
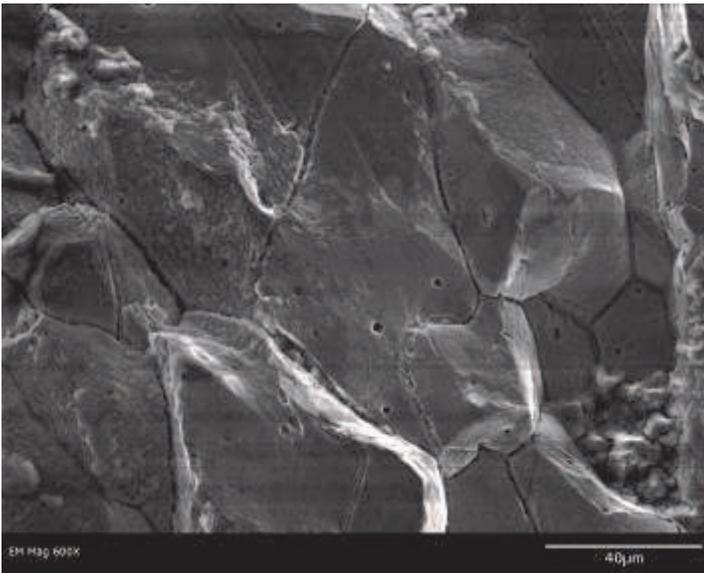


Figure 4. SEM images show higher magnification of the primary fracture surface of the Failed Clevis. Intergranular fracture morphology was noted.

seen in Figures 6. Again, deep, IGA penetration was observed.

#### Failed and Un-failed Clevis Remote Cross Sections

Remote (exemplar), transverse cross sections were observed on both the failed and un-failed clevis samples. The general, bulk microstructure remote from the IGA was evaluated on the failed clevis. The grain structure was variable depending on the location in the cross section. Some areas displayed equiaxed austenite grains and some twinning, whereas other areas displayed regions of high crystalline deformation (plastic deformation from cold or hot working). Higher magnification revealed deeply etched grain boundaries and evidence of sensitized grain boundaries necklaced with carbides (Figure 7).

The un-failed Clevis cross section did not exhibit any regions of IGA. Higher magnification images of the bulk microstructure revealed equiaxed grains with some twinning. No evidence of sensitization, such as carbide necklaced grain boundaries, was observed (Figure 8).

#### New Clevis

Transverse cross sections were observed on the new clevis sample in the unetched and etched conditions. In the unetched condition, a large inclusion content was observed (Figure 9). In the etched condition, the grain boundaries and carbides were decorated more than the failed and un-failed

clevis samples. The microstructure of the new clevis was aberrant for Type 316 stainless steel.

#### Chemical Analysis

Samples from the failed and un-failed clevises were analyzed to determine the chemical composition. Chemical analysis determined that the composition of the un-failed clevis matched Type 316 stainless

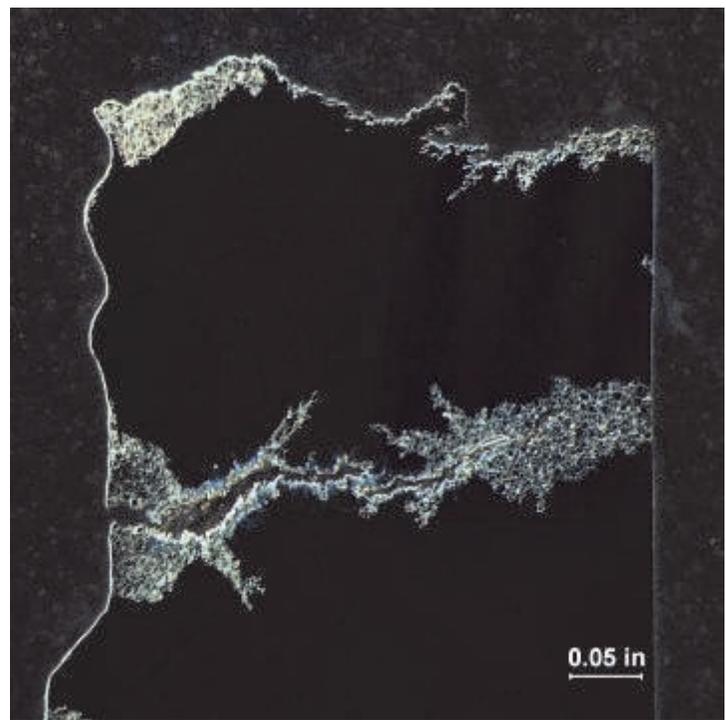


Figure 5. Photograph shows a cross sectional image of the secondary fracture surface on the Failed Clevis. An adjacent crack is also visible in the image. Intergranular morphology was noted.

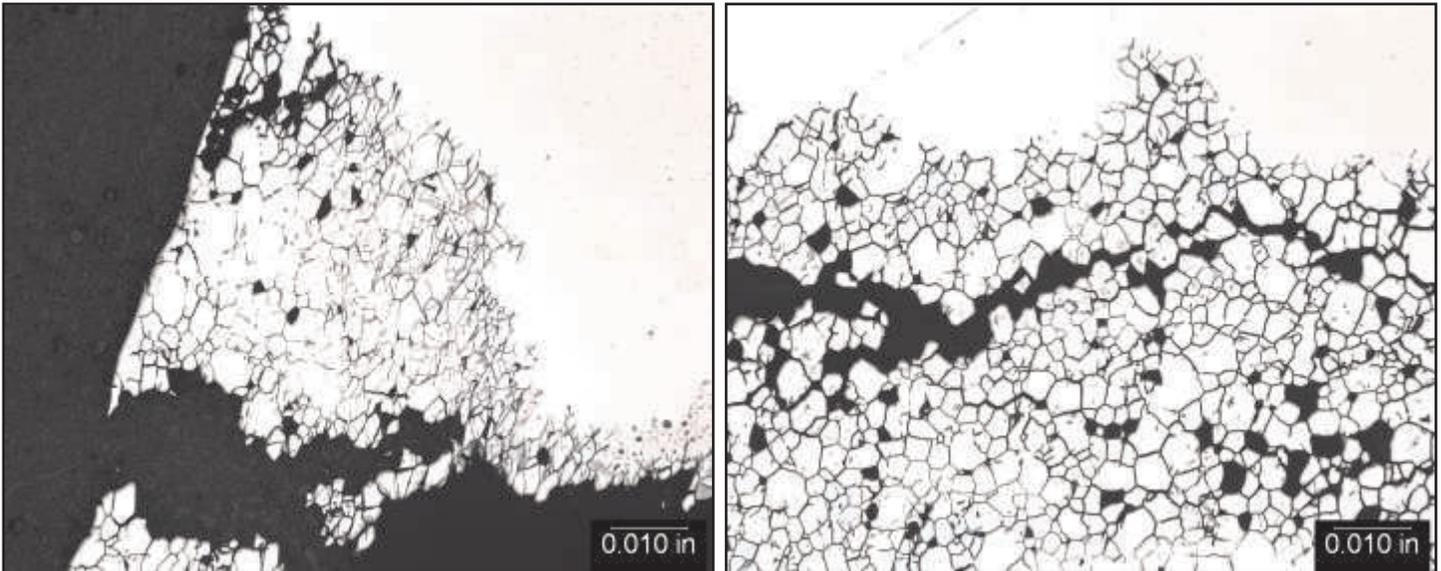


Figure 6. Photomicrographs show the secondary crack morphology in the unetched condition. Severe intergranular attack was noted to penetrate into the bulk of the Failed Clevis. Magnification: 50X, Etchant: None

steel, as well as the high carbon variant (316H). The failed clevis neither matched the common Type 316 stainless steel, nor the high carbon variant (316H). In both cases, the carbon content was too high and the molybdenum content was too low. Table 2 shows the chemical analysis results for the two clevis samples.

#### ASTM A262 - Detecting Susceptibility to IGA

The remote, failed and un-failed clevis transverse cross sections, as well as the new clevis transverse cross sections were prepared for testing using

ASTM A262, Practice A: *Oxalic Acid Etch Test for Classification of Etch Structures of Austenitic Stainless Steels*. The purpose of the test was to determine the susceptibility of the failed, un-failed, and new clevis samples to IGA. All samples were identically prepared and tested; however, only the failed clevis and new clevis samples (remote cross section) **indicated susceptibility to IGA due to the “ditched”** structure in the grain boundaries. The un-failed **clevis sample exhibited no “ditched”** structure in the grain boundaries. This indicated susceptibility to environmental assisted corrosion in the failed clevis. Images of the failed, and un-failed clevis test

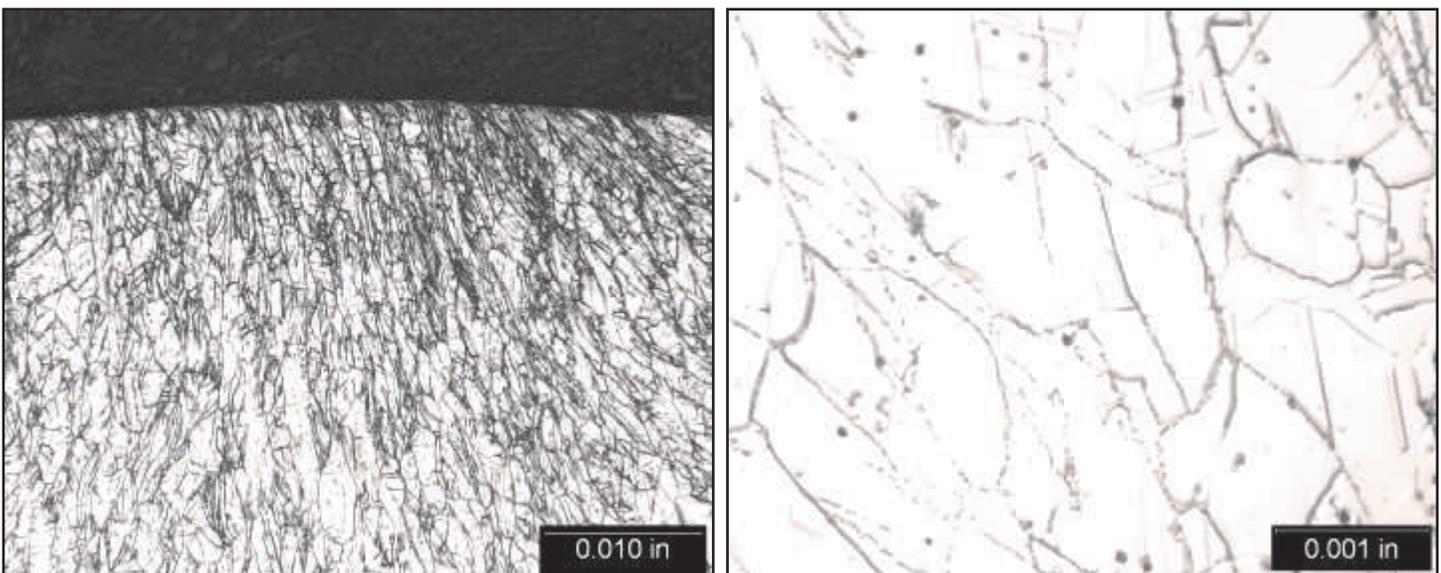


Figure 7. Photomicrographs show the typical grain structure of the Failed Clevis. The grain structure was heavily worked due to plastic deformation, as manufactured. Carbides were observed to necklace the grain boundaries. (Left) Magnification: 100X, Etchant: Nitric 60 Percent Electrolytic, (Right) Magnification: 1000X, Etchant: Nitric 60 Percent Electrolytic

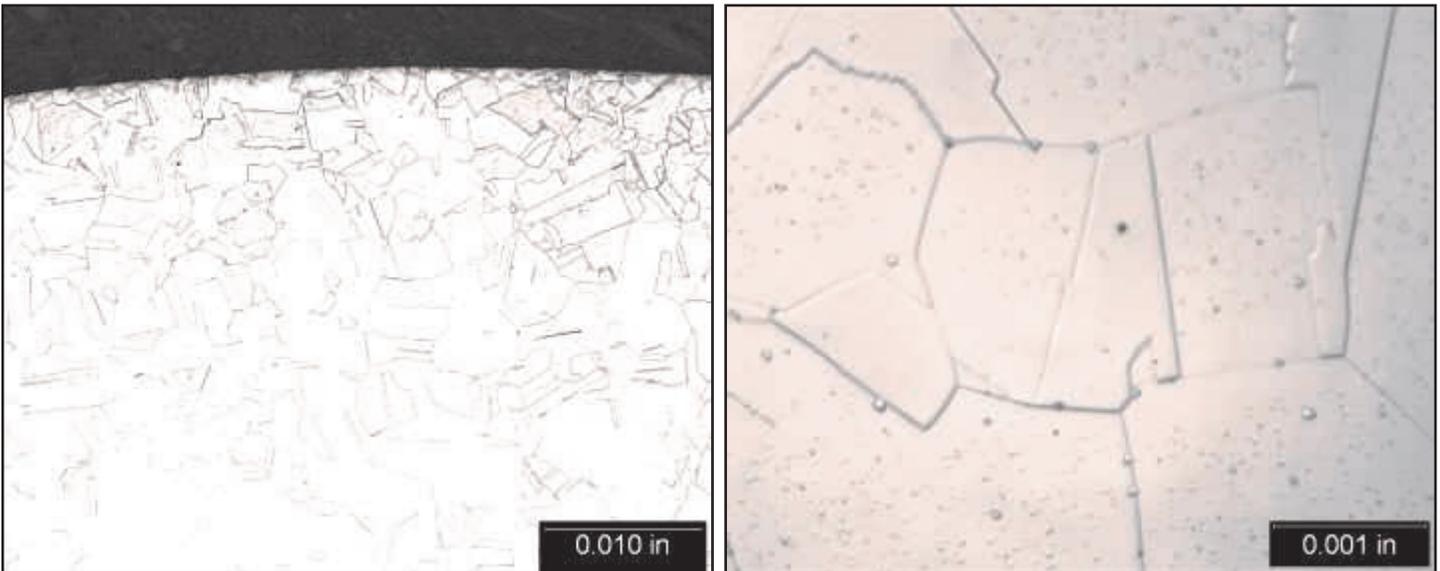


Figure 8. Photomicrographs show the typical grain structure of the Un-failed Clevis. Equiaxed, austenitic grain structure was observed through-out. (Left) Magnification: 100X, Etchant: Nitric 60 Percent Electrolytic, (Right) Magnification: 1000X, Etchant: Nitric 60 Percent Electrolytic

results per ASTM A262 can be seen in Figure 9 and Figure 10 respectively.

### Discussion

The fractures were fully intergranular, which commonly is associated with environmentally-assisted cracking, such as certain types of stress corrosion cracking (SCC). Additionally, corrodents were observed on the fracture surface such as chlorides and sulfides. In sufficient concentration over time, these corrodents can affect stainless steels such as Type 316. However, only one of the two clevis samples was affected, and to such a degree that fracture resulted. The other clevis

sample was completely unaffected. This observation led to the suspicion that the real cause of cracking may have been sensitization, where the stainless steel alloy has little or no resistance to intergranular attack (IGA). In this scenario, the IGA is more a result of an aberrant alloy structure than environmental exposure to corrodents.

It should also be recalled that the clevis samples have slightly different cross sectional thickness. The failed clevis is significantly thicker. This evidences manufacture from differing mills or different stainless steel bar stock.

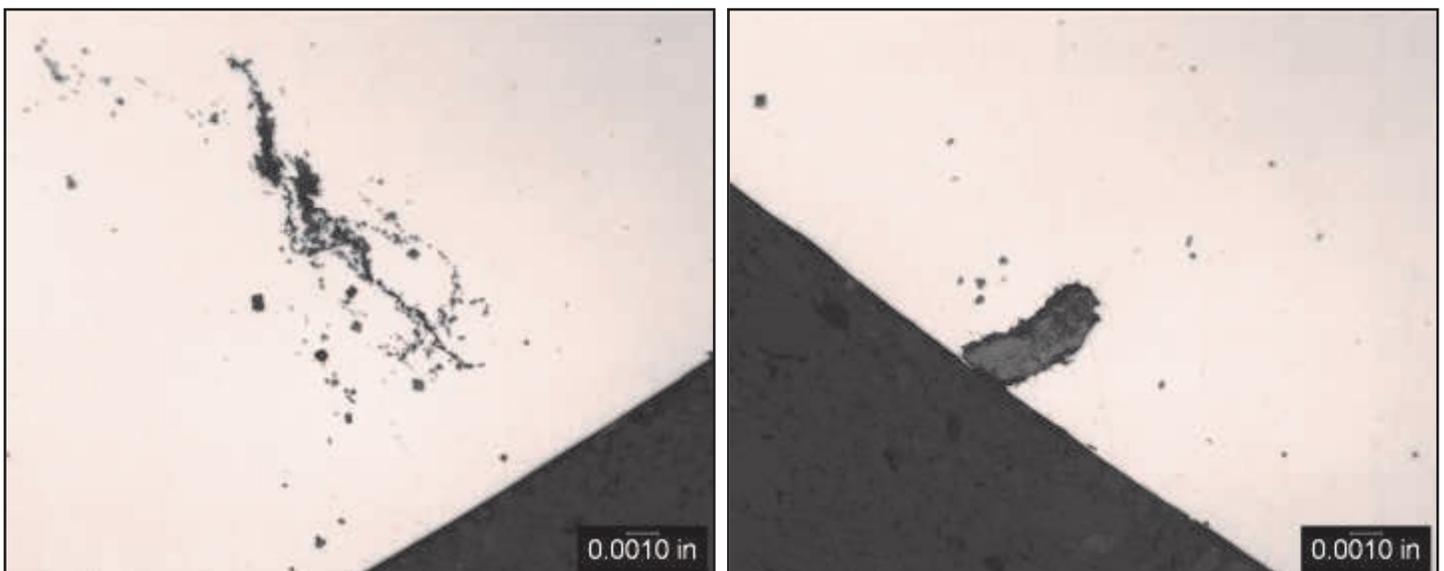


Figure 9. Photomicrographs show the high inclusion content observed in the new clevis microstructure. Magnification: 100X, Etchant: None

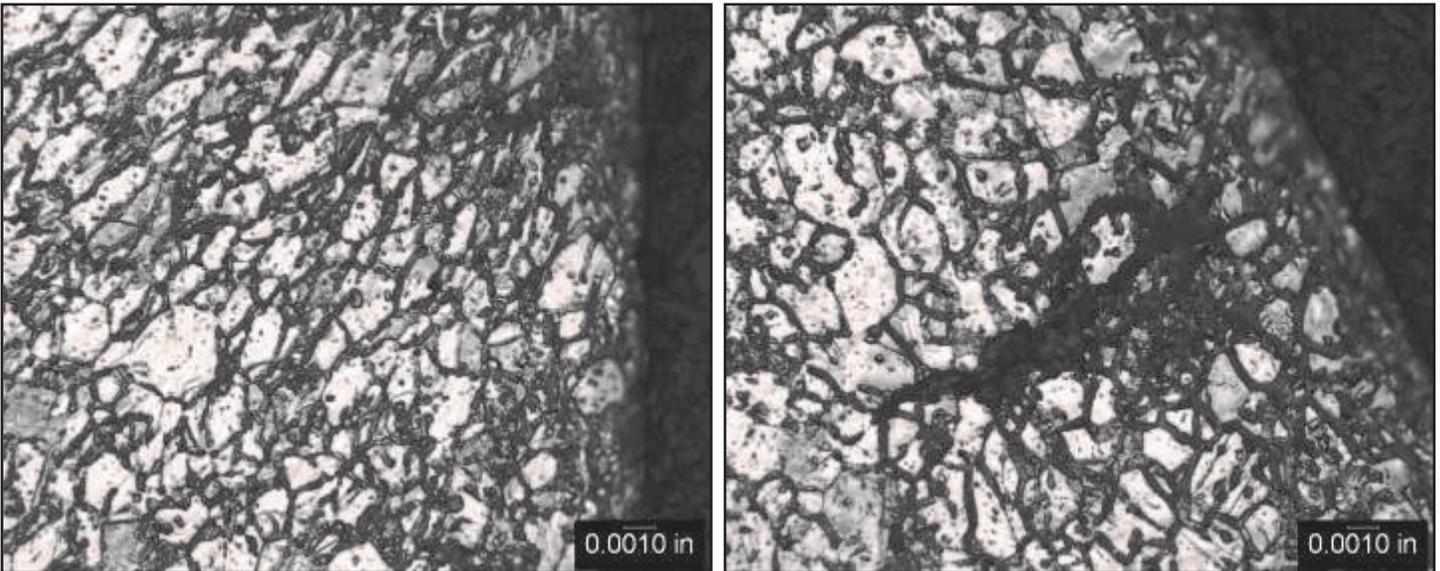


Figure 10. Photomicrographs show the typical ASTM A262 test results on the New Clevis. Ditching was observed in the grain boundaries, indicating susceptibility to intergranular attack. Magnification: 200X, Etchant: Oxalic Acid

Chemical analysis of the two clevis samples indicated that the failed clevis did not meet the specifications for Type 316 stainless steel. The failed clevis contained too much carbon and too little molybdenum. The excess carbon may have led to abnormally high precipitation of chromium carbides in the grain boundary regions. Said precipitation of chromium carbides will result in a locally chromium-denuded layer adjacent to the grain boundaries, and it is the primary cause of sensitization leading to IGA. The molybdenum imparts pitting and corrosion resistance to the alloy. The deficit of molybdenum will also likely have some affect on the ability of the alloy to resist corrosion.

Microstructural evaluation revealed severe IGA of the failed clevis. The IGA penetrated deep into the bulk material and was also observed in areas remote from either of the two fractures and the crack. The failed clevis and new clevis also exhibited evidence of heavy cold work in the microstructure and carbide decoration of the grain boundaries. In contrast, the un-failed clevis exhibited no IGA

and no signs of cold working and no grain boundary decoration.

Testing per ASTM A262 indicated that the failed clevis and new clevis were indeed susceptible to IGA, and the un-failed clevis was not. The failed **clevis and new clevis both revealed a “ditched”** structure around the grain boundaries that was absent on the un-failed clevis. The ditching is caused by the chromium denuded grain boundaries and the preferential attack of this area by the etchant.

The most common cause of sensitization in stainless steels, such as Type 316, is welding and

**Table 2. Summary of Clevis Sample Chemical Composition (Weight %)**

Element	Failed Clevis	Un-failed Clevis	Type 316 Stainless Steel	Type 316 Stainless Steel (High Carbon)
Carbon	0.11	0.06	0.08 maximum	0.04 – 0.10
Manganese	0.96	1.11	2.00 maximum	2.00 maximum
Phosphorus	0.035	0.023	0.045 maximum	0.040 maximum
Sulfur	0.021	0.006	0.030 maximum	0.030 maximum
Silicon	0.36	0.37	1.00 maximum	1.00 maximum
Nickel	10.02	10.38	10.00 – 14.00	10.00 – 14.00
Chromium	16.41	16.57	16.00 – 18.00	16.00 – 18.00
Molybdenum	1.69	2.02	2.00 – 3.00	2.00 – 3.00
Copper	0.65	0.24	Not specified	Not specified
Nitrogen	0.06	0.09	Not specified	Not specified
Iron	Balance	Balance	Balance	Balance

could have affected the lives and livelihoods of safety harness users. Fortunately no one was injured using these fall support harnesses.

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### *Brian Kennedy,* Laboratory Technician



Brian joined M&M Engineering Associates, Inc. in May 2014 as a Laboratory Technician. Brian holds a degree in Welding Technology, and is currently studying to obtain AWS-CWI and Level 2 NDT Weld Inspector credentials. He also holds certificates in Ultra High Purity Piping, Inert Gas Welding and Plate Welding.

While enlisted in the US Marine Corps, Brian gained experience as a F/A-18 Power Plant and Fuel System Technician. He also has work experience as a gas turbine engine technician, a combustion turbine power plant operator, and has extensive experience with aircraft engines.

Welcome Brian, we are glad to have you!

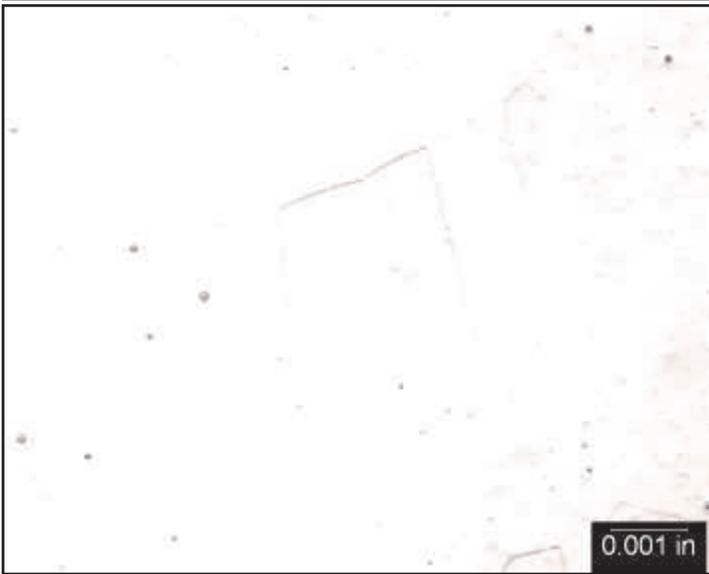


Figure 11. Photomicrographs show the typical ASTM A262 test results on the Un-failed Clevis. No ditching was observed in the grain boundaries, indicating no susceptibility to intergranular attack.

(Left) Magnification: 200X, Etchant: Oxalic Acid  
(Right) Magnification: 500X, Etchant: Oxalic Acid

post weld stress relief. It does not appear that the failed clevis was fabricated by welding. Rather, such a commodity object would normally be fabricated from bar stock by forging, forming, and machining. It is clear that the bar stock that was sourced for manufacture of the failed and new clevis samples was not only sensitized, but failed to meet chemical specifications and contained large, aberrant inclusions as well. This is a text book example of how important it is to properly screen and source procured material, even for commodity items. Insidiously, although these were commodity items, they played a critical role in a safety device that

## Did you know...

- The chemical element Titanium has the symbol Ti and atomic number 22.
- Pure titanium is a transition metal with a lustrous silver-white color.
- Titanium will always be found bonded with another element, it does not naturally occur on its own in a pure form.
- British pastor William Gregor discovered titanium in 1791. It was later named by German chemist Martin Heinrich Klaproth who called it titanium after the Titans of Greek mythology. It was not until 1910 that titanium was produced to 99.9% purity by New Zealander Matthew A. Hunter. The method became known as the Hunter Process.
- Titanium has two very useful properties: it is resistant to corrosion (including in sea water and chlorine) and has the highest strength-to-weight ratio of any metal.
- Titanium is as strong as a lot of steels, yet it is 45% lighter. The metal is also 60% denser than aluminum but is over two times as strong.
- Titanium has a melting point of 3,034°F (1,668°C) and a boiling point of 5,949°F (3,287°C).
- Titanium is non-magnetic and is not very good at conducting heat or electricity.
- Even in large doses, titanium remains non-toxic and does not have any natural role inside the human body, usually passing through without being absorbed.
- Titanium is present in most igneous rocks and their sediments, it is the 9th most abundant element in the Earth's crust and the 7th most abundant metal.
- Many elements such as iron, aluminum, nickel, and vanadium are alloyed with titanium to produce strong, lightweight alloys. These titanium alloys are used in the manufacturing of naval ships, spacecraft, missiles, and aircraft, with around two thirds of all titanium metal produced used in aircraft engines and frames.
- Titanium metal is also used in the production of high-end racing cars and motorcycles, where reducing weight but maintaining strength is important.
- Titanium's strength-to-weight superiority has seen the metal used as a component in many other products in recent times, including: laptops, firearms, tennis rackets, golf clubs, lacrosse sticks, football helmet grills, bicycles frames, camping cookware, and utensils.
- Around 95% of all titanium is used to produce the compound titanium dioxide, which is a very bright and refractive white pigment that is used in paints, plastics, toothpaste, sunscreens, sports equipment, and paper.
- The famous Guggenheim Museum in Bilbao, Spain is covered in titanium panels.
- The fact that titanium is strong, light, non-toxic, and does not react with our bodies makes it a valuable medical resource. It is used to make surgical implements and implants, such as hip joint replacements that can stay in place for up to 20 years.
- Titanium is now popular in designer rings and other jewelry due to its durability, its resistance to seawater and chlorine in swimming pools, and as it is non-toxic.
- Titanium is present in meteorites, the sun, and other stars.

Source: <http://www.sciencekids.co.nz/sciencefacts/metals/titanium.html>



# ANNOUNCEMENTS

## Come visit our Renovated Website!

Learn more about what we do and who we are at

[www.mmengineering.com](http://www.mmengineering.com)

## Congratulations

**Dr. James R. Ciulik, Ph.D., P.E., CWEng, CWI**

In May, Jim Ciulik passed the AWS CWEng exam and is now a certified welding engineer. He also passed the AWS CWI exam using the D1.1 Structural Welding Code and is a certified welding inspector.

What is a certified welding engineer (CWEng)?

A CWEng has several responsibilities, usually related to the design of weldments, including joint design, welding methods, choice of welding filler metals, and determining the appropriate preheating and postheating temperature requirements (if needed) to ensure that welded joints meet specific service requirements and contract documents, and comply with the code and standard requirements. A CWEng can evaluate the cost effectiveness of various welding/joining processes and determine which one is most cost effective for a particular design or fabrication process. If weld repairs are to be performed, a welding engineer often determines which weld repair process and procedure is required to perform proper repairs that satisfy code/standard requirements. A welding engineer may develop welding procedure specifications (WPS) and related procedure qualification records (PQR), supervise and document welder qualifications, support production with manufacturing and repair expertise, and work with contractors, welders, suppliers, and NDE personnel to ensure that finished products meet the design requirements and comply with applicable codes and standards.

What is a certified welding inspector (CWI)? A CWI is a trained welding inspector who has numerous responsibilities, including the following:

- inspection of welds to determine if they meet the requirements of applicable codes and standards;
- **verifying welding procedure specifications (WPS's) and procedure qualification records (PQR's);**
- witnessing welder performance qualification and welding procedure qualification;
- verifying that the specified base metals and filler metals are being used in welding procedures;
- verifying joint geometry compliance;
- witnessing of welding operations;
- verifying inspection records compliance;
- verifying NDE procedure compliance;
- verifying welder qualification compliance;
- developing visual inspection procedures; and
- verify implementation of nondestructive and destructive evaluation methods.

Not all of these are performed on each inspection project, but often many of them are performed.



# Preventing Failures in Steam Generating Equipment

## Fall Session - Encore



Due to an overwhelming interest in our February workshop, M&M Engineering is planning a fall session. If you would like to be added to the attendee list for the fall session, please let us know by completing the sign-up form on our website:

<http://mmengineering.com/encore-edition-seminar-preventing-failures-steam-generating-equipment/>

or by faxing or emailing the pre-registration form (backside of page) to [Lalena\\_Kelly@mmengineering.com](mailto:Lalena_Kelly@mmengineering.com).

A final date will be decided based on the number of pre-registered attendees by August 1, 2014. If you have questions, please feel free to call us at (512) 407-3775.

**M&M Engineering's workshop provides valuable insight to producers of steam, be it used in power or process applications.** Our 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.

### Day 1

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

### Day 2

- 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



# PRE-REGISTRATION FORM

## ENCORE PRESENTATION

### *PREVENTING FAILURES IN STEAM GENERATING EQUIPMENT*

Due an overwhelming response from our Spring workshop, M&M Engineering wants to invite interested parties to pre-register for an encore workshop to be held the last week of September or the first week of October, 2014. Should you wish to reserve a seat, please complete the form below to be placed on our attendee roster. Pre-registration will close on August 1, 2014. Should we have enough interest to meet the minimum seating requirements, a date will be chosen and details of the location, hotel, etc. will follow in an email, along with a formal registration form.

ATTENDEE INFORMATION			
<input type="checkbox"/> Mr. <input type="checkbox"/> Mrs.	<input type="checkbox"/> Miss <input type="checkbox"/> Ms.	First Name:	Last Name:
Title:		Department:	
Company Name:			
Plant/Facility Name:			
Mailing Address:			
City:		State:	Zip Code:
Office Number:	Mobile Number:	Fax Number:	
(   )	(   )	(   )	
Email:			
2 DAY WORKSHOP INFORMATION			
Registration Fee: \$750.00 (continental breakfast and lunch provided)			
Location: Austin, Texas (or surrounding area)			
Date: Tentative time set for the last part of September or the first part of October 2014 (exact date to be determined)			

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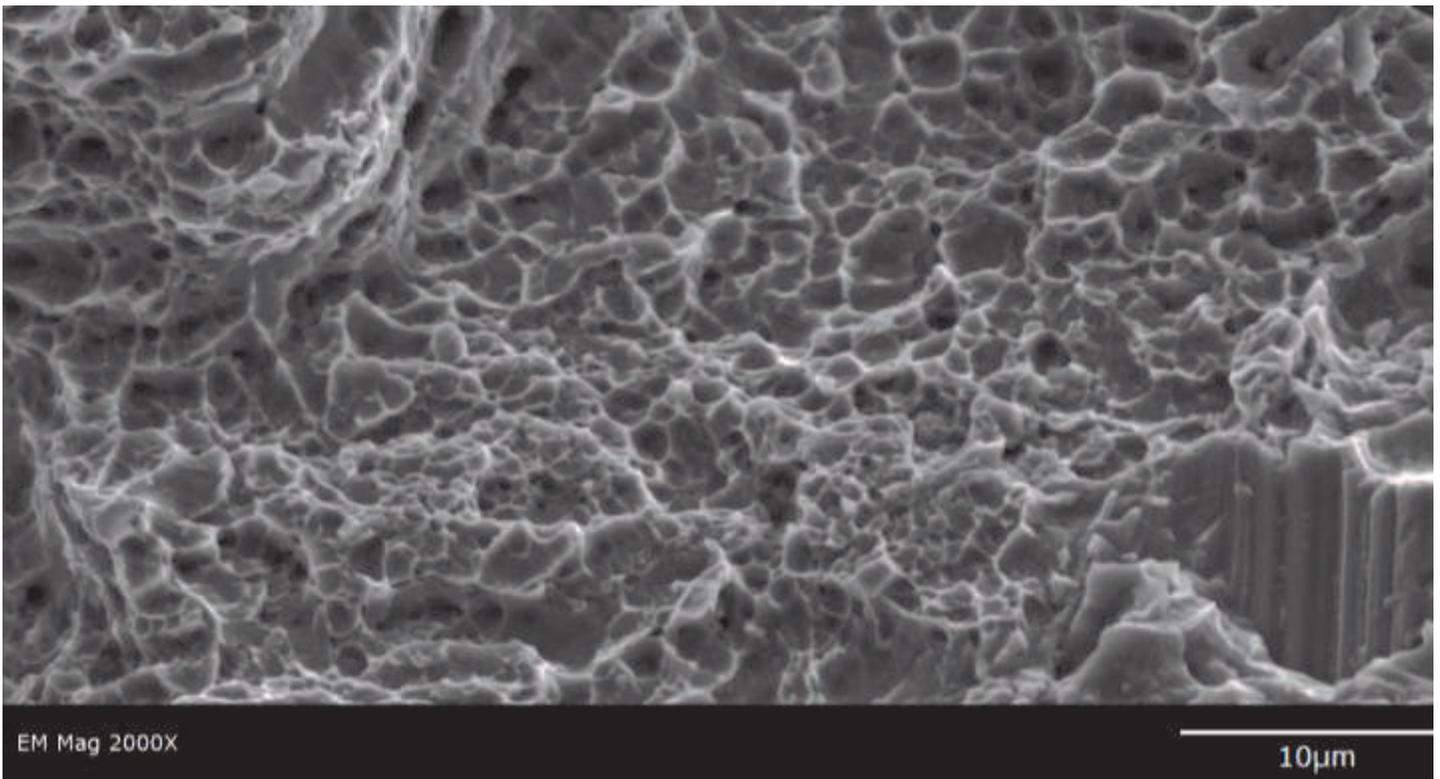
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