the Conduit

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Corrosion of Galvanized Piping in Domestic Water Systems

By Catherine Noble

Senior Engineer

Construction of a set of high-end condominiums had recently been completed when residents began to complain about rusty water coming out of the faucets, staining sinks and showers, and stopping up dishwashers and other hot water-using appliances. The source of the rust was discovered to be sections of galvanized carbon steel piping located downstream of a conventional water softener and before the hot water boiler. The soft water, particularly when heated, quickly removed the protective zinc coating, leaving the carbon steel underneath vulnerable to attack.

Hotels, high-end residences/condos, stadiums, hospitals, etc. often have specifications that require the builder to use copper piping for all potable water pipe that is 2 inches in diameter or smaller, but allow substitution of other suitable materials for larger piping. Large hot water systems in these types of complexes that use circulated hot water have defaulted to using galvanized carbon steel piping for these larger diameter pipe sections.

This is due to the lower cost of galvanized pipe compared to copper or other materials. The degradation of the galvanized piping in a soft water system can occur in a short period of time, and problems can arise in as few as two to five years after a new installation (Figure 1). This degradation is a major issue that should be addressed.

Water is softened to minimize calcium carbonate scaling that can occur when hard water is heated. In municipal systems, treatment and additives are often already in use in the potable water to prevent this scaling, but builders often think that completely soft water is in some way better.

Hardness in water consists of calcium and magnesium compounds, which are important for human health and impart taste to the water. However, when hard water is heated, the calcium carbonate precipitates and builds-up debris/scale on the pipe walls. This is the reverse of many

Figure 1. Photographs show examples of corrosion in galvanized piping hot, softened water service.

(Continued on page 2)

(Continued from page 1)

Figure 2. Photograph shows corrosion along a rolled seam at the end of a galvanized pipe

Figure 3. Photograph shows galvanized pipe that was examined after six years in service. This sample was from the cold, softened water line prior to the heat exchanger, but after the circulating hot water return. Pitting was significant.

compounds, which usually have increased solubility at higher temperatures. Softening the water removes the calcium and magnesium and replaces them with sodium (or sometimes potassium).

Softened water is actually aggressive (corrosive) to carbon steel and galvanized materials. The zinc (galvanized) layer on the steel pipe gains much of its protection from a zinc carbonate layer that forms on the surface. The presence of some hardness (calcium carbonate) in the water is beneficial, as it aids in forming the protective layer. In addition, the combination of a thin layer of calcium carbonate and the zinc carbonate are more resilient to corrosion than the zinc carbonate alone in completely softened water. When hardness has been completely removed, the protective layer does not properly form and the zinc layer is susceptible to corrosion. It this situation, the galvanized layer first acts as a sacrificial anode and corrodes preferentially to the steel underneath it. However, once the zinc is completely gone, the steel pipe itself begins to corrode and iron corrosion debris gets into the water.

This process does not take long. M&M Engineering has seen failures in piping systems that are only a couple of years old.

Another issue with using galvanized piping is that the pipes are often threaded or seam rolled in the field during installation. This destroys the galvanized layer wherever the machining or rolling took place. Sometimes these areas are covered over with zinc-rich paint or primer after forming, but this does not provide as much protection as the original zinc coating. Therefore, corrosion often occurs first at threaded fittings, seams, or rolled grooves

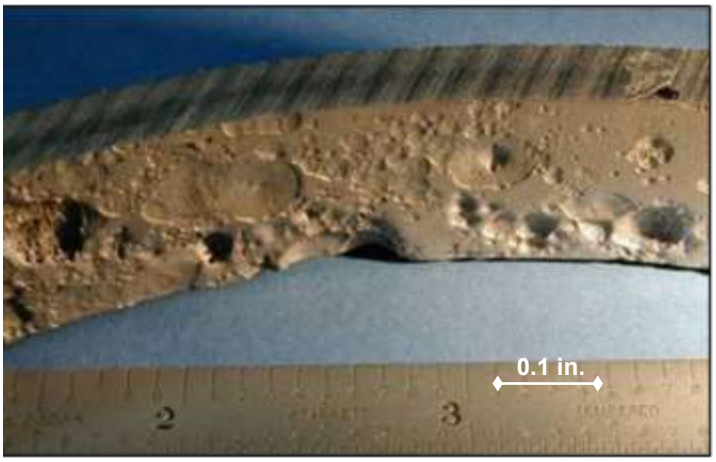

Figure 4. Photograph shows condition of internal surface of galvanized pipe after cleaning.

Figure 5. Photograph shows severe pitting in a cross section of the galvanized pipe.

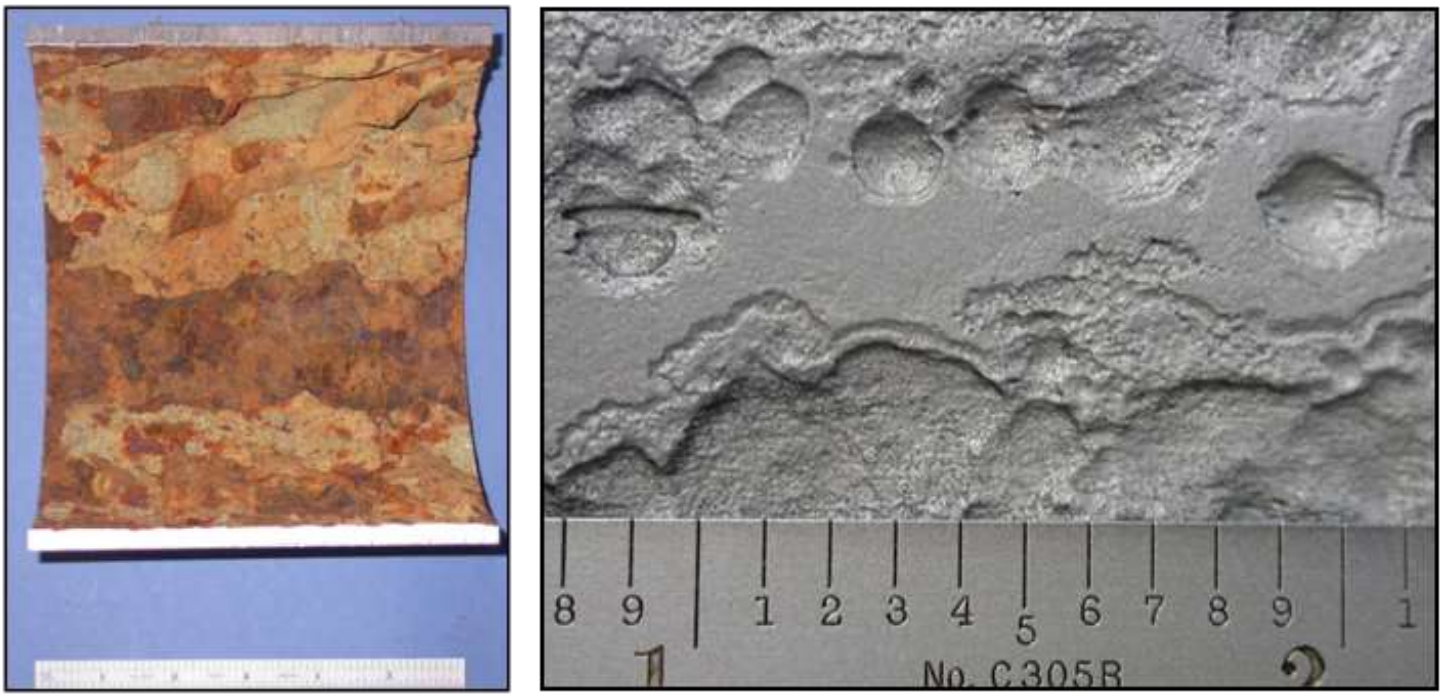

Figure 6. Photographs show galvanized pipe from a hot, softened water line that was examined after two years in service. Pitting was significant on both sides of the pipe, but worse on the bottom of the pipe (shown here).

in the galvanized pipe (Figure 2).

While building owners and builders are often aware of a corrosion problem long before the first failure occurs, the corrosion debris leads to brown, rusty water in sinks and bathtubs, and can also plug appliances that results in actual damage. Piping failure is also a possibility, and M&M Engineering has seen multiple leaks in hot, softened water systems that used galvanized piping.

Figure 3 shows a water pipe from a hotel with internal corrosion that led to multiple complaints about rusty water. Severe pitting was noted on the internal surface of the pipe (Figure 4 and Figure 5). In addition, most of the piping samples had no remaining galvanized layer present, particularly after the softener. This system was only six years old, and much of the piping had to be replaced. Figure 6 shows a pipe from hot, softened domestic water service in a stadium. Much of this piping system had internal corrosion, and failures had also occurred. This pipe was only two years old, and thousands of feet of piping were replaced in the facility.

The bottom line is that galvanized piping should not be used for hot, softened water service, regardless of how much cost savings is gained. It is just a matter of when it becomes a corrosion issue, not if it will. Any piping after the softener should be made of copper or some other suitable material that does not experience accelerated corrosion rates in hot softened water, such as PVC or stainless steel.

M&M Engineering offers Wind Turbine Inspection...

Today there are an unstated number of Wind Energy Farms, utilizing numerous sizes and manufactures throughout North America and around the world. Some, if not most, have been in operation for many years and now require greater attention to maintenance to ensure the reliability and continued operation of the Wind Turbines/ Generators.

M&M Engineering Associates, Inc. has an experienced staff that is available to conduct a thorough survey/inspection of the wind farm, including the substation transformers and switchgear. We will examine the ,maintenance records and procedures to determine if the equipment is being maintained and operated in accordance with the Original Equipment manufacture's (OEM) recommendations, Industry guidelines and Good Engineering Practices.

M&M Engineering also has the qualified personnel to conduct an inspection of the

The 6 Deadly Sins of Costly Outages and ISO 9001

By Kaye Emmons

Senior Consulting Specialist

What does an hour or a day of downtime cost you? Ask yourself—if you could avoid that downtime, what would it be worth? Often when you drill all the way down to the real root cause of many un-planned facility outages or extended planned outages you will find one or more of the following "six deadly sins":

1. lack of training for operators and maintenance personnel,
2. lack of operating procedures and/ or emergency procedures,
3. lack of adequate maintenance,
4. improper spare parts inventory,
5. lack of maintenance planning,
6. inadequate documentation control and management of change

ISO 9001 is an international standard that defines requirements for a Quality Management System (QMS). Many organizations have implement ISO 9001 and obtain ISO certification because it assures customers that the company has a good QMS in place. An organization with an effective QMS will typically meet customer expectations better than an organization that does not. Many organizations require their suppliers to have ISO 9001 Registration. Other organizations implement an ISO 9001 QMS because it has proven that it leads to better operations, improved performance, and improved profitability.

Case Study One

A combined cycle power plant's lack of maintenance prioritization and planning resulted in the facility's maintenance strategy being primarily reactive in nature. Equipment would fail, and based on Operations prioritization, the maintenance staff would repair it, hopefully with the proper parts available to do so. Often, work order prioritization was non-existent or vague, and many times, due to budget constraints or lack of training, the necessary parts were not in stock and had to be obtained on an emergency basis. The plant staff did not include a dedicated planner. Additionally, no formal QA/ QC program was in place, without which there was an increased amount of re-work and poor quality craftsmanship. This was especially important during planned maintenance outages, where it is critical to complete the outage within budget and time constraints. While the facility had a decent training budget, there had been no formal training or certification program for Operators since startup.

All of these were factors that decreased reliability and availability, increased maintenance costs, and increased the risk of a lost-time accident. These factors were all brought to a head during a Root Cause Analysis (RCA) of a water carryover into the HRSG superheater which caused damage to the superheater and could have severely damaged the HP turbine.

Subsequent to this event there was a facility audit where additional issues were discovered:

- Training records were reviewed, Operations staff was interviewed, and a gap analysis was performed to ascertain what training needs were not being met.
- Operating and emergency procedures were audited. In some cases these procedures were difficult to find and/or use. This had the potential to cause incorrect responses during critical or emergency situations.
- It was determined that there was no defined alarm management program in place at the facility, and nuisance alarms were numerous, especially during start-ups or upset conditions. This caused confusion in the control room and made it more likely that the Control Room Operator might overlook more critical alarms. This had caused one incident where the hydrogen generator seals were lost and seal oil leaked into the belly of one of the combustion turbine generators. Fortunately, there was no serious damage, but the incident highlighted the need for both additional training and better alarm prioritization.

Although many of these problems uncovered did not seem overly concerning at the time, when seen together during the audit it was clear that some of these issues had directly contributed to several extended, and expensive, unplanned outages. It was obvious that something needed to be done. The audit outlined areas as priorities that needed to be addressed, and this resulted in much more attention by upper management.

As a result, the plant:

- Provided training for both operations and maintenance on how to properly prioritize maintenance activities and purchase critical parts.

- There was a renewed focus on emphasizing preventive and predictive maintenance activities, the corrective to PM/PDM maintenance ratio was substantially reduced, and priority maintenance activities were addressed.
- Operations and Maintenance personnel identified QA/QC activities needed and assisted with setting up documentation and training. As a result, the facility was able to reduce outage budget overruns, as well as, to complete their outage activities within the desired timeframe.
- An alarm management system was put in place to eliminate nuisance alarms and ensure that critical equipment alarms were properly prioritized.

M&M Engineering now has the expertise to support Facility Operations and Maintenance Audits such as these. This can be part of a root cause analysis (RCA) of a failure or near miss or generally review plant activities that will improve reliability, availability, and reduce overall costs.

Case Study Two

A power facility had a client requirement to be ISO 9001 certified or "certifiable". There were a number of issues found during an ISO 9001 compliance audit. The audit found that the plant had no Management of Change (MOC) program in place. This increased the risk of equipment damage or even injury to personnel. Additionally, their document control system was reviewed and it was determined that staff did not have the necessary software to update drawings nor the time and personnel to review and update all the procedures on a periodic basis. The compliance audit also found:

Procedures were outdated in some cases, and many were past the required review date.

Drawings did not reflect changes in plant equipment configurations that had been implemented following start-up.

Changes, whether temporary or permanent, were not documented properly, leading to errors in safety documentation and inaccurate Operations and Maintenance procedures.

To address these findings:

Tools and resources needed to execute a document control system, review and update procedures, and manage any changes or updates to these systems were identified and implemented.

An MOC procedure was developed, incorporating input from members of both Operations and Maintenance staff. Training on the importance and use of MOC was provided, and subsequently, the site was able to significantly reduce the risks associated with undocumented equipment or procedural changes.

After the appropriate changes were implemented, the plant was able to close out the majority of the audit findings, they regained their ISO "certifiable" status and lowered their risk of accidents or incidents due to the use of inaccurate drawings, procedures or undocumented changes. Ultimately, the site was later formally ISO 9001 certified.

A similar in-depth management audit can be part of the process for becoming ISO 9001 certified/ registered or certifiable. M&M Engineering personnel have experience with this methodology and requirements.

M&M Engineering's Facility

O & M Assessments

In the past, our engineers and specialists have conducted site water treatment / chemistry evaluations and rotating equipment risk appraisals. We have recently added staff experienced in the day to day operation and maintenance of generating stations. When these three areas are combined they cover most of the high risk and often overlooked areas of risk in a plant. In adding the evaluation of Operations and Maintenance programs and practices we have also improved the format of the assessments to provide a quantified "report card" scoring system for each area.

Here are several of the O&M topics we can review:

Operations

- Contractors
- Shop, Tools
- Quality Control
- Planning, Prioritizing
- Spare Parts
- Outage Philosophy / LTSA / Parts Agreements

Maintenance

- Procedures
- Training, Certification
- Alarm Mgmt. / Plant Historian
- Rounds & Readings
- Communications
- Document Control / MOC

Let M&M Engineering help you collect and use this information to help your facility owners and plant staff:

- Become or remain ISO 9001 compliant
- Support continuous improvement initiatives
- Reduce the risk of unplanned outages and down-time
- Provide justification for capital improvement projects and other expenditures
- Support preparation for ISO 9001 implementation
- Highlight risk mitigation options and opportunities
- Support due diligence efforts prior to asset purchases

Water and Steam Chemistry Audits—taking the independent view

By David Daniels

Principal Scientist

How much is your water and steam chemistry costing you? Not just the price of the chemicals, but the cost of corrosion and deposits on critical steam generating equipment. What about the closed and open cooling water systems? Are corrosion and deposits in the condenser and heat exchangers causing efficiency losses and tube leaks?

At many sites, the chemical treatment for the boiler and feedwater costs relatively little. The major chemical treatment costs are generally in the cooling water. However, the boiler and steam system is where major and very expensive damage can occur, when the chemistry is not controlled properly. In some cases, the site representative for the chemical supplier may be more focused on where the money is, than where the risks are. And there is always the temptation to promote the "new and improved" treatments, when they may not represent a real improvement for your process.

However, the vendors are not always to blame. Even the best water treatment programs can be thwarted by equipment problems or a lack of proper application and training on the operator's part. You can hardly blame the doctor if the patient refuses to take the prescribed medication as directed.

- What plants need is an independent look at the chemistry program by someone who doesn't sell chemicals and therefore has competing objectives.

M&M Engineering performs water and steam chemistry audits on all types of industrial and utility steam systems—from small industrial systems to large supercritical utility boilers. We look at the steam cycle, water treatment, and cooling water systems. We can provide an assessment of whether the current treatment program is right for your system, whether the site and chemical vendor are performing the right testing to keep the treatment applied properly, and if operating and equipment conditions or operator training are hindering the application of the program.

The audits are thorough and detailed, proving specific recommendations to the plant on where improvements can be made to bring them up to the industry standard.

If you would like more information on having a water and steam chemistry audit performed at your site, in conjunction with or separate from the Operations and Maintenance Assessment, contact David Daniels, david_daniels@mmengineering.com for more information.

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Brinell Hardness Tester

We've added a new capability to our laboratory: a Brinell hardness tester. Invented in 1900 by the Swedish engineer Johan August Brinell, the Brinell hardness test is often described as the oldest hardness test in common use today. Most Brinell hardness tests are performed using a 3000 kg test force and a 10mm diameter tungsten carbide ball, although soft metals are usually tested using a 500 kg test force. The indenter ball makes a smaller indentation in a hard metal and a larger indentation in a soft metal. The lower 500 kg test force used on soft metals avoids embedding the indenter, which could happen if the 3000 kg test force were to be used on a soft metal. To determine the Brinell hardness, the diameter of the indentation is measured and the Brinell hardness number is calculated using a simple equation that includes the load, the diameter of the indentation, and the ball diameter. The Brinell indentation is much larger than the indentation from a Rockwell B scale or Rockwell C scale hardness test, which makes it more useful for measuring the hardness of castings and forgings, which can have large grain sizes and non-uniform microstructures. Rockwell hardness testing of these products can result in a wide variation in hardness readings due to the small size of the indentation. {We need a closing sentence.}

Preventing Failures in Steam Generating Equipment

M&M Engineering Associates, Inc. will be hosting a two day conference that will focus on the issues most common in steam generation systems. Suggested audience includes the pulp and paper industry, refineries, power generation, or anyone who produces steam for use in power or processes.

April 3 - 4, 2013

Aloft Austin at the Domain
11601 Domain Drive
Austin, Texas 78758

Conference Registration

$500.00 for both days

(Continental Breakfast and Lunch Provided)

Registration will close on March 25, 2013

Enrollment limit of 20 people

Please call or e-mail Candice Chastain to register or for additional information

(512) 407-8598 or candice_chastain@mmengineering.com

Accommodations

Rooms may be reserved at Aloft by calling (866) 932-7660. Please be sure to mention the M&M Engineering conference to receive a special rate for attendees.

Conference Schedule

April 3rd

Session 1	Feedwater Heaters and Damage Mechanisms
Session 2	Damage Mechanisms in Deaerators
Session 3	Water Touched Boiler Tubing Failure Mechanisms
Session 4	Steam Touched Boiler Tubing Failure Mechanisms
Session 5	High Energy Piping: Damage Mechanisms and Correction

Laboratory & Facility Tour to follow in the early evening

April 4th

Session 6	Water/Steam Cycle Chemistry Overview
Session 7	Steam Turbine Failures
Session 8	Condenser and Cooling Water Failures
Session 9	Non-Destructive Inspection
Session 10	*Optional* – Flexible topic on Gas Turbines, HRSGs, or other requested topics submitted by attendees

New Employee Joins M&M Engineering

Jim Ciulik joined M&M Engineering in November 2012 as a Senior Principal Engineer.

Jim has been interested in metallurgy for 30 years, starting as a metallurgical laboratory technician and eventually becoming interested in metallurgical engineering and R&D of engineering materials. He has more than 20 years experience in failure analysis and laboratory testing.

Jim has an A.S. degree in Metallurgy Technology, a B.S. in Metallurgical Engineering, an M.S. in Metallurgy and Materials Engineering, and a Ph.D. in Materials Science and Engineering. Despite these educational adventures, he prefers practical engineering, failure analysis investigations, and the materials aspects of engineering design.

A licensed professional engineer in Texas and Ohio, he has numerous publications and presentations, and has been awarded two patents: co-inventor of a robot blade design for semiconductor processing equipment, and inventor of a new method for growing single crystal metals in the solid state. He is active in TMS (The Minerals, Metals & Materials Society) and is currently chair of the Refractory Metals and Materials committee. He was active for many years in SEMI (Semiconductor Equipment and Materials International) contributing to fabrication specifications, and has been an active member of ASM International (the Materials Information Society) for 34 years.

Prior to joining M&M Engineering, Jim worked for Element Materials Technology in Houston, Texas conducting failure analyses, at The University of Texas at Austin teaching materials science and engineering courses and doing research on refractory metals, at Applied Materials as an engineer/manager supporting robotics and mainframe design, at Radian International in Austin, Texas as a metallurgical engineer and failure analyst, and at Seal Laboratories in Los Angeles, California as a materials failure analyst.

In his spare time, Jim occasionally plays a good game of racquetball and watches a lot of movies, especially noticing mentions of metallurgy (in O' Brother Where Art Thou, Ulysses Everett McGill says, "Or, if not smithies per se, were you otherwise trained in the metallurgic arts before straitened circumstances forced you into a life of aimless wanderin'?").

Seminars & Workshops

Jim Ciulik will be giving a presentation entitled *The Creep Behavior of Molybdenum and Other Commercial-Purity Refractory Metals* at the 142nd TMS (The Minerals, Metals & Materials Society) Annual Meeting and Exhibition in San Antonio on March 4, 2013 in the Refractory Metals 2013 symposium.

Catherine Noble will be attending the CORROSION 2013 (NACE International) Conference March 17-21, 2013 in Orlando, Florida. She will be presenting a paper entitled *PAPERPAPERPAPERPAPERPAPER* at the TEG-163X Committee Meeting (Boiler Waterside Failure Analysis) on Sunday, March 17th from 2:00-4:00 pm

Please visit us at www.mmengineering.com for additional information regarding conferences and events.

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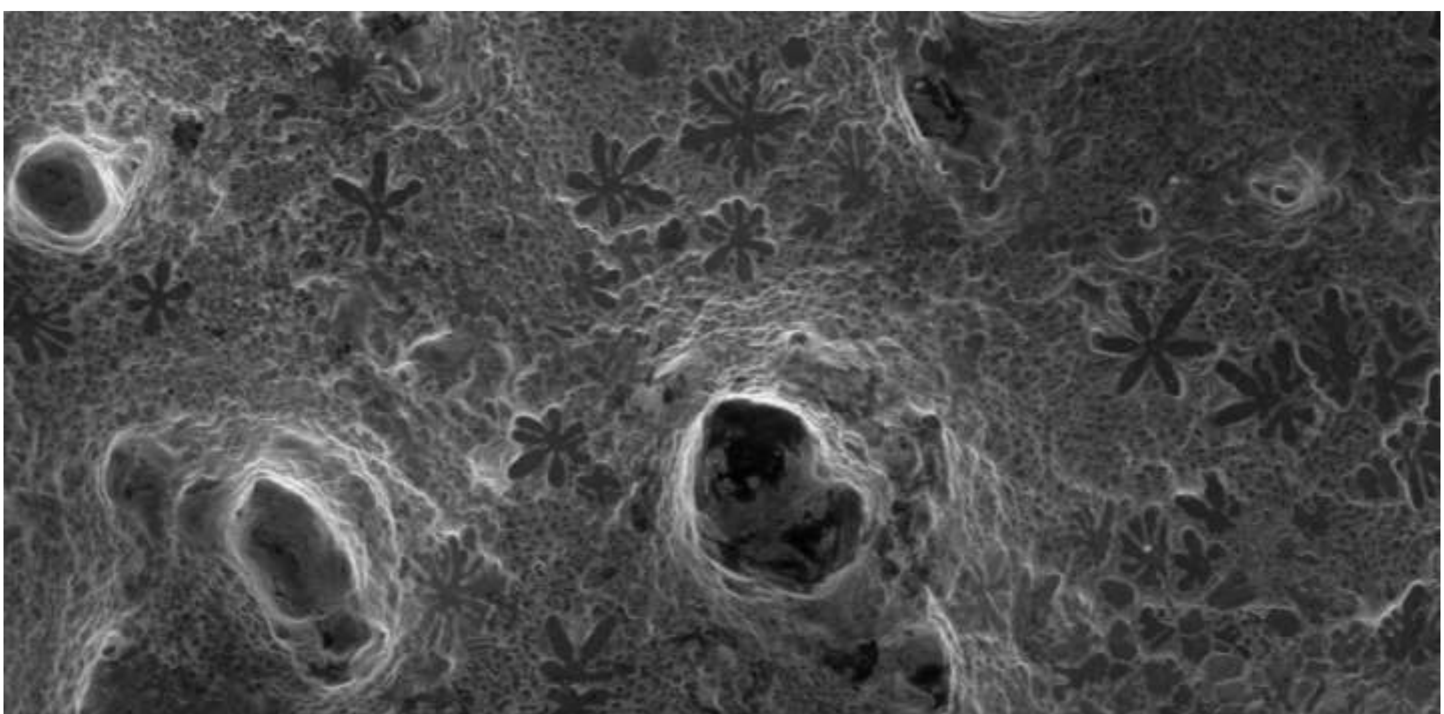
The metal never lies.

We're on the web
www.mmengineering.com

Season's Greeting from M&M Engineering

Let it snow, let it snow, let it snow!



Dendrites in cross section, fracture surface on copper motor mount . 100x