the Conduit

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INSIDE THIS ISSUE:

Combustion Turbine Compressor Hygiene and Component Longevity

By John Molloy, P.E.
Senior Consulting Engineer

Introduction

A typical F-class compressor will ingest nearly 1000 lbs of air per hour of operation. Entrained in the air is a spectrum of minerals, salts and volatile organic compounds that are present in the ambient atmosphere. Locally high concentrations of corrosive compounds may also be present due to surrounding industries or even from the power plant itself, such as cooling tower drift or water treatment effluent.

In addition to fouling the gas path area of the compressor blades and vanes, which results in a drop in compressor efficiency, these contaminants can serve as nucleation sites for under-deposit corrosion cells that have dramatic implications for component life, as well as adding risk of catastrophic failures. Online and offline compressor water washing with detergents has been utilized with some success by utilities as a method for mitigating the effects of deposit accumulation. However, invariably, tenacious deposits will accumulate over time. Activation of these deposits, by the presence of moisture, results in a corrosion cell that can quickly corrode the stainless steels typically used for blade and vane construction. The higher strength PH stainless steel blades and vanes suffer a larger loss in fatigue threshold properties from pitting, and tend to suffer more airfoil liberations due to cracking nucleated at pitting.

On forward blades and vanes, M&M Engineering has also observed a combined effect of leading edge erosion and pitting. The erosion is most often the result of on-line water washing, but can also be the result of improper filtration selection. The roughness of the eroded leading edge is an ideal area for compressor deposits to become deeply embedded.

Given the fall in compressor efficiency, the irreversible damage due to erosion and corrosion pitting, and the risk of catastrophic damage due to fracture initiation at corrosion pits, it is advisable to have a strategy to mitigate compressor deposit accumulation. Moreover, the strategy

Figure 1. SW501D5 compressor blades with fractured tip and heavy deposits.

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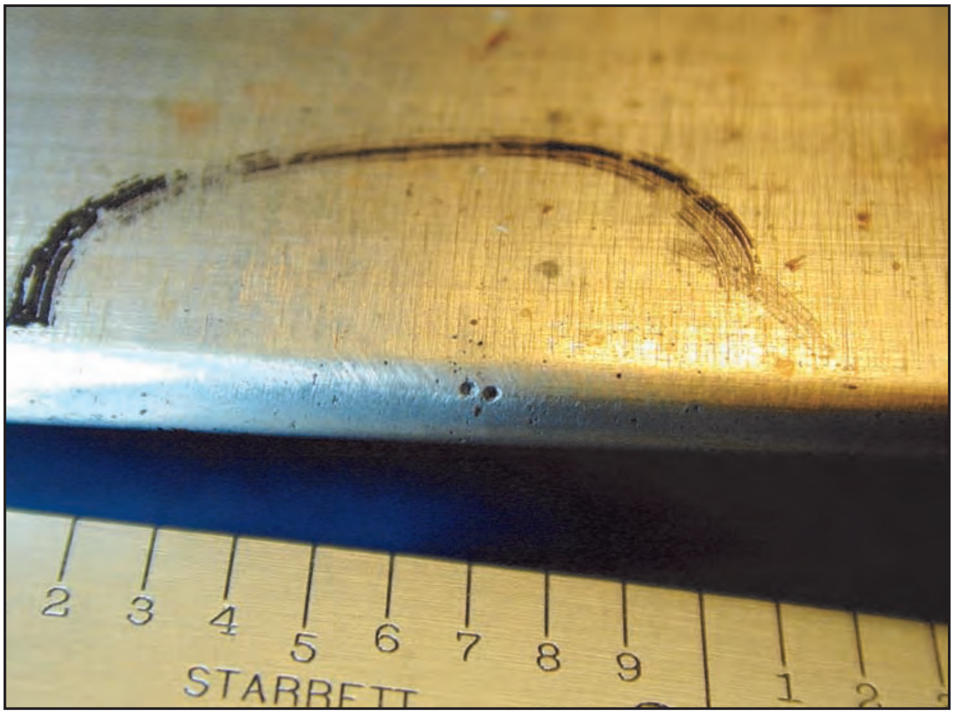

Figure 2. Pitting observed on the leading edge of GE 7FA compressor blade.

selected should also consider a scenario where some deposit accumulation is unavoidable and how to reduce the activation of these deposits.

Finally, particular consideration should be given to units that have a history of blade failures due to a design limitation that makes them more susceptible to corrosion fatigue cracking. In which case the unit has a very low tolerance to the presence of corrosion pitting.

Typical Sources of Contamination

Soil

Depending on the local geological conditions, any given soil can contain large amounts of calcium, iron, magnesium, aluminum potassium, sodium, phosphorus, and sulfur; as well as other less common species, including chlorides where the dry land used to be a sea bed. These elements are always present as a compound, such as an oxide or a salt. Even with reasonably high efficiency filtration that removes 99.7% of the particulates within a given particle size range, the remaining 0.3% contamination multiplied by 1000 lbs/hr of influent air results in a high rate of deposit accumulation. Chlorides in salts will rapidly corrode (pit) any and all of the stainless steels used in gas turbine compressors. The only class of compressor materials reasonably immune to chloride or under deposit corrosion is the titanium alloy blades and vanes used in flight turbines and possibly some aeroderivative units. Sulfur containing compounds are commonly found on the airfoils of compressor blades and vanes, but they have also been found in large quantities in turbine wheel cracks on the Inconel 706 wheels used on F-class units.

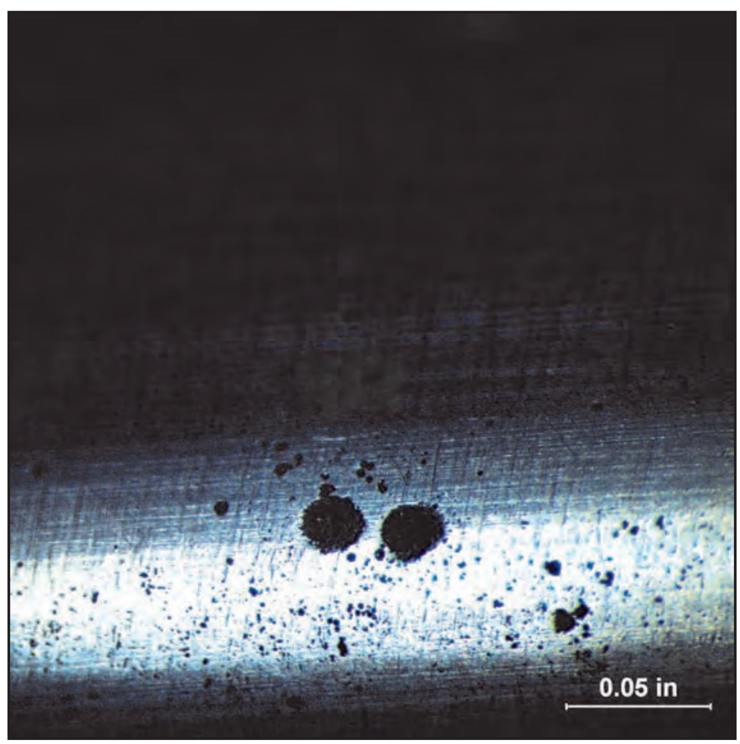

Figure 3. Closer view of pitting on GE 7FA compressor blade.

Air

The quality of air entering the compressor is highly variable, but nevertheless dependent on geographic location. Coastal regions have an obvious problem with humid, chloride laden atmosphere. Units in this particular environment are especially vulnerable to chloride pitting. Special inlet ducting and tailored filtration may provide some level of protection.

Local environments, established by the proximity of inlets relative to cooling towers or the use of sodium hypochlorite for microbial control of cooling tower water, can result in a chloride-laden influent to the unit. In this case the solution may be as simple

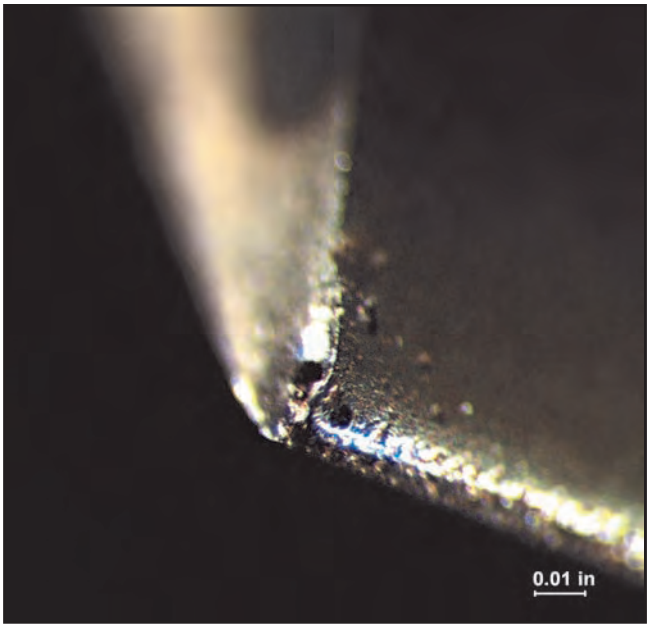

Figure 4. Leading edge pitting from airborne chlorides and adjacent fracture surface on GE 7FA vane.

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as using a non-chloride based biocide for microbial control. In some cases the corrodents can come from non-typical activities at the plant, such as excursions of acid vapors from the water treatment facilities (sulfuric acid or hydrochloric acid).

Proximity to local industry, such as steel mills, coal or lignite fired boilers, or refineries can result in a large influent concentration of sulfur bearing compounds. Sulfur bearing compounds, when incorporated into a deposit layer, can accelerate under-deposit corrosion and pitting.

Water

The water source used for online and offline water washing, as well as water used for power augmentation (misting, evaporative cooling, etc.) should be demineralized quality or better. The use of city water or another source of hard water is discouraged. Online water washing with a hard water source will result in increased deposit accumulation at and beyond the phase transition area where the water boils to vapor and deposits the minerals in solution. Power augmentation by closed loop chiller systems also affords the opportunity for contamination due to leaks in the chilled fluid. These fluids can have variable water quality as well as chemicals added to the chiller loop. Non volatile constituents of the chilled water would leave deposits in a similar fashion as hard water. As mentioned, on-line water washing can cause leading edge erosion if the droplet size is not controlled, or leaking occurs during operation.

Historical Contaminants Observed in Compressor Deposits

Over the course of many years, M&M Engineering has sampled the deposits laden on blades and vanes from gas turbine units in nearly every geographic region of the world. A pattern of contaminants (the usual suspects) has been observed, with some exceptions. The deposits observed are biased largely by one of the dominating contributors: Coastal conditions, soil conditions, or local environment (industry or local effluent).

Energy Dispersive Spectroscopy (EDS) provides qualitative elemental analysis of materials under scanning electron microscope (SEM) examination based on the characteristic energies of X-rays produced by the electron beam striking the sample. The relative concentrations of the identified elements are determined using semiquantitative, standardless quantification (SQ) software.

Conclusions

The pitting on the compressor blades and vanes is always the result of under deposit corrosion aggravated by the presence of corrosive species in the

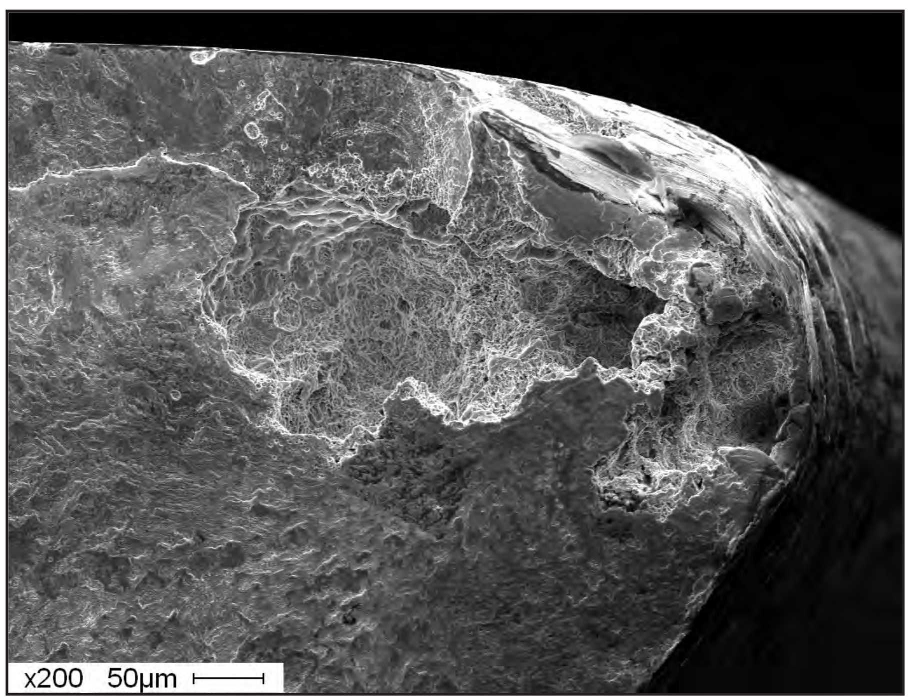

Figure 5. Closer view of leading edge chloride pitting and resultant fracture on GE 7FA vane .

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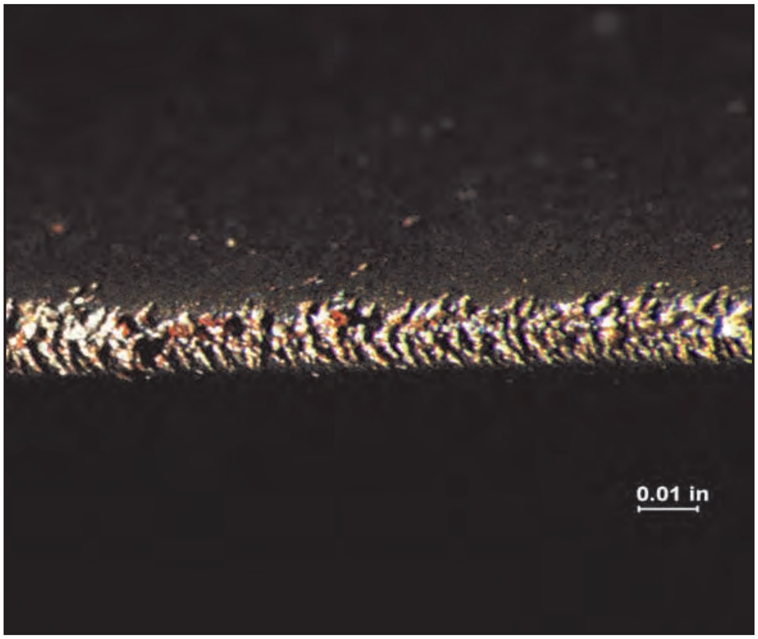

Figure 6. Leading edge erosion provides nucleation sites for additional pitting.

deposit. The corrosive species are most often sulfur and chlorine-containing compounds, but pitting can also occur simply from the presence of oxygen under the deposit. The pitting is proof of corrosive deposits, and trace amounts of corrosive species identified by EDS at the bottom interface of the pits identifies the active corrodents so that treatment can be fine-tuned for that species.

The source of the corrodents can be local to the plant (cooling tower drift), in the soil, from the atmosphere (coastal chlorides) or from local industry (burning lignite or low grade coal). In some cases the corrodents can come from non-typical activities at the plant, such as the use of sodium hypochlorite (bleach) for biological control, or excursions of acid vapors from the water treatment facilities (sulfuric acid or hydrochloric acid). Plant operations can identify, address and mitigate the local sources.

Regarding low fired hours units, the life limiting pitting is difficult to understand without considering the effect of offline corrosion. For units operating in cycling duty, a substantial amount of time is spent in idle mode. During idle periods, the unit is normally on turning gear for some daily period, and there may not be a provision for supplying dry air. These are the periods where corrosive deposits, combined with moisture, create conditions ideal for pitting. particularly if the airfoil deposits contain a substantial concentration of sulfur and chlorine-containing compounds.

Mitigation

Units may be water washed online each day when operated and the ambient temperature is greater than about 50°F. Offline water washing may be performed prior to performance testing or to restore lost capacity. In both cases the water washing is performed to provide performance benefits and also to prevent the accumulation of corrosive deposits. However, performing an online water wash prior to operation does not remove the deposits accumulated during the subsequent operation cycle, nor does it remove much deposit beyond the second stage due to phase transition from liquid to vapor. Moreover, if the subsequent operation cycle is followed by a long idle period in cool, humid weather, the deposits can absorb the ambient moisture and activate the corrodents. If possible, the online water wash should be performed near the end of the cycle period, but with sufficient time to ensure proper drying of the compressor and residual, tenacious deposits. Offline washes must be performed with demineralized water and a cleaning solution tailored to the deposits. Proper rinses with conductivity measurements taken at the drain ports are advised. Offline water washing is much more effective at removing compressor deposit accumulation, but proper drying is necessary to prevent pitting under remaining, tenacious deposits.

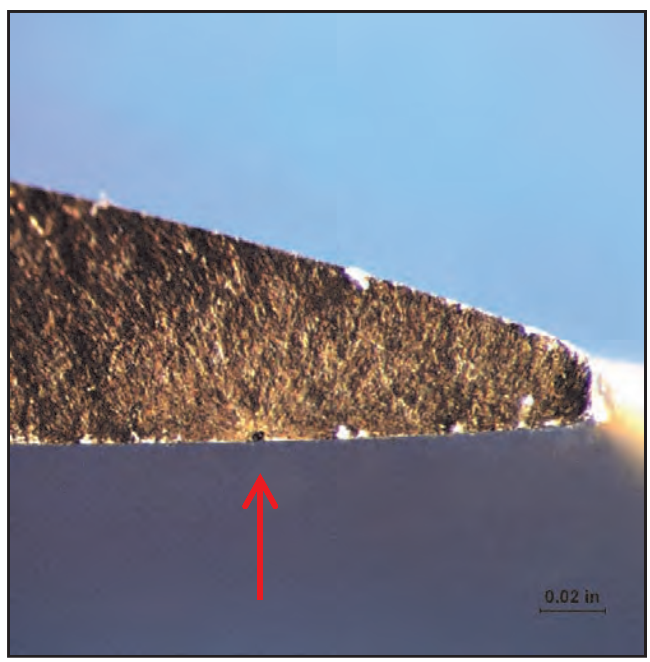

Figure 7. Image shows a GE 7EA vane fracture that originated at a corrosion pit on the suction side of the airfoil.

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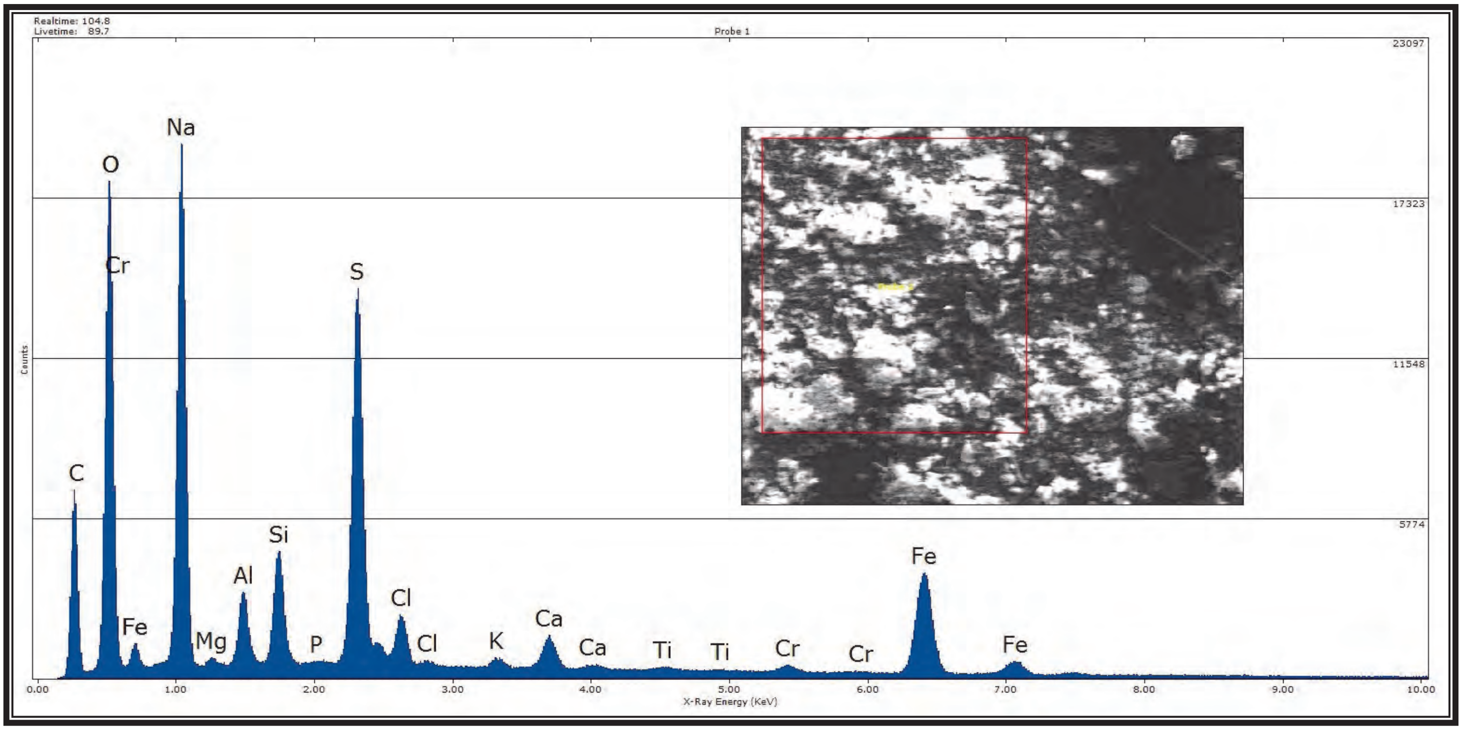

Figure 8. EDS spectrum shows typical compressor deposits. Sodium, sulfur and chlorine indicate potentially corrosive compounds in the deposits.

Another aspect of the operation that can affect the compressor deposits and moisture is proper sealing of the inlet filter house. All seams should be sealed with a weatherproof material and the fitment surfaces should be in good condition. Water leaks from the roof or any other area that causes standing water should be addressed.

From a mitigation standpoint, two aspects must be addressed to reduce the susceptibility to pitting. First, the accumulation of deposits must be reduced. This may be achieved by higher efficiency filtration media (such as Gore® Conical and Cylindrical Filters Pairs) and more aggressive offline water washing with a cleaning solution tailored to the deposits. Second, the presence of water (i.e. moisture) must be reduced. Water washing should be followed by operation to ensure all moisture is evaporated. Water repelling filtration (such as Gore® filtration media) may reduce some of the water ingestion during wet weather, and may also prevent some of the influent from cooling tower drift (Gore® filtration medial is quite expensive, so a cost-benefit analysis may be required to justify the additional expense). Long idle or layup periods should be combined with closure of the bellmouth and with a dry air source (heater or dehumidifier) to ensure that corrosive deposits are not activated. Mist eliminators and auto-close stack dampers are also beneficial, and should have some effect on reducing the ingress of moisture into the combustion turbine unit.

Figure 9. Image shows a pre filter used to collect the majority of airborne particulates. This would not be the appropriate filter in a moist environment. Braden also manufactures the PFS-4P for high moisture environments.

Get In and Get Dirty!

Ronald Landing, P.E.
Senior Consulting Engineer

You can't always send equipment to the laboratory when it malfunctions. Often, it takes being on site and climbing into the equipment to fully understand the problem and its extent. The engineers, scientists and technicians at M&M Engineering Associates, Inc. crawl through all kinds of equipment to examine, test and evaluate damage. Like a doctor looking for symptoms of a disease, we are looking for information that will lead us to the mechanism responsible for the damage. As technical professionals focused on metals and materials, we inspect and test for cracking, corrosion, distortion, and oxides or deposits that will point to the damage mechanism and possibly track down the root cause of a failure.

Boilers are constructed of tubes, tubes, and more tubes. Testing, examination, and inspection can consume a large amount of outage or turnaround time. On-site nondestructive and metallurgical testing is enhanced by the presence of a knowledgeable engineer who can provide real-time interpretation of the damage and aid in repairs or replacements.

Heat recovery steam generators (HRSG) have limited access, finned tubes, and tightly packed headers. Therefore, HRSG's have their own set of inspection and examination needs. Thinning due to flow accelerated corrosion (FAC) and cracking due to corrosion or fatigue can be hard to find in such tight spaces.

Figure 1. Batch digesters require protective overlay weld installed periodically. This welding requires on-site metallurgical quality assurance to confirm the correct alloy, overlay thickness and weld quality.

Pressure vessels and tanks, their non-pressurized brethren, can have both internal and external corrosion problems, as well as issues with corrosion cracking and erosion. Even just locating the damage takes knowing where to look. Pressure vessels are critical pieces of equipment not only because of their importance to the plant process, but also their potential to explode. Tanks, while less prone to catastrophic failure, may have massive amounts of liquid that can quickly become an environmental headache.

The right knowhow is a must have when something is broken and you need answers yesterday. If you need someone to get in and get dirty, give M&M Engineering a call..

Figure 2. HRSG finned tubes burned away after plugging for thinning.

Figure 3. Vacuum sucks! A tank with an inward wall collapse required an on-site failure investigation to help determine the cause and repairs required.

New Employees Join M&M Engineering

Kaye Emmons joined M&M Engineering Associates, Inc. in September 2012 as a Senior Consulting Specialist. Kaye brings in-depth experience with equipment, operations and maintenance at combined cycle power facilities to the M&M Engineering team. She has over 25 years experience in the power generation field, including safety and environmental compliance, water treatment programs and monitoring, maintenance management, field operations and equipment commissioning, and plant management. Throughout the course of her career, she often participated in both EHS and O&M audits, as well as, Root Cause Analysis exercises. Utilizing her background and experience, Kaye will be supporting M&M Engineering in the development of Operations and Maintenance assessments for power facilities and business development in Latin America. Kaye holds a bachelor's degree in Environmental Management from the University of Houston, Clear Lake. She has spent 10 years working in Latin America, and is fluent in Spanish. Prior to joining M&M Engineering, Kaye was the Regional Engineering Manager for 5 facilities in Mexico, concentrating on long-term engineering and equipment management projects. Before that, she was a Plant Manager for a facility in southern Mexico, and the Engineering Manager at another Mexico plant where she implemented multiple QA/QC programs for maintenance outages and a Management of Change policy and procedure. In her spare time, Kaye enjoys spending time with her daughters and grandchildren, playing with her two dogs, cooking and playing piano.

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Fall is Here!

Don't forget
to turn **back** the clock
one hour

on
November 4, 2012
At 2:00 a.m.

Oscar Quintero joined M&M Engineering in September 2012 as a Metallurgical and Materials Engineer.

Oscar holds a Master of Science in Metallurgy and Materials Engineering from the University of Texas at El Paso (UTEP) and a Bachelor of Science in Electrical Engineering with an emphasis on Semiconductors from UTEP. His interest in Metallurgy and Materials Engineering began before finishing his Electrical Engineering degree, when he discovered the world of Failure Analysis during a technical elective course in Materials. After that, he never looked back. His graduate school course work included the study of superalloys, failure analysis, biomaterials, iron and steel production, and systems engineering management.

Prior to joining M&M Engineering, Oscar worked for Bell Helicopter at the Fort Worth, Texas facility doing Failure Analysis on helicopter parts (customer returns, parts from manufacturing, and fatigue tested parts), as well as Accident Investigations. He has also worked for Delphi Automotive Systems at the Mexico Technical Center in Cd. Juarez, Chihuahua, Mexico conducting Failure Analysis and Materials Characterization for automotive parts.

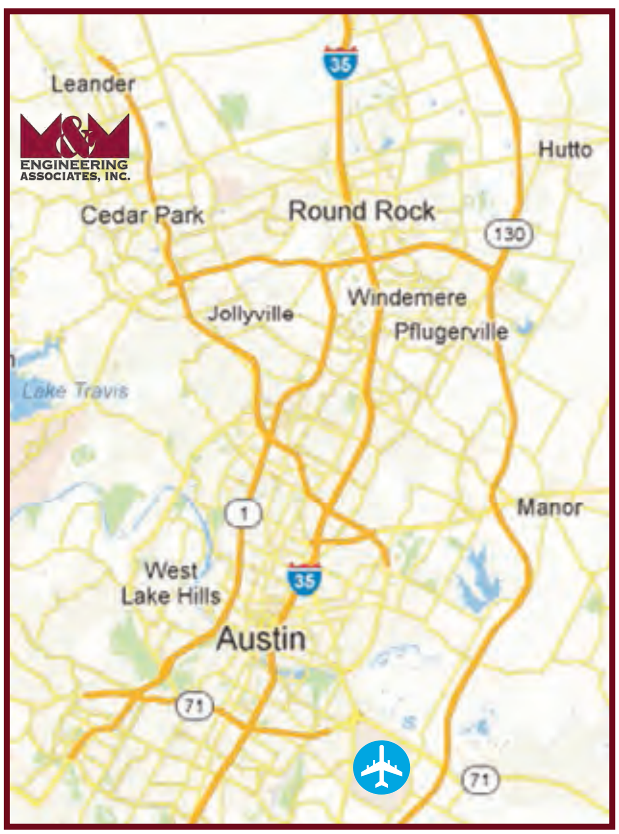
In his free time, Oscar enjoys spending time with his wife Adriana. They both enjoy dining, museums, hockey, movies, and music. Oscar also enjoys going to concerts, and reading about failure analysis.

Our New Home!

1815 S Highway 183, Suite 100

Leander, Texas 78641

With rent in Austin increasing, after nearly eleven years at our Howard Lane facility, M&M Engineering decided to look at other facility options in the Austin area. We looked in many of the surrounding communities, Pflugerville, Round Rock, Cedar Park and Leander. After almost a year of searching, we found a beautiful building in Leander, Texas.



Leander is a small community just northeast of Austin established in 1882, though the first settlers arrived in the area around 1845, having received bounty land grants in exchange for service in the Texas Revolution. Today Leander has a population of over 30,000 and, according to the 2009 US Census, it is the 37th fastest growing city in the United States. The City has been very welcoming. The Leander Development Board, Chamber of Commerce, Fire and Police Departments, all of which are right down the street, have been great to work with.

We made some renovations to the facility to accommodate our laboratory and machine shop.

This gave us the opportunity to install new hoods and revise the layout of some of our equipment.

We now have a conference room that will comfortably seat 12 people and is separate from our library area which is located on the second floor. These had shared the same space at our old facility. A portion of the building is subleased to a tenant that had been occupying the space prior to our moving in. We extended the lease but eventually this area will provide space for expansion for M&M Engineering. This may be coming sooner than expected as we just added two new technical staff members with another new hire joining us in November.

The new building is ladder block design. You can watch a slide show of our building being built at http://www.ladderblock.com/photos.htm. The concrete strut design allows complete reconfiguration of the internal walls, so remodeling is very easy. The building was designed with

Conference Room

many green features including a solar reflective metal roof guttered to collect rain water in two silos at the south end of the building, rainwater collection system that is valved into the landscape watering system, landscaping using native Texas plants, window awnings, and covered walkways that provide shade for the building's low-E double paned glass front which provides natural lighting to the office spaces.

Our office is now approximately 30 miles from the Austin Bergstrom International Airport and just 10 miles north of our old facility. We are also approximately one half mile from the Capital MetroRail commuter station that services multiple stations between Leander and downtown Austin. While we are no longer in the "big city," we have numerous restaurants and shopping areas nearby. The local Starbucks® is 3 doors down, just shy of the pizza parlor.

New Holiday Inn and Candlewood Suites hotels are located less than 5 miles away. The next time you are in the area, please stop by and say hello.

Wet Lab

Laydown Area

Machine Shop

Seminars & Workshops

Max Moskal and Ronald Lansing presented at the TAPPI PEERS conference in Savannah, Georgia on October 14th through October 18th, 2012. Max presented an informal hot topics session on boiler tube stress-assisted corrosion. Ron was a presenter in the Corrosion & Materials Engineering workshop on flow accelerated corrosion in boiler feedwater and HRSG systems. TAPPI is the engineering association for the Pulp and Paper industry and M&M Engineering has made a commitment to keep up to date by yearly participation and leadership in the Corrosion and Materials Engineering sub committee. Max has been an industry leader in TAPPI Engineering for the last thirty years.

Max Moskal attended the fall meeting of BLRBAC (Black Liquor Recovery Boiler Advisory Committee) in Atlanta, Georgia on October 1st through October 3rd, 2012. This year celebrates BLRBAC's 50th Anniversary (1962-2012).

David Daniels will be presenting a paper at the International Water Conference (IWC) entitled *Proper Sampling Makes a Difference* in San Antonio, Texas on November 4th through November 8th, 2012. Mr. Daniels will also be teaching a workshop at the conference entitled *HRSG and High Pressure (Above 900 psig/60 bar) Boiler Water Treatment and Operation.*

David Daniels' article *Water and Power: Will Your Next Power Plant Make Both?* for *Power* magazine (published in the September 2012 edition) is now available for your reading pleasure at www.mmengineering.com under the *Announcements* section.

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

Save the Date

Failures in Power and Steam Generation Workshop

M&M Engineering will be hosting its 2nd annual training class on *Failures in Power and Steam Generation* in the spring of 2013 in Austin. Topics include discussing failures for the following equipment and processes:

- Steam Cycle Corrosion
- Deaerators
- Feedwater Heaters
- Steam Kissed Boiler Tubes
- High Energy Piping
- Water Kiss Boiler Tubes
- Water Chemistry 101
- Steam and Gas Turbines
- Condensers and Cooling Water

Please keep us in mind when planning your training budgets for next year.
Additional details will follow in the next issue of the Conduit.

the Conduit is distributed free of charge by M&M Engineering Associates, Inc.. We welcome your comments, questions, and suggestions, and we encourage you to submit articles for publication.

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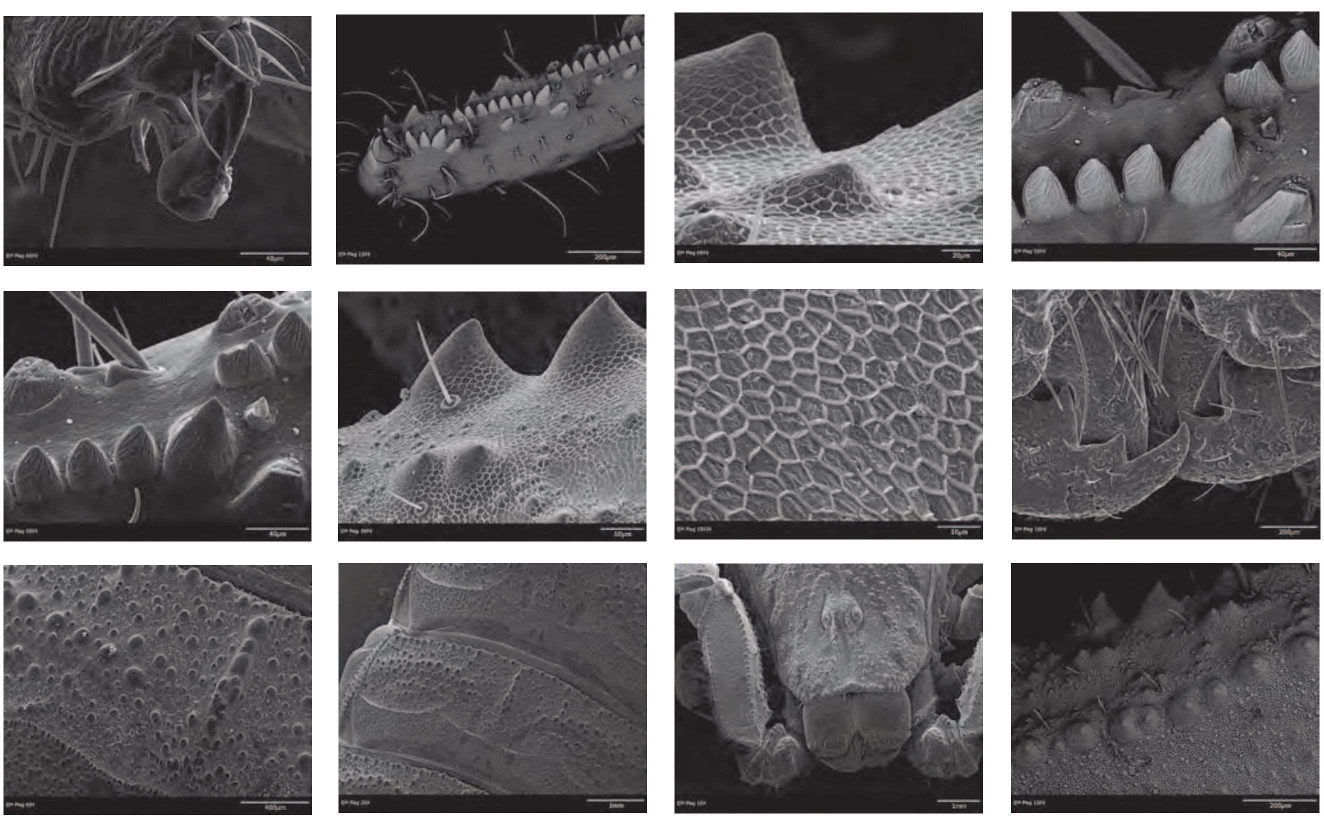
Which creepy crawly am I?



Answer: Striped Bark Scorpion C. vittatus

Images captured using a Scanning Electron Microscope.