the Conduit

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INSIDE THIS ISSUE:

Using Risk-Based Analysis Tools For Managing Rotating Equipment Outage Intervals

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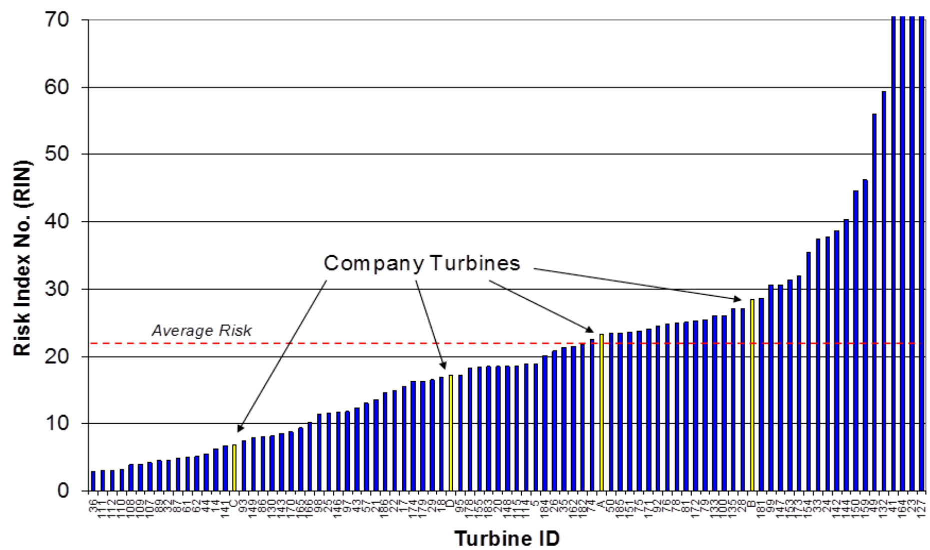

STRAP benchmarking of turbines. Which turbines can go longer between overhaul outages? What needs to be done to lower the risk for my highest risk turbine? What is driving my risk?

THE PROBLEM: With the highly competitive nature of today's markets, companies cannot afford to perform major rotating equipment outages too frequently. The outages are expensive to execute and you may incur additional expenses and/or lost revenue while the unit is off-line for the outage. Of course, waiting too long to perform an outage may result in more damage to repair, or worse, having to undertake a forced outage to repair disabling damage. However, over the past decade, it has been demonstrated that steam turbines and generators can successfully run longer than 5 to 6 years between major outages. In fact, many are now reliably running eight to ten years between major overhauls. So, how do you decide what is the right interval to accomplish major outages for each critical piece of rotating equipment and how do you ensure that the longer outage interval is reliably and safely achieved? How does your equipment and engineering practices compare to other companies with similar equipment?

THE SOLUTION: Utilizing risked-based analysis tools can provide guidance on what and where the risks are, how the time between major outages can be extended with minimal changes in risk, how the risk levels for potential lost revenue can be reduced, and how to prioritize maintenance, monitoring, upgrades, and sparing decisions so that company resources can be cost effectively justified and applied to equipment with the most need. M&M Engineering has developed several of these risk based analysis tools for the assessment of Steam Turbine Generators; STRAP (Steam Turbine Risk Assessment Program) and TOOP (Turbine Outage Optimization Program). For centrifugal and axial compressors, M&M Engineering developed the RAC (Risk Assessment of Compressors) program.

WHY RISK-BASED PROGRAMS?

These programs were developed by HSB and M&M Engineering Associates, Inc. to provide a consistent, independent evaluation of steam turbine, generator, and compressor risks. Most machines are capable of running longer between outages, but

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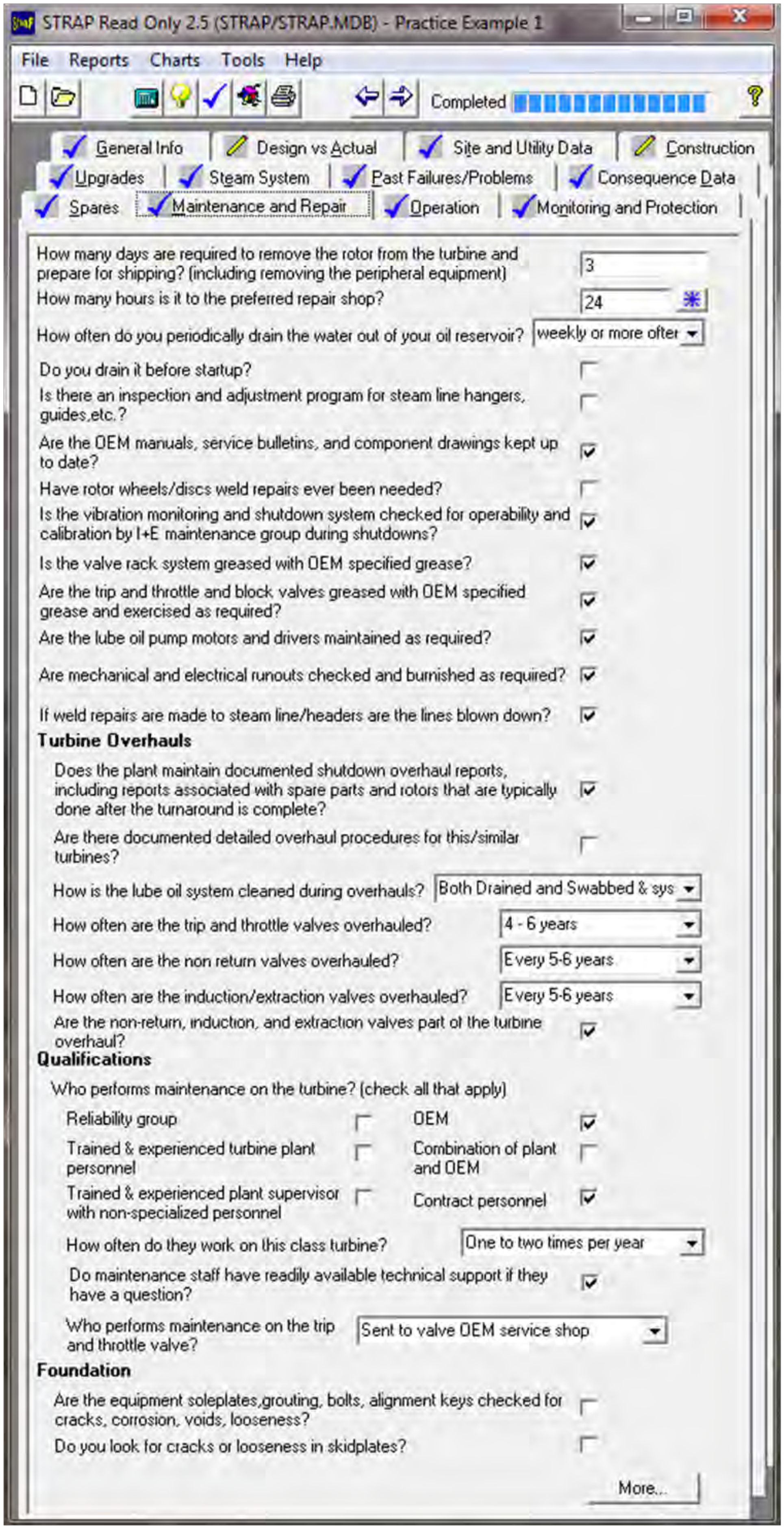
there have not been consistent and objective means of quantifying that capability. Equivalent operating hours (EOH), fixed time intervals, OEM and consultant estimates alone have been subjective and not cost effective for scheduling outages. Risk models can quantify that capability because they are inherently concerned with probabilities of failure, consequences of those failures, and the factors that may increase or decrease the failure probabilities and/or consequences. Risk models combine technical and reliability factors with financial consequences to arrive at the best possible decision.

WHAT ARE THE STRAP, TOOP, AND RAC PROGRAMS?

These programs consist of algorithms that calculate risk (risk = probability of failure x consequence) for steam turbine generators and compressors from the data (probabilities of failures, failure consequences, and engineering modifying factors) included in the programs. These engineering factors take into account machine specific history, design, inspection, spares, and upgrades, etc. along with company maintenance, operation and monitoring practices. These factors are determined by completing a risk-based questionnaire for the specific machine being evaluated.

The reliability and risk factors were developed by HSB, leading members of the power generation industry, process (refinery, petrochemical, chemical products), and repair industries, drawing on their skills and experience together with M&M Engineering Associates' failure analysis and risk assessment experience and HSB's decades of experience as an insurer of these machines. The HSB,



M&M Engineering, and industry team experience was leveraged to establish what attributes are important and necessary for a unit to achieve a longer time between major outages and corresponding lower risk levels. These attributes were converted into risk modifying factors to view specific rotating equipment on a holistic basis-design and construction, operation, maintenance, monitoring, and condition at past outages. The factors were calibrated with analyses of units of all kinds. The models and associated risk levels were then grounded with units that have run longer intervals.

The risk models were developed based on ASME's Risk Based Inspection Guideline methodologies. The models have been the subject of technical papers or presentations at ASME, EPRI, NUSIS, PowerGen, SAE, TAPPI, API, and Turbomachinery conferences.

Analyses have been completed for over 282 steam turbines, 111 generators, and 62 compressors. These results reflect 21 turbine manufacturers, 11 generator manufacturers, and 10 compressor manufacturers.

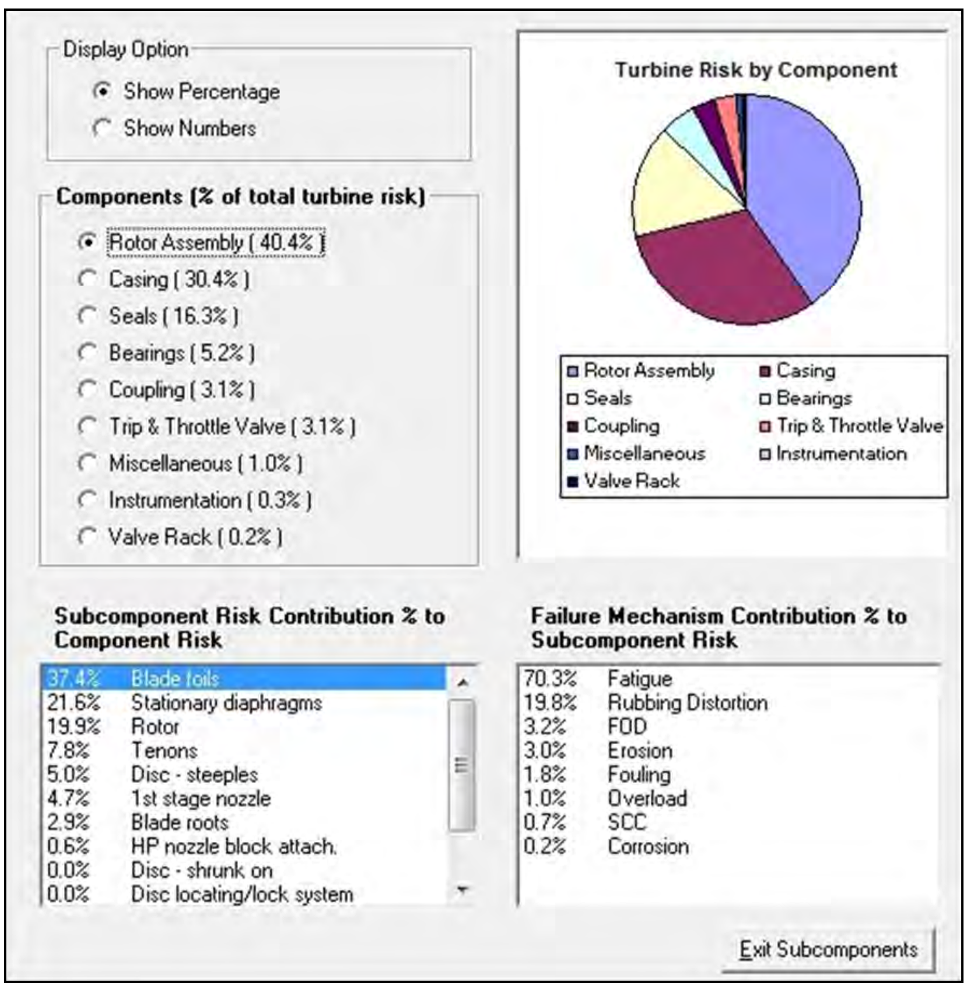
What is the Process for the Risk-Based Evaluations?

First, an initial evaluation is accomplished. M&M Engineering personnel visit the plant to obtain the information necessary for completing the risk-based questionnaires. Typical information reviewed or discussed during plant visits includes: past major and minor outage reports; current mechanical and electrical maintenance practices including outage workscope and inspections; past operational history

EXAMPLES OF RISK MODIFYING QUESTIONS:

- *Is the steam monitored for cation conductivity? (Yes or No)?*
- *Is the monitoring continuous, per shift, or daily?*
- *Has this turbine experienced any shutdowns due to fouling (Yes or No)?*
- *Is your vibration monitoring (periodic, continuous, or both)?*
- *Is the turbine steam from (dedicated boiler, process or dedicated waste heat boiler, multiple sources, external supplier)?*
- *Was anything found during the last overhaul that could have led to a failure (i.e. cracking, severe erosion, severe corrosion, etc.)?*
- *Is the trip and throttle valve exercised (weekly, monthly, quarterly, not exercised)?*

Risk Assessment Database	Total	OEMs	Failures
Steam Turbines	282	21	613
Generators	111	14	24
Compressors	62	10	25



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(vibration, lube oil condition, water chemistry, starts, overspeeds, testing, problems, etc.); monitoring capabilities (health detection and protection); log sheets; and walk-down of the unit and the associated piping and controls. After the questionnaires have been completed, the risk levels are calculated and a preliminary report is provided to the plant for review. After incorporation of any corrections or changes to questionnaire responses and buy-in by the plant on the required recommendations and timing to implement, a final calculation is performed and a final report issued.

WHAT ARE THE DELIVERABLES FROM THE RISK-BASED EVALUATIONS?

The risk-based reports identify the components and subcomponents of most concern, failure mechanisms, and operating regimes that are the major risk drivers for the rotating equipment, as applicable. The recommended time interval to the next outage is specified along with recommendations to reduce these risks through improved maintenance practices, additional monitoring, plant improvements, spares support, and upgrades. Extensive benchmarking of equipment with a company's fleet of machines and with industry machines equipment type, size class, and OEM in the STRAP/TOOP/RAC databases is also provided.

WHAT IS THE VALUE PROPOSITION?

In principle, there are three ways extending outages saves money; first, there is the time-based valued of designated overhaul/expense funds for each time period the outage interval is extended; second there is the increased availability of the unit for the same period; and thirdl there are the savings of eliminating 1 to 3 outages over the remaining life cycle of the machine. The time-based value of funds represents the value of designated funds not spent on the overhaul or having to buy electricity during the overhaul. Similarly, if there is additional lost revenue because of not selling power to a utility or loss of efficiency costs (higher fuel costs because of using PRV stations instead of the turbine), the time-based value of those funds or increased availability is also a savings. If the extended outage interval is extended for the life cycle of the machine, those time-valued savings will apply to each outage. The largest savings, however, are from eliminating major outages over the life cycle of the machine.

EVERGREEN MODEL!

The algorithms used for the risk assessments are evergreen. As new data is collected or technology is available, the models are modified or confirmed as accurate. New risk modifying questions are asked, potential answers are added, and as more operating years of data are gathered probabilities are modified. For example STRAP now has over 3800+ turbine operating years. There have been over 430 failures (a failure is an event that caused lost production) with information surrounding the failures captured. Examples of other data collected: 22 outages have been extended because of failures or damage found during the outage, two turbines have operated in rotating reverse, one turbine had an overspeed event, two turbines had water inductions, and five compressors had liquid slugs. Tracking events such as these assists in updating and refining the model.

Failure Analysis Case Study: Pulp Mill Stainless Steel Warm Water Tank Leaks

By Ronald Lansing, P.E.
Senior Consulting Engineer

M&M Engineering was asked to determine why a client pulp mill's only Warm Water tank had been "weeping" (arrow in Figure 1) for more than a year. The tank was central to the mill feed water system and there was no back-up water tank. The mill was in an ocean side environment and they had thought the sea air was causing the leaks.

The tank was 20 foot diameter and approximately 60 feet tall composed of Type 304L stainless steel courses. The welding process was not specified on the construction drawings; however, the welds appeared to have been automatic inert gas arc welds (MIG). The tank held 120°F warm untreated water drawn from a reservoir with maximum water temperatures of up to 140°F. Water testing the previous year had found 7 ppm chloride content and a pH of 5.8.

M&M Engineering visited the mill to visually examine and nondestructively test the tank internally and externally. Areas were tested using dye penetrant (PT) and multiple indications were observed (Figure 2). A coupon was removed for metallurgical laboratory examination.

The coupon through the lower course horizontal weld found multiple branched transgranular

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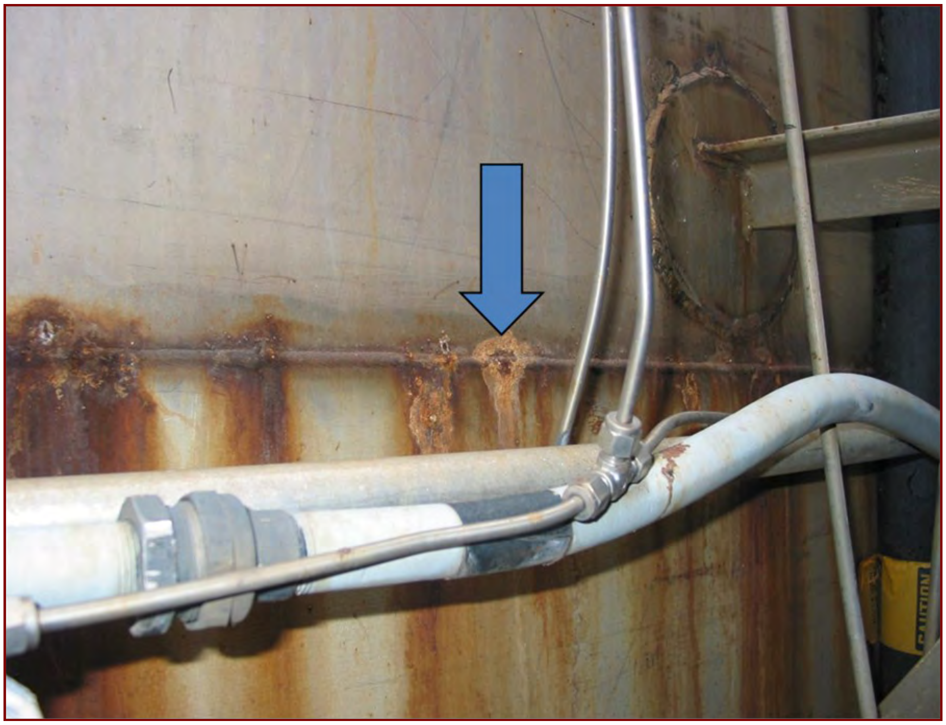

Figure 1. Close-up of leaks at first course weld.

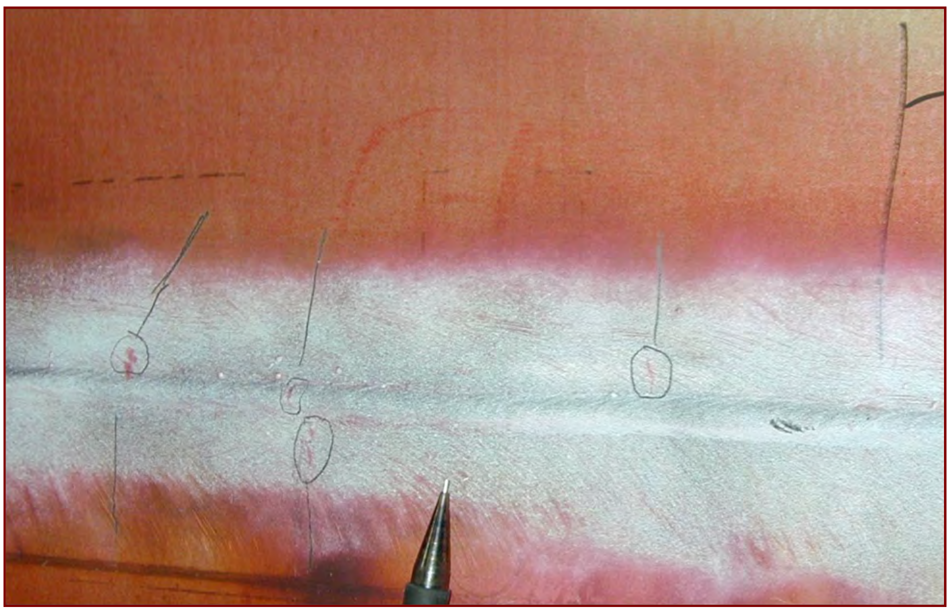

Figure 2. PT indications adjacent to sample location.

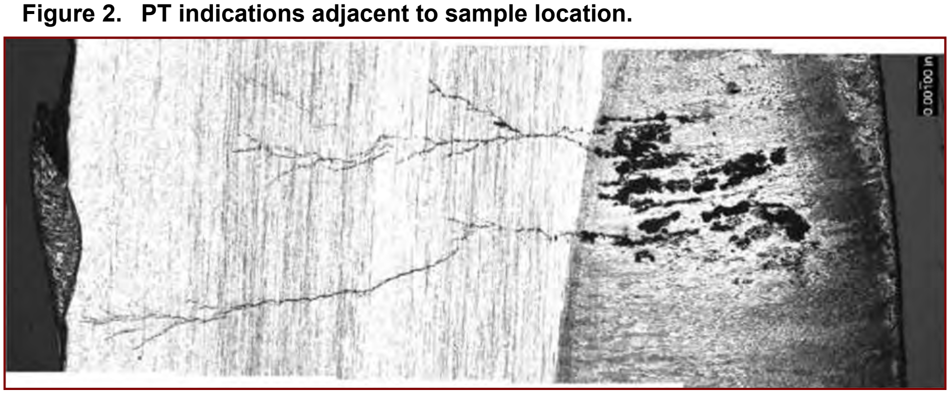

Figure 3. SCC progressing from inside weld porosity out toward the outside surface (left).

cracks characteristic of stress corrosion cracking (SCC). The leaks were caused by SCC propagating from the internal welds toward the outside surface of the tank (Figure 3). Type 304L is susceptible to chloride SCC, increasing with elevated temperature (100°F plus) and chloride concentrations (<5 ppm).

The cracks were found to originate in areas characteristic of weld porosity and/or Microbiologically Induced Corrosion (MIC). High chloride concentration in the original weld porosity or MIC defects were the most likely cause for the SCC. Water analysis showed chloride (due to chlorine only) levels at 7.0 ppm. Levels of chloride in the water may have been greater than this since chloride content should be based on total chlorides present and concentration of chlorides in the confined porosity could have occurred. *In situ* chemical analysis using a scanning electron microscope with energy dispersive chemical spectroscopy (SEM/EDS) suggested that similar trace amounts of chloride were present in the cracks and in crack covering interior surface deposits (tubercles).

The tank was replaced since the SCC was wide-spread and not repairable. The problem can be avoided with the use of a more SCC-resistant material or, if MIC was present, biocide water treatment could be used.

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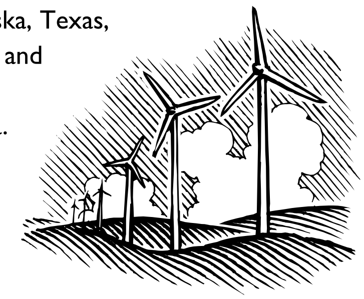
Announcements

This past August, Metallurgical Technician, Kristin Cockrum passed her AWS CWI exam using the D1.1 Structural Welding Code and is now officially a Certified Welding Inspector. In December 2011, she also completed an Associates of Applied Science Degree in Code Welding with an emphasis in Inspection and Non-Destructive Testing. Along with this degree, she passed the course necessary to become a Level I certified NDT Technician. At the completion of the current semester, she will become a Level II certified NDT Technician.

New Employees Join M&M Engineering

Ken Steele joined M&M Engineering Associates, Inc. on January 3, 2012 as a Principal Specialist. Ken Served in the United States Navy for 20 years before retiring as a Senior Chief Machinist Mate. During his service in the Navy, Ken operated and maintained main propulsion and auxiliary steam turbines and diesel power generation equipment. He joined the Hartford Steam Boiler Inspection and Insurance Company (HSB) on July 10, 1978 as a Boiler/ Machinery Inspector and eventually was designated as a Senior Technical Risk Consultant. In 2005, American International Group (AIG) purchased HSB and Ken continued to serve AIG in the same capacity. On January 2, 2012, Ken retired from AIG.

Over the past 34 years, Ken has been responsible for accessing and determining the risk of multiple fossil fuel and gas fired utility power generation facilities as well as simple cycle and combined cycle gas turbine installations, hydro electric power stations and wind turbine generation units. Until his retirement from AIG, Ken held a National Board Commission and State commissions in Colorado, Nebraska, Texas, Kansas and South Dakota.



We're Moving!

1815 South Highway 183, Suite 100
Leander, Texas 78641

M&M Engineering Associates, Inc. will be moving into a new building next month! Leander is a small community just north of Austin. It is easily accessible from the Austin International Bergstrom Airport via the toll road or Highway 183.

We are very excited about the move as the new facility has 1,000 more square feet than our current facility. The building has a green design complete with a rain water collection system for landscape and irrigation purposes. There will be a feature article complete with photographs in the next issue of *the Conduit*.

Seminars & Workshops

Catherine Noble co-presented at the HRSG User's Group Annual Conference & Expo in Houston, Texas on February 27, 2012. She discussed development and welding issues of Creep Strength Enhanced Ferritic (CSEF) steels with a focus on T23/P23 material for the Regulatory Updates Affecting HRSG Users Pre-Conference Workshop.

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

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