SPRING 2011 VOLUME 30

NEWS & VIEWS

Structural Integrity Associates, Inc.®

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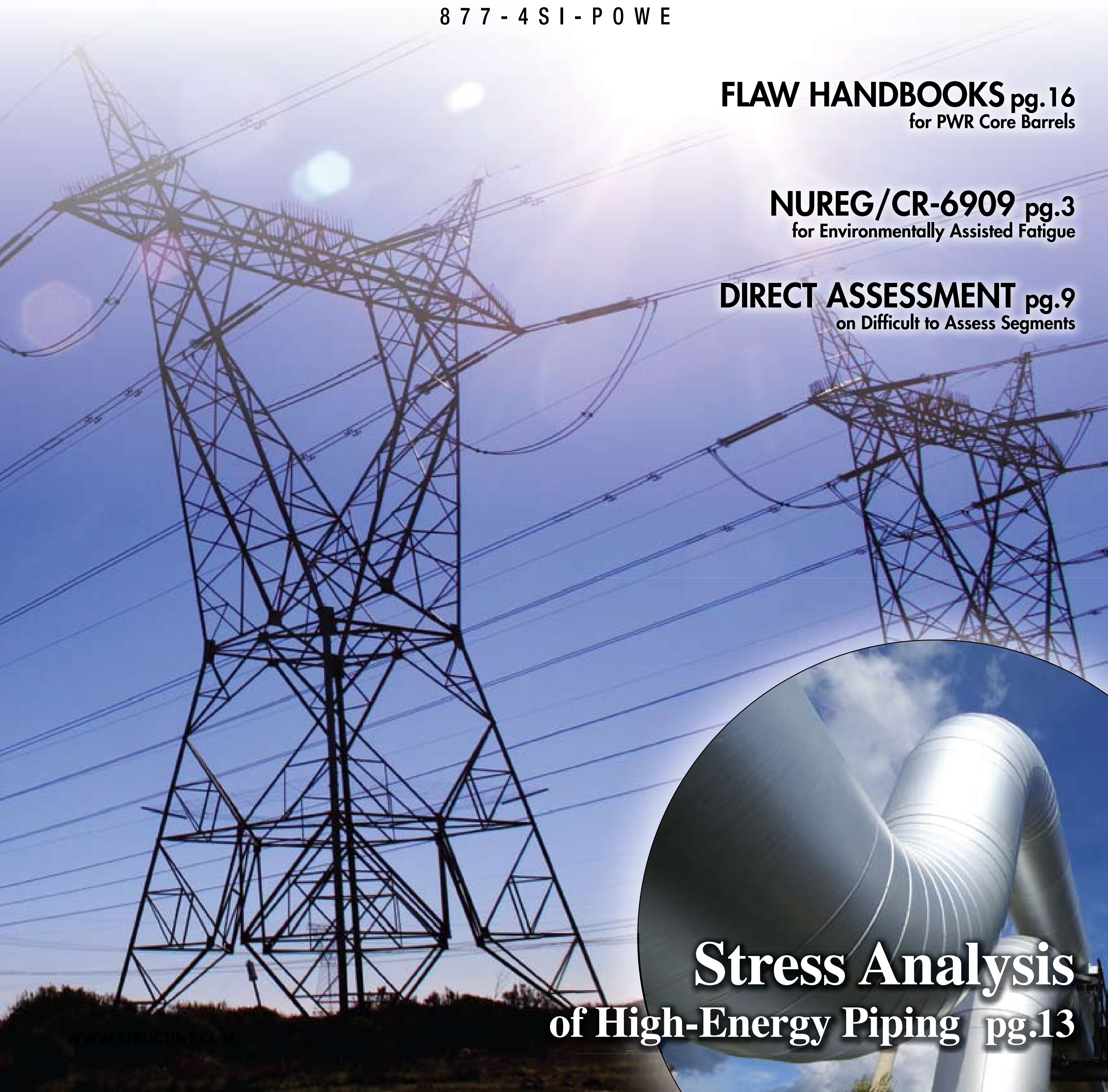

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By: LANEY BISBEE
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Company Size – Does it Matter?

I get a lot of questions about Structural Integrity and over time, I have developed a pretty comprehensive list of answers to address them. But there's one question I struggled with when making an "Introduction to Structural Integrity Associates, Inc." video back in 2006. Is SI a small or large company? A definitive answer is no clearer to me today than it was back then, but now I'm more accepting of the apparent ambiguity because I see clear benefits to each.

With 230 staff, ten offices, numerous partnerships, overseas affiliates, we might be considered large when compared to other privately owned consulting firms but small when compared to OEMs or A/E firms. I have no doubt that there are definitely benefits of being both larger and smaller than our competitors, and I believe our clients would agree.

STRUCTURAL INTEGRITY AS A LARGE COMPANY, OUR CLIENTS BENEFIT FROM:

- Our in-house breadth of expertise in a wide range of complementary technical areas, including all engineering disciplines, nondestructive testing, instrumentation, plant operations and maintenance, codes and regulatory issues, research and development, laboratory evaluations and litigation support,
- Our equally varied staff of entrepreneurs, technical and subject matter experts, innovators, and emergent talent and support staff at all levels,
- A project management infrastructure that ensures our clients receive consistent, responsive support,
- A balanced diversification strategy that identifies market specific issues and develops innovative solutions, and technologies that can be transposed to address challenges in other energy markets.

The diversity in competencies, disciplines and expertise enables us to deliver a vast range of innovative, fully integrated, problem specific solutions that smaller consulting firms can't touch.

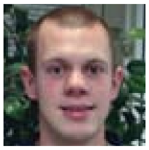
HOWEVER, STRUCTURAL INTEGRITY AS A SMALL COMPANY:

- We are agile and can respond rapidly to client needs without the corporate barriers and proprietary information constraints that exist in larger, sluggish companies.
- We know where to quickly find the right in-house expertise and how to directly engage them to build a team for a timely solution, and we can be reached any hour of any day.
- We maintain more business intimacy, internally and externally, resulting in a more responsive, flexible, collaborative and client-specific service and experience.

When you call us, you can expect the client-centric response of a small service-oriented supplier with world class capabilities rivaling the nation's largest engineering companies in our areas of expertise. In the end, we're best characterized as being the right size company that is ready to help.

NUREG/CR-6909

FOR ENVIRONMENTALLY ASSISTED FATIGUE



By: MATTHEW WALTER
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As part of the process of renewing the operating license for an additional 20 years after the original 40-year license term, nuclear plant owners are required to show that they are managing the effects of aging of systems, structures, and components. The NRC issued NUREG-1801, Generic Aging Lessons Learned (GALL), Revision 2 in December 2010.

This GALL identifies acceptable aging management programs, including programs for fatigue and cyclic operation. This includes fatigue usage analyses that account for reduced fatigue life for components in a reactor water environment. Earlier revisions of the GALL report identified the need for plants to perform environmentally-assisted fatigue (EAF) analyses. It indicated that an acceptable means for performing these evaluations was to use the guidance in NUREG/CR-6583 (for carbon and low alloy steels) and NUREG/CR-5704 (for austenitic stainless steels), which were developed in 1998 and 1999, respectively. GALL Revision 2 specifies that the rules in NUREG/CR-6909, issued in 2007, be used for nickel alloy materials, and allows its use for carbon, low-alloy and stainless steels as an alternative to NUREG/CR-6583 and NUREG/CR-5704.

Structural Integrity Associates, Inc., (SI) is currently performing EAF calculations for the Limerick generating station, Units 1 and 2, using NUREG/CR-6909 as part of Limerick's license renewal application (LRA) which is scheduled to be submitted to the NRC in September 2011. This represents one of the very first uses of NUREG/CR-6909 for all material types by a license renewal applicant.

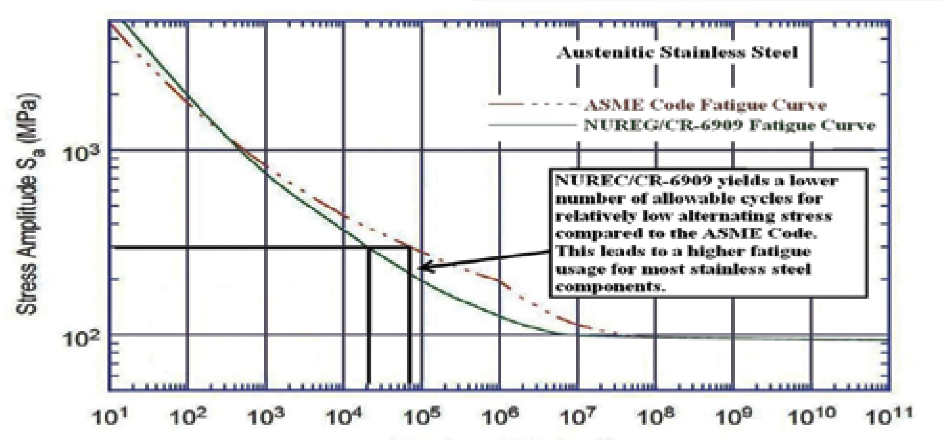
NUREG/CR-6909 differs from the NUREG/CR-6583 and NUREG/CR-5704 in two basic ways:

1. Fatigue curves have been modified from the ASME Code to more accurately reflect the effect of light water reactor (LWR) environments on fatigue resistance of materials.
2. Fatigue life models have been updated to reflect more recent experimental observations and data trends. The environmental correction factor, F_{en}, equations have been modified accordingly.

Based upon work we performed, when converting from ASME Code fatigue curves to those in NUREG/CR-6909, fatigue usage values were lower for low alloy steel components, lower for stainless steel and nickel alloy components when the transient events contributing to the majority of fatigue usage have relatively high alternating stress, and higher for stainless steel and nickel alloy components when the transients contributing the majority of fatigue usage have relatively low alternating stress.

Parameters such as material type, thermal transient temperatures, strain rate, dissolved oxygen content and dynamic loading all have an effect on F_{en} values. In order to reduce conservatism in the fatigue analysis, these parameters need to be determined and refined such that the environmental penalty factor, F_{en}, remains low.

We analyzed both piping and reactor vessel components for Limerick Units 1 and 2. Nearly all components yielded acceptable results by performing a NUREG/CR-6909 fatigue analysis. A few components required a more refined analysis to show acceptable results. This project represents an early real world application of NUREG/CR-6909 and perhaps the first for a license renewal applicant. Environmentally assisted fatigue is just one area in which Structural Integrity can assist utilities in the preparation of their LRA for additional years of plant operation.



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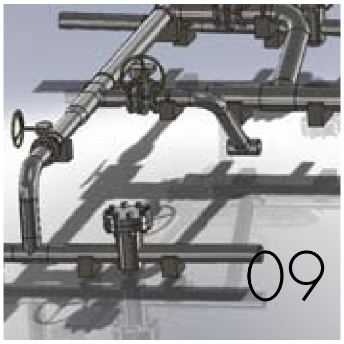

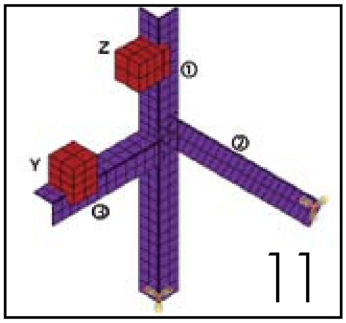

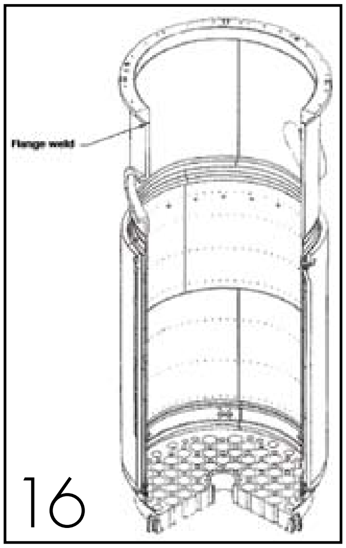

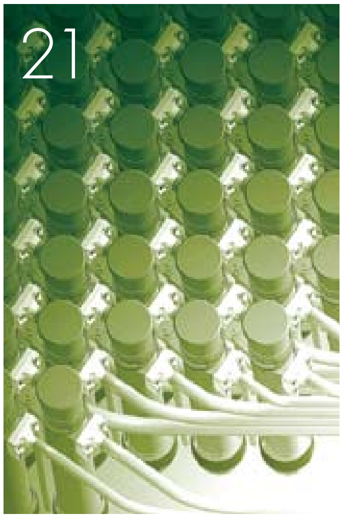
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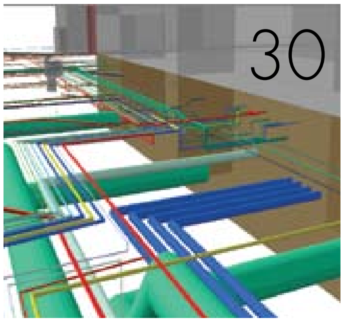
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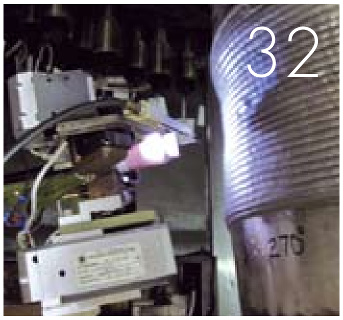
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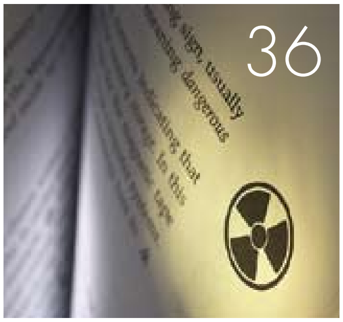
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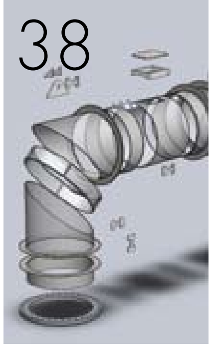
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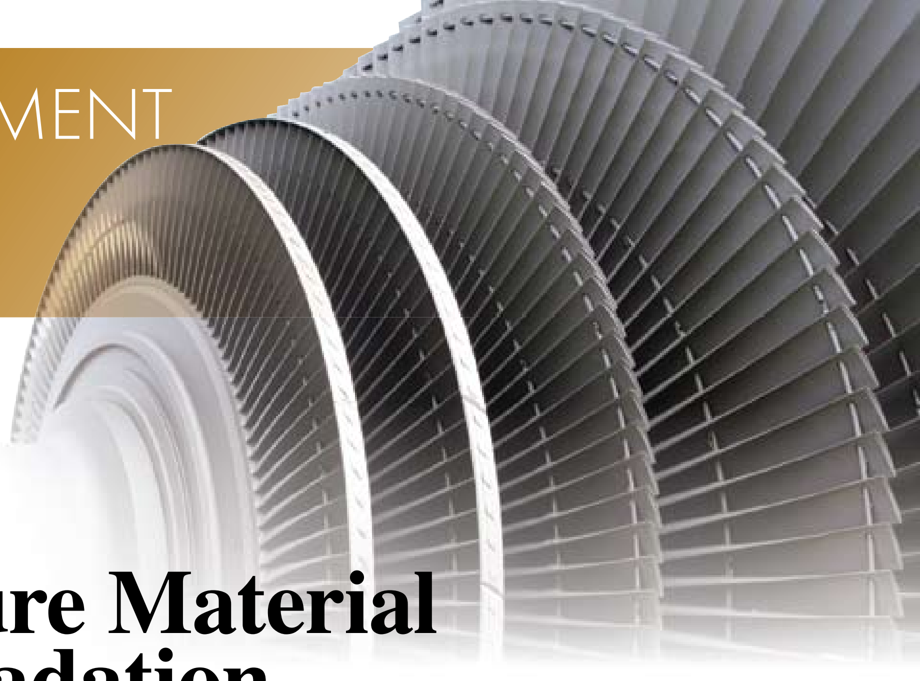

High Temperature Material Properties Degradation

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Important considerations in typical turbine and generator rotor condition assessments generally involve:

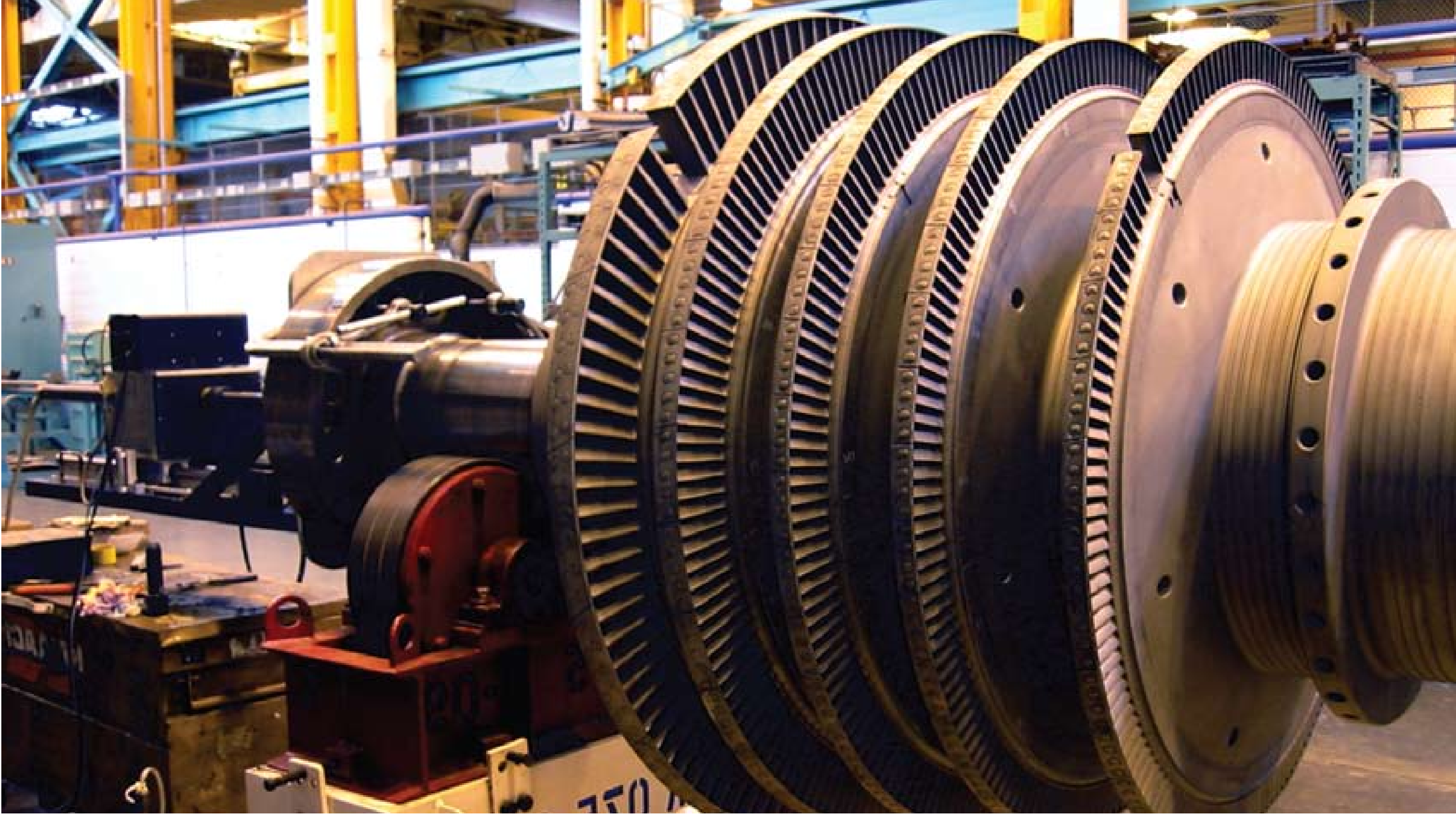
- nondestructive evaluation (NDE) of critical locations
- stress analysis, as appropriate to the location,
    - rotational stresses
    - bending stress
    - thermal stresses
    - possibly vibration stresses
- fracture analysis, also based on location, including
    - low cycle fatigue associated with start/stop operation
    - high cycle fatigue associated with once per revolution bending or vibration
- flaw link-up analysis

These are mechanical considerations that vary from rotor to rotor depending on the specific operating considerations and material properties of the rotor forging. However, in these 'typical' assessments, the material properties are assumed constant over time. Another consideration, and one that is frequently not considered but is becoming increasingly important, is that of damage by high temperature mechanisms that cause gradual degradation of the material properties over time. So, while the more typical assessment involves flaw assessment under known operating conditions and specific, constant material properties, the second involves degrading properties and therefore diminishing the capacity to sustain a specific flaw.

The purpose of this article is not to describe relevant, operative, high temperature damage mechanisms in great detail, but simply to provide sufficient information to enable a reasonable understanding of the significance of these mechanisms and the source of increasing concern for potentially susceptible rotors. Two high temperature mechanisms can degrade the properties of a rotor; creep and temper embrittlement.

CREEP MECHANISM

Creep occurs essentially by atomic level diffusion of defects in the atomic structure. When subjected to temperatures above about 850°F and sufficient stress, vacancies (missing single atoms) and dislocations (missing groups of atoms) migrate within the atomic structure until they reach a grain boundary, at which point they are pinned.



At this stage, flaw sizes are at the atomic level, and the flaws are not observable even under high magnification. As the process proceeds, additional "flaws" continue to accumulate at the grain boundaries, eventually forming microscopic voids or cavities.

At first, these voids or cavities will be distributed relatively randomly, but eventually, as the process continues, they become "oriented", i.e., more prevalent along grain boundaries that are normal or near-normal to the principal stress direction. Ultimately, the size and density of cavities become sufficient that they begin to link to form micro-cracks, and these eventually coalesce to form macro-cracks. Once cracks are formed, they can propagate by creep, fatigue, or a combination creep-fatigue mechanism. In its initial stages, creep is considered more a materials properties degradation mechanism in that the properties begin to degrade before any measurable flaw can be detected or otherwise observed. However, once cracks are formed, creep is a double- edged sword. Not only is a flaw present, but it is growing through material that has likely been degraded via creep cavities and/or micro-cracks. Once creep damage reaches this point of progression, it accelerates and failure is typically not far behind. Because creep damage progression worsens with increased temperature, the higher temperature locations within the rotor are the most susceptible and therefore the first to experience degradation. This most often involves the rotor blade attachment dovetails in the first few stages of HP and IP sections and the associated bore regions beneath. Specifically, the HP Curtis stage and near-bore material beneath it are typically most susceptible.

Down-bore miniature sampling tool

TEMPER EMBRITTLEMENT MECHANISM

Temper embrittlement is another damage mechanism that can be operative in higher temperature rotors. Whereas creep involves diffusion of atomic level vacancies and dislocations, temper embrittlement involves diffusion of certain impurity elements (i.e., phosphorus, tin, lead, sulfur, arsenic, etc.) to prior austenite grain boundaries. Here they provide easy fracture paths, lowering fracture toughness and increasing the fracture appearance transition temperature (FATT) accordingly. Temper embrittlement typically occurs in the temperature range of 600°F - 1000°F, with the degree of embrittlement being greatest in the range of 600°F to 750°F, targeting the back ends of the HP and middle of the IP sections. It seems more than logical that increased content of tramp elements would increase susceptibility to temper embrittlement and that quantitative chemical analysis could be used to determine the level of tramp elements in the material. However, no correlation to composition with which to predict susceptibility is known to exist.

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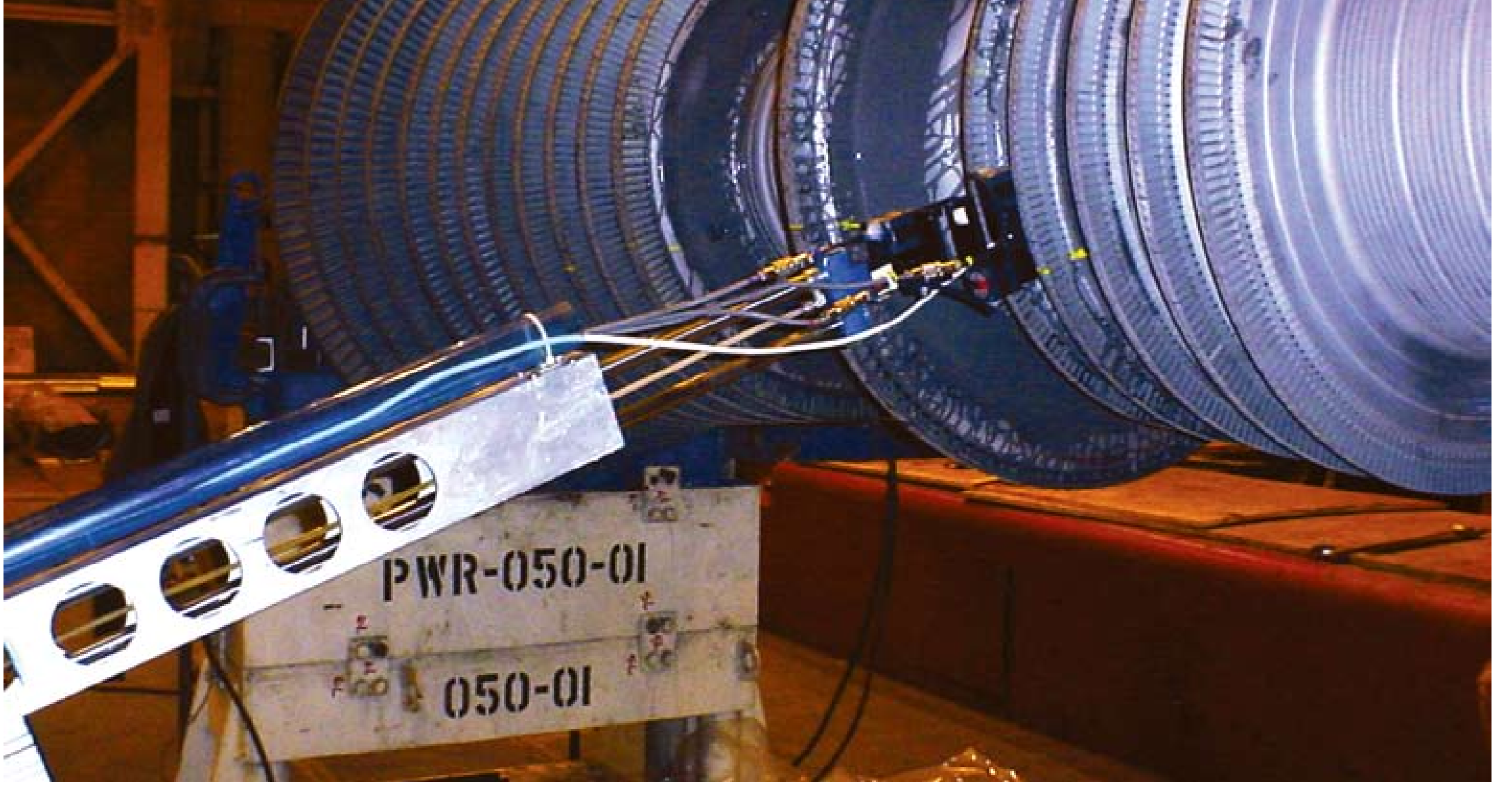

For creep damage the implications are relatively straight forward. Unfortunately, creep damage is microscopic until the very latter stages of progression. In other applications where creep is an operative damage mechanism, such as along weld fusion lines in high temperature piping system welds, special ultrasonic procedures using highly focalized beams can be used to detect creep damage once it reaches the stage of relatively heavy cavity alignment. Because the damage is contained within the narrow confines of the heat affected zone (HAZ) of the weld, it is more planar macroscopically. Consequently, it forms a more-or-less planar sheet, which can be detected using the focused beam ultrasonic procedures. In a rotor forging, there is no HAZ, and therefore no macroscopic preferential orientation. Rather, the damage is distributed volumetrically and therefore not detectable until very late in life, even using a highly focalized ultrasonic beam. Additionally, the fine spot size of the focused beam dictates very fine scan increments, resulting in very time consuming scans – totally impractical for large rotors.

Temper embrittlement similarly occurs volumetrically and degrades the properties. Consequently, either of these damage mechanisms result in a lower tolerance for flaws. The end results being that the material properties become life limiting at some point, even in the absence of detectable flaws. Any NDE inspection has a detection threshold – a flaw size beneath which the flaw will not be detected. In the absence of detected flaws, the stress and fracture evaluation is performed using this default flaw size, based on the assumption that a flaw of a size just beneath the detection threshold could unknowingly exist in the rotor. With these time-dependent damage mechanisms, it is possible, in fact assured, that at some point the critical flaw size for the degraded properties will fall below the detection threshold of the inspection, at which time the material properties become life limiting. And this is for rotors with no detectable flaws. For those having detectable (and hence larger) flaws, properties degradation mechanisms become life limiting earlier.

Why is this becoming more and more important? Very simply because we are running rotors well past their intended design lives, accumulating more hours of service at elevated temperature, accumulating creep and temper embrittlement damage, and in many cases not performing the appropriate assessments.

WHAT ARE THE APPROPRIATE ASSESSMENTS?

A first level assessment includes conducting appropriate NDE – boresonic inspection of the central material and linear phased array (LPA) ultrasonic inspection of the first few stages of blade attachment dovetails in the HP and IP sections of the rotors for creep and further downstream for temper embrittlement. These represent the high stress locations within the high temperature regions, where damage is more likely to form first. Coupled with inspection, analytical assessments should be performed to define the most susceptible locations within the rotor and to estimate possible properties degradation over the operational life of the unit. These analytical assessments, in combination with detected flaws or, where none are found, default threshold flaw sizes, are used to estimate when properties have or will become a significant factor. When that point is reached, then the analytical results, having defined the most likely initiation locations, can guide material sampling locations. Miniature material sampling can be used to extract small samples of material from the rotor bore and other key locations. These can be used to fully quantify a range of material characteristics inclusive of chemistry, microstructure, hardness, yield stress, ultimate strength, FATT, fracture toughness, and, most importantly, the degree of creep and/or temper embrittlement degradation.

Structural Integrity is the sole resource able to provide all aspects of this assessment – inspection, analytical assessments, and miniature material sampling and testing.

DIRECT ASSESSMENT ON DIFFICULT TO ASSESS PIPING SEGMENTS

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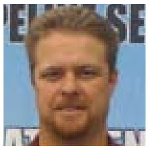

Direct Assessment (DA) techniques are PHMSA approved methodologies for assessing the condition of buried pipelines. DA methods rely on a programmatic assessment approach based on fundamental engineering practices involving a four step process specific to each type of major corrosion threat (External, Internal, and Stress Corrosion Cracking):

(1) Pre-Assessment: Collecting and assessing information about the design factors, construction, operation, and maintenance of the pipeline.
(2) Indirect Inspection: Collecting data and performing analysis of the data to supplement the pre-assessment data and prioritize areas likely to exhibit the identified corrosion threat.
(3) Direct Examination: Excavating and examining the pipeline at those identified areas as prioritized in Step 2.
(4) Post Assessment: Analyzing the results, assessing whether additional repairs or excavations are required, determining the effectiveness of the approach, and identifying future mitigation and remediation actions as well as a re-assessment interval.

Since the implementation of the Pipeline Safety Act of 2002 and subsequent Integrity Management Regulations by the Department of Transportation, difficult-to-assess pipeline segments such as cased segments and station piping have posed significant challenges to operators relying on External Corrosion Direct Assessment (ECDA) and Internal Corrosion Direct Assessment (ICDA) as integrity assessment methods.

STATION PIPING

Terminal, compressor, fabricated gate and generating stations pose some significant challenges to the use of traditional Direct Assessment. The data collection and analysis process is typically much more challenging as stations can have multiple pipelines varying in design characteristics, operating parameters, and varying degrees of corrosion susceptibility throughout the facility. Drawings may not be accurate and data, if documented, is likely to be spread across multiple and disparate sources. Additionally, traditional indirect inspection tools may have limited effectiveness and excavations can be complicated by unusual depth and multiple pipelines in the dig region.

Structural Integrity has designed and implemented a specific program incorporating unique tools to overcome some of these challenges. As a first step, we perform a site walk-down to validate drawings and collect missing data elements. All data and drawings are then consolidated into a Geodatabase and incorporated into 3-Dimensional GIS and CAD drawings for a complete relational mapping and orientation of the piping and attributes throughout the facility. Using these modeling tools, we can better organize, analyze, and manage the pipeline data and facilitate the completion of pre-assessment forms as well as identify the proper indirect inspection tools. In addition to assisting in the analysis, the database output also results in more organized and auditable data records.

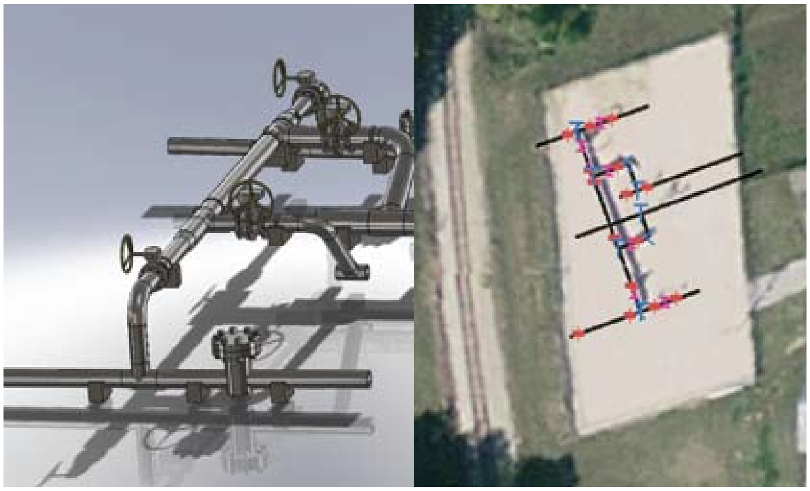

Figure 1. 3-Dimensional GIS Illustration

Traditional ECDA indirect inspection tools such as Close Interval Survey (CIS), Direct Current Voltage Gradient (DCVG), and Alternating Current Voltage Gradient (ACVG) techniques collect potential values that are a measurement of an area associated with the location of the reference cell placement. Figure 1 depicts the relationship of a reference cell and the area of potential measurement as a function of the pipe depth.

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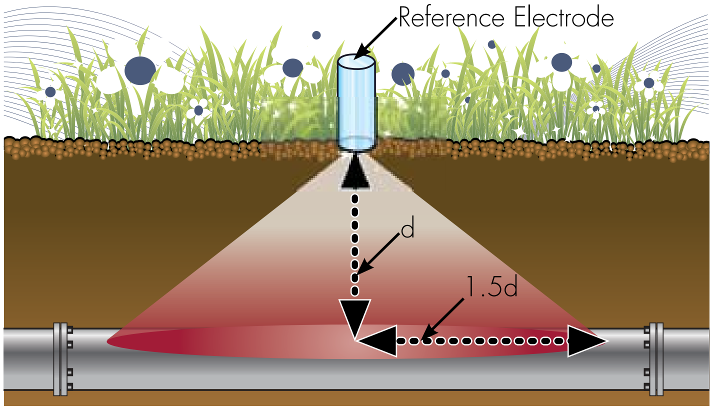

Figure 2: Area Potential as a Function of Pipe Depth

Note in Figure 2, that the area potential measured by the reference cell is a cone with a radius of 1.5 times the depth of the pipe. In a congested area of piping such as a station or plant, many additional structures may exist within this conical area, constructed from various materials (copper, zinc, steel, stainless steel, etc.), sometimes drastically influencing the potential measurements of the intended structure to be assessed. Low potential indications may be a factor of adjacent structures, not a lack of coating or cathodic protection.

STRUCTURAL INTEGRITY'S APEC INDIRECT SURVEY TECHNIQUE

To overcome the misinterpretation of indirect inspection measurements, we've designed the APEC indirect survey technique. APEC is a combined CP survey technique that collects area potential measurements based on a modified CIS approach in combination with an evaluation of the earth current movement using an enhanced 3-half cell DCVG methodology (see Figure 3). In a terminal or station environment, it is important to know where any corrosion cell is operating and where CP currents are flowing. When CP system rectifiers are cycled "ON" and "OFF", the migration of CP current around the plant can be understood and used to adjust and balance the overall performance of a CP system.

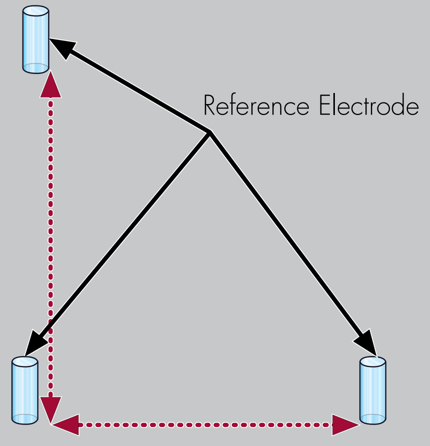

Figure 3: APEC Reference Electrodes and Picture of Example Survey

Determining ICDA excavation locations can also be a difficult process as the piping is likely to be routed throughout the facility having several inclination changes and changes in dimension. Using 3D GIS and CAD based models, flow variation among different segments can be bracketed and an analysis can be performed so that excavation selection can be optimized to areas most likely to accumulate liquid.

CASED SEGMENTS

Similar to station piping, cased segments present a significant challenge to ECDA Indirect Inspection. As illustrated in Figure 4, casings shield the carrier pipe from CP current. As such, traditional Indirect Inspection methods (CIS, DCVG, ACVG, etc.) are ineffective at determining the level of polarization or measuring potential within the casing – measurements typically used as an indication of corrosion control. Another inspection method, Guided Wave Testing, can be a useful tool and is deemed an acceptable assessment approach as long as the prescriptive PHMSA 18-point requirements are followed. However, compliance with these requirements is difficult for longer cased segments and segments with non-favorable coating conditions (such as thick Coal-Tar and Bitumen).

We've also developed a unique program that is not only aligned with recent PHMSA guidelines for performing ECDA on cased segments, but have further developed integrated indirect inspection tools and protocols to more closely follow NACE practices in determining areas of active corrosion. In addition to polarization levels and other commonly used tools and protocols to determine electrolytic or metallic shorts, our program also takes into account actual Cathodic Protection (CP) current density at each end of the cased segment and trends this data to determine if there is adequate CP on the carrier pipeline.

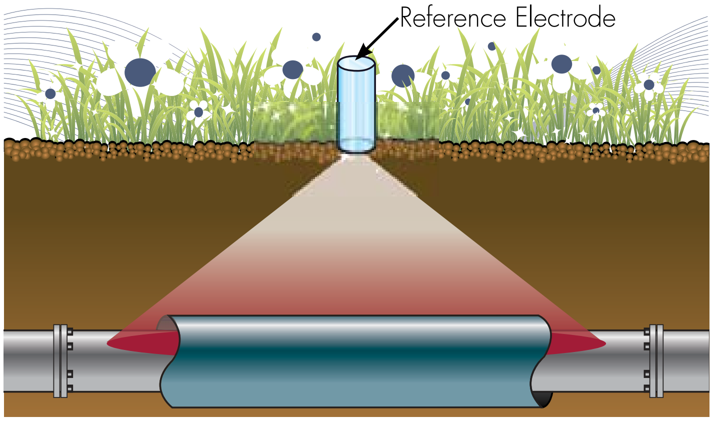

Figure 4: Pipeline Potential - Shielding from the Casing

As a result, a more robust program that prioritizes further examination of cased segments based on susceptibility to corrosion that is aligned with NACE practices can be implemented. In addition, as we are directly involved at each step of the project, we can utilize our engineering knowledge captured during pre-assessment combined with our NDE expertise to apply additional assessment tools when appropriate.

VIBRATION CORNER

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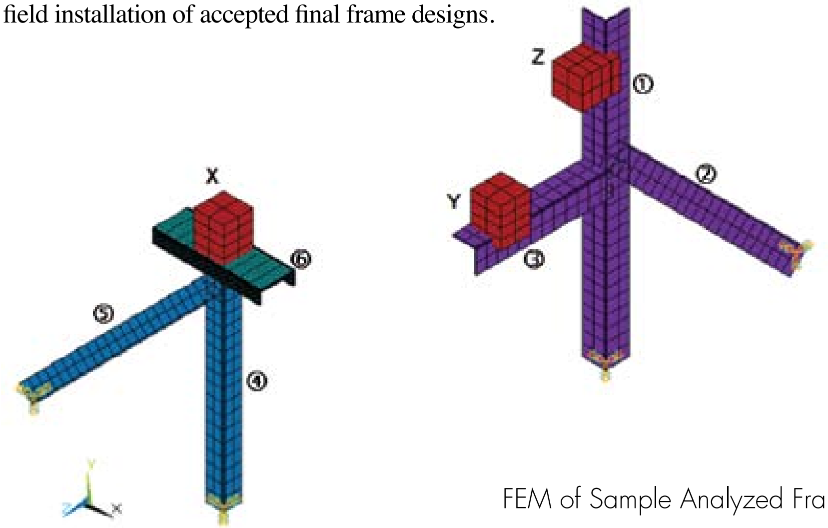
MODAL ANALYSIS OF LANYARD POTENTIOMETER SUPPORT FRAMES

The preoperational and startup testing for a new Advanced Boiling Water Reactor, (ABWR) plant will use lanyard potentiometers (LP) to monitor thermal movements as well as displacements due to vibration. The LPs will be mounted on steel frames in 3 orthogonal directions. The frequency range of interest for the measurements is up to 20 Hz and stiff mounting frames are required for correct results.

Acceptability of the frames is determined through modal analysis. Modal analysis produces the frequencies and mode shapes that characterize the response of a structure to dynamic excitation. The mode shapes and frequencies are characteristics of the configuration, stiffness and mass of the structure. The first modal frequency of a structure or component is often used to determine flexibility or rigidity. In most seismic analysis, rigid structures and components have frequencies of at least 33 Hz and the non-seismic loads (e.g., SRV actuation) have a cut-off frequency of 60 Hz, for example. Since the pipe frequency is expected to be in the 1-20 Hz range, a stiffer LP support system is desired, with first natural frequencies between 80 and 100 Hz.

Structural Integrity performed the modal analysis of proposed frame designs using finite element modeling (see illustration), improved upon the original design and will participate in field installation of accepted final frame designs.



FEM of Sample Analyzed Frame

STRAIN GAGE DATA COLLECTION FOR MUR POWER ASCENSION

In the fall of 2010, we supported a US nuclear power plant with the acquisition of vibration data during implementation of measurement uncertainty recapture (MUR). MUR is a type of power up-rate that typically increases reactor power by up to 2%. MUR is achieved by implementing advanced techniques for determining reactor power, including the addition of highly accurate flow meters in the feedwater line, whose readings are used to calculate reactor power. Specifically, Structural Integrity used its previously installed 32-channel strain gage data acquisition system which collected vibration data related to pressure pulsations in main steam lines. The data was collected throughout power ascension to

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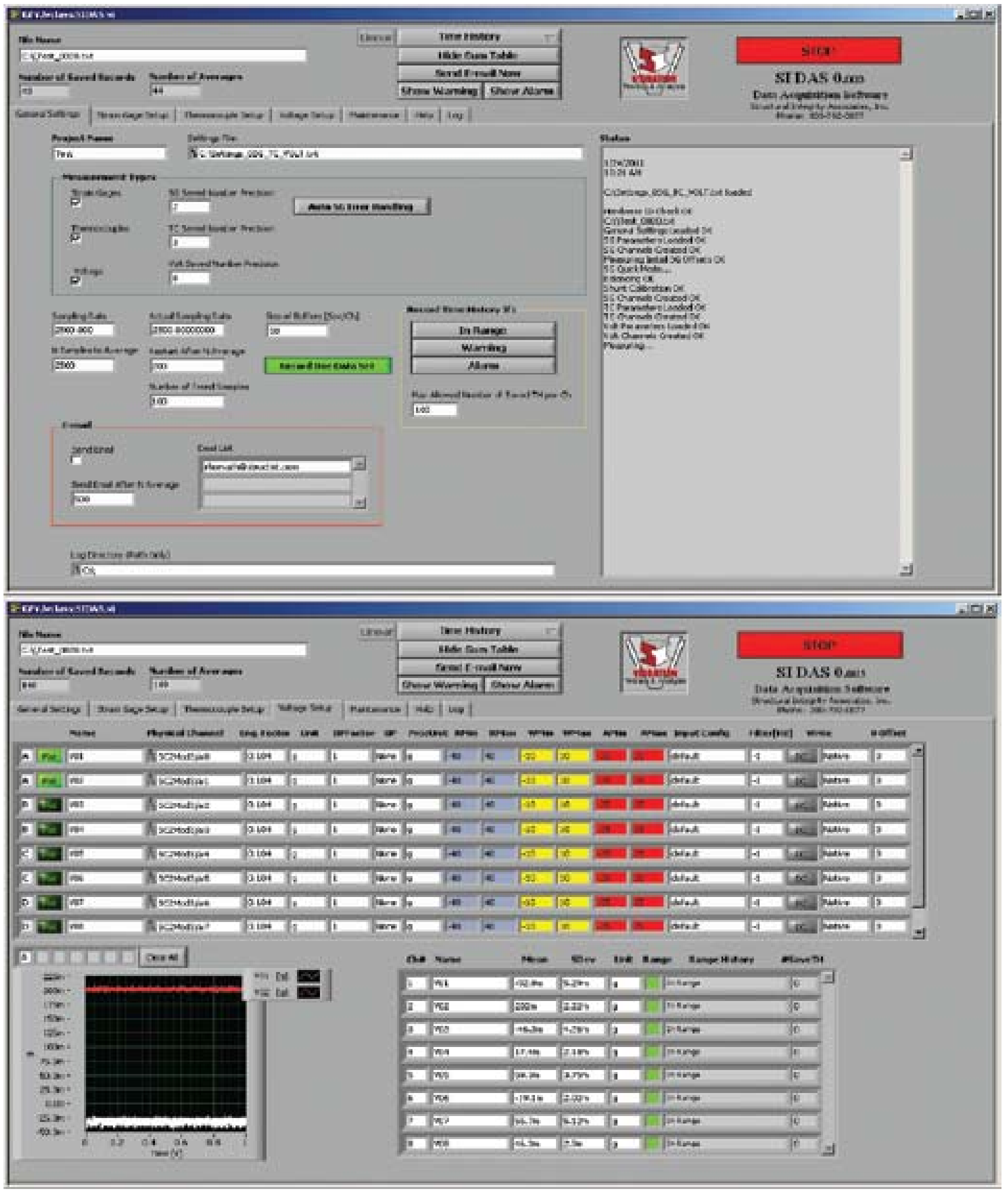
the new MUR power level, which was then used for comprehensive data analysis. The results of the analysis will be used to determine the likelihood of encountering an undesirable resonance condition during Extended Power Uprate in so far as steam flow in the main steam lines.

SI-DAS™
UNIVERSAL DATA ACQUISITION SOFTWARE DEVELOPED BY STRUCTURAL INTEGRITY.

We have developed new software to address the increasing need of data acquisition for field applications. The developments targeted are based on many years of field experience. Our software developers had to solve several industrial problems such as accurate long term strain measurement. SI-DAS is able to read data from 90% percent of the sensors used in the industry, operate extended period of time, and run on a simple Windows-based system.



SI-DAS™ User Interface

SI-DAS MAIN FEATURES:

- Long term acquisition (multiple days, weeks, months even years)
    - Trend only
    - Trend with event capturing
- Short term acquisition: high sampling rate
- Readable text based data file that can be opened with Excel.
- List of sensors:
    - Bridge type sensors (Strain Gauges, Load Cells)
    - Thermocouples
    - Any Voltage or Current output sensors:
        - Accelerometers
        - Pressure and proximity probes
- One measurement with any sensor type combination (for example strain gauges with accelerometers.)
- E-mail sending function (status report)
- User defined warning and alarm settings with optional e-mail notification.
- Stand alone operation
- Data acquisition task is loaded from a text file (Settings.txt).

# of High- gy Piping

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Damage rates in high-energy piping (HEP) systems are directly dependent on the amplitude and distribution of local stress. Effective high-energy piping programs recognize this fact and quantitatively account for it through engineering stress analysis. Proper analysis, such as those conducted by Structural Integrity Associates, Inc. (SI), consider creep and fatigue damage accumulation resulting from static and cyclical loads, and rigorously model the predicted performance for both initial design and aged conditions. In the case of creep, it has been demonstrated that an increase in operating stress by roughly 16% can reduce calculated service life by one-half. Clearly, minimizing uncertainty in predicted stress creates substantial safety and financial returns through informed decisions regarding inspection intervals,
ing practices and replacement strategies.

N ANALYSIS

itial design analysis of a piping system is based
stic analysis to ensure that the maximum stresses
flections fall within established code limits for a
material, and to determine the appropriate hanger
ement. Such analyses take into account component
eight, design pressure and temperature, and terminal
displacements. Permanent strain induced during
s of extended operation in the creep regime (which
st materials is above 850ºF) causes a redistribution
ss through creep relaxation. Since the difference
n the elastic and redistributed (inelastic) stress
en shown to correlate with locations of damage,
ning an inelastic analysis in addition to the elastic
is is essential for an accurate representation of the
system.

rrent with creep straining of the piping and
ated geometric changes, the systems support
s (both constant load and variable spring types)
ange compared to those prescribed by the designer.
ystematic change (caused by creep deformation)

Continued on next page

frequently combines with support mechanical malfunctions to significantly alter system stresses. The extent of change that occurs at any specific support is an indication of the potential for change in the operating stresses of piping in the area of that support. What typically is observed by station personnel is that supports are "topped out" or "bottomed out". Physically this means that the support is operating outside its design travel range, and means they are no longer supporting its prescribed original design load. This often leads to very high local stresses far above the original design stress, which, if not rectified, will result in accelerated damage and weld failure.

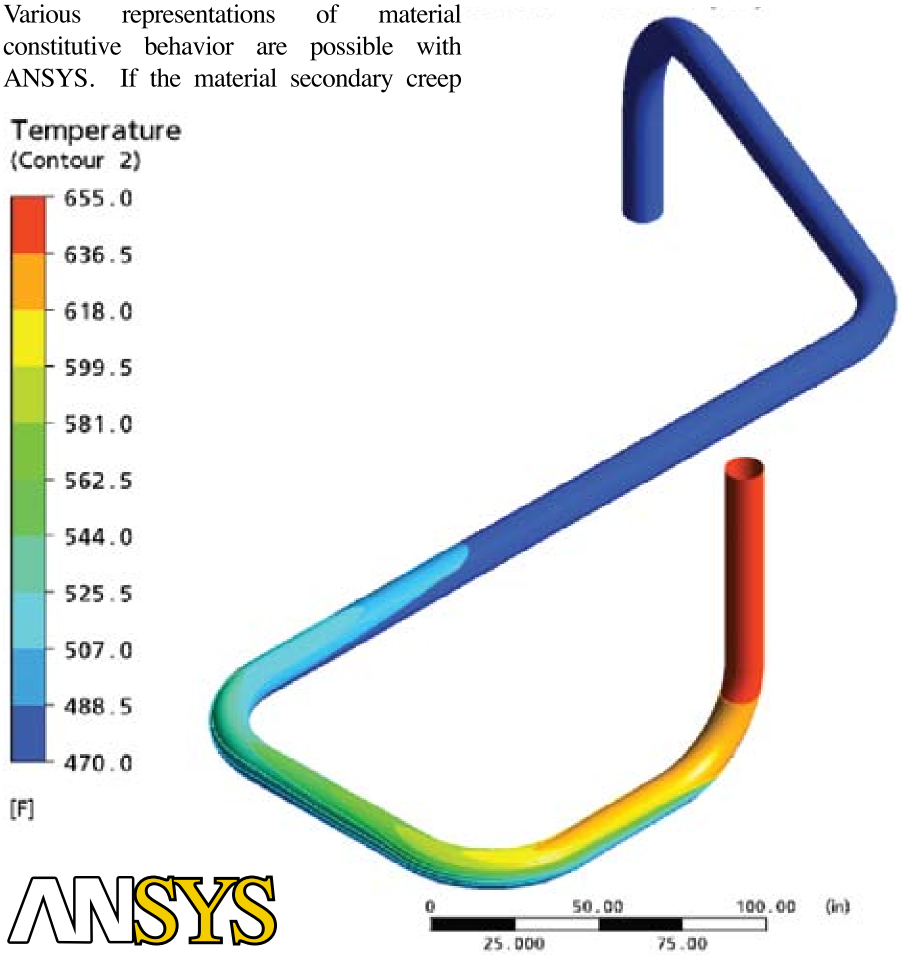
Piping analyses require hanger specifications and hanger, header, and turbine/intercept valve settings and displacements from hot and cold walk-downs. The range of system deflections and moments should be nearly elastic and conform to the initial design calculations. However, because of stress redistribution by creep, part of the initial cold spring will be lost, and the mean values of deflections and moments will differ from the initial design conditions. The design positions of the system headers, hangers, and turbine/intercept valve connections in the hot and cold conditions should be provided. Significant deviations between measured and design positions indicates excessive stress, malfunctioning hangers and the need for modifications to reduce the rate of accumulation of creep damage.

To our knowledge, no PC-based piping analysis code is currently available which can account for time-dependent material characteristics necessary to perform accurate creep redistribution analyses. Methods do exist using successive elastic calculations with estimated displacements to approximate the redistribution of stress. However, these methods are subject to large errors and consequently reduced confidence in analysis results. Therefore, we perform creep redistribution analyses using the ANSYS Code.

ANSYS CODE

We have found that the ANSYS program provides a complete analysis package for performing both elastic and inelastic evaluations of high energy piping systems. Various representations of material constitutive behavior are possible with ANSYS. If the material secondary creep rate versus stress relationship is incorporated, all solutions of creep deformation and stress redistribution appear to "shake-down" to the same distribution after long-time exposure. Recovery periods at reduced load and elevated temperature may increase the rate of secondary creep. Transient loading effects accelerate the shakedown process, but not the final distribution of stress. Such effects allow a period of stress relaxation for each load cycle, and this stress relaxation contributes to creep rupture damage if it occurs at low strain rate. Under complex combinations of steady and cyclic stress, deformation may occur in each cycle such that the stationary shakedown distribution is not reached. In these cases local bulges or wall thickness changes may occur in the piping.

Elastic stress results predicted by ANSYS can be used to perform code checks for minimum wall thickness and allowable stresses. Creep redistributed stresses predicted by ANSYS can be used in life fraction, and crack growth and critical flaw size calculations, and are recommended for use in dispositioning system defects.



For stress analysis of high energy piping systems, Structural Integrity conducts a series of analyses to assess the elastic and creep redistributed stress of a system:

1. The first analysis evaluates the balance between system dead weight (piping and insulation) and hanger loads. For a system which is perfectly balanced, this analysis would predict no displacement at hanger locations. When significant displacements are predicted by this analysis, it indicates an error in the specified hanger loads and/or component weights. We typically perform several dead weight analyses adjusting hanger loads or material density to minimize predicted displacements. The final predicted displacements are used to adjust the hanger travel gaps so that the indicated travel ranges determined from system walkdown data are maintained.

2. The second analysis performed addresses the effects of system cold springing. Cold springing is simulated by specification of a gap in the line at the specified cold spring location(s). This gap is then closed through application of displacement constraint equations which specify that the sum of the displacements of the model nodes, which compose the two ends of the gap, move through a distance equal to the amount of cold spring. Displacements predicted at hanger locations are used to adjust the gap sizes for each hanger during the thermal displacement analyses.

3. The third analysis performed simulates the effect of system dead weight, cold pull, and system temperature/pressure operation. This analysis is an elastic analysis and is used to compare system stresses versus code standards. Hanger gaps are specified based on the system walkdown data and adjusted by the results of the dead weight and cold spring results.

4. The final analysis performed is the creep redistribution analysis. In this analysis the same load and hanger gap data used in the elastic analysis are used. Time dependent material properties are input and an iterative solution is performed simulating 10,000 hours of system operation. Our evaluations indicate that the majority of redistribution occured in this time frame.

Our recommendation is that analyses performed include both elastic and inelastic (creep) material models to provide the maximum amount of information to the HEP Management Program. Typically an HEP Program will utilize life-expenditure estimates for the system components (welds, pipe spools) based on time-at-temperature data compared with component material creep-rupture curves, but also can include the performance of component-specific flaw dispositioning. Regardless of the management tool(s) applied the operating stress and its range are primary inputs. Therefore the incorporation of creep redistribution in a system analysis will be more representative of the time-dependent material response of high-energy piping materials.

In performing stress analyses on systems that have accumulated significant service time, it is important to note that while creep deformation will result in geometric changes, the ‘range’ of system deflections and moments (between cold and hot conditions) should be nearly elastic and conform to the initial design calculations. Significant deviations between measured and design positions indicates increased potential for excessive stress, malfunctioning hangers and the need for modifications to reduce the rate of accumulation of creep damage.

2011 FOSSIL PLANT WORKSHOPS

Structural Integrity is hosting several workshops for Fossil plant operators and engineering managers in 2011. These workshops will focus on recent issues and topics associated with ensuring the Safe and Reliable operation of your most critical components.

TOPICS WILL INCLUDE:

- Development & Implementation of High Energy Piping Management Programs
- Managing your P91 Systems & Components
- Effective FAC Programs
- Boiler Tube Failures & How to Avoid Them
- Integrating Fitness for Service Tools into Your Asset Management Programs

PLANNED SPEAKERS:
Jeff Henry, Barry Dooley, Steve Gressler, Dan Peters, Matt Dowling

June 21st - 23rd, Nashville, TN
HRSG Workshop: Emerging HRSG Issues and P91/T91 Issues

August 23rd - 24th, Austin, TX
Boiler and Piping Systems: Critical Plant Component Asset Management, P91/CSEF Material Issues

September 13th - 14th, Pittsburgh, PA
Critical Plant Asset Management Boiler and Piping Systems:

For more information, please contact
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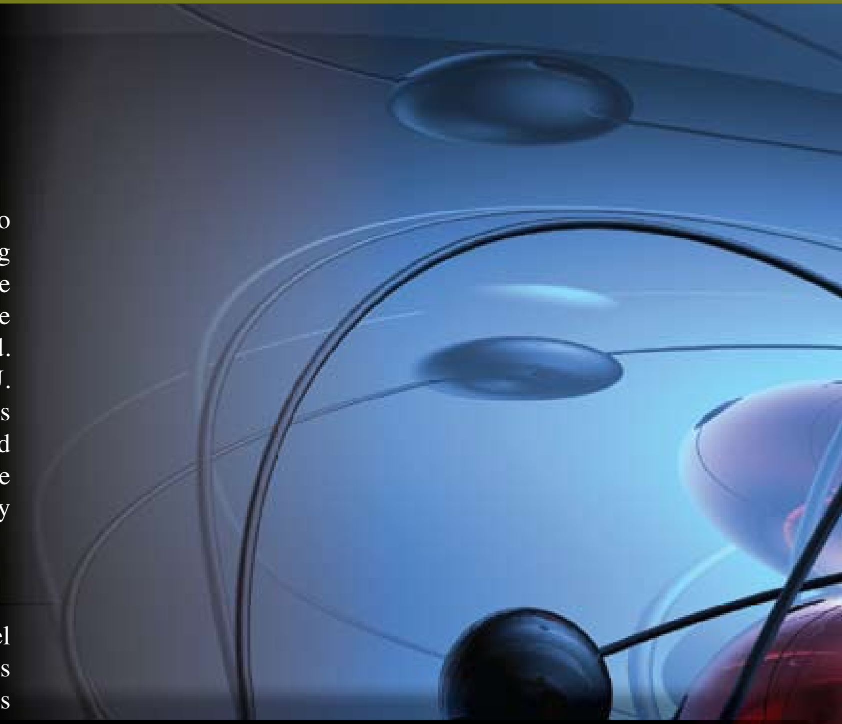
FLAW HANDBOOKS FOR PWR CORE BARRELS



By: TIM GRIESBACH
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Pressurized Water Reactor (PWR) vessel internals are known to be susceptible to age-related degradation, and the effects of aging must be managed during the operating plant life including the period of extended operation. This is becoming a near-term issue for many plants as they begin to enter the license renewal period. Under the NEI 03-08 Materials Initiative, all PWR plants in the U. S. are required to develop vessel internals management programs by the end of this year per the EPRI MRP-227 guidelines, and several plants will begin inspections of the vessel internals in the next few years to meet the inspection schedule for the primary (i.e., most limiting) components.

CORE BARRELS

Typically, one of the primary components is the core support barrel (or core barrel). The core barrel is a cylinder which surrounds the core shroud and houses the fuel bundles (see Figure 1). Its function is to resist static loads from the fuel assemblies and othe internals, and dynamic loads from normal operating hydrauli flow, seismic events, and loss-of-coolant-accident (LOCA) event The core barrel also supports the lower internals assembly and the core support plate, upon which the fuel assemblies rest. The core barrel upper flange is a thick ring that supports and suspends the core barrel from a ledge on the reactor vessel. Maintaining the integrity and functionality of the core barrel and its related structural components is vital to the safety of the plant. Large loads on the core barrel can occur due to seismic events or a Loss-of-Coolant-Accident (LOCA), and concerns for materials degradation make this a high priority for inspections to assure integrity, particularly at the upper core barrel flange weld. To date, no indications of cracking have been detected at these locations in PWRs. However, there have been a number of core shroud weld cracks due to inter-granular stress corrosion cracking (IGSCC) found in similar structural components in Boiling Water Reactor (BWR) vessel internals, and this became a major issue requiring evaluation and repairs for the BWRs.

INSPECTIONS

Inspections combined with flaw evaluations and/or remedial measures are often the steps needed to assure all intended safety functions are maintained. Since the inception of the issue, Structural Integrity Associates, (SI) has provided technical support and evaluations to BWR utilities for managing this issue. This same approach is directly applicable to PWR internals components, and actions for managing these issues are incorporated by reference in the commitments for license renewal.

Planning for the inspections requires that consideration be made for the unlikely event that cracks are actually found during the inspection because the question then becomes, “Is the structure flaw tolerant and able to maintain its function even with these cracks?” It is prudent for utility planners to prepare for these kinds of questions in advance by having a Flaw Handbook or Flaw Readiness Evaluation.

A Flaw Handbook or Flaw Readiness Evaluation enables an efficient flaw evaluation of the core barrel locations for any indications that may be detected during component inspections. Therefore, using available design information for the core barrel, the process documents the relevant geometry, materials and loads, as well as general flaw evaluation guidelines that should be used to evaluate any indications in this component. A PWR Core Barrel Flaw Handbook can provide a quick and defensible disposition of indications found during inspections of the welds in the core barrel. The disposition of the inspection findings is based on a flaw tolerance methodology. This methodology uses the applicable failure mode of material: linear elastic fracture mechanics (LEFM)/elastic-plastic fracture mechanics (EPFM)/limit load (LL), based upon the cumulative neutron fluence at the end of the selected evaluation interval, stress corrosion cracking (SCC) growth rate (if applicable), material fracture toughness applicable to the failure mode selected (K_{IC}, J-R curve, flow stress). We employ the techniques in accordance with existing flaw evaluation guidelines and applicable Code margins. The methodology used is consistent with methods of Section XI of the ASME Boiler and Pressure Vessel (B & PV) Code and with methods developed to perform flaw evaluation of BWR internals including the core shroud.

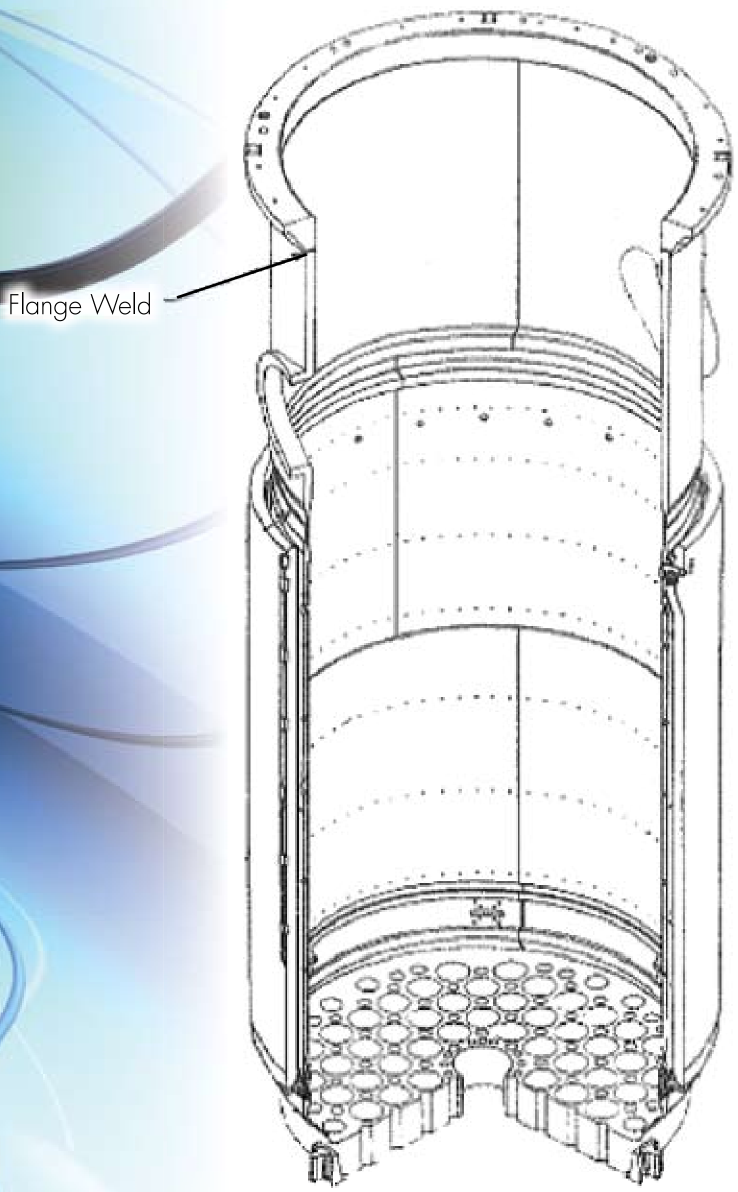


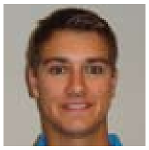
Figure 1
Typical Westinghouse Designed Vessel Internals
Core Barrel

A PWR Core Barrel Flaw Handbook can be performed for plant specific or bounding conditions. The maximum loadings for each selected weld for each service level are to be used for all service levels. These loadings include: Deadweight, Mechanical and Pressure Differential loads, Impact loads, Hydraulic loads, Flow induced vibration loads, Thermal loads, Seismic loads, LOCA loads, and Normal handling loads. In the event that plant specific loads are not available, Code stress allowable values could be used for all service levels in the development of Flaw Handbook. This would provide a bound on acceptable flaw sizes (i.e., flaw lengths) but could be overly conservative. In addition, a parametric approach on the stress can be adopted, instead of the use of bounding allowable stresses. The results of the Flaw Handbook is a set of flaw tolerance sizes (i.e., flaw depths and lengths) to be used to disposition reportable indications identified during inspection of the core barrel. It can also be used for training NDE personnel on the magnitude of the flaw sizes of concern in specific plant components. Any indications smaller than the tolerance flaw sizes reported in the Flaw Handbook are acceptable for continued operation until the end of the chosen evaluation interval without further evaluation (considering additional flaw growth). The flaw acceptance size can be formulated for different levels of stresses such that the Flaw Handbook results can be readily applied to indications in different welds or locations where the stresses could be vastly different. Flaw Handbooks could also be developed for many other internals components that are to be included in future inspection programs. Such handbooks have been proven to be very useful to utility engineers having to manage the vessel internals issues for extended plant life.

Our experts have extensive expertise and experience in these areas and can provide technical support for managing aging effects in PWR internals.

INTEGRATED ENGINEERING EXPERTISE WITH ADVANCED NDE

Example Case Studies



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Structural Integrity (SI) has performed a considerable number of assessment services for piping systems ranging from oil and gas transmission pipelines, power generation, petrochemical and terminal station piping, to various other industries. To optimize the value of these assessments, SI integrates state-of-the-art technology, such as Guided Wave Testing, with advanced engineering and material expertise for a complete condition assessment of piping assets.

We have some unique projects in which clients have leveraged our assessment and engineering expertise to make more informed decisions about the continued operation of their critical piping assets.

re 1: Photo showing area with water dripping from above in tunnel

Figure 2: External corrosion on chilled water system

CORROSION AT MAJOR AIRPORT

A major metropolitan airport experienced an increase in the number of leaks caused by corrosion in a condenser water system. The hot water and chilled water service piping was also deemed susceptible to corrosion. Shutting these systems down to allow for major repairs or pipe replacement would have been very costly and a major inconvenience due to the HVAC system's reliance on this piping.

We were contracted to perform an assessment to identify locations and determine the extent of degradation in these systems so that a fitness for service decision could be made.

HOT AND CHILLED WATER SYSTEMS

On the hot and chilled water systems, the following methods were used to assess the piping.

1. Guided wave ultrasonic testing (GWT)
2. External visual inspection
3. Pit depth gauge measurements
4. B-Scan ultrasonic thickness testing

We discovered external corrosion on the chilled water system associated with water dripping on the insulated pipe from an overhead tunnel. See Figure 1. This water appeared to contain minerals/salts which, when in contact with cold, insulated, and bare steel pipe, caused significant external corrosion pitting. See Figure 2.

To prevent further degradation one of our recommendations was to install a gutter system to redirect the water so that it would not come in contact with the chilled water pipes.

CONDENSER WATER SYSTEM

Excessive vibration prevented GWT from being a viable inspection method for the condenser water system. Instead, 23 locations representing 389 square feet of 48-inch diameter pipe were assessed with B-Scan, a semi-automated UT thickness method. Generalized and localized corrosion were found. Figure 3 shows the internal pitting observed with B-Scan.

Wall thickness data was collected and analyzed and fitness for purpose calculations were performed. We recommended the use of corrosion inhibitors to slow the rate of internal corrosion and a re-inspection interval of two years to establish the new corrosion rate.

CONCLUSION

We were able to assess the threat of corrosion on the identified piping and recommend to airport management continued operation with minimal risk of a critical failure. We also recommended further actions to mitigate the threat of external and internal corrosion to extend the life of these systems.

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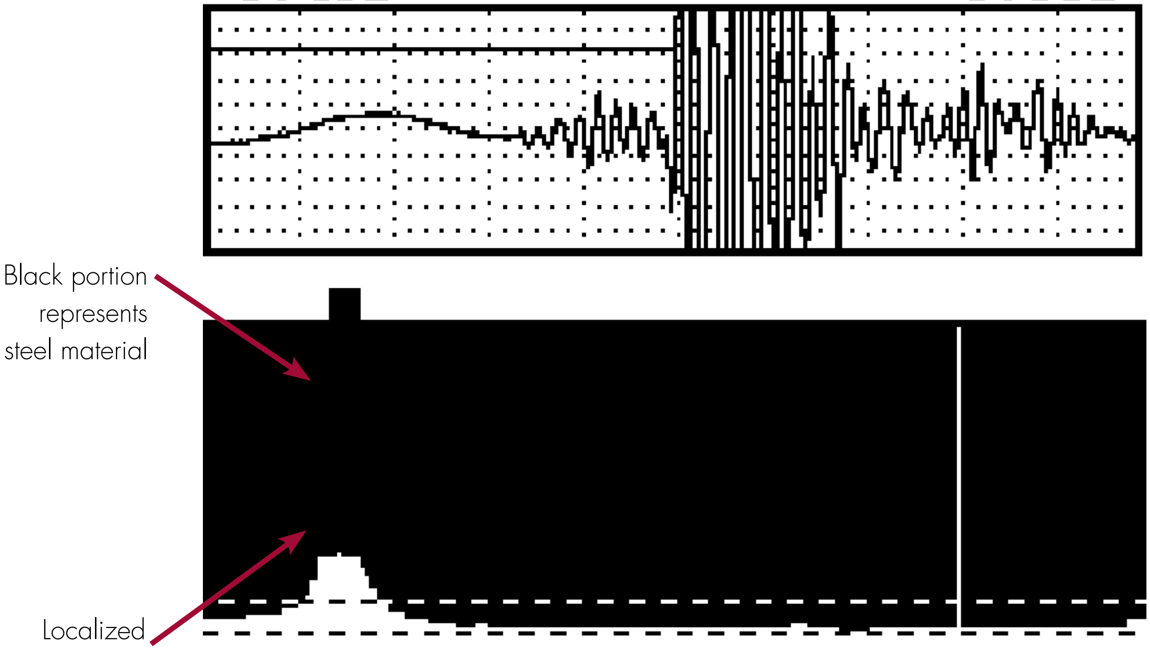

Black portion represents steel material

Localized corrosion pit

Figure 3:
B-Scan screen capture showing internal profile of pipe

OIL STORAGE – DOCK LINES AND REFINERY FEED – DETECTING AND REMEDIATING CORROSION UNDER INSULATION (CUI)

A major refinery and distribution facility was concerned about the risk of potential oil leaks from dock piping that served as an unloading facility for barges on a major waterway in the US. In addition to the significant environmental damage that any potential leaks would cause, the lines were critical feed lines to a refinery and any interruption of these lines would cause a major shutdown of the facility. Due to the large span of piping, removing insulation and/or directly examining all insulated piping would have been expensive and time consuming.

The piping had a potential for accelerated external corrosion since the insulation was capable of absorbing and trapping water. Also there were multiple regions that had a high probability of exposure to saltwater and freshwater due to tidal action, flooding, and pipeline appurtenances that created discontinuities in the insulation jacket, exposing coatings that provided different levels of protection. We performed a comprehensive assessment, using Guided Wave Testing (GWT), visual inspection, and risk informed analysis on degradation mechanisms and susceptibility, to evaluate approximately 4 miles of insulated piping to determine locations with the greatest potential extent of corrosion and recommend corresponding remediation activity (See Figures 3 and 4). The inspection data, combined with likelihood of failure data (e.g., insulation type, coating type, and exposure to water sources), as well as consequence of failure information (e.g. proximity to major waterways and corresponding regulatory requirements), was used to create a risk model to identify CUI regions for targeted mitigation activity.

Figure 3. Piping Region Susceptible to Corrosion

To better organize the large amount of data collected (e.g., over 250 GWT test shots), all pertinent data, such as test shot location, major indications, appurtenances, and risk level by CUI region, was stored and presented in a Geographic Information System (GIS). Incorporating results in GIS allowed us to correlate the results to geographic locations within the facility, enabling a simple method to sort and view results, easily identify sections for mitigation, allow for integration and correlation of different datasets, and trend and track severity of indications for future inspections.

CONCLUSION

Based on this assessment, we determined that the majority of piping was in an operable condition. Through a structured remediation program that addressed a few problem areas, mitigation activities on identified high-risk CUI regions, and a re-assessment program, the system was determined to be suitable for continued operation for an extended period.

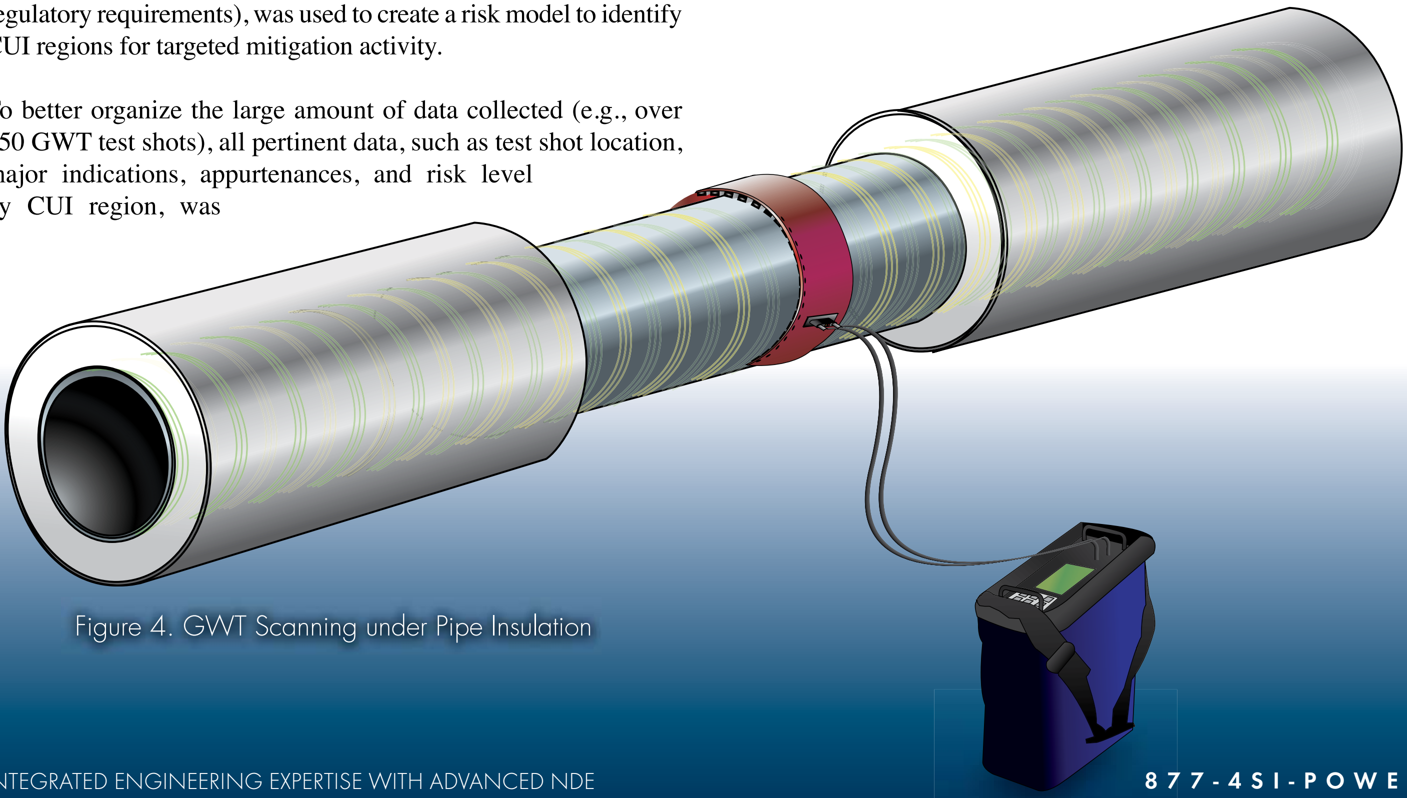

Figure 4. GWT Scanning under Pipe Insulation

CANDU Activities with Fatigue Management

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Structural Integrity has recently extended its extensive application of the low cycle fatigue management and FatiguePro™ product to the CANDU fleet. The similarity to the pressurizer light water reactor (PWR) has been key to our understanding the unique needs of the heavy water reactor technology of the CANDU ("CANada Deuterium Uranium") design. Customized FatiguePro installations have been deployed at 84 units at over 55 commercial sites worldwide, including applications at PWRs and BWRs, and work is underway at two CANDU plants.

FatiguePro applications, developed by Structural Integrity for EPRI®, have been customized and deployed at Wolsong in Korea and Point Lepreau in Canada. In both cases, the first step was to perform a detailed survey of the plant fatigue design bases in terms of plant transients and components, regulatory commitments and industry experience. This survey was presented in a “Recommendation Report,” which summarized the important attributes of the fatigue design bases and current and expected regulatory requirements (both in the current and license extended periods of time), and provided a detailed, recommended road map for developing and deploying a fatigue management program to accomplish the stated goals.

On February 16, 2011, we participated in the CANDU Fatigue Management Program Development Workshop sponsored by the CNSC (Canadian Nuclear Safety Commission), AECL, COG (CANDU Owner's Group) and NB Power in Ottawa, Ontario, Canada (beautiful ice sculptures were featured that week in downtown Ottawa). Over 50 industry professionals attended this periodic workshop. Through attendance by CNSC and US NRC, the Regulators’ perspective was well represented. Besides sponsor representatives, other participants included, Bruce Power and OPG, AECL, EPRI, Kinectrics, AMEC, Anric and Carleton University. We discussed valuable technical and programmatic information. Dave Gerber of Structural Integrity and Anthony Scovil of NB Power presented Thermal Fatigue Management at Point Lepreau Generating Station. This presentation provided a full understanding of the process of implementing a fatigue management system at Point Lepreau Generating Station (PLGS), from original survey of fatigue design basis and issues to on-line monitoring of plant transients and fatigue usage.

Continued on next page

The contents of the NB Power/SI presentation were:

- ***Thermal Fatigue Monitoring Pilot Project at PLGS***
  - I. Summary of Technical Basis for PLGS Fatigue Program
    - PLGS Fatigue Program Objectives
    - Purpose of Fatigue Monitoring Pilot Project
    - Summary of Key Results from Recommendation Study
    - Resolution of Open Items
    - Comparison to GALL
  - II. Environmental Fatigue and PLGS Chemistry History
  - III. Determining Cumulative Usage Factors and 60 Year Projections
- ***Fatigue Management Plan Development***
  - I. Monitoring Methods being Considered
  - II. Outstanding Issues

A result of the Point Lepreau Recommendation Report is a fatigue management plan that includes an automatic cycle counting (ACC) module that identifies, count and categorizes plant transients that contribute to fatigue usage of major Class 1 components. The fatigue management plan calls for deployment of cycle-based fatigue (CBF) and Stress-Based (SBF) fatigue algorithms to compute and monitor fatigue usage at fatigue sensitive locations throughout the plant.

The Wolsong FatiguePro program, which was co-developed by us and our partner in Korea, KEPCO Engineering and Construction, comprises an automatic cycle counting (ACC) module that identifies, count and categorizes plant transients that contribute to fatigue usage of major Class 1 components. CBFSfatigue algorithms are deployed to compute and monitor fatigue usage at fatigue sensitive locations throughout the plant.

This experience, as well as the development of a Recommendation Report for Bruce Power's Bruce-A and B power plants on Lake Huron, are examples of our extensive understanding of FatiguePro and ability to assist plants with fatigue management issues.

COMPLEMENTARY INSPECTION TECHNIQUES of Waterwall Circumferential Cracking at Great River Energy

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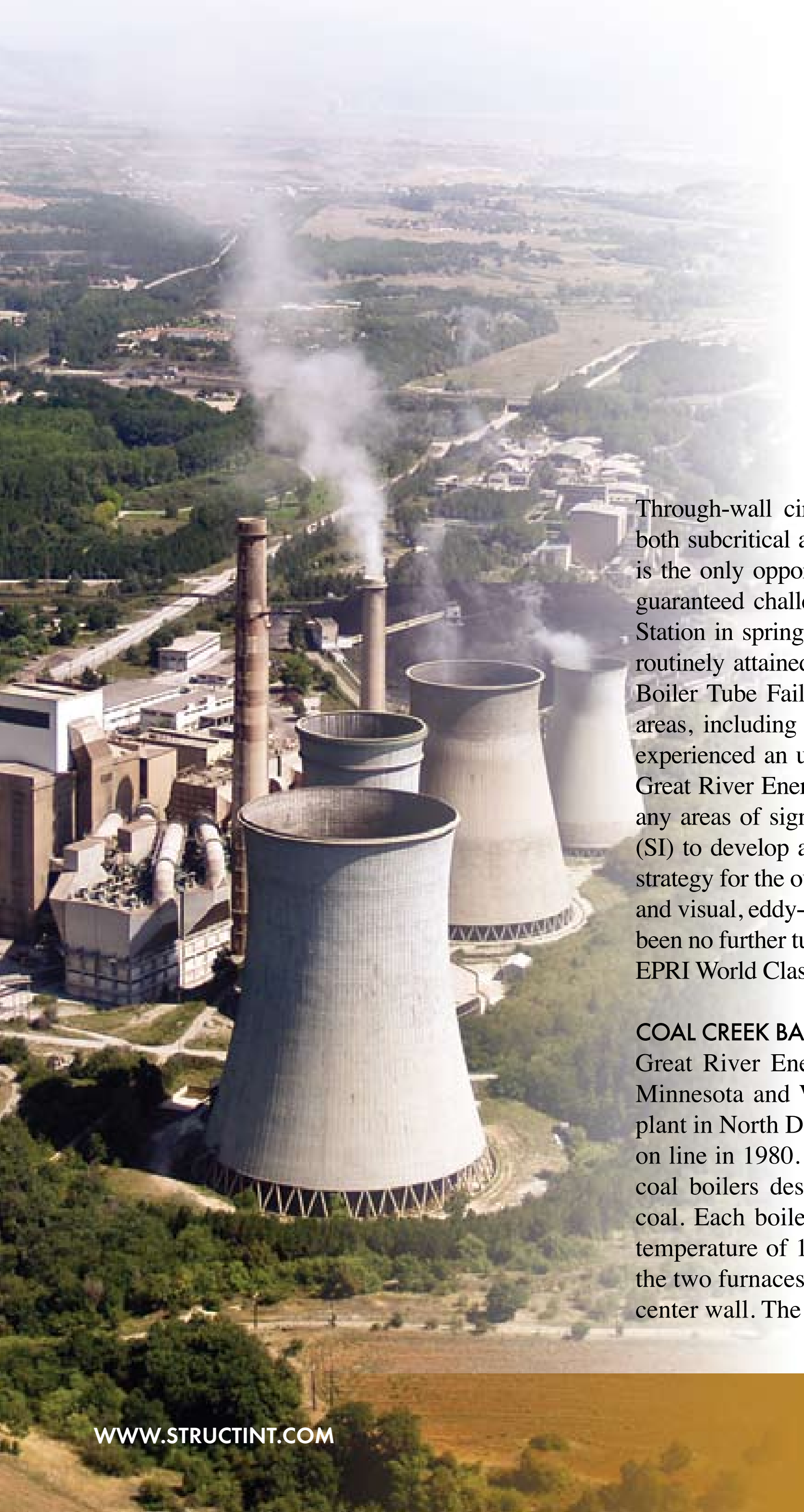
By: MARK KNOLL
GREAT RIVER ENERGY



Through-wall circumferential cracking can occur in furnace waterwall tubing in both subcritical and supercritical coal-fired boilers. While a brief scheduled outage is the only opportunity to determine the extent and severity of any cracking, it's a guaranteed challenge. That was the situation at Great River Energy's Coal Creek Station in spring 2009. For six years straight, two-unit subcritical Coal Creek had routinely attained World Class Status under the Electric Power Research Institute's Boiler Tube Failure Reduction Program, with near-perfect scores in nine different areas, including equivalent availability loss. But beginning in 2008, Coal Creek experienced an unexpected series of circumferential cracks in its waterwall tubing. Great River Energy scheduled a quick outage for spring 2009 to identify and repair any areas of significant cracking, and called in Structural Integrity Associates, Inc. (SI) to develop a suitable waterwall inspection approach for the brief outage. Our strategy for the outage was a complementary combination of tube surface preparation and visual, eddy-current, and linear phased-array ultrasonic examination. There have been no further tube failures since the outage, and Great River Energy is closing in on EPRI World Class Status once again.

COAL CREEK BACKGROUND

Great River Energy provides electric service to 28 distribution cooperatives in Minnesota and Wisconsin. Its 1.2 GW Coal Creek Station is the largest power plant in North Dakota. Unit 1 was commissioned in 1979, and Unit 2 was brought on line in 1980. The station has two subcritical controlled-circulation pulverized coal boilers designed by Combustion Engineering to fire North Dakota lignite coal. Each boiler produces 3,730,000 lb/hr of 2990 psig superheated steam at a temperature of 1005° F steam. Both boilers have a divided-furnace design, with the two furnaces—Furnace A and Furnace B—in each unit separated by a hanging center wall. The eight burner corners are located in the front and rear boiler walls.

Continued on next page

THE TWO UNITS FIRE ABOUT 22,000 T/D OF LIGNITE.

Coal Creek's boiler firing systems have been modified over the years, and these modifications held possible clues to the circumferential cracking that later developed in waterwall tubing.

- In 1998, changes were made to burner tips, and secondary overfired air (SOFA) ports were installed; smooth-bore waterwall tubing near the SOFA ports was replaced with rifled tubing.
- Subsequent inspections to check on the altered furnace environment found no sign of significant wastage or circumferential cracking in the waterwalls.
- Main steam turbine throttle pressure was increased as well in 1998, from 2520 psig to 2574 psig, while steam drum pressure was maintained at 2650 psig.
- The steam flow rate of Unit 2's boiler was increased from 3.79 million lb/hr of superheater steam to over 4 million lb/hr.
- In 2007, the size of Unit 2's SOFA port openings was increased, while the unit's auxiliary air openings were trimmed to further manage air entering the furnace. New burner panels were installed to accommodate the increased SOFA port size.

UNEXPECTED WATERWALL FAILURES

Great River Energy implemented EPRI's Boiler Tube Failure Reduction (BTFR) Program at Coal Creek in Spring 2001. The plan included a more comprehensive inspection strategy as well as root-cause analysis of tube failures. To achieve EPRI BTFR World Class Status, a plant must achieve near-perfect scores in nine different areas, and the area that counts the most is equivalent availability loss. From 2003 to 2008, Coal Creek's BTFR program routinely attained EPRI World Class Status. But on August 11, 2008, a setback occurred when a leak developed in a boiler waterwall tube adjacent to Burner Corner 5 in the front wall of Unit 2's boiler (Front Wall Tube 296, elevation 2056' 0"). Less than six months later, on February 14, 2009, two leaks occurred on the front wall, mid-span between Burner Corners 1 and 4. (Front Wall Tube 120 between elevations 2056' 10-1/2" and 2058' 6-3/4" and 126 between elevations 2058' 6-1/2" and 2061' 0-1/2"). And just two days after this failure, on February 16, 2009, a third failure occurred, at Burner Corner 4 in the front wall. (Front Wall Tube 217 at elevation 2053' 0"). The common features of the failures: all leaks were located on the front wall; all developed in both the left and right furnaces; and all occurred just above the close-coupled overfired air port. Failed waterwall tubing sections were 1.75" OD x 0.203" MWT carbon steel material produced in accordance with SA-210 A1.

CULPRIT: CIRCUMFERENTIAL CRACKING

Our metallurgical examination of the August 11, 2008 failure revealed that the leak had occurred at a circumferential crack that had propagated via a corrosion-fatigue mechanism through the tube wall thickness. In addition to the circumferential cracking, there had been measurable loss of wall thickness on the furnace side of the tube due to external corrosion, with average furnace wall thickness values reduced by 34-44 mils, compared with average wall thickness on the casing side of the tube. The telltale presence of sulfur was confirmed in the external deposit and oxide scale. The circumferential cracking on the furnace side of the tubing was present along the entire length of the sample, and crack depths ranged from through-wall at the leak to 50% or less of the tube wall thickness elsewhere.

In response to the February 2009 failure, Great River Energy removed and destructively examined three tube sections. Circumferential cracking was observed on the furnace side of the tubes in all samples. The cracking in one of the tubes was contained in an OD pad weld. After hardness measurements of the tubing from the February 14, 2009 failure, we noted slightly lower hardness values on the furnace side of the tube, suggesting some thermal softening. However, the active damage mechanism identified for these failures is corrosion-fatigue grooving driven by cyclic thermal stresses. We found that the cracking in all samples contained a sulfur-rich spine, commonly observed in circumferential waterwall cracking. Similar to the August 2008 failure, cracking was present along the entire length of each sample, and crack depths ranged from the through-wall leak sites to less than 50% of tube wall thickness.

In May 2009, there were two additional failures at Coal Creek Unit 2. The first, on May 3, 2009, was located on a front waterwall tube. (127 between elevation 2059' 9" and 2059' 11-1/2"). This failure was discovered after the unit was brought off line to address a reheat tube failure. No metallurgical evaluation of this failure was performed, and the cracking was temporarily repaired by pad welding. The repaired tube was later removed during the spring 2009 outage. The second May 2009 failure—exact date unknown—was discovered after grit blasting to prepare for the spring 2009 outage's NDE inspections. The tube, located on the front wall, (tube 124 at elevation 2057' 1-1/2") was discolored by corrosion and dripping. Figure 1 shows the failure.

Figure 1 Overall view of the leak of Front Wall tube 124 noted during the field examinations on May 15, 2009.

STRUCTURAL INTEGRITY'S OUTAGE INSPECTION STRATEGY

In response to these failures, Great River Energy planned a brief outage to identify and repair areas of significant cracking, and asked us to develop an appropriate inspection strategy. The catch was that outage inspection time and access for the Unit 1 and 2 furnaces would be limited, which in turn limited inspection options. We were aware that traditional examination approaches—visual examination, magnetic particle testing, and exploratory grinding, either alone or in combination—would not be viable at Coal Creek because they would take too much time and they could not accurately characterize crack depth. We instead recommended nondestructive examination: a quick NDE overview of large areas of the furnace to identify tubing with the most severe cracking, followed by slower,

EDDY CURRENT GRADING

GRADE	DESCRIPTION
1	High - Large areas of cracks deeper than 0.050″
2	Medium - Multiple cracks deeper than 0.050″
3	Low - Isolated cracks deeper than 0.050″
4	No cracks greater than 0.050″ deep
5	Not Prepared

LINEAR PHASED ARRAY UT GRADING

GRADE	DESCRIPTION
1	Multiple cracks deeper than 0.100″
2	Single crack deeper than 0.100″
3	Cracking deeper than 0.050″ but not deeper than 0.100″
4	Cracking below ECT threshold
5	No Cracking
6	Not Accessible
7	Not Prepared

Table 1 Nondestructive Examination Grading System

	ECT OF AS-SAMPLED TUBES			ECT OF CLEANED TUBES		
ELEVATIONS	TUBE			TUBE		
1	122	121	120	122	121	120
2	N/A	N/A	LOW	N/A	HIGH	HIGH
3	LOW	HIGH	MEDIUM	N/A	HIGH	HIGH

Table 2 Laboratory Eddy Current Test Results

more-focused NDE techniques to gather accurate information on crack depth. Based on previous experience inspecting circumferential cracking in waterwall tubing, we also underlined the importance of tube surface preparation for this particular inspection. Circumferential cracks in waterwall tubes are usually not detectable under normal tube slag and scale, but they are visible after grit blasting. The inspection strategy that we ultimately developed for the particular circumstances at Coal Creek relied on a combination of visual examination, eddy-current testing, and linear phased-array ultrasonic testing.

TAKING IT STEP BY STEP

Visual examination was the first phase of our Coal Creek inspection strategy. Visual examination would enable inspectors to focus their more rigorous NDE efforts on locations where circumferential cracking was clearly present, and to expend minimal time on tubing that appeared to be uncracked. Because clean tubes are critical for visual examination, these examinations would be performed after tubes were grit blasted.

CRACK CLASSIFICATION

Once we identified cracked areas, the next step in our inspection strategy was crack classification. Previous laboratory analyses of Coal Creek tubes had identified crack depths ranging from through-wall (approximately 0.200”) to 0.003” in depth. In one section of the February 14, 2009 failure, a dozen cracks ranging from 0.003” to 0.016” were measured. While these cracks were relatively shallow, the number of cracks was high. One location away from the failure had a crack density of 16 cracks per inch. Because only those cracks with the potential to cause leaks in the short term would be of immediate interest, a method for identifying the deeper cracks was needed. We identified ferrous eddy-current testing (ECT) as a possible screening tool, notably Zetec, Inc.’s MIZ-21 eddy-current instrument. Laboratory testing using sections of one of the failed Coal Creek tubes determined that ECT could reliably measure crack depth if the depth did not exceed approximately 0.050”. Cracks greater than 0.050” in depth can be detected by the ECT equipment, but they cannot be accurately sized because of the limited depth of penetration of eddy currents in ferromagnetic materials. Based on the range of crack depths present in the Coal Creek Unit 2 waterwall tubes as identified in the tube sample analyses, the 0.050” upper threshold provided by the ECT system was considered an acceptable value for screening to reduce the number of cracks requiring further evaluation. Each tube section would be inspected with the Zetec eddy-current instrument and graded in accordance with Table 1.

LINEAR PHASED ARRAY ULTRA SONICS

After ECT screening, the next step in our inspection strategy was to examine any cracks that were deeper than 0.050” with linear phased-array ultrasonics, using an OmniScan linear phased-array (LPA) ultrasonic system from Olympus Corp. The swept-beam LPA ultrasonic technique that we proposed and ultimately used for the Coal Creek examinations employed 16- or 32-element linear array transducers mounted on a 55° shear wedge to produce an ultrasonic shear wave that is swept in 1° increments from 35° to 85°. The corresponding sector scan display allows for real-time flaw interrogation. Manipulation of the focal laws for the multi-element transducers would permit the Coal Creek examinations to be optimized for sizing what were anticipated to be relatively shallow cracks (0.050” to 0.150”), based on analysis of the February 14, 2009 failure. Each tube section inspected with LPA testing would be graded in accordance with Table 1.

While developing our inspection strategy, we also considered the effects of tube surface preparation on inspection data accuracy. Just as visual examination of tubing is influenced by tube surface condition, the effectiveness of ECT and LPA testing would be limited if applied to unclean tubes. To some extent, ECT will detect cracking under scale, but crack depth cannot be accurately determined due to the increased distance between the eddy-current coil and the metal tube surface. Additionally, at the time of the Coal Creek field examinations, the effectiveness of eddy-current crack detection through scale had not yet been validated, so we had to consider crack detection on unprepared tubes to be unreliable. Further emphasizing the importance of tube surface preparation, the LPA ultrasonic equipment used for this project was not capable of scanning through the layer of scale.

Continued on next page

PUTTING OUR STRATEGY INTO ACTION

Great River Energy was convinced by our inspection strategy, and an SI team arrived at Coal Creek in spring 2009 to support the awaited outage. Coal Creek plant personnel had already planned their own outage inspection and repair activities, including removing and replacing circumferentially cracked tubing as needed. A contractor was on hand to prepare the waterwall tubing surface, after which our team would lay out the furnace inspection grid and inspect the tubing.

Preparatory activities for the brief outage, included developing a detailed inspection scope using tube failure data and available visual inspection information. We were on site for a total of seven days, but actual inspection activities had to be completed within a five-day window after tube surface preparation. The initial inspection scope included all four outer furnace walls, as well as both sides of the center/division wall. Because of the apparently localized nature of the failures, inspections were confined to specific areas on each wall. Although the inspections did not cover the entire furnace area, approximately 6,700 sq ft of tubing had to be evaluated for cracking. Every third tube was examined over a predetermined length, with the exception of the front wall in Furnace A, where—because of the number of tube failures that had occurred on that wall—every tube within the designated area was inspected.

We had also mobilized a team built for speed, one that would provide inspection data in a timely manner, and support immediate run/replace waterwall decisions. Our 18-person team included the project manager, engineering and material leads, data analysts, and NDE technicians. To optimize Coal Creek inspection activities, work was performed on two 12-hour shifts. Adjustments had to be made to accommodate the fact that all activities within the furnace had to be conducted using swinging or suspended scaffolds. The scaffolds, although adequate, would limit overall inspection production rates.

Layout of the furnace inspection grid was our first on-site activity. The grid consisted of 1-ft-high horizontal bands on all furnace walls. To save time, some members of our team conducted visual examination of the waterwall tubing while others laid out the inspection grid. This activity took approximately two shifts to complete. To save even more time, a portion of the eddy-current and linear phased-array testing was performed just as soon as technicians completed visual inspections.

OXIDE COMPLICATIONS

We had to work around an added complication-tube surfaces had been prepared by workers grit blasting from suspended scaffolding, so the overall prepared surface condition was less than optimum. As shown in Figure 1, the external oxide and scale which remained in place, masked the underlying cracks. This affected both inspection productivity and data quality. While the grit blasting had removed a substantial amount of ash and slag from the tubing, patches of external oxide remained on the surface of some tubes. External oxide can conceal cracking, interfering with visual examination. Oxide can also reduce the effectiveness of NDE techniques that employ probes that remain in contact with tube base metal. When our technicians began screening areas with the ECT technique, these discontinuous external oxides caused the probe to lift off the tube surface. This lift off, and the oxide topography, influenced the resulting measurements. Fortunately, while surface conditions affected specific ECT readings, the impact on overall assessment was minimal, because there were clean areas available for testing within the 1-ft lengths of tubes tested. Still, surface condition did impact the overall production rate for ECT testing because technicians had to search for oxide-free areas to examine. This activity took about eight shifts to complete. But in the end, our use of complementary NDE techniques optimized data collection activities, increased the accuracy of crack sizing, and reduced the total time needed to perform Coal Creek's inspections. Once we screened an area with ECT, teammates moved in to perform LPA ultrasonic inspections on locations with damage above the ECT threshold of 0.050". The LPA inspections were completed within just five shifts.

WHAT INSPECTION REVEALED

In all, Structural Integrity examined about 10% of the nearly 70,000 sq ft of furnace tubing at Coal Creek Units 1 and 2. The good news-within the areas inspected, damage was confined to less than 250 sq ft, and most of that (about 200 sq ft) was in just two areas on the front wall of Furnace A. The remaining damage consisted of a small area on the front wall of Furnace B, and isolated tubes on both the front and rear walls. No circumferential cracking whatsoever was detected on side or center walls. We entered the data from the ECT and LPA examinations into TubeTrack, a graphics database, for convenient storage and presentation. ECT data for the front wall showed that cracking was most extensive on the right side of Furnace A, with only a few tubes on the left of Furnace showing any signs of damage. As illustrated in Figure 2, the damage extends from the top burner elevation almost to the top of the SOFA opening, and is slightly skewed toward Burner Corner 4. LPA results for Furnace A are shown in Figure 3. For all of the tubes with cracks greater in depth than the ECT threshold of 0.050", LPA confirmed that most of the cracks were below 0.100" deep. A much smaller population contained cracks greater than 0.100", either as isolated cracks or multiple cracks.

SURFACE PREPARATION COUNTS

Even with field inspection at Coal Creek completed, our work wasn't over yet. A sample panel of tubes that included various levels of circumferential cracking was sent to our Materials Science Center in Austin, Texas, for further nondestructive evaluation and destructive metallurgical testing. This panel contained a section of tubing that still retained external scale: the purpose of these last laboratory tests was to determine the effects of inadequate tube surface preparation. We conducted ECT on a 2-ft length of three of the tubes, representing the portion of the panel that retained the in-situ tube surface preparation found in the Coal Creek boiler. The area was then grit blasted down to white metal and a second ECT scan performed. The results shown in Table 2 illustrate the considerable effect of external scale on the accuracy of damage classification.

Of the six measurements classified before and after proper preparation, two classifications remained the same, three increased in damage level, and one decreased. While the change in classification was limited to one level in some areas, there were two instances where the level changed two or more classes, underscoring the importance of proper surface preparation.

Of particular concern was the fact that most classification changes were non-conservative. The damage level identified on an improperly cleaned tube tended to be lower than it would be on a properly cleaned tube. Additionally, the damage did not change in a consistent manner or by a consistent amount. While in the lab, we also looked more closely at LPA testing, evaluating the effects of different transducer sizes and frequencies on the ability to size the deeper indications in the Coal Creek samples. The conclusion was that smaller, higher-frequency probes provided better separation of multiple surface cracks. Finally, our technicians took and measured metallurgical sections to corroborate the damage classifications, and found good agreement between SI's NDE results and the measured crack depths for properly cleaned tubes.

PROOF OF SUCCESS: NO LEAKS

In the final analysis, outage inspection of Coal Creek's waterwall tubes revealed one previously undetected through-wall crack and several other cracks with significant depths of greater than 0.100" through-wall. While the effectiveness of the inspection was limited by aspects of surface preparation and scaffolding access, Great River Energy considered the effort a success. The inspections were performed within the brief outage window that was available, enabling Coal Creek to replace tubing as needed in the same quick outage. Based on outage inspection results, recommendations were made to replace a few isolated areas and single tubes. Coal Creek Units 1 and 2 have not experienced any waterwall leaks from the time of the spring 2009 outage to Coal Creek's latest 2010 outage, confirming the effectiveness of our strategy.

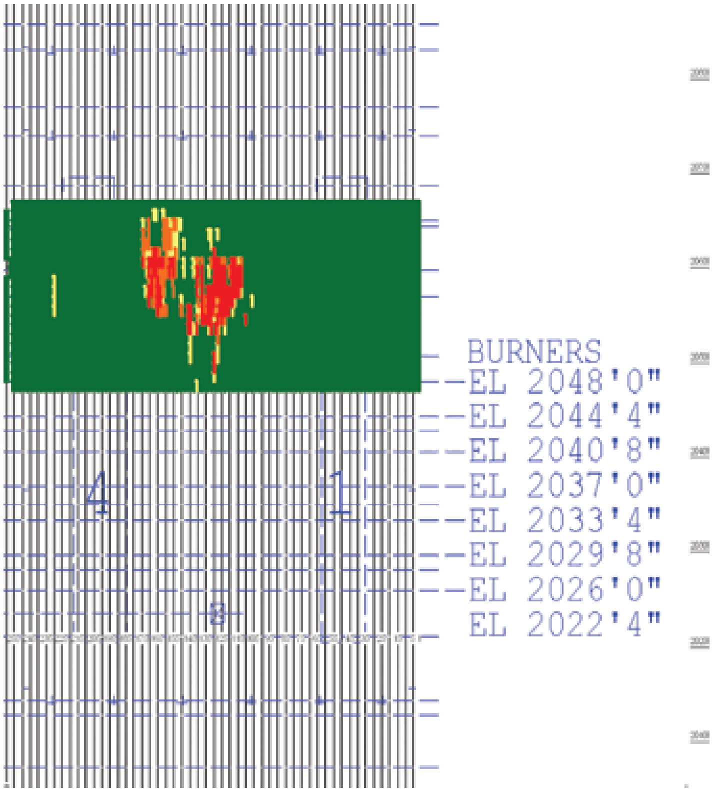


Figure 2

Eddy current results for the "A" furnace Front Wall.

(Note colors correspond to damage grades provided in Table 1)

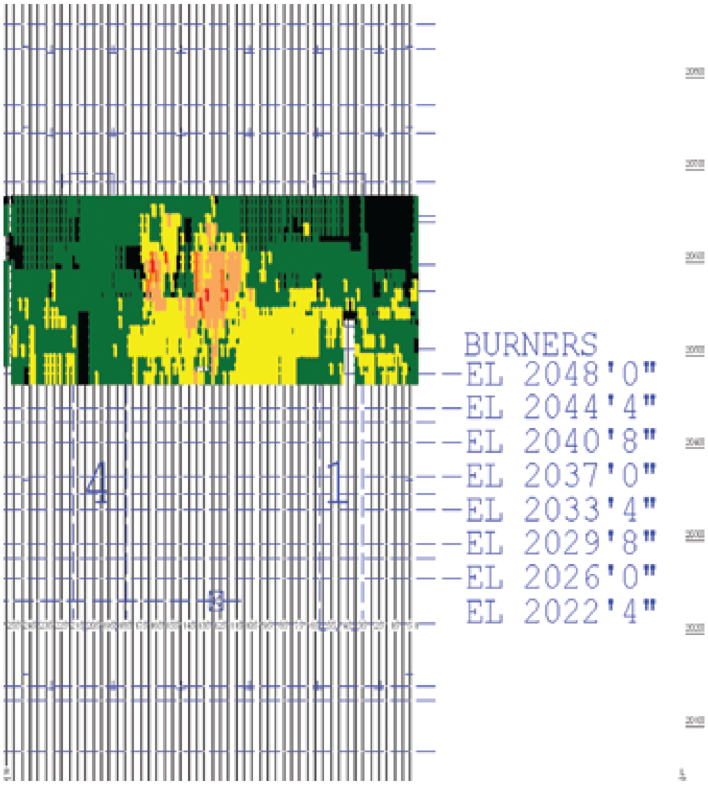


Figure 11

Linear Phased Array results for the "A" furnace Front Wall.

(Note colors correspond to damage grades provided in Table 1)

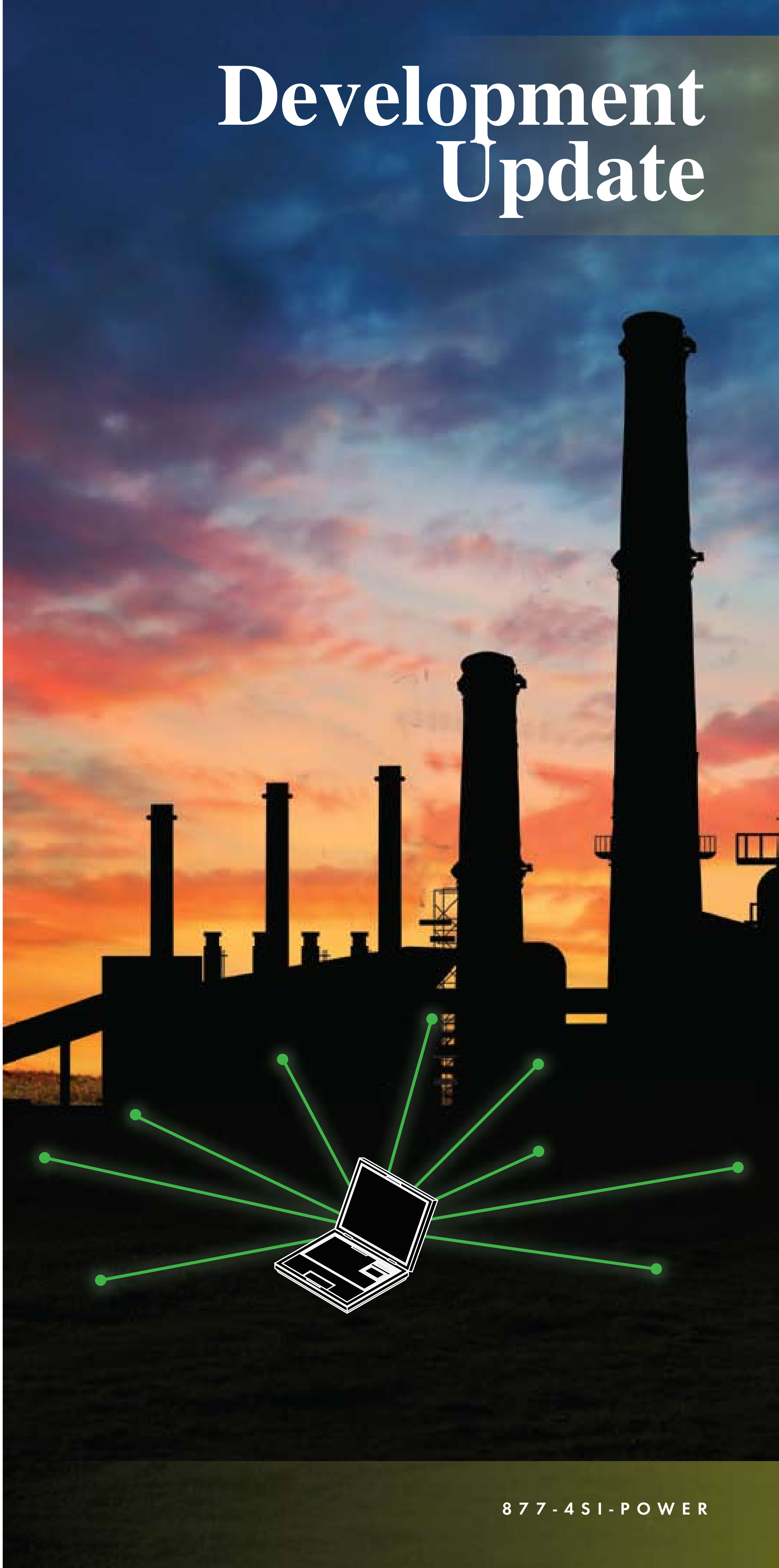
CONGRATULATIONS
DICK SMITH

Join us in congratulating Dick Smith, a Senior Associate at Structural Integrity, as an AWS Fellow. This award by the American Welding Society acknowledges distinguished contributions to the field of welding science and technology, and for promoting and sustaining the professional stature of the field. Election as a Fellow of the Society is based on the outstanding accomplishments and technical impact such as having advanced the science, technology and application of welding, as evidenced by:

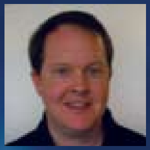
- Sustained service and performance in the advancement of welding science and technology
- Publication of papers, articles and books which enhance knowledge of welding
- Innovative development of welding technology
- Society and chapter contributions
- Professional recognition

The AWS made him a fellow late last year citing his understanding and promotion of the integrated applications of materials and welding technologies, applied fracture mechanics and stress analysis needed for innovative welded repairs of electric power generating equipment. Dick exemplifies the on-going engineering expertise we provide our clients. Congratulations, Dick!

Development Update

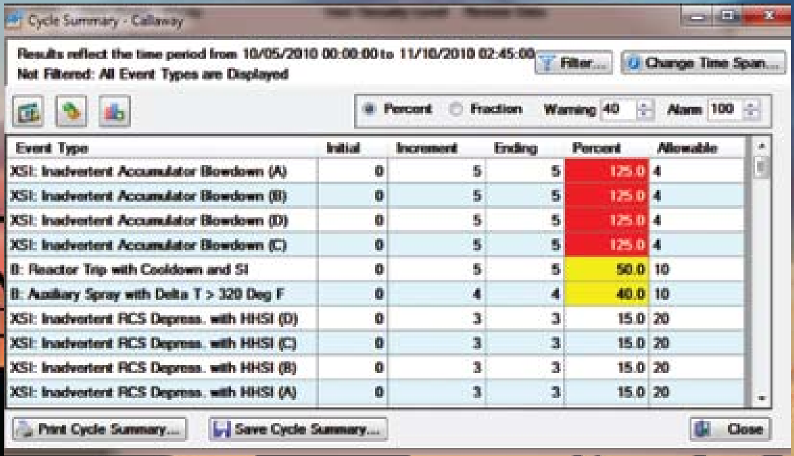


FATIGUEPRO 4.0



By: *TIM GILMAN*
tgilman@structint.com

Structural Integrity is currently developing FatiguePro^{TM} Version 4 (FP4), the next generation of fatigue monitoring EPRI$^{®}$-licensed software for the nuclear industry. FP4 will include both significant technical and user interface/usability improvements. On the technical side, FP4's new stress-based fatigue (SBF) module will represent a quantum leap in technology from the previous version.



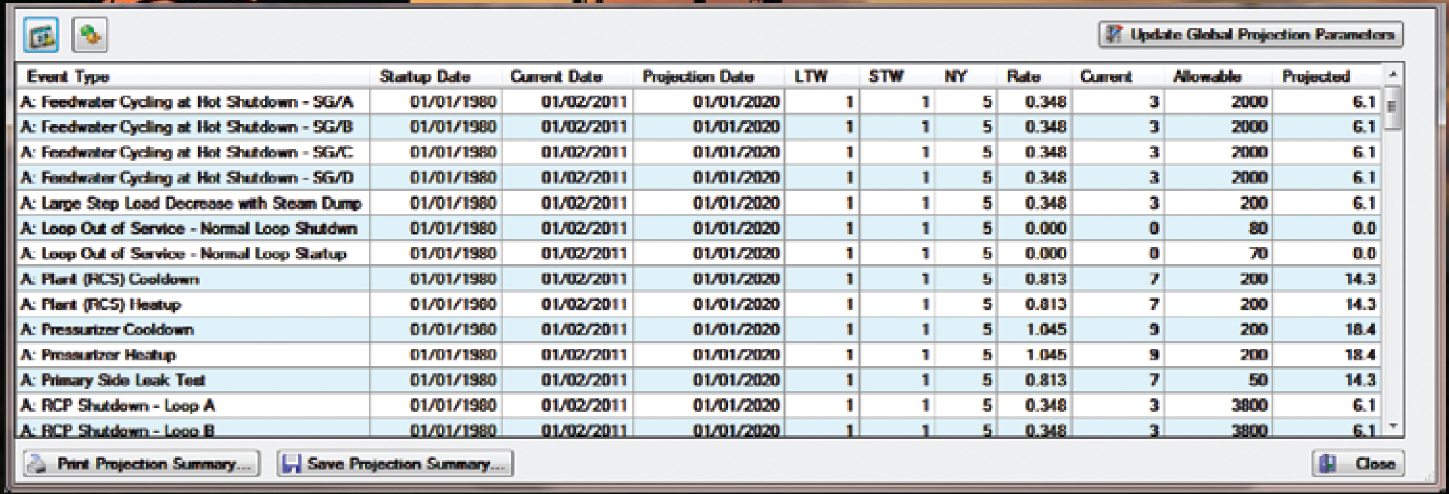
Results reflect the time period from 10/05/2010 00:00:00 to 11/10/2010 02:45:00
Not Filtered: All Event Types are Displayed

Event Type	Initial	Increment	Ending	Percent	Allowable
XSI: Inadvertent Accumulator Blowdown (A)	0	5	5	125.0	4
XSI: Inadvertent Accumulator Blowdown (B)	0	5	5	125.0	4
XSI: Inadvertent Accumulator Blowdown (D)	0	5	5	125.0	4
XSI: Inadvertent Accumulator Blowdown (C)	0	5	5	125.0	4
B: Reactor Trip with Cooldown and SI	0	5	5	50.0	10
B: Auxiliary Spray with Delta T > 320 Deg F	0	4	4	40.0	10
XSI: Inadvertent RCS Depress. with HHSI (D)	0	3	3	15.0	20
XSI: Inadvertent RCS Depress. with HHSI (C)	0	3	3	15.0	20
XSI: Inadvertent RCS Depress. with HHSI (B)	0	3	3	15.0	20
XSI: Inadvertent RCS Depress. with HHSI (A)	0	3	3	15.0	20

Specifically, these improvements include:

(1) Multiaxial stress cycle counting. The new SBF module will compute all six components of the primary, secondary and peak stresses, in accordance with the ASME Code Subarticle NB-3200, to address NRC concerns, as expressed in Regulatory Information Summary 2008-30. Sophisticated, first of a kind algorithms are being developed to count stress cycles, taking the multiaxial and order-dependent nature of the stresses into account, while also being consistent with the requirements of the ASME Code.

(2) Automatic calculation of environmental fatigue. Unlike the previous version, FP4 will include an option to automatically calculate environmentally-assisted fatigue usage in accordance with applicable NRC NUREGs for license renewal and new plants and the latest industry guidance for calculation of integrated F_{en}'s.



Event Type	Startup Date	Current Date	Projection Date	LTW	STW	NY	Rate	Current	Allowable	Projected
A: Feedwater Cycling at Hot Shutdown - SG/A	01/01/1980	01/02/2011	01/01/2020	1	1	5	0.348	3	2000	6.1
A: Feedwater Cycling at Hot Shutdown - SG/B	01/01/1980	01/02/2011	01/01/2020	1	1	5	0.348	3	2000	6.1
A: Feedwater Cycling at Hot Shutdown - SG/C	01/01/1980	01/02/2011	01/01/2020	1	1	5	0.348	3	2000	6.1
A: Feedwater Cycling at Hot Shutdown - SG/D	01/01/1980	01/02/2011	01/01/2020	1	1	5	0.348	3	2000	6.1
A: Large Step Load Decrease with Steam Dump	01/01/1980	01/02/2011	01/01/2020	1	1	5	0.348	3	200	6.1
A: Loop Out of Service - Normal Loop Shutdwn	01/01/1980	01/02/2011	01/01/2020	1	1	5	0.000	0	80	0.0
A: Loop Out of Service - Normal Loop Startup	01/01/1980	01/02/2011	01/01/2020	1	1	5	0.000	0	70	0.0
A: Plant (RCS) Cooldown	01/01/1980	01/02/2011	01/01/2020	1	1	5	0.813	7	200	14.3
A: Plant (RCS) Heatup	01/01/1980	01/02/2011	01/01/2020	1	1	5	0.813	7	200	14.3
A: Pressurizer Cooldown	01/01/1980	01/02/2011	01/01/2020	1	1	5	1.045	9	200	18.4
A: Pressurizer Heatup	01/01/1980	01/02/2011	01/01/2020	1	1	5	1.045	9	200	18.4
A: Primary Side Leak Test	01/01/1980	01/02/2011	01/01/2020	1	1	5	0.813	7	50	14.3
A: RCP Shutdown - Loop A	01/01/1980	01/02/2011	01/01/2020	1	1	5	0.348	3	3800	6.1
A: RCP Shutdown - Loop B	01/01/1980	01/02/2011	01/01/2020	1	1	5	0.348	3	3800	6.1

FatiguePro is the most widely-deployed fatigue monitoring system for nuclear plants with installations at more than 80 units worldwide. The technical basis for the new SBF technology will culminate in an EPRI MRP report this year. FP4 development is scheduled to support initial plant-specific deployment in 2012.

Please contact Tim Gilman (tgilman@structint.com) for more information and the latest development efforts.

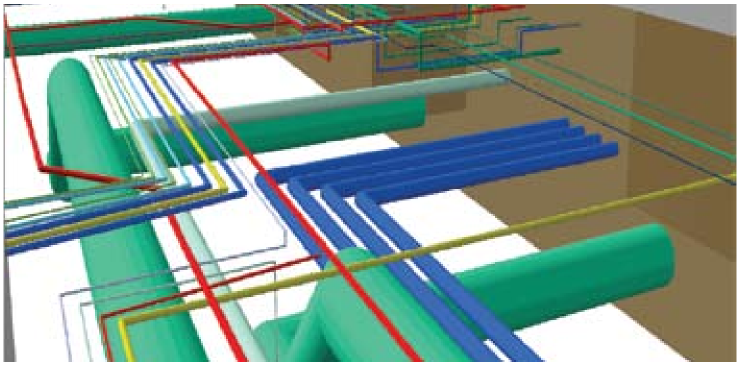
MANAGING BURIED PIPING & UNDERGROUND ASSET INTEGRITY

By: STEVE BIAGIOTTI
■ sbiagiotti@structint.com

Managing all the data pertaining to buried and underground pipe and tanks at nuclear power plants takes a robust program. The information is used to minimize unexpected failures and the impact of those failures. Due to the importance and management required of that data, NEI Initiative 09-14 rev 1, Guideline for the Management of Underground Piping and Tank Integrity, established formal goals, responsibilities, and deadlines for risk ranking buried pipe and ultimately conducting inspections on these systems to achieve reasonable assurance of structural and leak integrity.

> ***Structural Integrity has been at the forefront and an instrumental contributor in creating a program to meet the NEI Buried Pipe Initiative.***

EPRI contracted with Structural Integrity in 2009 to develop the BPWorks™ 2.0 database and software interface. This database provides the industry with a robust data structure for storing and editing design, operating and inspection information for piping systems.



To complement BPWorks 2.0, we developed the MAPPro™ family of buried pipe applications. These engineering tools allow utilities to:

- Perform external and internal corrosion-based risk ranking of buried pipe, tanks and other structures not currently addressed in BPWorks 2 risk algorithms
- Import high volumes of data
- Evaluate the trends associated with cathodic protection, soil testing, tritium monitoring wells and inspection data (e.g., GWT, BEM, UT, etc.)
- Visualize all BPWorks database information in an interactive, graphical GIS environment through our MAPProView™ tool.

Our current list of Managing Aging Piping applications; a.k.a. **MAPPro** Apps, that are available or under development are:

MAPProView™ – Structural Integrity's data integration and visualization tool to allow system engineers to rapidly utilize database information, overlaid onto plant drawings or aerial imagery in either 2D or 3D. Photographs, as well as PDF and DWG files can be linked into this system for instant viewing.

MAPPro Risk – Addresses all pipe materials, fluid types, soil conditions, etc., and adjusts the risk model based on, but not limited to, corrosion mitigation (i.e. cathodic protection) and inspection results. It also provides the ability to adjust the risk model based on unique plant conditions or operating experience.

MAPPro Tank – Addresses tanks, sumps and other buried structures. Data can be managed in this module and used in risk calculations. The risk results can be evaluated alone or integrated with pipe risk results within the same system.

MAPPro GWT– Allows input and management of GWT inspection results such that they can be reviewed in BPWorks or MAPProView 2D/3D.

MAPPro CP – Imports Cathodic Protection measurements into BPWorks and performs trending analysis to expose issues.

MAPPro APEC – Views and evaluates results from the coating condition and CP system effectiveness inspection technology - APEC. APEC data is also viewable in MAPProView.

MAPPro Inspection Planning – Identifies applicable NDE methodologies based on characteristics and can prioritize inspection dates based on risk ranking. Results can be exported or linked to plant site workflow management software.

MAPPro LCM – Calculates and displays leak evolution curves as part of a quantitative Life Cycle Management study. Probability and number of leaks can be plotted as a function of time for a single component or for a system.

MAPPro Reports – Extracts and presents data from the BPWorks database.

MAPPro Query – Search the BPWorks database based on custom needs.

MAPPro Cable – Manage information about low and medium voltage cables as part of a Cable Aging Management program. Data can also be linked for viewing in MAPProView.

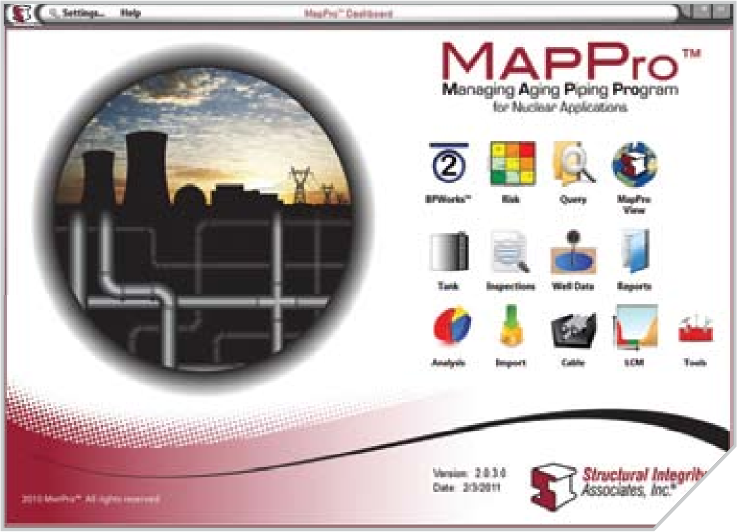
MAPPro N513 – Applies the principles of Code Case N-513-3 to provide remaining wall thickness threshold guidance when performing excavations and UT inspection. Calculator can be used to generate preliminary flaw tolerance estimations in advance of an inspection or excavation.

MAPPro Well – Stores measurement data collected at tritium monitoring wells and lists the nearest buried pipe to the well. Data also linked to MAPProView for visualizing results as measured values change.

SoilPro™ – Models measured soil parameters into effective pitting corrosion rate models for use in remaining life and re-inspection interval determination.

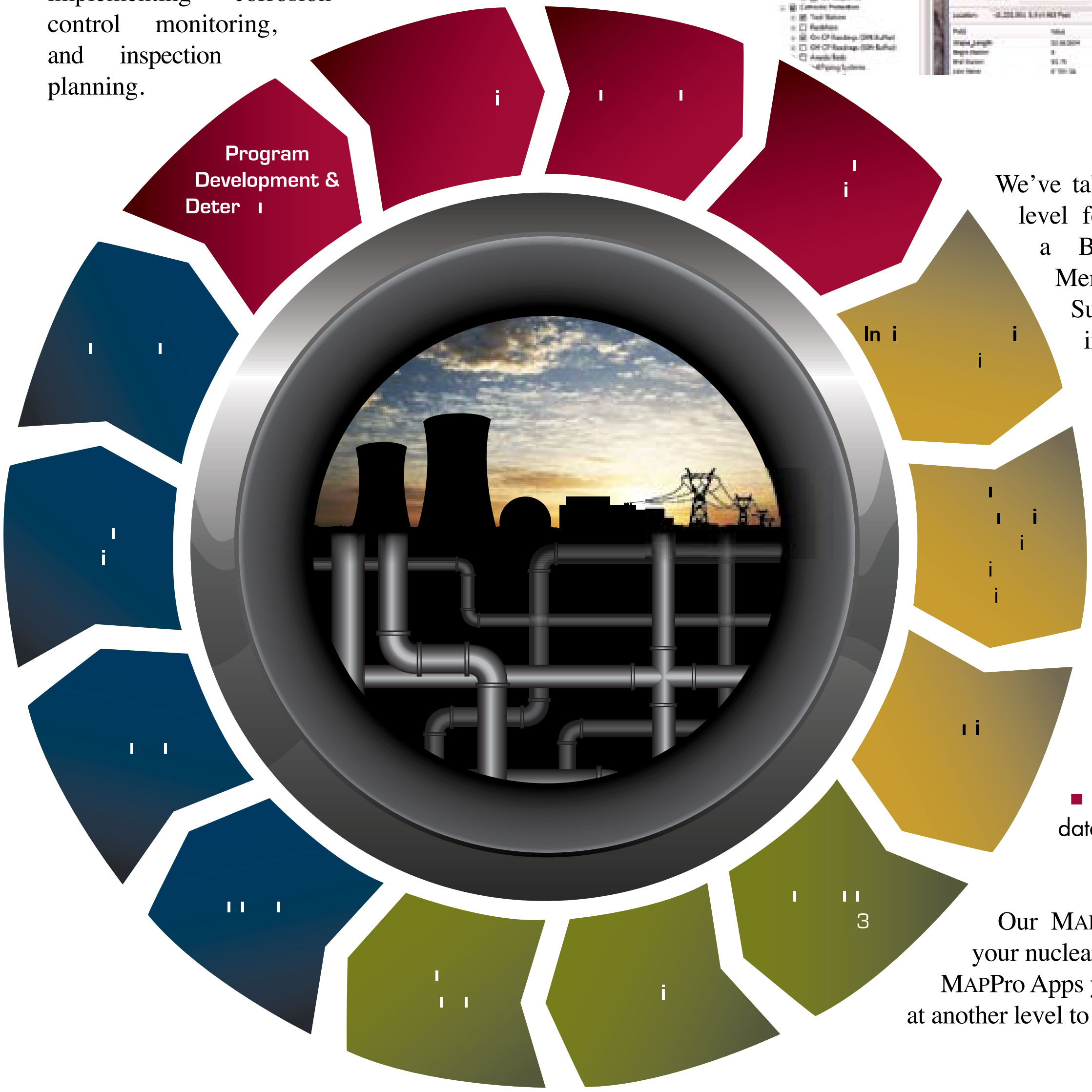
View our online brochure at www.structint.com/mapprobrochure

SITES USING ONE OR MORE MAPApps INCLUDE:
Exelon, Entergy (ANO, Grand Gulf, Indian Point, Waterford), Constellation (Calvert Cliffs, Ginna, Nine Mile Point), STARS (Callaway-only using MAPPro and MAPRisk, Gary Barta at Comanche Peak, Diablo Canyon, SONGS, STP, Wolf Creek), TVA Sequoyah, Xcel (Monticello), and USA (Cooper, Fermi).



We have successfully aligned our specialized engineering and pipeline corrosion control experience to address underground asset integrity issues. We have inspection solutions that evaluate external coating condition and corrosion potential (APEC), soil testing and characterization programs that yield effective corrosion rates for exposed steel, and GWT to extend the range of UT inspections to increase confidence that the worst case locations are being quantitatively evaluated.

A large portion of the domestic nuclear fleet is using our corrosion engineering expertise and software tools for data discovery, risk ranking, inspection planning, inspection execution, excavation evaluation support, coating condition and cathodic protection system evaluation (i.e., APEC), CP system design, and installation flaw disposition, life cycle management studies, implementing corrosion control monitoring, and inspection planning.



INTRODUCING OUR BURIED PIPE USER COMMUNITY

We've taken our MAPPro Apps to another level for our clients. We are creating a Buried Pipe User Community. Membership benefits in the new Support and Maintenance program include:

- Participation in the guidance and development of new tools
- Free access to all tools as soon as they're developed
- Exclusive invitations to online webinars
- Secure access to specialized training
- Free engineering or software support
- Support for updating BPWorks 2.0 data and MAPProView

CUSTOMIZED FOR YOU

Our MAPPro Apps can be customized to your nuclear plant needs or you can choose the MAPPro Apps you most need. It's customization at another level to meet your needs.

ALLOY 600 UPDATE

By: BUD AUVIL
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By: JIM PUZAN
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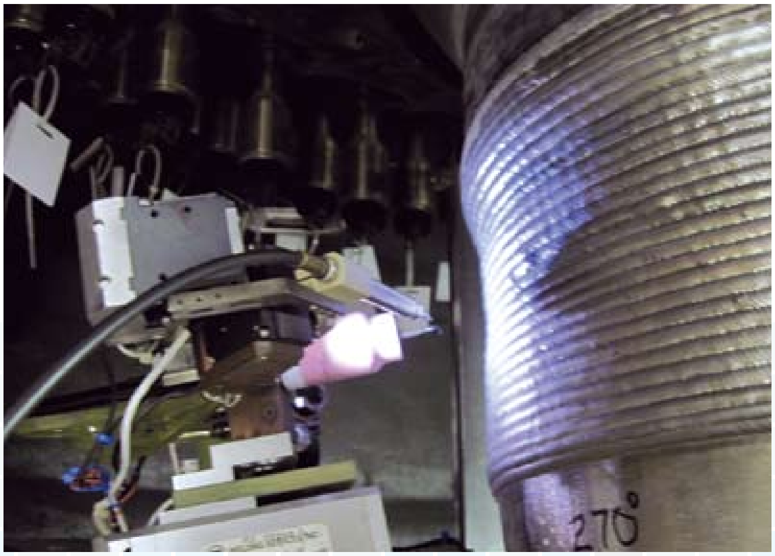
WELD OVERLAY REPAIRS

W(SI)^2 was recently awarded and has commenced work related to planned, preemptive weld overlay repairs of North Anna-1 steam generator-to-hot leg Alloy 600 nozzle welds (3 total welds). These large diameter welds (more than 40 inches) are the thickest to be overlaid to date (more than 5 inches), and are planned for repair in Spring 2012.



LINEAR PHASED ARRAY (LPA) UT

Our team completed the linear phased array (LPA) UT examination of 25 dissimilar metal welds during Calvert Cliffs-2 Spring 2011 outage. Structural Integrity Associates, Inc. provided the LPA UT support and WSI provided weld surface preparation support where required. The project was completed well ahead of schedule with no recordable flaws detected.

ALLOY 600 REPAIRS

In recent years, W(SI)^2 has established itself as the dominant international supplier of Alloy 600 repairs. Since our last "W(SI)^2 Update", the team has successfully completed pressurizer refurbishment-related overlays at one plant in South America, and one in Asia. Six additional pressurizer refurbishments are contracted for completion over the next two years – four in Asia and two in Europe.

UT IN LIEU OF RT

W(SI)^2 recently supported two non-safety replacement component projects employing UT in lieu of RT at one plant site. UT in lieu of RT provides nuclear (and non-nuclear) utilities a cost-effective means of averting the logistical and schedule challenges of construction radiographic testing (RT) using code-acceptable ultrasonic testing (UT) methods. We also have previously supported several nuclear safety-related Alloy 600 replacement projects using UT in lieu of RT under NRC-approved relief based on ASME Code Case N-659.

ABOUT

W(SI)^2 is the team of Aquilex Welding Services Inc. (WSI) and Structural Integrity Associates Inc. (SI). This 25-year partnership started with weld overlay repair of BWR primary system welds (due to IGSCC damage). In recent years, this team has set the industry standard for the engineering, licensing, implementation, and inspection of Alloy 600 component repairs.

Risk-Based Approach Enhances District Energy System Reliability

By: *JOE MACIEJCZYK*
jmac@structint.com

Failures and unplanned outages of critical infrastructure piping and boilers can be avoided with a proactive, risk-based inspection program.

For the first time in 60 years of U.S. Energy Information Administration recordkeeping, electrical consumption in the United States decreased for two consecutive years. The recession certainly played a part in this, as did Americans' increased awareness of their energy use and the need for conservation. Suppliers of all types of energy have had to accommodate this reduced demand.

As district heating customers have used less energy, boiler operators have seen curtailed operation, more hot standby and cyclic operations. This type of operation poses unique challenges to capital equipment and infrastructure piping creating the potential for problems that, if left unaddressed, could lead to unplanned outages, unbudgeted expenditures and disruptions of service to customers.

Typical inspections of boilers and piping are not designed to identify these types of problems. They generally focus on baseloaded operation, such as the yearly inspection of the boiler and relief valves by an authorized inspector. Distribution piping inspections are most often handled on an exception basis: When leaks and failures create a forced outage, they are repaired, and the system is put back into operation. Cyclic operation exacerbates these issues.

Failures and forced outages can be avoided, however, with a program of proactive boiler and piping inspections and repairs that are prioritized on the basis of system risk factors. Structural Integrity Associates, Inc., (SI) has led numerous targeted inspection programs during normal scheduled outages that are crucial to keeping district heating systems operational and safe until the next scheduled inspection.

BOILER INSPECTIONS

Boilers are typically not designed to handle cyclic operations. Startups and shutdowns, even though they are within operating parameters for pressure and temperature, generate metal temperature gradients and set the stage for cracking and through-wall defects most likely from either thermal fatigue, an external phenomenon, or corrosion fatigue, an internal actor. Undetected cracking that is allowed to grow unchecked can result in forced shutdowns and safety concerns for operating personnel. Planning a program of risk-based inspections to prevent such issues is fairly straightforward for boilers, given that boilers tend to be quite standard in design (as compared with the unique nature of most piping installations). The areas presenting the greatest potential for problems typically include welds, boiler tubing and exhaust ducting, and internal boiler water wall tubing.

Thermal fatigue cracking is most likely to occur at or near welds. Inspecting every weld in a boiler may be possible, but it is impractical in terms of time and cost. Thermal transients in boilers will flex components that are the farthest away from rigid anchors. This flexing causes fatigue cracks to form and grow. Suspect areas include welded rigid anchors and boiler-tube-to-header connections.

Continued on next page

Corrosion fatigue cracking, an internally generated attack of cold-side water wall tubing, most often shows up as a pinhole leak at the toe of a weld.

Review of the boiler construction drawings can locate the main anchors and supports in the system for inspection planning. In lieu of drawings, a visual inspection of the boiler internals can also locate these anchors. Our technical support team completes a nondestructive examination (NDE) of these anchors to verify their integrity and looks at the high-flex connections associated with them to form the basis of a sound inspection program.

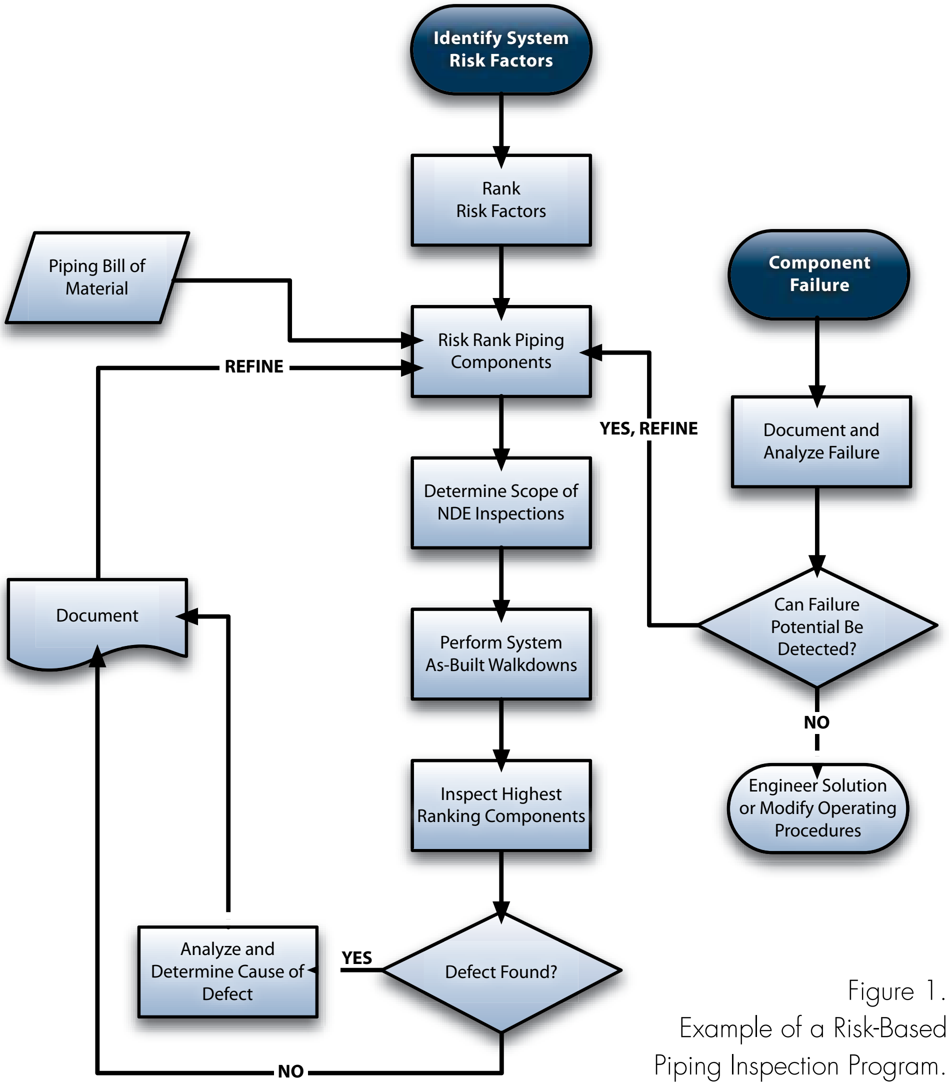


Figure 1.
Example of a Risk-Based Piping Inspection Program.

The type of NDE typically done for welds in boilers to detect external cracking is magnetic particle testing. Internal tubing issues are found through such NDE techniques as fiber optic visual inspection, radiography or linear phased array ultrasonic scanning. Depending on the particular defect, it may either be removed by weld repair, tracked for followup or analyzed more rigorously if it appears to indicate a larger, more systemic problem. Technologies for more in depth analysis include field metallography and finite element modeling with software such as ANSYS.

Cyclic boiler operation can create other issues that, if unchecked, can also result in forced outages and loss of revenue. Some of these include external corrosion of boiler tubing and exhaust ducting, and internal boiler water wall tubing failure. Cyclic operation can put boiler components in the dew point temperature range that will promote the condensation of acids, which can rapidly destroy tubing exterior or ducting, and other components. Loss of cycle chemistry during downtime, startups or load changes can lead to deposit formations in water walls, which can initiate underdeposit corrosion and oxygen pitting. Review of operational logs and targeted followup inspections can locate these issues and result in procedural refinements to mitigate their occurrence.

PIPING INSPECTIONS

Over the past 20 years, significant advancement has been made by industry and professional organizations, including Structural Integrity, in the area of risk-based inspections of equipment and piping. Some notable examples of guidelines they have produced include the American Petroleum Institute's standard API 581 (Risk-Based Inspection) and the American Society of Mechanical Engineer's standard PCC-3 (Inspection Planning Using Risk-Based Methods). API 581 takes a quantitative look at specific equipment and lets owners

calculate a risk factor that can be applied to their equipment as a ranking input to an inspection program. ASME's standard takes a broad approach and recommends reviewing both quantitative and qualitative factors as a basis for an inspection program.

We fully understand the multiple interrelated factors that affect the overall risk of an individual piping component

These include:
- Fluid service
- Component location
- Potential damage mechanisms

The type of fluid being conveyed in the piping system is a critical factor in prioritizing piping inspections. The fluids utilized by an energy supplier range from natural gas and fuel oil to steam and chilled water. The relative hazard posed by each of these fluids needs to be considered together with other facility specific factors to determine the risk of an individual piping system component. For example, chilled water is generally treated as a low hazard fluid; but a chilled water line rupture in a tunnel distribution system can potentially expose personnel to an inundation risk thus elevating the hazard rating of the piping component in the affected areas.

The location of the piping drives its relative risk factor. Components located in vaults or manholes, or near a building or tunnel egress, all garner a higher risk factor, but for different reasons. Vaults or manholes are typically permit confined spaces with single point egress. Failure of a piping component while these spaces are occupied by personnel would obviously have major consequences, thus elevating the relative risk factor.

Buildings or tunnels have multiple egress points, which would seem to suggest they are safer; but piping components located near any routine use egress point have a high 'man pass' frequency and, consequently, a higher relative risk.

Other location specific risk factors for piping components include their proximity to vehicular traffic, whether they are buried or above ground, and their relative accessibility. It is self evident, for example, that an exposed, unprotected piping system is at greater risk of a catastrophic impact by a vehicle than piping components that are remote to roadways. The same is true for piping located above ground versus components below ground. An inaccessible component, however, can create risks that are easy to underestimate and that can even obscure multiple other attendant risks. For example, a piping component installed in a location with inadequate clearances to walls, floors or other obstructions may not allow for proper fitup and welding; and the initial construction inspection of this component's welded joint could have been subpar or even overlooked. Because of this piping component's inaccessibility, it has an increased risk of failure and would therefore rank high in priority in a risk-based inspection program.

In addition to fluid service and component location, the potential damage mechanisms that may affect piping systems also need close scrutiny. One common issue faced by energy suppliers is the myriad causes of piping corrosion which range from microbial, poor water chemistry control and underinsulation to flow accelerated corrosion and cathodic protection failure in buried piping. This corrosion can manifest itself as either systemwide or highly localized issues all with varying degrees of detectability. Another damage mechanism, cyclic thermal stress, can initiate localized fatigue cracking. An as-built stress analysis of the piping system can identify areas to inspect for this.

Identifying the risk potential that these damage mechanisms hold for a piping system requires a failure analysis program and recordkeeping methodology that feeds and refines the inspection program, a program that we fully understand and have years of experience working with. Risk ratings for failure mechanisms can be based on a number of factors such as consequences of failure, ease of detectability, rate of progression or probability of occurrence. These factors can be considered individually or combined with multiple factors to achieve a relative risk rating for each affected piping component.

Once risk factors have been identified and rated, they need to be applied to individual piping components so an overall ranking for each component can be achieved. Routine walkdowns of the piping system with as-built drawings will help identify new exceptions such as unreported, broken or missing hangers and supports, incorrectly specified piping components or previously unreported hazards. Our nondestructive examination team then plans to inspect the highest risk components. Results are evaluated, documented and fed back into component rankings to continue to refine a system's fitness for service (Figure.1).

Our inspections alone will not eliminate or mitigate all potential risks. Components that have reached their end of life will need capital investment to maintain system integrity and safety. For example, a pipe elbow that has corroded past its minimum safe wall thickness will need replacement instead of additional inspections. Human error is another risk factor that cannot be eliminated by inspections; it is best handled instead by operational or managerial procedures. But a proactive program of boiler and piping inspections will reduce the risk of forced outages, increase equipment availability, increase the safety of personnel, help eliminate service disruptions to customers and provide knowledge for making informed decisions.

When all these risk factors are calculated and reported, we then work with you to cost effectively fix any issues found. Give us a call at 1-877-4SI-POWER and we'll put a plan together for you.

NRC REGULATORY GUIDE 1.147

Revision 16 Highlights

ROBERT MCGILL
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The NRC issued Revision 16 of Regulatory Guide (RG) 1.147 last summer. This RG lists ASME Section XI Code Cases that are approved by the NRC for utility implementation without special approval. Some Code Cases have conditional acceptance where certain limitations are specified by the NRC for their use. The previous revision was nearly 3 years old, so there are some significant changes. Some highlights include:

CODE CASE N-513-3 (new revision), Evaluation Criteria for Temporary Acceptance of Flaws in Moderate Energy Class 2 or 3 Piping is now conditionally accepted. The NRC took exception to the new definition of "temporary period of acceptance" (as with the previous -2 revision, it remains until the next scheduled outage). Revision 3 of this Code Case makes applying branch reinforcement rules easier for dispositioning through-wall flaws. It also provides new flaw combination rules for nonplanar flaws.

CODE CASE N-504-4 (new revision), Alternative Rules for Repair of Class 1, 2, and 3 Austenitic Stainless Steel Piping is conditionally accepted. New NRC conditions have been added compared to the previous revision.

CODE CASE N-638-4 (new revision), Similar and Dissimilar Metal Welding Using Ambient Temperature Machine GTAW Temper Bead Technique is conditionally accepted. Allows an increase in temperbead surface area to 500 square inches over ferritic material without new relief. The 48 hour hold is now allowed to start after the third temperbead layer rather than having to wait for the weld to cool to room temperature before starting the hold period. This revision also limits interpass temperature to direct measurement except when it is impractical due to inaccessibility of the weldment area or extenuating radiological conditions.

CODE CASE N-661-1 (new revision), Alternative Requirements for Wall Thickness Restoration of Class 2 and 3 Carbon Steel Piping for Raw Water Service is conditionally accepted. This Code Case provides design criteria for wall restoration of raw service water piping (carbon steel). This revision addresses one of the three previous NRC conditions.

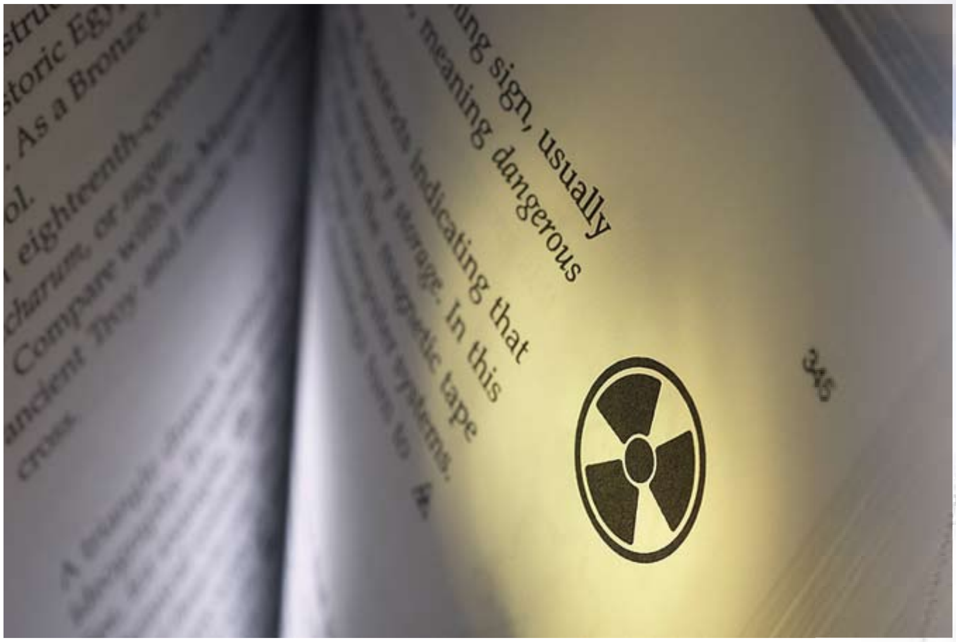
CODE CASE N-666 (new to the RG), Weld Overlay of Class 1, 2, and 3 Socket Welded Connections is accepted without condition. This Code Case provides weld overlay repair rules for socket welds.

CODE CASE N-705 (new to the RG), Evaluation Criteria for Temporary Acceptance of Degradation in Moderate Energy Class 2 or 3 Vessels and Tanks is accepted without condition. This is the sister Code Case to N-513 for vessel/tank leakage.

Note that the conditional acceptance for **CODE CASE N-597-2**, Requirements for Analytical Evaluation of Pipe Wall Thinning remains unchanged. This Code Case is currently being rewritten in ASME committee to address the NRC conditions.

Finally, **CODE CASE N-740-2**, Dissimilar Metal Weld Overlay for Repair of Class 1, 2, and 3 Items and **CODE CASE N-770-1**, Alternative Examination Requirements and Acceptance Standards for Class 1 PWR Piping and Vessel Nozzle Butt Welds Fabricated With UNS N06082 or UNS W86182 Weld Filler Material With or Without Application of Listed Mitigation Activities have not been approved in this revision of the RG.

While Revision 16 has been published, 10CFR55a Codes and Standards has not been updated to point to the latest RG 1.147 revision. 10CFR55a is expected to be updated later this summer.



COOL FACTS

By *ERIC HOUSTON*
ehouston@structint.com

Collectively, Structural Integrity has a lot of useful knowledge, but what about the useless? Impress your coworkers by sending us your most trivial, entertaining science and engineering knowledge for the next edition of Cool Facts to info@structint.com.

Alternative Fuels that Flopped

(or at Least Need More Development)

A short list of alternative fuels that could change the world, or waste the next three minutes of your life.

SOLAR PAINT:

Swansea University researchers seemingly stumbled upon the idea for solar paint after studying how sunlight degrades paint on metal building exteriors. A £1.5 million research grant will allow the exploration of a new type of photovoltaic cell that can be painted on during manufacturing. They hope to manufacture enough panels to produce 4.5 GW annually (and that is assuming only a 5% energy conversion rate).

http://www.swansea.ac.uk/news_centre/NewsArchive/2007-2008/Headline,21753,en.php

DIRTY DIAPERS:

Pyrolysis converts organic refuse material into fuels that can be burned. So why is the push to use just diapers and not household garbage? Consistency. The process is most efficient when the organic material is consistent. Ordinary garbage could contain all sorts of different things. However, we know what diapers are made of, and we know what our kids put in the diapers. A plant near Montreal is under development to produce this "diaper diesel."

http://auto.howstuffworks.com/fuel-efficiency/alternative-fuels/5-alternative-fuel-ideas.htm

FORD NUCLEON:

Ford's concept car of the late 1950's was to be powered by a miniature reactor (it's unclear if it was to be a PWR or BWR). The project never produced a prototype, but designers hoped to get 5,000 miles between fill ups.

http://media.ford.com/article_display.cfm?article_id=3359

Straightening Out Your Piping

ONE DRAWING AT A TIME

By: SEAN HASTINGS
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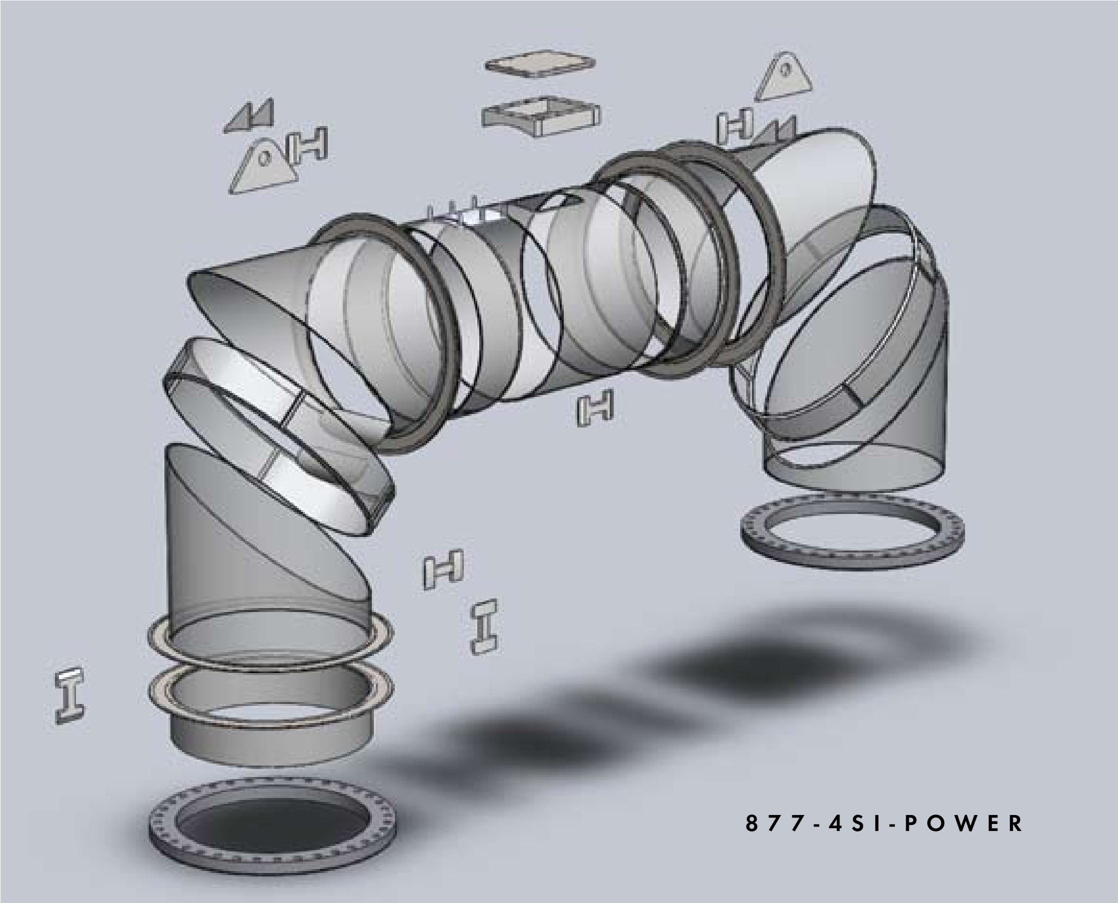
By: KEVIN HALEY
■ khaley@structint.com

Typically piping engineers have architectural drawings of their plant systems, and in many cases they originated from the OEM, drawings which were generated to determine a Bill of Material, construction parameters, and relevant code applications. Typically these drawings are 2D, and lack any mechanism or tools to aid in the management and operation of the system. Further, in many utilities and plants there may have been changes that have resulted in changes in the system from a multitude of sources. The result is huge stores of information that is scattered, hard to maintain, and at times makes getting detailed information on the systems very challenging.

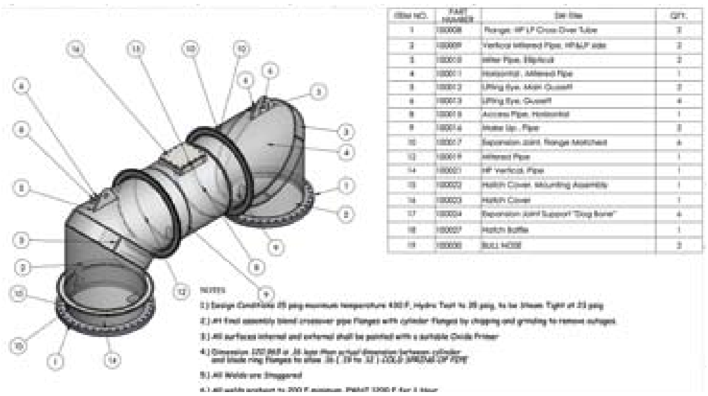
Structural Integrity Associates (SI) has been assisting clients with simplifying the management of these drawings and information relative to these systems for many years. SI can provide a "road map" to complicated piping systems and assist resource challenged utilities by creating drawings to clearly document the history of individual piping systems. This is typically accomplished via a 3D model which is used to uniquely identify all the relevant components, including pipe spools, weld type and locations, hangers support and their positions, and expansion joints. The historical references for each of the components in the system are then documented clearly on a drawing that can be used to track the chronology of the components in the system, in conjunction with inspection and life assessment project for piping systems and components. The ability to track this information is critical to providing proper life assessment of key assets during inspection periods for the systems.

The service functionality of this can be as simple as producing drawing for a road map to the utilities archive of historical drawings, or expanded into a database system for tracking key asset information. Steam Piping Information Modeling is something we have been performing for a number of years. In any asset assessment program, a key factor in its success is the ability to store and disseminate information accurately, and efficiently. We have also constructed 3 dimensional intelligent models of piping systems, positioning utilities



PRODUCT OFFERING DEFINITION

Structural Integrity offers complete documentation of historical data relative to key piping system assets. This service can be done stand alone or in con junction with piping system assessments, stress analysis, inspection, and overall life management programs. We have the trained staff to handle any complex piping system, with proven capability in model generation of piping systems containing thousands of components, and miles of piping.



to turn their piping programs into well defined efficient centralized visual databases, leading utilities toward true Building Information Management, (BIM) that satisfies their individual need.

Further enhancing the level of intelligence of parts and assemblies, items such as piping system calculations, inspection records, or even a copy of a maintenance log can also be embedded within the part or assembly. This can be displayed and archived as a part of the drawing.

If you would like assistance in documenting the complete history of your critical piping systems, contact us at info@structint.com.

ITEM NO.	COMPONENT ID	DESCRIPTION	REFERENCE DWG #	REFERENCE ID
31	MS-10-2	12" SCH 160 PIPE, A335-P11	3-102-O-0028-01	12"SGA-A-2, 1B
32	MS-10-3	6" SCH 160 PIPE, A335-P11	3-102-O-0028-01	12"SGA-A-2, 2
128	BP-1	6" VALVE	3-102-O-0028-37	SGA-2009
129	BP-2-1	6" SCH 160 90° ELBOW, SA-234 WP11	3-102-O-0028-37	6" SGA-J-1
130	BP-2-2	6" SCH 160 PIPE, A335-P11	3-102-O-0028-37	6" SGA-J-1
131	BP-2-3	6" SCH 160 90° ELBOW, SA-234 WP11	3-102-O-0028-37	6" SGA-J-1
132	BP-2-4	6" SCH 160 PIPE, A335-P11	3-102-O-0028-37	6" SGA-J-1
133	BP-2-5	6" SCH 160 45° ELBOW, SA-234 WP11	3-102-O-0028-37	6" SGA-J-1
134	BP-3-1	6" SCH 160 PIPE, A335-P11	3-102-O-0028-37	6" SGA-J-2
135	BP-3-2	6" SCH 160 90° ELBOW, SA-234 WP11	3-102-O-0028-37	6" SGA-J-2
136	BP-3-3	6" SCH 160 PIPE, A335-P11	3-102-O-0028-37	6" SGA-J-2
137	BP-3-4	6" SCH 160 90° ELBOW, SA-234 WP11	3-102-O-0028-37	6" SGA-J-2
138	BP-3-5	6" SCH 160 PIPE, A335-P11	3-102-O-0028-37	6" SGA-J-2
139	BP-4-1	6" SCH 160 90° ELBOW, SA-234 WP11	3-102-O-0028-37	6" SGA-J-3
140	BP-4-2	6" SCH 160 PIPE, A335-P11	3-102-O-0028-37	6" SGA-J-3
141	BP-4-3	6" SCH 160 90° ELBOW, SA-234 WP11	3-102-O-0028-37	6" SGA-J-3
142	BP-4-4	6" SCH 160 PIPE, A335-P11	3-102-O-0028-37	6" SGA-J-3
143	BP-4-5	6" SCH 160 90° ELBOW, SA-234 WP11	3-102-O-0028-37	6" SGA-J-3
144	BP-4-6	6" SCH 160 PIPE, A335-P11	3-102-O-0028-37	6" SGA-J-3
145	BP-4-7	6" 1500# W.N. FLANGE, SA-182 F11	3-102-O-0028-37	6" SGA-J-3, 6" cL1500 RF W/N FLG
146	BP-5	12" x 6" RED. ANGLE FLANGED VALVE	3-102-O-0028-37	SGA-2010
147	BP-6-1	12" 1500# W.N. FLANGE, SA-182 F11	3-102-O-0028-37	12" SGA-J-4, 12" cL1500 RF W/N FLG
148	BP-6-2	12" SCH 160 PIPE, A335-P11	3-102-O-0028-37	12" SGA-J-4
149	BP-7	12" ISOLATION VALVE	3-102-O-0028-37	SGA-2011
150	BP-8-1	12" SCH 160 90° ELBOW, SA-234 WP11	3-102-O-0028-37	12" SGA-F-1
151	BP-8-2	12" SCH 160 PIPE, A335-P11	3-102-O-0028-37	12" SGA-F-1
152	BP-8-3	12" SCH 160 90° ELBOW, SA-234 WP11	3-102-O-0028-37	12" SGA-F-1
153	BP-8-4	12" SCH 160 PIPE, A335-P11	3-102-O-0028-37	12" SGA-F-1
154	BP-9-1	12" SCH 160 90° ELBOW, SA-234 WP11	3-102-O-0028-37	12" SGA-F-2
155	BP-9-2	12" SCH 160 PIPE, A335-P11	3-102-O-0028-37	12" SGA-F-2
156	BP-9-3	12" SCH 160 90° ELBOW, SA-234 WP11	3-102-O-0028-37	12" SGA-F-2
157	BP-9-4	12" SCH 160 PIPE, A335-P11	3-102-O-0028-37	12" SGA-F-2
158	BP-9-5	12" SCH 160 90° ELBOW, SA-234 WP11	3-102-O-0028-37	12" SGA-F-2
159	BP-9-6	12" SCH 160 90° ELBOW, SA-234 WP11	3-102-O-0028-37	12" SGA-F-2
160	BP-9-7	12" SCH 160 PIPE, A335-P11	3-102-O-0028-37	12" SGA-F-2
161	BP-9-8	14" x 12" CONC. REDUCER, SA-234 WP11	3-102-O-0028-37	12" SGA-F-2, 14" x 12" CONC RED
162	MS-BSW1	SHOP GIRTH WELD	3-102-O-0028-37	-
163	MS-BFW1	FIELD GIRTH WELD	3-102-O-0028-37	FW
164	MS-BFW2	FIELD GIRTH WELD	3-102-O-0028-37	FW
165	MS-BSW2	SHOP GIRTH WELD	3-102-O-0028-37	-
166	MS-BSW3	SHOP GIRTH WELD	3-102-O-0028-37	-
167	MS-BSW4	SHOP GIRTH WELD	3-102-O-0028-37	-
168	MS-BSW5	SHOP GIRTH WELD	3-102-O-0028-37	-
169	MS-BFW3	FIELD GIRTH WELD	3-102-O-0028-37	FW
170	MS-BSW6	SHOP GIRTH WELD	3-102-O-0028-37	-
171	MS-BSW7	SHOP GIRTH WELD	3-102-O-0028-37	-
172	MS-BSW8	SHOP GIRTH WELD	3-102-O-0028-37	-
173	MS-BSW9	SHOP GIRTH WELD	3-102-O-0028-37	-
174	MS-BFW4	FIELD GIRTH WELD	3-102-O-0028-37	FW
175	MS-BSW10	SHOP GIRTH WELD	3-102-O-0028-37	-
176	MS-BSW11	SHOP GIRTH WELD	3-102-O-0028-37	-
177	MS-BSW12	SHOP GIRTH WELD	3-102-O-0028-37	-

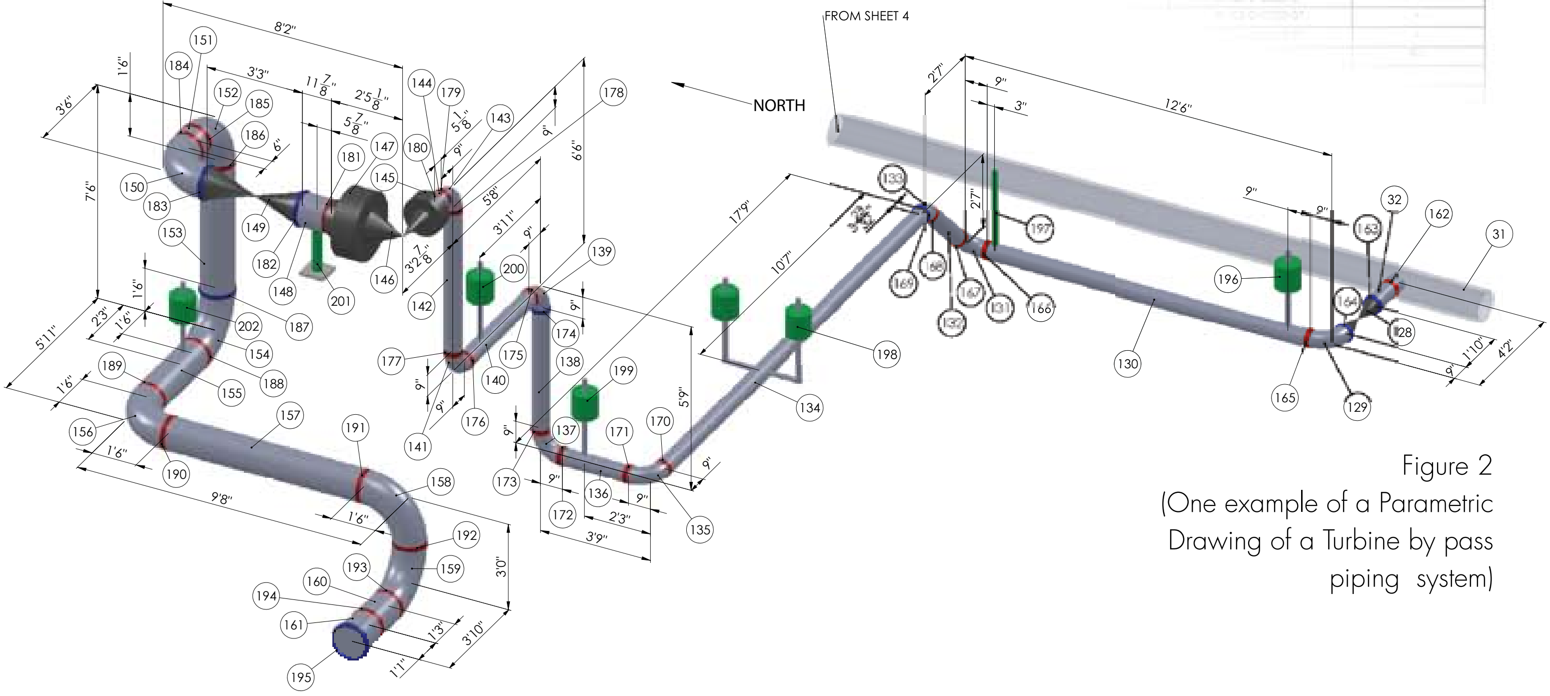


Figure 2

(One example of a Parametric Drawing of a Turbine by pass piping system)

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WEBINARS:

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Nuclear Buried Piping-CP, Degradation
Presented by Andy Smart *August 14, 2:00 PM EST*

WORKSHOPS:

Structural Integrity/ TVA Technical HRSG-Grade 91-Root Cause Analysis Workshop:
Emerging HRSG Issues & P91/T91 Issues
Nashville, TN, *June 21-23, 2011*

Structural Integrity Technical Boiler and Piping Systems Workshop: *Critical Plant Component Asset Management, P91/CSEF Material Issues*
Austin, TX, *August 23-24, 2011*

Structural Integrity Technical Critical Plant Asset Management Boiler and Piping Systems Workshop:
Boiler and Piping Systems: Critical Plant Component Asset Management, P91/CSEF Material Issues
Pittsburgh, PA, *September 13-14, 2011*

TRADESHOWS:

EPRI European Major Component Reliability Workshop and Users Group Meeting
Barecelona, Spain, *April 12-14, 2011*

ASME Power Plant and Environmental Committee
Austin, TX, *April 18-20, 2011*

EPRI NDE Technology Week
Asheville, NC, *June 13-17, 2011*

EPRI Welding and Fabrication Technology for New Power Plants and Components
Fort Myers, FL, *June 22-24, 2011*

102nd Annual IDEA Conference & Trade Show
Toronto, Ontario, Canada, *June 26-29, 2011*

EPRI Buried Pipe Integrity Group
St. Louis, MO, *July 11-14, 2011*

ETD High Temp Materials International Conference
Chicago, IL, *August 4-6, 2011*

TMS Environmental Degradation Conference
Colorado Springs, CO, *August 7-11, 2011*

NACE Corrosion Technology Week
Las Vegas, NV, *September 18-22, 2011*

For more information on these events and Structural Integrity, go to:

www.structint.com/news-and-views-spring-2011

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Chicago, IL	815-648-2519
Denver, CO	303-792-0077
Mystic, CT	860-536-3982
Salt Lake City, UT	801-676-0216
San Jose, CA	408-978-8200
Toronto, Canada	905-829-9817

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