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NEWS & VIEWS

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CELEBRATING 30 YEARS 1983-2013

Structural Integrity Associates, Inc.®

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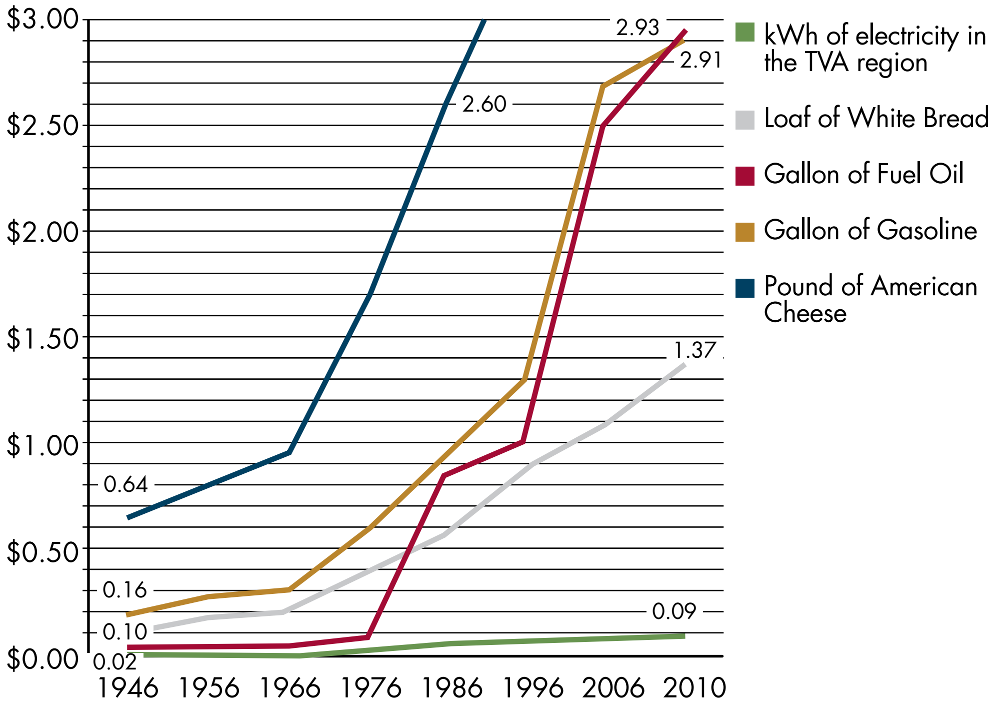
Putting Electricity Into Perspective

An article in an industry newsletter last year got my attention, and I'm still amazed by the revelation I experienced through it. I read this newsletter every week and find it contains a lot of useful market information and data, but this particular article really surprised me with a new perspective -- even though I've been in the utility industry for 35 years. The topic was how utilities are struggling to quantify the value of their product -- electricity -- and the need to identify new ways to communicate that value. Maybe one reason it stuck with me is that Structural Integrity is often faced with this topic – conveying to clients the true value of our services – but that's another article for another day.

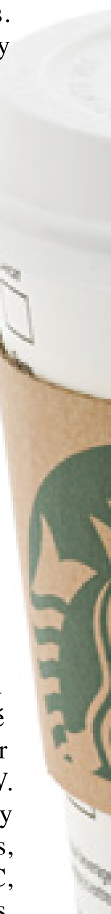
While we all know that producing and delivering electricity to every consumer requires literally billions of dollars, apparently few consumers really care. As I've said in prior articles, as long as that light comes on when I, the consumer, hit the switch and my bill stays the same or goes down -- I'm fat and happy. Regardless of the investment, maintenance, upgrades, new builds, efficiency gains, etc. that are made by utilities, consumers only want more reliability and lower costs for their electricity.

Retail prices from 1946 to present in 10-year increments



If Mother Nature directs her vengeance on the distribution system for my neighborhood and wins, I'm furious. Where are the crews? Why haven't they restored my power immediately? How could they let this happen and inconvenience me? And, I'd better not see an increase in my bill for their efforts. I want -- no, expect -- more reliability in service at a lower cost.

If we stop for a moment and inventory the many ways we use electricity in our everyday lives, we will quickly realize it's one, if not THE most under-appreciated, under-valued and necessary infrastructural components of our family, society, economy and the world. Electricity underpins everything. Yet -- and here's what I should have known but didn't fully appreciate until I read the article -- the reported average cost of electricity for a typical household is about what you would pay for a café latte or a fast-food double cheeseburger (and no fries!) – just over $3.50! WOW. Think of all that you and your family rely on electricity to provide in a day (lights, refrigerators, ovens, microwaves, A/C, TV, computers, phones, internet, printers, copiers -- there's a seemingly endless list) -- all for the cost equivalent to a cup of coffee or a double cheeseburger.



Look around and you'll likely see that we've become far more dependent on electricity than our parents. However, the inflation-adjusted electricity price has been constant or even declined a little in the past 20 years. So while we have become more and more dependent on electricity in our life -- to the point where it is no longer a service but an entitlement -- the industry has made significant investments and corresponding improvements in the production, reliability, environmental impact, efficiency, transmission, distribution, etc. at relatively no additional cost to us.

Considering the quality of life it allows, electricity seems like the best value of any product I've ever paid for -- especially a latte or double cheeseburger.

STRUCTURAL INTEGRITY CELEBRATES 30 YEARS

CELEBRATING 30 YEARS 1983-2013

This year, Structural Integrity Associates is celebrating many things as you'll see throughout this issue of *News and Views*. Our 30th Anniversary is one of them.

Structural Integrity was founded in 1983 as an engineering consulting firm to the nuclear power industry. In the three decades since, the company has become a trusted partner to every sector of the energy industry – from nuclear and fossil power plants to oil and gas pipelines and renewable energy companies.

Over the years, we have branched out geographically to serve a growing global client base. We maintain headquarters in San Jose, California, and have added offices throughout the United States and Canada, as well as affiliates in China, Korea, Spain, and Taiwan.

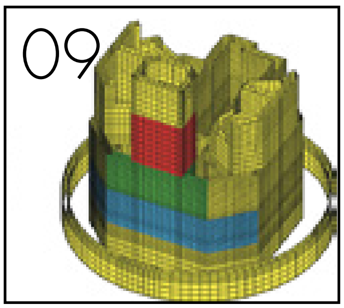
While much has changed for us in the past 30 years, our core business remains the same: preventing and managing structural and mechanical failures. It's what we do best, and our clients have come to count on Structural Integrity for creative, customized solutions.

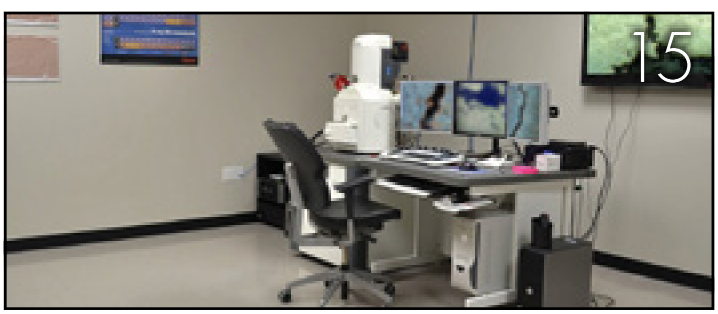
Our employees are the heart of our success, and we remain an empowered, employee-owned enterprise. Our 250-strong team includes some of the brightest minds in the business. And our close-knit culture of continuous improvement has led to the development of some of the industry's most advanced tools and technology.

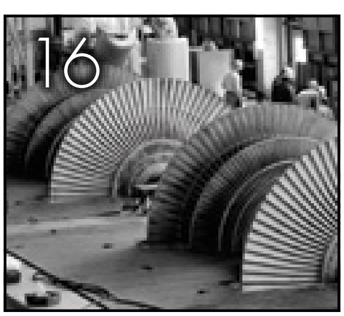
Clients from around the world continue to choose Structural Integrity Associates for our integrity, insight and innovation. We thank you for your business and look forward to the next 30 years!

Thank You!

Structural Integrity Associates, Inc.®





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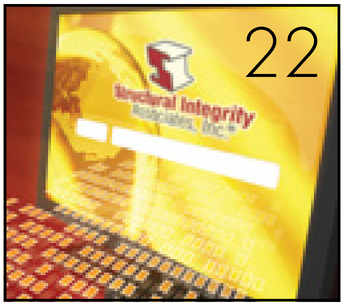
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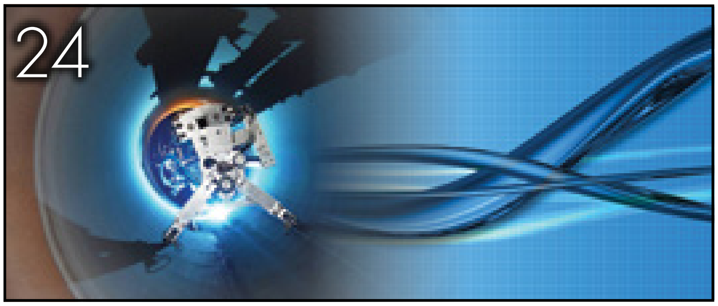
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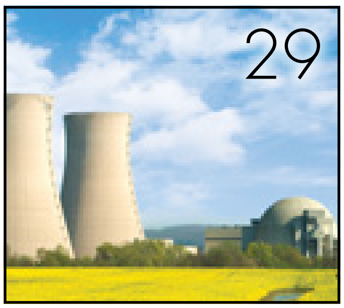
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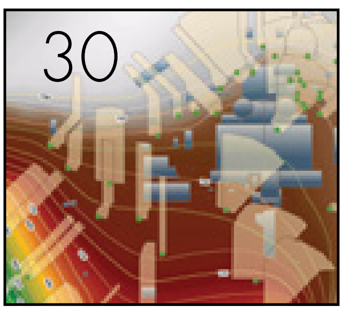
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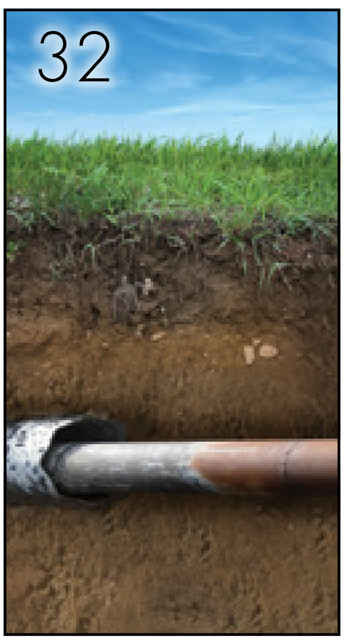
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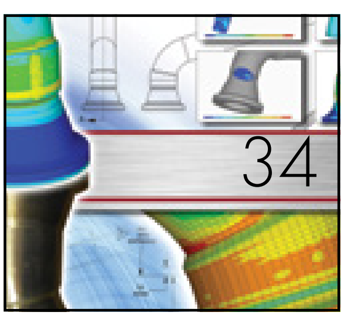
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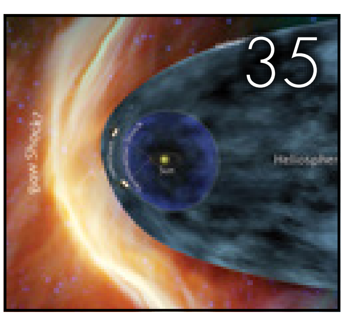
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STRUCTURAL INTEGRITY EXPANDS ENGINEERING LEADERSHIP

Structural Integrity Acquires ANATECH

Structural Integrity Associates is once again significantly expanding our engineering leadership. We are excited to announce that Structural Integrity has acquired ANATECH Corporation, another industry leader in engineering and scientific consulting.

Many of you may already know ANATECH as they've supported nuclear power plants since 1978 and worked with the Department of Homeland Security, Army Corps of Engineers, and others. ANATECH has provided exceptional engineering solutions for the development and application of state-of-the-art structural and thermal-analysis methods. These methods predict the actual behavior of complex, nonlinear systems across a broad set of applications. These applications include seismically vulnerable civil and nuclear structures, nuclear fuel rods and assemblies and storage and transportation casks for radioactive and hazardous materials.

Their expertise in nuclear fuel analysis, structural engineering, and dynamics analysis has been applied across the global nuclear fleet, EPRI, and OEMs and others.

ANATECH is widely regarded as the foremost authority in nonlinear, predictive analysis of complex structures subjected to loading beyond their design basis. And we look forward to integrating their innovation, resources and skills within the Structural Integrity organization. Through many years of collaborative association, it is clear that their mission and core values for innovative solutions and top quality service closely match our own.

Structural Integrity also has much to offer ANATECH and their clients, by means of extended resources, additional competencies, and a supportive corporate infrastructure.

Through the acquisition, we'll expand our presence across the U.S. with their additional three offices in San Diego, California, (ANATECH headquarters) Albuquerque, New Mexico, and Poughkeepsie, New York.

As you evaluate your seismic and concrete evaluation needs, keep Structural Integrity-ANATECH in mind, as we now have even more capabilities for providing an integrated engineered solution.

ANATECH A Wholly Owned Subsidiary of Structural Integrity Associates, Inc.®

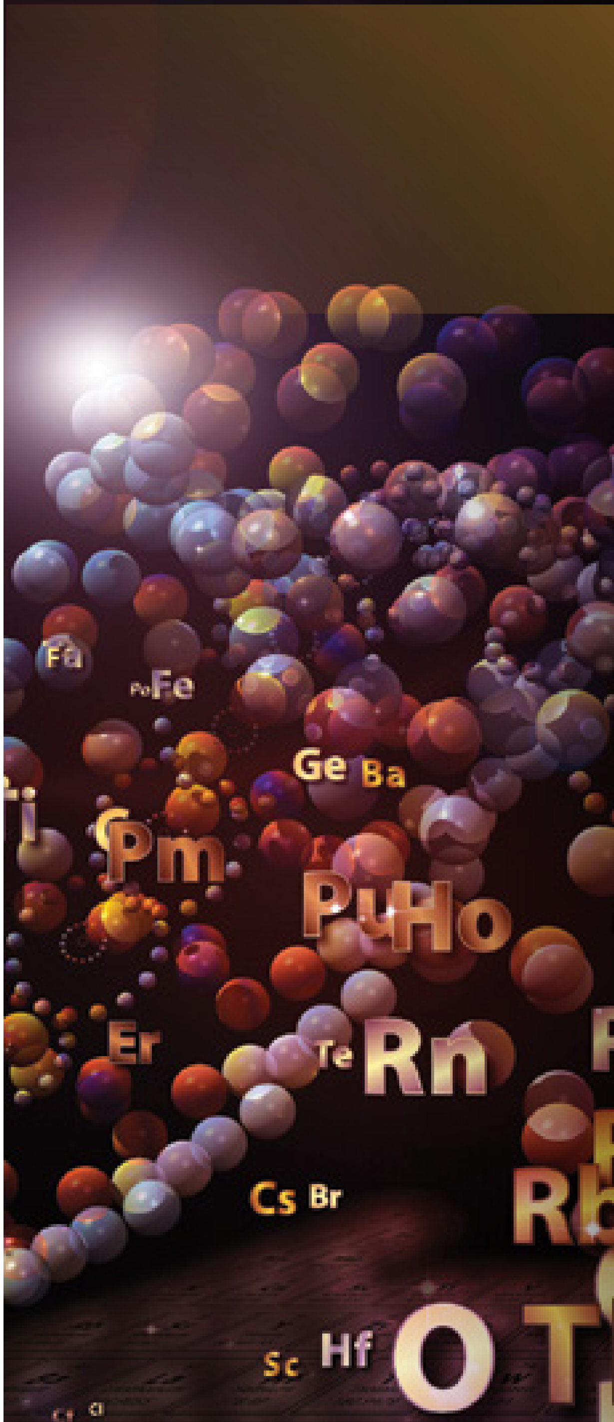

Figure 1. Fractured Alloy 718 Stud

STRESS ACCELERATED GRAIN BOUNDARY OXIDATION (SAGBO) IN NICKEL ALLOYS

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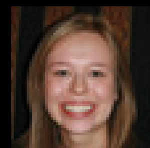

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Modern nickel-iron superalloys have enabled certain high pressure components, such as gas turbine blades, turbine studs, springs, and nozzles to operate at higher temperatures. Many of these superalloys have been found to suffer from a unique damage mechanism called stress accelerated grain boundary oxidation (SAGBO) cracking. SAGBO is a subclass of stress corrosion cracking that is caused by the synergistic effect of tensile stress (either residual or applied), temperature, and the presence of oxygen. SAGBO occurs when oxygen diffuses along the grain boundaries and through either embrittlement or oxide wedging, the grain boundaries separate.

THE TWO (2) PROPOSED MECHANISMS MOST OFTEN DISCUSSED IN THE LITERATURE ARE:

1. Oxidation Precedes Crack Growth: Oxide is formed at a crack tip and preferentially continues along the grain boundary. The wedge shaped oxide forces the grain boundary apart. Oxygen diffuses down the new crack tip and the process repeats.

2. Embrittlement Precedes Crack Growth: Oxygen diffuses into the grain boundary and causes embrittlement, possibly by brittle phase formation, solute segregation, or removal of strengthening precipitates. As the grain boundary weakens, the local tensile stresses cause the grain boundary to open. Oxygen then diffuses at the front of the new crack tip.

Typical characteristics of SAGBO are preferential oxide formations along grain boundaries, intergranular oxide-filled cracks, and the presence of an "oxygen getter" along the grain boundaries. The literature has proposed that niobium oxide can form on the grain boundaries ahead of the crack tip, which leads to the brittle intergranular fracture. SAGBO usually occurs at a temperature range of one-third to one-half the material's melting temperature.

CASE STUDY 1

Structural Integrity received a fractured Alloy 718 stud from the high pressure section of the inner casing of a steam turbine. During normal operation, the area is exposed to dry steam (approximately 800°F at 800 psia). Discussions with plant personnel indicated that:

- The stud had been exposed to higher temperatures due to a gland packing failure.
- The temperature and pressure inside the inner shell that these studs hold together is approximately 1,000°F and 3,500 psig.
- The stud was in service for approximately 1.5 years before it failed.

The fracture surface was examined using a stereoscope to evaluate the fractographic features. The surface was rough and irregular and several secondary cracks were observed (Figure 1). Based on the visual examination, the origin of the fracture and the fracture path were identified.

Two cross-sectional samples were removed through the fracture for metallographic examination. At high magnifications it was evident that the fracture and secondary cracks were primarily intergranular (around grain), with a few transgranular (through grain) branches (Figure 2). Additionally, several apparently disconnected cracks were observed. All of the secondary cracks were lined with oxide (Figure 3). No creep damage,

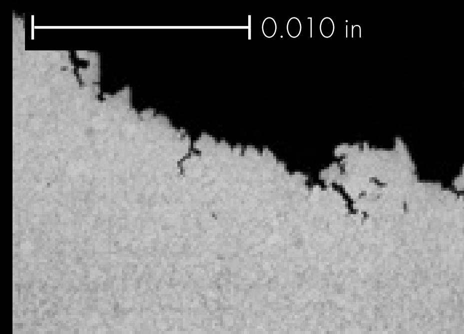


Figure 2. Fracture Surface

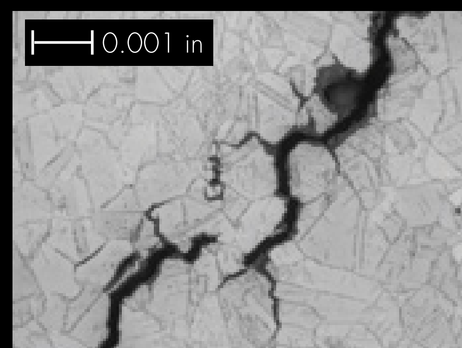


Figure 3. Secondary Cracks

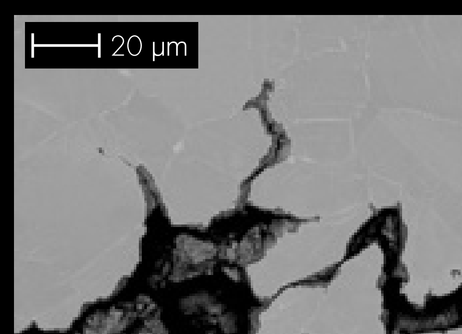


Figure 4. SEM Image of Crack

Continued on next page

such as voids or microcracks, was observed. The oxide-lined intergranular cracks with a brittle appearance are characteristic of SAGBO in Alloy 718.

We examined both the fracture surface and one of the cross-sectional samples in a scanning electron microscope (SEM). The SEM analysis of the fracture confirmed the primarily intergranular surface appearance, with significant branches. Figure 4 shows a high magnification image of the secondary branches. Several of the transgranular branches appeared to be propagating along twinned grains within the austenite matrix. Energy dispersive X-ray spectroscopy (EDS) analysis of the cracks revealed oxygen and niobium within the grain boundaries. No corrosive contaminants were identified. Niobium was also observed along the microstructural twinning within the matrix. The presence of niobium along the twinning and grain boundaries results in a microstructure susceptible to SAGBO, because a grain boundary phase acts to enhance oxygen diffusion. Tensile and chemistry tests met the specifications for Alloy 718.

The stud failure mechanism was confirmed to be SAGBO. The turbine stud exhibited extensive oxide-filled intergranular branched cracking with niobium present along the grain boundaries.

CASE STUDY 2

Structural Integrity received a desuperheat nozzle from a main steam attemperator that contained a failed Nimonic 90 spring. It was in service less than one year, where it was believed to have experienced temperatures between the normal steam temperature (1075°F) and the water temperature (330°F). A concern was that the nozzle was getting stuck open and the spindle was not fully reseated once there was no water pressure. If this occurred, the spring could have experienced a quick temperature change of about 700°F, leading to thermal shock.

One of the fracture surfaces was removed from the spring for further evaluation (Figure 5). The fracture surface was examined in an SEM including in situ EDS analysis. Aside from the elements in Nimonic 90, only oxygen was detected on the fracture surface. Following the EDS analysis, the fracture surface was ultrasonically cleaned and re-examined in the SEM. The fracture surface was relatively rough and irregular and exhibited secondary cracks that appeared to be intergranular.

Following the SEM examination, a cross-section through the fracture surface was prepared for metallographic examination. The metal along the surface of the spring exhibited minor preferential grain boundary oxidation. A secondary crack that was observed adjacent to the primary fracture exhibited branching with extensive branching at the tip (Figure 6). The crack was oxide-filled with a light phase in the center of the oxide. The metallographic sample was examined in the SEM for evaluation of the oxide layers within the secondary crack, and in particular, the light phase in the center of the crack (Figure 7). EDS analysis revealed that the light phase along the center of the crack was rich in nickel.

The failure of the nozzle spring was attributed to SAGBO based on the general appearance of the secondary intergranular crack in the spring with the Ni-rich

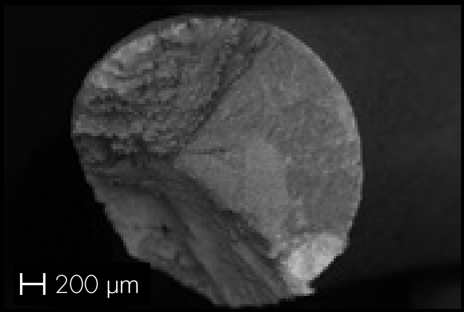


Figure 5. Fractured Nimonic 90 spring

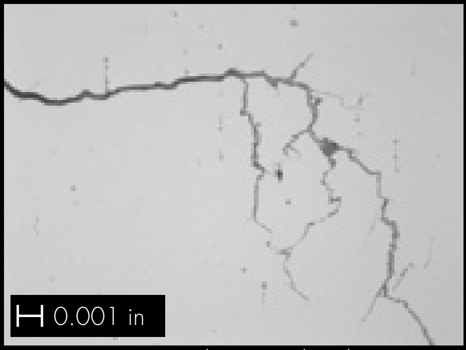


Figure 6. Secondary crack adjacent to the primary fracture

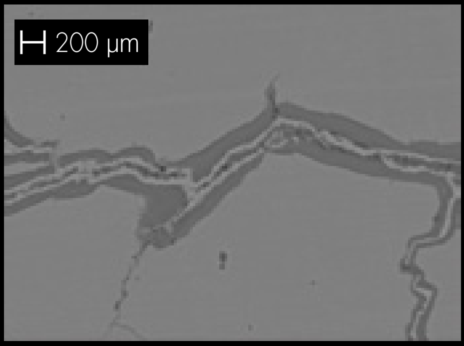


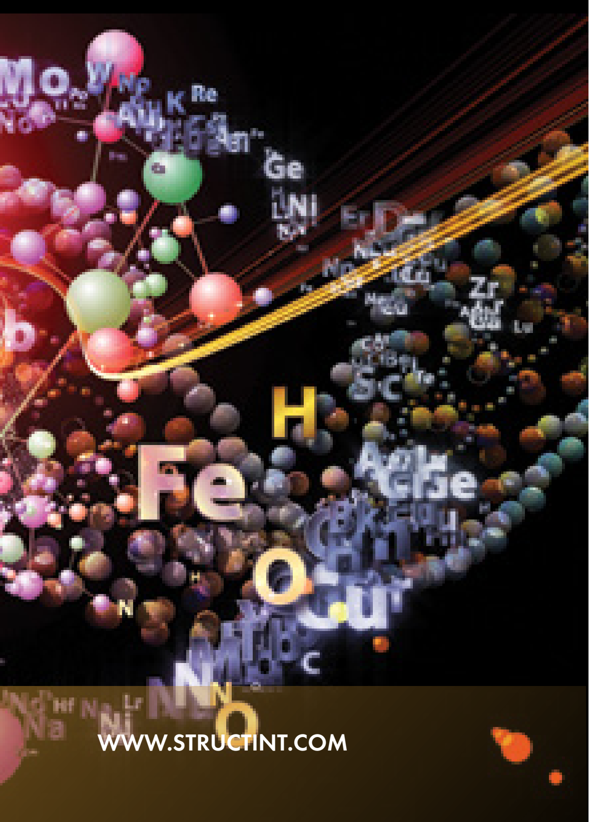
Figure 7. SEM image of secondary crack

filament. The failure was consistent with the nozzle having stuck open after the valve was closed, which can reportedly expose the spring to steam temperatures up to 1075°F, putting it in a temperature range in which it is susceptible to SAGBO.

RECOMMENDATIONS

Are there nickel-iron superalloys in your facility that could be experiencing SAGBO damage? Over the past several years, Structural Integrity has identified SAGBO failures in numerous different components (turbine studs, springs, and nozzles) fabricated from three different materials (Alloy 718, Inco 901, Nimonic 90). However, nickel-iron superalloys operating in high temperature oxygenated environments are susceptible. Since SAGBO failures typically initiate at the surface exposed to oxygen, nondestructive techniques such as Penetrant Testing (PT) are helpful for identifying damage.

There are several methods to reduce or mitigate the formation of SAGBO, which include reducing the applied tensile stress, decreasing the oxygen partial pressure, modifying chemical composition (by initiating a material change), modifying microstructure (through heat treating), modifying thermomechanical processing, and the application of an oxidation resistant coating. Any changes to the system should be reviewed with the OEM to determine the potential effect on other system components and overall system performance.



STRUCTURAL INTEGRITY TEAMS WITH ENERCON

High Powered Team Established for Seismic 2.1 Reevaluation

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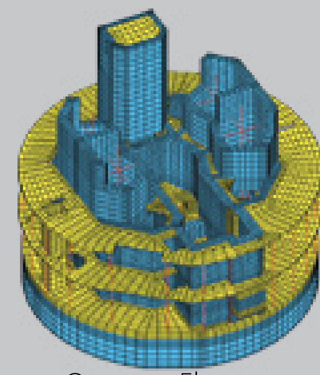
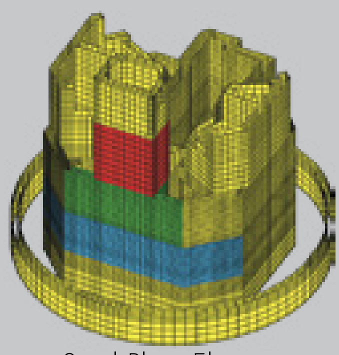
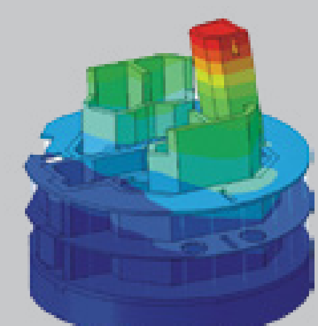


Concrete Elements



Steel Plate Elements



First Fundamental Mode Shape

Ongoing NRC initiatives in response to recent major earthquakes have highlighted the importance of demonstrating seismic safety. Utility responses to the March 12, 2012, NRC 50.54(f) request for information letter require in-depth and comprehensive seismic evaluations. ENERCON has assembled a team of experts with the industry experience and technical knowledge necessary to develop and implement strategies to demonstrate the seismic safety of the domestic commercial nuclear power fleet in accordance with EPRI's "Seismic Evaluation Guidance: Screening, Prioritization and Implementation Details (SPID) for the Resolution of Fukushima Near-Term Task Force Recommendation 2.1: Seismic." This comprehensive approach follows the stages of data gathering, analysis, assessment, and mitigation. Focusing on all stages of seismic evaluation within the context of plant operation allows ENERCON and its team to provide effective, efficient, and high-quality solutions.

Structural Integrity and its wholly owned subsidiary, ANATECH, are vital members of the ENERCON team for the analysis stages of the evaluation by supplementing ENERCON's structural response analysis capabilities with expertise in advanced linear and non-linear finite element modeling for nuclear structures, leading to generation of refined in-structure response spectra.

INCORPORATING ADVANCED NDE TOOLS IN BELL HOLE INSPECTIONS

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As the resolution and probability of detection in In-Line Inspection (ILI) tools improve, particularly for crack detection, the ability to accurately characterize and document degradation during follow-up direct examinations has increased in significance. No longer is the detection of threats using solely traditional methods such as conventional Ultrasonic Testing (UT) and Magnetic Particle Testing (MT) sufficient when compared to the benefits of incorporating more advanced non-destructive evaluation (NDE) tools.

Combining Structural Integrity's advanced arsenal of NDE tools with certified SI specialists who have extensive expertise in evaluating pipeline integrity ensures a more thorough integrity assessment. An example of some of these advanced tools include:

- Specialized Time of Flight Diffraction (TOFD) for crack sizing,
- C-Scan imaging using a Phased Array UT Wheel Probe, and
- Fully Automated / Encoded UT.

STRESS CORROSION CRACKING - CRACK SIZING

As the prevalence of ILI crack detection tools increase, the likelihood and frequency of detecting critical crack-like flaws grows accordingly. While MT provides a robust and inexpensive method of detection, it is unable to determine the through-wall depth of the cracks. Stress Corrosion Cracking (SCC) occurs in piping due to the combination of material susceptibility, environment and stress.

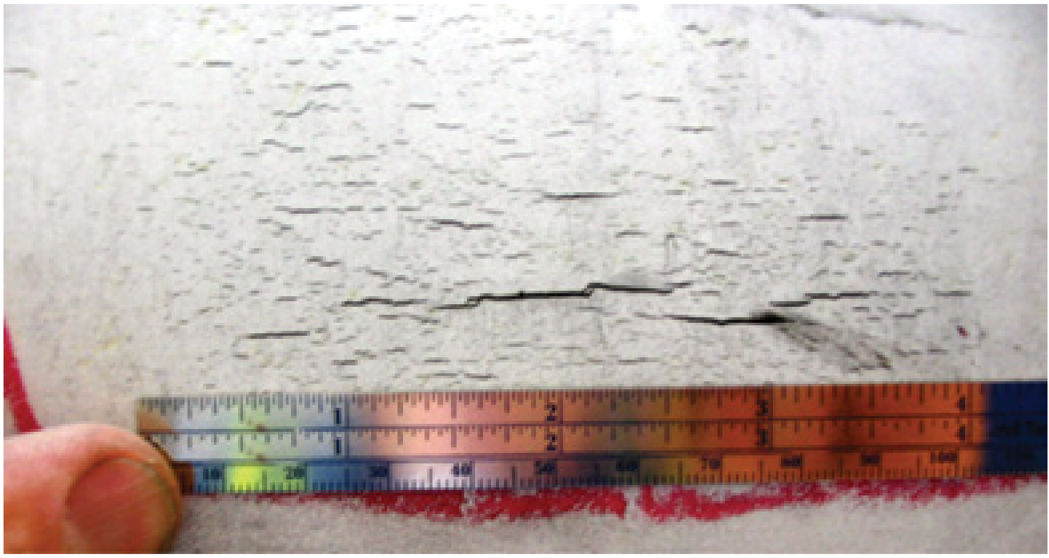


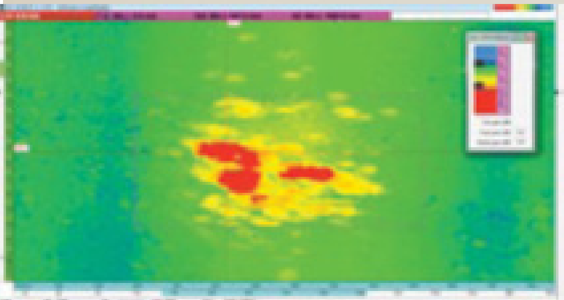
Figure 1: Illustration of Typical SCC

SCC in the pipe body typically forms as colonies containing a number of cracks. A high length-to-depth ratio is typical, often in the range of 20-50:1. Crack depth sizing can be a challenge due to a low through-wall dimension (TWD), as well as the close proximity with adjacent cracks within the colony.

Structural Integrity uses several different sizing techniques, depending on size, orientation or other conditions. We developed a specialized variation of the Time-of-Flight-Diffraction (TOFD) technique for providing consistently accurate and repeatable sizing of SCC flaws. Our micro-TOFD system uses high frequency, small diameter transducers with very low probe center spacing. Our system is designed to locate the diffracted energy from the crack tip. Micro-TOFD has been shown to be effective on thin wall materials and relatively small cracks. This system requires two probes, one on either side of the crack. Linear phased array techniques can also be effective in measuring crack depth and are beneficial for situations where access to the crack is limited to a single side. The phased array approach uses a transducer array and timing delays (phasing) to direct and focus the beams to the desired location. This technique can use longitudinal waves or shear waves and the transducer array is housed in a single probe, permitting sizing when only one side of the flaw is accessible. The technique may be pulse-echo, thru-transmission, or pitch-catch as applicable.

CORROSION MAPPING - PHASED ARRAY UT PROBE

We have found that conventional UT to provide a comprehensive thickness scan of the excavated/exposed section is an efficient means for detecting areas of wall loss. However, if extensive degradation is discovered, a more detailed mapping of the corroded area can provide advantages through more accurate input into remaining strength analyses as well as more auditable records and documentation for resultant decisions. Thus, Structural Integrity has incorporated a handheld phased array wheel probe to further characterize any internal pipe wall thinning discovered. The probe is field rugged and designed for efficient hand scanning of pipeline surfaces using phased array UT and is compatible with standard UT phased array systems. The unit acquires encoded thickness data (as many as 90,000 data points per square foot) as the probe is rolled along the surface and is capable of outputting the data captured in tabular form for use in pipeline remaining strength models as well as advanced imaging/resultant scan output (see Figure 2 below for an example image of the probe and mapped C-Scan image of a corroded pipeline). This approach provides the field rugged and efficiency benefits of a conventional UT system with the encoded and detailed analysis benefits of a more automated approach.



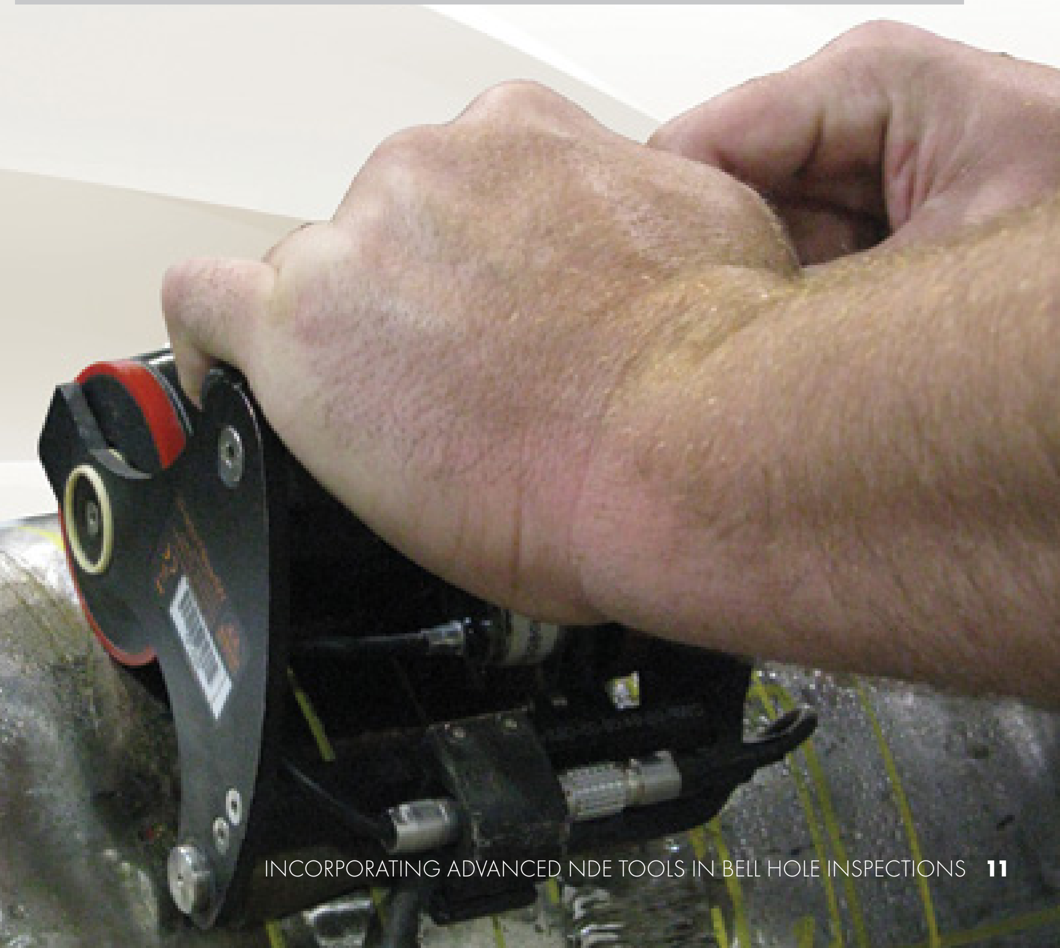


Figure 2: Illustration of the Roller Probe and Scanned Output of Corroded Area

CONCLUSIONS

Due to improvements in ILI inspection capabilities, particularly for crack detection, follow up of ILI indications using direct examinations require more advanced technologies for degradation characterization than traditional techniques. This, in combination with the benefit of employing technologies which can encode and store data for model input and record tracking over time, has resulted in the need for more advanced inspection solutions. As such, Structural Integrity has recently added several new technologies into our oil and gas inspection offerings.

NEI 03-08 MATERIALS INITIATIVE-DECEMBER 2013 DEADLINE APPROACHING

Flaw Handbooks for PWR Control Rod Guide Tube Lower Flange Welds

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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-A guidelines.

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. One of those components is the control rod guide tube (CRGT) and its lower flange welds.

The CRGT assembly provides the guidance path for the rod cluster control assembly through the upper internals and into the core. It also protects the control rods from coolant flow when they are withdrawn from the core. There are two lower flanges in the CRGT lower flange assembly. These flanges are connected by welds to a series of vertical beams and c-tubes that make up the assembly.

The lower flange assembly is at the bottom of the CRGT assembly and provides the interface between the assembly and the upper core plate. Figure 1 shows the CRGT assembly, and Figure 2 shows the CRGT lower flange assembly. There are two main flanges and intermediate flange plates (see Figure 2) in the lower flange assembly and eight corresponding beam welds per main flange (see Figure 2 and Figure 3). These CRGT assembly lower flange welds are designated as a MRP-227-A primary component. These welds are to be inspected as part of the vessel internals augmented exams.

MRP-227-A has designated an EVT-1 inspection procedure for examining components with surface-breaking flaws that are at risk for age-related degradation. Any visual inspection for cracking requires a reasonable expectation that the flaw detectability meets the resolution requirements of the observation technique. Per the requirements for these components, the relevant condition for the CRGT assembly lower flange welds is the presence of crack-like, surface-breaking indications. Since the individual beam-to-flange welds are relatively short, measuring the crack length is not practical and there is no way to establish flaw depth size using an EVT-1 technique. Therefore, any observed crack-like indication in these welds is defined as a relevant condition, and is assumed to have completely failed the weld.

The acceptance criteria for continued service of the CRGT is based on a minimum number of intact welds in the lower flange assembly beam, such that functionality (i.e., ability to drop the rods) during an accident condition is maintained. Random patterns of failed welds are assumed, and analyses are performed to determine if the CRGT still maintains its function and can remain in service. If failed welds are detected, the structure, with its pattern of remaining intact welds, can be shown by analysis to remain functional.

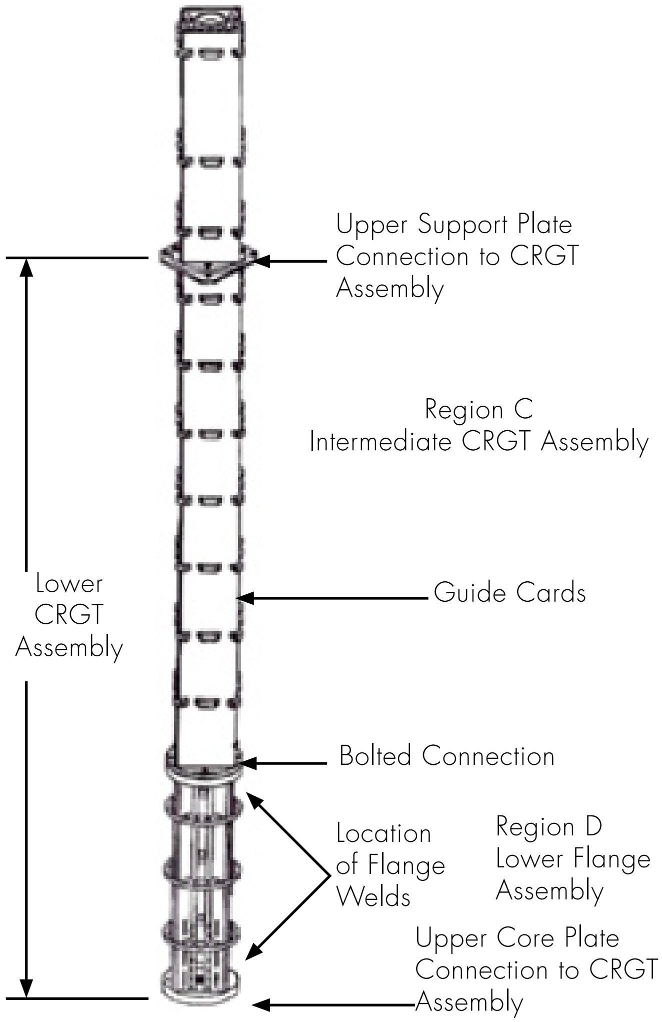

Figure 1
Typical Westinghouse Designed Vessel Internals Control Rod Guide Tube

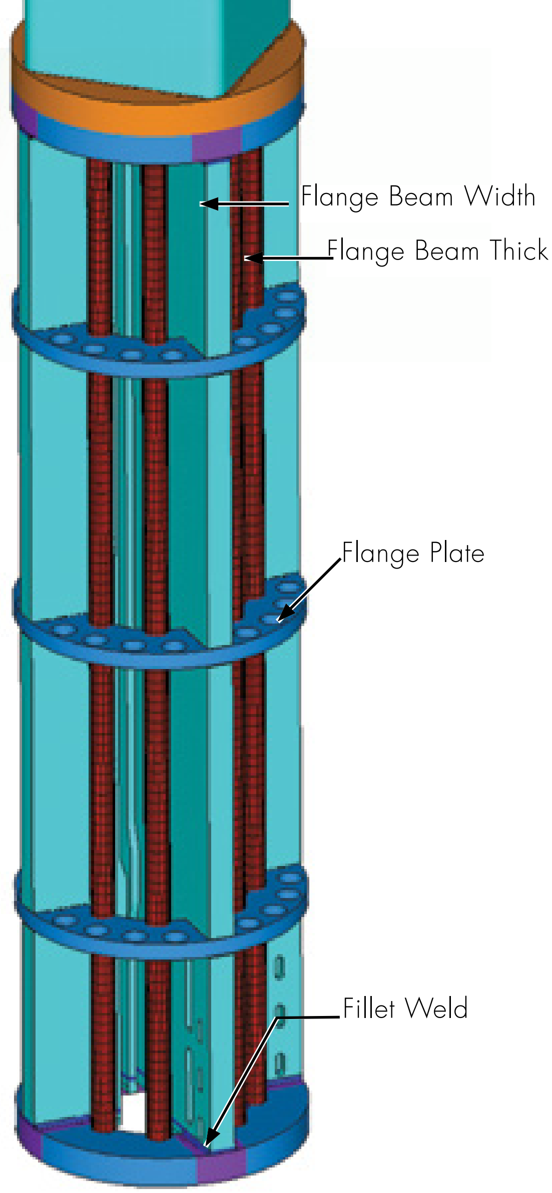

Figure 2
CRGT Lower Flange Assembly

Planning for the inspections requires consideration for the unlikely event that cracks in welds are actually found during the inspection. In which case, the question 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 a more efficient flaw evaluation of the CRGT weld locations for any indications that may be detected during future component inspections. Therefore, using available design information for the CRGT, this handbook documents the relevant geometry, materials and loads, as well as general flaw evaluation guidelines that should be used to evaluate any future indications in this component. Structural Integrity has developed a PWR CRGT Flange Weld Handbook for one of the first utilities facing these inspections as the tool for handling flaw occurrences. The PWR CRGT Lower Flange Weld Handbook can provide a quick disposition of indications found during inspections of the welds in the CRGT during a refueling outage. The disposition is based on conservative analyses. Maximum deflection due to design basis loads is shown to be acceptable.

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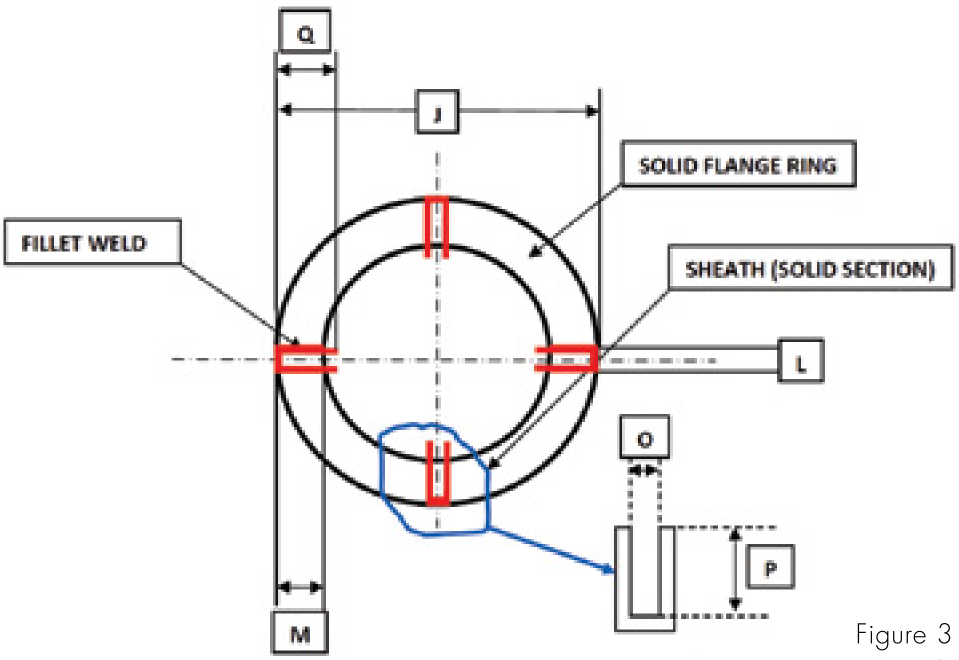
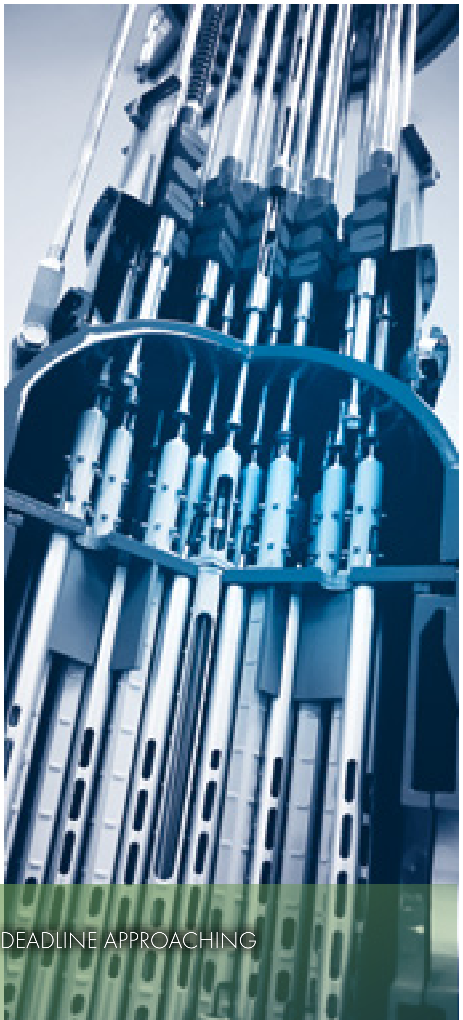
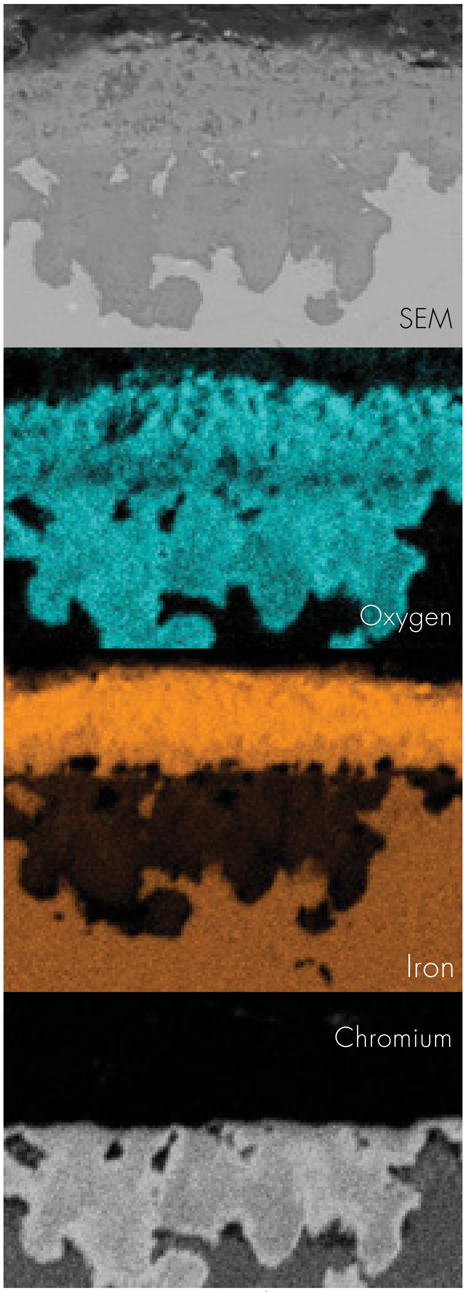


Figure 3
CRGT Lower Flange Beam Welds

We recommend a PWR CRGT Lower Flange Weld Handbook be developed on a plant-specific basis with use of common design features and loading as appropriate. The maximum loadings on the component needs to be considered, including seismic loads and LOCA loads. The resulting Flaw Handbook is an evaluation of indication weld patterns (i.e., cracks observed for a pattern of welds) to be used to disposition reportable indications identified during inspection of the CRGT lower flange welds. Such handbooks have been proven to be very useful to utility engineers having to manage the vessel internals issues for extended plant life.

Structural Integrity experts have extensive expertise and experience in these areas via many years of similar BWR-related experience. This experience, and our involvement in the PWR internals issue since its inception, position us well to provide technical support for managing aging effects in PWR internals.





SEM image (upper) and Energy Dispersive X-Ray Spectroscopy (EDS) mapping of Fe, O and Cr in an ID scale cross section from an HRC3 (stainless steel) boiler tube in good metallurgical condition. The uneven oxide penetration into the base metal is considered common for HR3C tubes.

State-of-the-Art Lab Offers Advanced Inspection and Technologies

By: WENDY WEISS
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Structural Integrity's skills include a wide range of component analyses, life assessments and inspections. Providing valuable insight in these areas demands a multidisciplinary approach that brings together advanced inspection and analysis technologies with advanced materials evaluation. Our ability to combine these disciplines when needed proves its worth time and time again as we tackle some of the industry's most challenging problems.

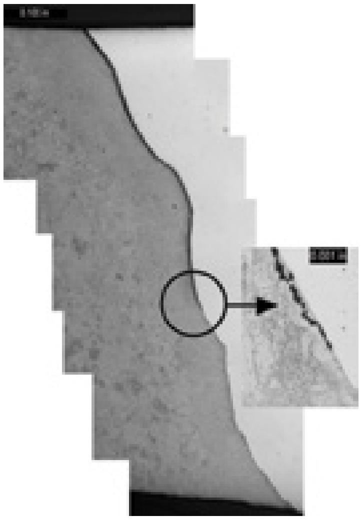
Our state-of-the-art materials laboratory in Austin, Texas, allows our metallurgical experts to analyze and test materials to characterize their existing condition, identify damage mechanisms and quantify the effects of damage, such as thermal degradation, creep, oxidation, corrosion and embrittlement – to name just a few! This data is invaluable for condition and remaining life assessment and failure investigations. And when combined with our inspection and analytical technologies, this information helps focus limited resources on mitigating the true root cause of equipment failure and avoid the downtime and costs associated with recurring problems.

SILICON DRIFT DETECTOR PROVIDES INCREASED SENSITIVITY & SPEED

As part of Structural Integrity's investments in the latest technologies, we recently upgraded our Energy Dispersive X-Ray Spectrometry (EDS) detector on our scanning electron microscope (pictured above) to a Silicon Drift Detector (SDD). When performing semi-quantitative elemental analyses or mapping on turbine, pipe, or boiler tube deposits, corrosion products, damaged metal surfaces, ID oxide/scale layers, or other samples in which contaminants need to be identified, our new SDD capability allows for accurate detection of elements down to Boron, even at concentrations as low as a few hundred ppm.

GRADE 91 DMWs

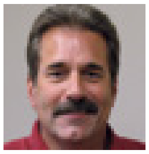
Recently, we investigated a number of dissimilar metal weld failures between Grade 91 and 300 series stainless steel made with an Inconel filler metal. As illustrated in the figure below, creep damage preferentially forms in the Grade 91 heat affected zone, immediately adjacent to the fusion line. Thicker section welds are particularly susceptible, due to a combination of residual stresses and constraint. Through a combination of metallurgical evaluations and stress analysis, we developed an understanding of this creep strain localization, which can occur as a result of elastic follow-up and which can be exacerbated by cycling service. It is well known that these dissimilar metal welds are vulnerable to failure (as evidenced by many notable examples, including stainless steel flow elements within Grade 91 piping systems). With a better understanding of the underlying cause, we assess the risk associated with particular welds. With the potential for increased use of this type of weld, particularly as stainless steels are used more widely in the next generation of combined cycle plants, these risk assessments can be used to help guide application and locations for such welds.



Creep-dominated damage concentrated within a narrow band of the Grade 91 material immediately adjacent to the fusion boundary in a DMW between Grade 91 and Type 316 stainless steel with an alloy 625 type filler metal.

Come Take a Virtual Tour at: http://structint.com/metallurigicallab

TURBINE & VALVE CASING CRACK SIZING



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Inspection of turbine and valve casings becomes more important with aging of the plant. Accumulated start/stop cycles, extended operation at high temperature, and steam borne corrosives can adversely affect long term operability of these components. Structural Integrity recently collaborated with EPRI to produce the Turbine Casing Crack Depth Sizing by Phased Array guide (EPRI, Palo Alto, CA: 2012. 1025334). ***The purpose of the guide is to provide guidance on implementation of an effective phased array ultrasonic flaw sizing inspection strategy for heavy walled cast components, especially inspection probe selection and use of ultrasonic modeling software. The guide also describes how finite element analysis and plant operational data are used for life assessment of these components.***

Flaws that are of interest in turbine and valve casings are typically surface-connected. These cracks have initiated and grown during service by fatigue, creep, corrosion-fatigue, thermal fatigue, or some combination of these damage mechanisms. The cracks normally initiate at a surface, most often at the inner surface, and are generally associated with some stress riser created by a geometric discontinuity, such as the crack shown in Figure 1 near an abrupt change in wall thickness.

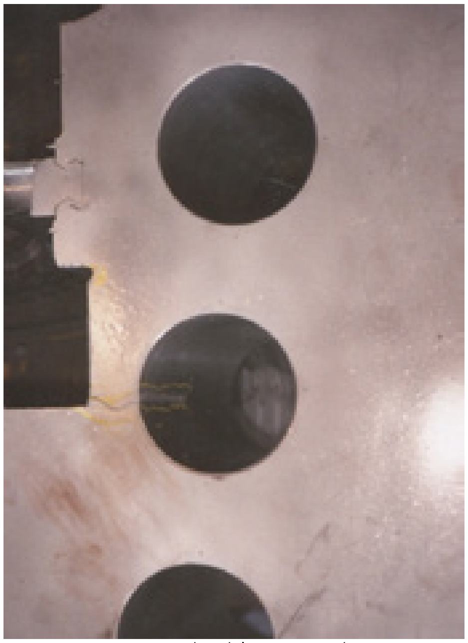


Figure 1. Cracked ligament between turbine shell inner surface and bolt hole.

Identification of the operative damage mechanism can be an important aspect of an assessment, since growth rates vary appreciably among the various potential mechanisms. Consequently, an understanding of the operative mechanism is fundamental to an appreciation for how best to effectively deal with detected cracks. Additionally, the most appropriate means to deal with damage, in terms of actual repair or continued monitoring, is a function of the operative damage mechanism.

Cracks in turbine and valve casings typically initiate at free surfaces and are routinely detected when the casings are disassembled for maintenance using various surface inspection methods, as can be seen in Figure 2. These include visual (VT), liquid dye penetrant (PT), or magnetic particle (MT) inspection methods. Detection using these methods is more than adequate, and the inspections can be accomplished

Figure 2. Valve Casing crack on inner surface

relatively quickly and at relatively low cost. However, once a crack is detected, it is often necessary to determine crack depth to enable assessment of impact on casing serviceability. Ultrasonic inspection (UT) provides the most accurate and most reliable method for crack depth measurement relative to other available methods.

Cast turbine and valve casings typically have a coarse grain structure and often other internal conditions such as porosity and shrinkage cavities that can attenuate and disperse ultrasonic energy. Additionally, the surface condition in the as-found state is often not suitable for UT inspection but can generally be improved by grinding or abrasive blasting. The inspection is further complicated by the fact that the casings are relatively thick, thereby introducing relatively long test distances, a factor that magnifies the impact of coarse grain structure on beam attenuation.

ULTRASONIC PROBE SELECTION

The influences of the cast material on the ultrasonic energy can be better understood by using ultrasonic simulation software and can be mitigated through careful ultrasonic probe selection.

The design parameters of the phased array ultrasonic probe will help determine depth of penetration, beam steering, focusing, and beam sweeping. The key parameters of any phased array probe include frequency, element size, number of elements, pitch (spacing of elements) and active aperture. As with many decisions in ultrasonic inspection preparation, there are trade-offs among these various test parameters that must be considered and balanced.

THE POTENTIAL TRADE-OFFS

Frequency – The probe's frequency defines the number of wave cycles completed per second. A probe's wavelength is inversely proportional to frequency. For thick and attenuative material, like cast valve and turbine shell components, a lower frequency transducer is preferred due to the longer wavelength required to penetrate the coarse grain structure and long metal path of the subject components. Penetration increases with lower frequency, while resolution and focal sharpness increase with higher frequency.

Element size – The width of the element inversely impacts the degree to which the beam can be steered. For a given transducer element, beam spread (beam divergence with increased propagation distance) increases with decreasing element size. Maintaining beam intensity at increasing beam steering angles requires that all elements contribute some intensity at the most extreme angles; consequently, as the element width decreases, individual beam divergence increases and beam steering capability increases accordingly. However, if large area coverage is required, then more elements are required and this increases the cost and complexity of the probe and ultrasonic inspection system.

Number of elements – Phased array probes most commonly have between 8 and 128 elements. A larger number of elements increases the focusing and steering capability, and also increases active aperture and area coverage, but both probe and instrumentation costs increase as well. Most portable phased array inspection systems can support 16 or 32 active elements and this, along with the coverage needed by the application, is typically what will drive the maximum probe element selection.

Pitch and active aperture – Pitch is the center-to-center distance between two successive elements. Active aperture is the total aperture, or length, from beginning of the first to the end of the last active element in the steering, or active, plane. An increase in active aperture can provide an increase in beam coverage and an increase in focusing distance.

Wedge – The wedge, usually made of plastic, is almost always used with a phased array probe. Wedges are used in both shear wave and longitudinal wave applications, including straight beam inspections. The function of the wedge is to couple the sound energy from the probe to the test piece so that it refracts at a desired angle in accordance with Snell's law. While phased array systems utilize electronic beam steering to create multiple angle sectorial scans using a single wedge,

Continued on next page

the refraction angle from the wedge should be near the middle of the angular steering range desired for the inspection.

Ultrasonic simulation software packages provide the ability to simulate ultrasonic beams and coverage, visualize defect responses, and provide data analysis features. In general, UT simulation software allows the user to create and optimize ultrasonic inspection techniques and to predict their performances in realistic NDE configurations as shown in the CIVA, (CIVA software was developed by the French Atomic Energy Commission [CEA]) (simulation in Figure 3). Ultrasonic beam calculations allow the user to model and visualize the ultrasonic beam, including beam spread, beam focus, and changing amplitude throughout the beam path. This functionality ensures that proper coverage for the inspection is attained and an appropriate scan plan is developed.

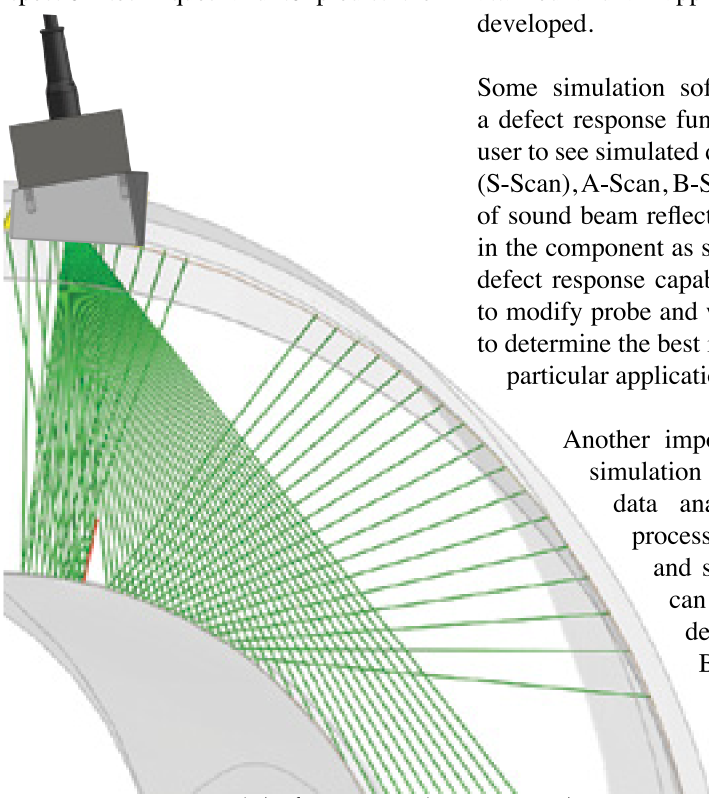


Figure 3. CIVA model of EDM notch on internal surface of valve

Some simulation software also provides a defect response function that allows the user to see simulated data in Sectorial Scan (S-Scan), A-Scan, B-Scan, or C-Scan views of sound beam reflections and diffractions in the component as seen in Figure 4. This defect response capability allows the user to modify probe and wedge characteristics to determine the best inspection setup for a particular application.

Another important aspect of UT simulation software is the data analysis tools. Signal processing, data cursors, and software gain control can be used to assist in detection and sizing. Being able to visualize the phased array ultrasonic beam and defect response in a three-dimensional model of a component greatly enhances the quality and accuracy of an ultrasonic inspection. Ultimately, it reduces the amount of time necessary to prepare for an examination and increases confidence in the results.

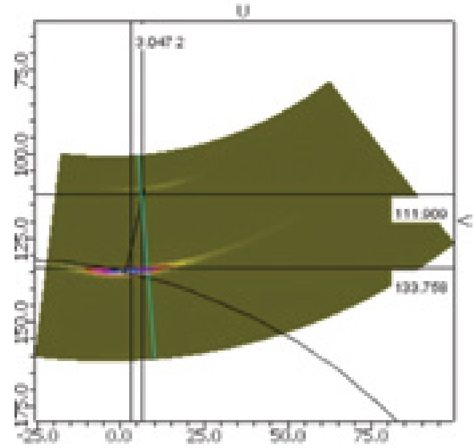


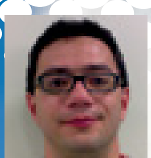
Figure 4.CIVA S-scan defect response

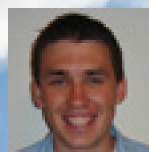
Structural Integrity has developed the use of linear phased arrays (LPAs) for crack sizing in casings. The LPA provides for beam steering in addition to electronic focusing, so less scanning is required and therefore the surface condition is less of an issue.

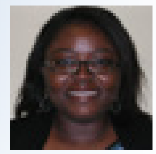
Flaw sizing using LPA is based on imaging the face of the flaw and determining the through-wall extent of the response with respect to the component geometry. This also requires identifying the echo dynamic characteristics of valid targets through pattern recognition. Since the examination data is digitized for a given position, we analyze the data set manually using angle corrected sectorial scans for any target not related to geometry, noise, or poor contact. We further identify targets by a response not associated with the geometric features and/or having amplitude greater or less than the normal geometric response. We determine the location of individual targets from depth and offset locations on the angle corrected sectorial scan. The phased array approach provides enhanced depth sizing capabilities by sweeping a beam across the face of a flaw, which allows for tip diffraction and/or sector angle measurements.

The resulting LPA sizing information is used in conjunction with Finite Element Analysis (FEA) models and plant operational data for the component life assessment.

FIV Monitoring Programs







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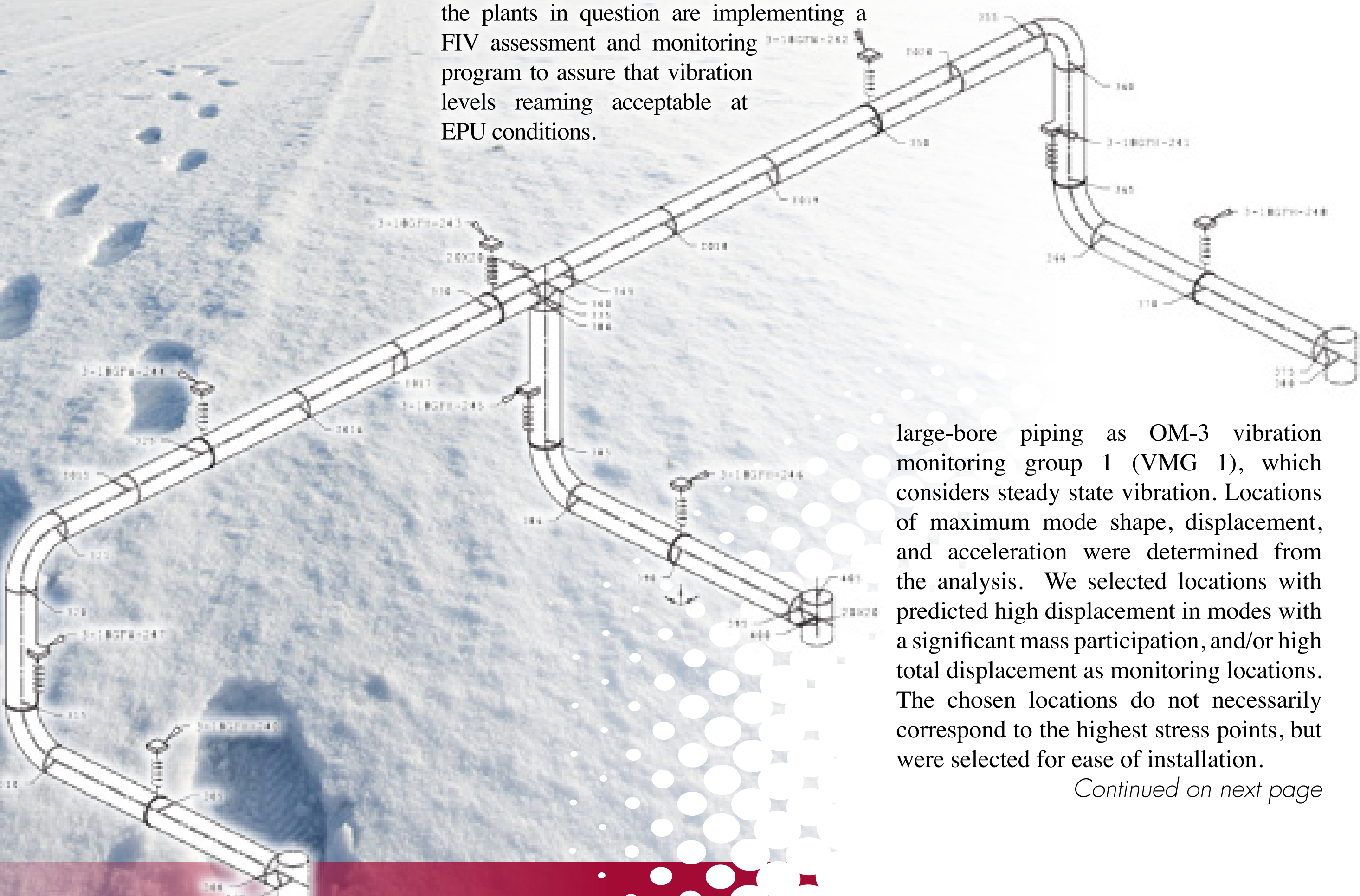
Structural Integrity recently performed analyses and assessments in support of extended power uprate (EPU) implementation at two U.S. boiling water reactor (BWR) plants. Industry experience at other sites has demonstrated the potential for failures of vessel internals, piping, and valves as a result of EPU implementation. The primary driver of those failures was an increase in flow induced vibration (FIV), stemming from the increased flow rates required to sustain EPU operation. To address these concerns, the plants in question are implementing a FIV assessment and monitoring program to assure that vibration levels reaming acceptable at EPU conditions.

Under the FIV monitoring program, various large-bore lines within the systems subject to increased flow will have their vibration levels monitored. In order to determine the locations of the transducers, we performed detailed piping analyses in accordance with ASME OM-S/G-2009 Part 3 (OM-3) – see figure for example. OM-3 provides requirements and criteria for developing vibration stress allowables and performing testing of nuclear piping systems. We classified all of the analyzed

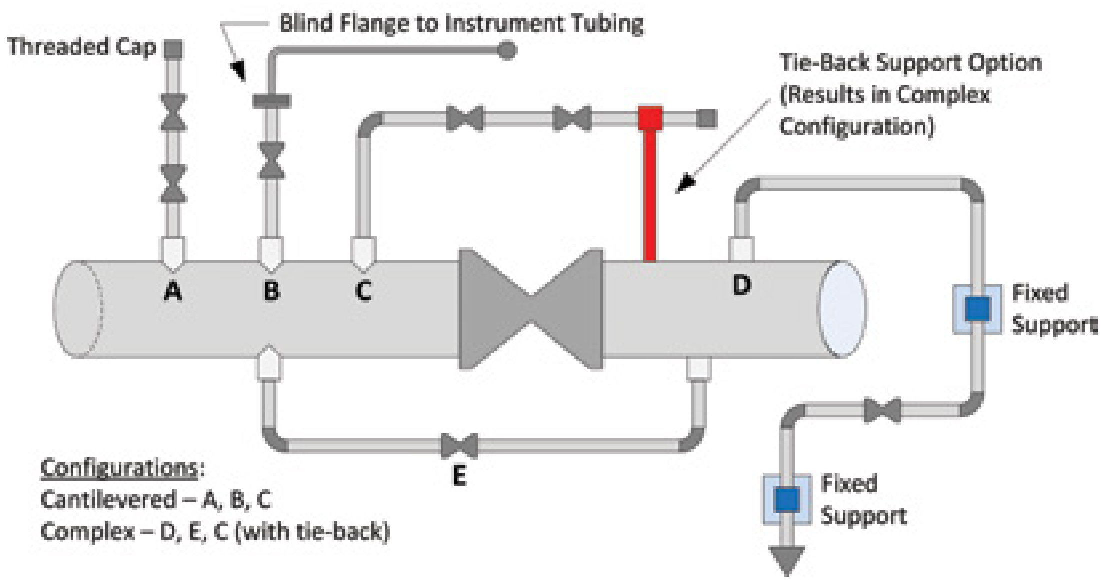


large-bore piping as OM-3 vibration monitoring group 1 (VMG 1), which considers steady state vibration. Locations of maximum mode shape, displacement, and acceleration were determined from the analysis. We selected locations with predicted high displacement in modes with a significant mass participation, and/or high total displacement as monitoring locations. The chosen locations do not necessarily correspond to the highest stress points, but were selected for ease of installation.

Continued on next page

In addition, we evaluated the small-bore branch piping attached to the in-scope systems for potential susceptibility to failure due to EPU-related increases in FIV. The means of assessment differed based on the routing configurations for each line, which were divided into two broad categories:

1. Cantilevered Line – Branch piping that includes one or more isolation valves or other masses, which terminates a short distance from the large-bore header without additional support (refer to Examples A, B, and C in accompanying figure)
2. Complex Line – Branch piping that does not fall into the Cantilevered category, featuring spans that are supported in multiple locations (refer to Examples C, D and E in figure below)



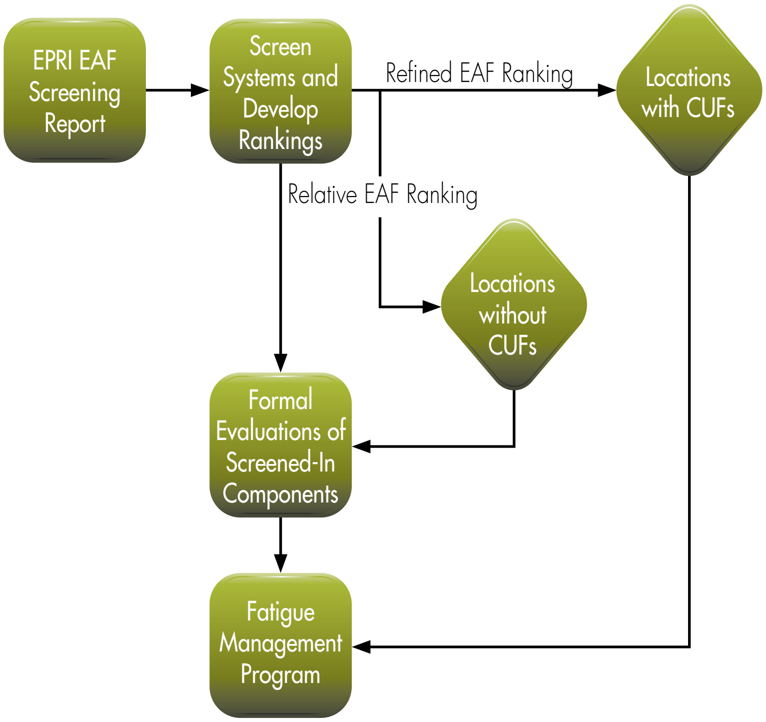
The assessment considered three prominent scenarios in which a small bore branch line is likely to experience failure as a result of FIV:

1. When one or more of the branch line resonant frequencies approach the operational frequencies of the header piping to which it is connected, resulting in a resonant response.
2. When the branch line is located near a source of forced vibration, such as pumps or control/throttling valves.
3. When the branch line is constrained in a rigid manner, such that vibration of the header piping (whether resonant or not) induces high stresses in the branch connection.

The initial assessment was primarily qualitative in nature, taking into account the pipe geometry, routing, support configuration, and location in the plant, among other factors. Over 500 lines were evaluated at each unit, and verification walkdowns were conducted to verify assumptions and note discrepancies. For lines identified as potentially susceptible, recommendations were provided to either reduce susceptibility or verify that vibrations are within acceptable limits.

Finally, in addition to the large bore analyses and small bore assessment, critical valves inside and outside of the drywell were evaluated for their FIV susceptibility. Operating experience at other BWRs has demonstrated the potential for both acoustic resonance and mechanical excitation of valve internal components, due to coincidence with flow rates and/or fluid instabilities. Our evaluation took into account valve design, manufacturer test reports, and data from EPU FIV monitoring efforts at other sites. Valves that were determined to be potentially susceptible were recommended for instrumentation and monitoring during implementation of EPU.

RECENT DEVELOPMENTS IN ENVIRONMENTALLY ASSISTED FATIGUE SCREENING



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In previous issue of *News & Views,* Spring 2012 Volume 32, Dave Gerber reported on what Structural Integrity is doing to resolve the issue of environmentally assisted fatigue (EAF), that is, the effect of the reactor water environment on fatigue damage in nuclear plant components. Dave described the report that we prepared for EPRI, which sets out a methodology for EAF screening to identify high fatigue locations (in addition to those previously identified in NUREG/CR-6260). That report has now been issued as EPRI Technical Report 1024995, (non-proprietary) and we have now performed evaluations using this methodology for several plants.

The first plant to apply this technology is the Callaway Energy Center, owned by Ameren Missouri. Structural Integrity used this process to demonstrate compliance with EAF and fatigue management commitments as part of Callaway's license renewal. The EPRI technical report is currently under review by the NRC as part of Callaway's License Renewal Application. Ameren was awarded an EPRI Nuclear Technology Transfer Award for the development and use of the EAF screening process at the Nuclear Power Council Advisory Meetings in January 2013.

Also, for an older vintage two-loop pressurized water reactor, Structural Integrity performed the first application of the common basis stress evaluation (CBSE) methodology. CBSE allows the review of locations for which no fatigue analysis has been performed, using a somewhat simplified stress and fatigue analysis methodology. Using CBSE, we have identified eight locations (in addition to those already monitored in some form) as sentinel locations for this plant, for which we are recommending additional monitoring or analysis. Considering the large number of possible locations for which fatigue could be an issue, this is a manageable sample size.

With the recent availability of SI:FatiguePro 4.0©, EAF usage can be tracked automatically as part of the newly updated stress based fatigue (SBF) methodology. If your plant is facing increasing requirements for tracking EAF, we can help.

Analytical Data Management Solution for Critical Plant Components

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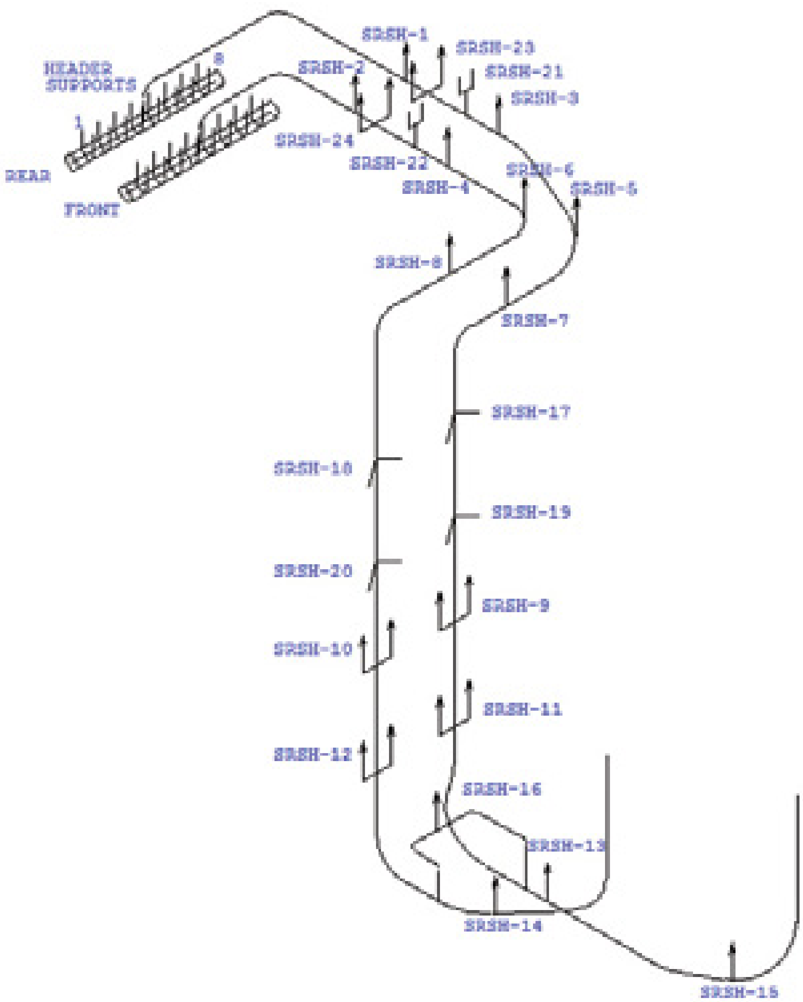
A data management system is a critical part of any effective asset management program. It not only stores data but it is capable of turning that data into concise information that you can easily use to make the right decisions -- decisions that will help ensure the safe and reliable operation of your plant.



Minimizing risk is the primary goal of any asset management program. This includes risk associated with safety, reliability, availability and profitability. With a 30-year history of consulting to the power industry, we have developed industry-leading program methodologies and techniques to achieve these goals. An essential part of any good asset management program is a system that warehouses the data associated with the implementation of the program. However storing the data is only the first step. The data management system should be capable of analyzing the data and transforming it into information that will help people make decisions. Ultimately the system and people using it will be able to turn the information into knowledge. This knowledge will help you proactively manage your plant.

To build upon our data management solutions, we acquired TubeTrack, and teamed with its founders, to develop a new data management system. This represents the integration of two industry leading systems, TubeTrack and SiCAMS. Many are familiar with TubeTrack. It was developed primarily to manage information associated with boiler tube programs. It includes an industry leading graphical interface that allows data to be readily displayed and analyzed. TubeTrack is currently installed in over 250 boilers worldwide. TubeTrack displays all tube failure records/inspection history to determine if there are any developing trends that can be corrected by procedural, inspection or maintenance efforts. TubeTrack applications include accurate, up-to-date drawings of the boiler parts, allowing accurate location of tube-related records. The simple intuitive interface promotes ongoing use of the system – a key to any data management tool. If a system is too complex to use, it inevitably becomes outdated and irrelevant.

SiCAMS (SI's Component Asset Management System) is a web-based data management tool specifically designed to meet the unique challenges associated with High Energy Piping (HEP) management programs. It was developed by HEP engineers for HEP engineers. Not only does it track key data but it also incorporates proprietary analytical tools for prioritizing inspection locations, trending inspection results and performing life assessments -- all key elements of an integrated approach to asset management to meet the targets of safety, reliability, availability and profitability.

BENEFITS OF OUR NEW PROGRAM

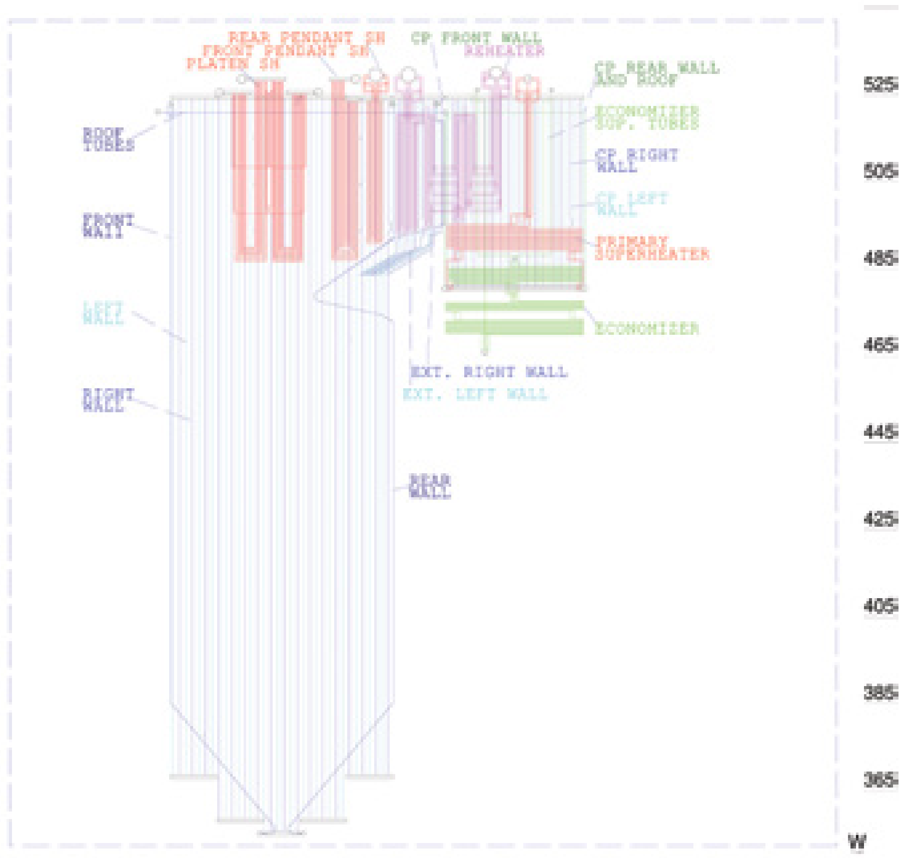
Our new program will encompass the strengths of these predecessor programs. Specifically, initial efforts focus on converting the current Windows version of TubeTrack to a web-based version, thereby offering a more scalable solution and enhancing the user interface to make it more intuitive and provide greater functionality. Current TubeTrack users will be hearing from us in the near future with details about upgrading from the legacy Windows version to the enhanced web-based version – a process we intend to fully support. The piping module, which retains the core from Structural Integrity's SiCAMS tool, will be upgraded to include a 3D graphical interface to improve usability and simplify access to data analytics, such as Structural Integrity's proprietary Vindex methodology for risk ranking. Future evolution of the software will expand functionality to a broad range of plant components, including HRSGs, turbine generators, feedwater heaters, etc.

As our new scalable solution data management solution evolves, we will integrate tools to facilitate proactive asset management. This will allow users to select an appropriate suite of tools to tackle the particular challenges they face. Examples include, integrated access to our Vindex risk ranking for high energy piping (including the state-of-the-art V91 technology for Grade 91 components) or our Gas Touched Length Analysis (GTLA) to facilitate life management of boiler tubing through calculation of local metal temperatures and subsequent risk assessment for key failure mechanisms such as creep and corrosion.

MORE TO COME

We are truly excited by the opportunities that this partnership brings to help our clients with both the everyday challenges of tracking component history and the longer-term goals to anticipate challenges to availability, reliability and profitability.

Side Sectional View
Drawing Produced by TubeTrack



STRUCTURAL INTEGRITY TEAMS WITH DIAKONT AND WSI

Inline Inspection and Repair Alternatives for Nuclear Buried Piping

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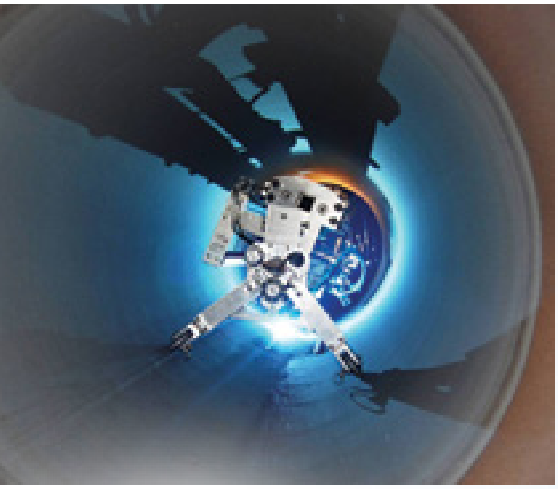
Structural Integrity has been an integral technology solution partner since the inception of the Underground and Buried Pipe and Tank Initiative (UPTI) that began in 2008. Throughout this evolving aging management effort, challenges have ranged from gathering and integrating data to establishing baseline risk assessments, to selecting and planing inspections to ensure these below-grade piping networks are safe and can continue to perform their intended functions.



Whether for NEI 09-14 inspections of all high risk lines, or license renewal inspection commitments, sites are faced with some of the most challenging lines to evaluate. These are lines that cannot be easily excavated or accessed for inspection using conventional NDE methods.

Structural Integrity recognized this industry challenge and responded with an engineered solution that offers the highest level of confidence in remaining wall thickness integrity and is suitable for safety-related and non-safety-related systems.

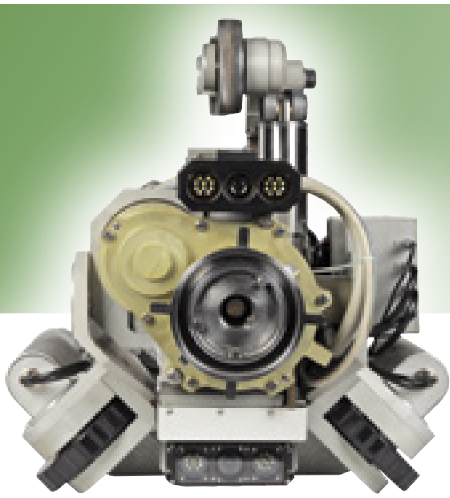
Structural Integrity has teamed with Diakont and Aquilex WSI (WSI) to develop a turnkey solution that allows for the insertion of a high-resolution EMAT ultrasonic sensor into carbon steel pipes ranging from 16" to 54" in diameter. The RODIS equipment can perform complete 360° UT inspections of the entire length of pipe. The inspection device is self-propelled from a single access point using a robotic delivery system, can navigate 45° and 90° fittings, traverse vertical or horizontal configurations, and is equipped with high resolution visual inspection cameras. The on-board cameras incorporate the same high-resolution, high definition technology that is used in Diakont's radiation- tolerant cameras used throughout the nuclear industry. NDE technicians review the data in real-time, providing instant feedback if issues are discovered. The advantage of EMAT sensors, unlike conventional UT sensors, is that couplant is not required. In addition, a greater degree of surface contamination and roughness can be tolerated due to the inherent design of the EMAT sensor stand-off.

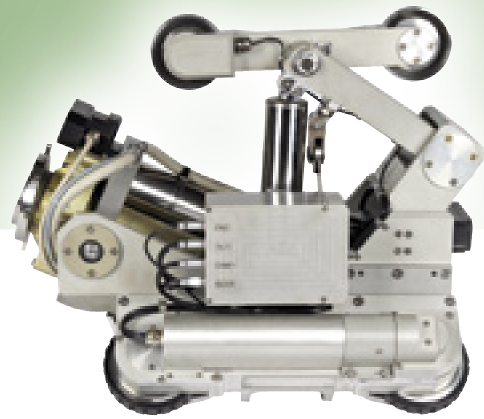
Structural Integrity establishes pre-inspection metal loss acceptance criteria and performs real-time disposition of anomalies in accordance with well-established ASME Section XI code-based principles, supported by Finite Element Analysis (FEA) modeling.

The challenges associated with gaining internal access are addressed with our industry partner, Aquilex WSI. WSI has a long history of working collaboratively with us to solve difficult industry challenges, particularly those involving materials/piping degradation

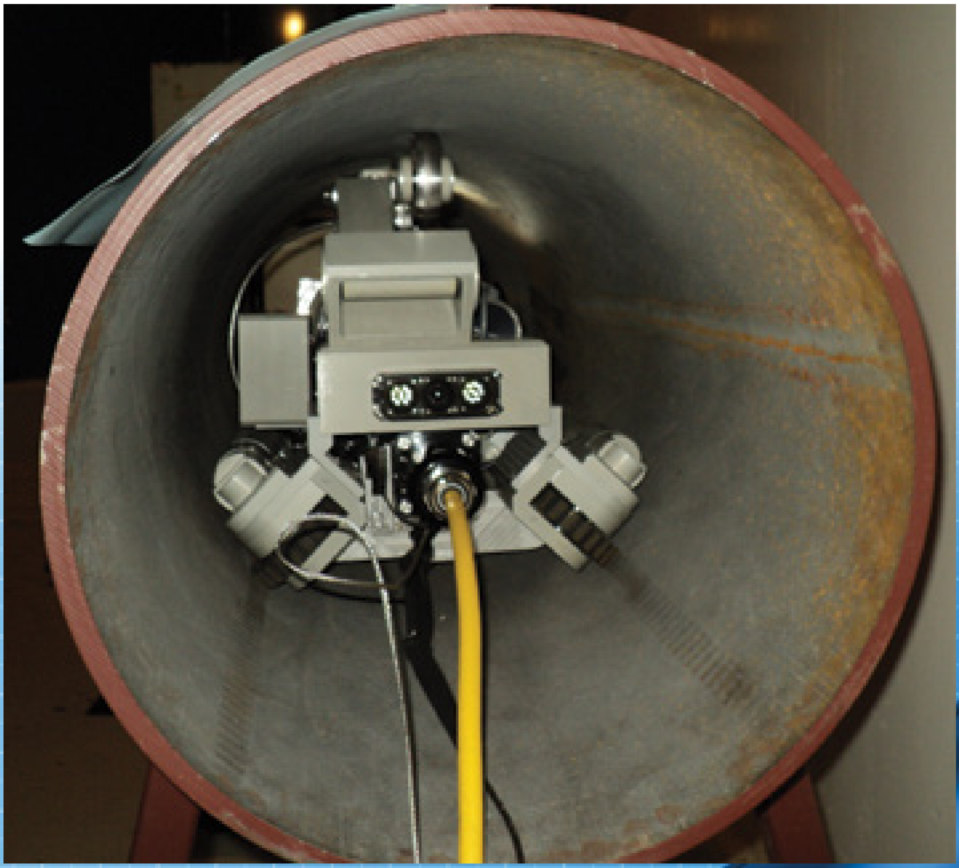
aquilex WSI NUCLEAR SERVICES

DIAKONT





and associated inspection and repair. Additionally, they bring years of experience working in plants worldwide, performing piping fabrication, machining, repair and/or replacement services. Projects are designed to reinstate existing piping configurations after inspection without the need for complicated piping design modifications in most cases. In the event that the system requires internal cleaning due to fowling or corrosion deposits, WSI – via broader corporate capability - is able to perform the required cleaning and dewatering necessary to obtain a meaningful inspection. WSI has also designed, fabricated, assembled, tested, and delivered remote machining and welding repair technologies to perform inline repairs.



STRUCTURAL INTEGRITY, DIAKONT AND WSI TURNKEY SOLUTION

- We quantitatively measure remaining wall thickness for OD metal loss
- Laser profilometry measures ID metal loss
- It allows for the insertion of a high-resolution EMAT ultrasonic sensor into carbon steel pipes ranging from 16″ to 54″ in diameter.
- The RODIS equipment can perform complete 360° UT inspections for the entire length of pipe.
- The inspection device is self-propelled from a single access point using a robotic delivery system and can navigate 45° and 90° fittings.
- It traverses vertical or horizontal configurations.
- The robot is equipped with multiple visual inspection cameras incorporating the same high-resolution technology found in Diakont's radiation-tolerant camera systems used throughout the nuclear industry.
- NDE technicians review the data in real-time, providing instant feedback if issues are discovered.

Detection of Dealloying in Cu-Al Alloys with Ultrasound

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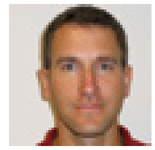

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Selective leaching is a corrosion process in which one constituent of an alloy is preferentially dissolved by the environment, leaving the dealloyed metal weak and often porous. This "dealloying" may occur uniformly or locally, often without a measurable change in dimension. The capability for the early detection, location, and characterization of dealloyed metal using nondestructive testing represents a critical factor in maintaining the integrity of power plant components constructed with these materials.

TWO TYPES OF SELECTIVE LEACHING

Selective leaching of copper alloys involves preferential dissolution of the alloying element (Zn, Sn, Al, Ni) added to copper to improve its mechanical properties. The very thing that is making the copper strong is dissolving, leaving behind copper "sponge", again weakening the material and producing leakage through the porous material. Aqueous environments increase the likelihood of selective leaching.

Selective leaching of cast iron (aka graphitic corrosion), which is used for piping, valves, pump casings, etc. in many water systems, results in a porous structure comprised of graphite flakes as the iron matrix is selectively dissolved. Cast iron can be susceptible to graphitic corrosion from both the water and the soil sides.

DEALUMINIFICATION IN Cu-Al ALLOYS

As described above, dealloying of copper alloys involves the preferential dissolution of the alloying element, such as aluminum in the case of Cu-Al alloys, removing both the strengthening effects of the aluminum and, worse, leaving behind a porous copper structure. The precise mechanisms of dealloying of copper alloys are not well understood. One mechanism involves the preferential dissolution of the alloying element, which is always a more active metal than copper, leaving behind the more noble copper. This appears to occur in both solid solution alloys as well as multi-phase alloys. The other mechanism involves the dissolution of material (both copper and the alloying element) followed by the re-deposition of the copper on the surface.

Dealuminification is the specific process of the leaching of aluminum in aluminum-bronze (or other Cu-Al) alloys. Aluminum bronze is commonly used in seawater or brackish water applications because of its good resistance to corrosion and erosion. For example, many ships use aluminum bronze piping and propellers. Aluminum bronze may consist of one, two, or three phases, α, β, and γ-2, which are listed in order of increasing aluminum content. The nature and distribution of the three phases will be a function of the alloy type (i.e., higher aluminum alloys will generally have greater amounts of β, and γ-2) and cooling rate. The aluminum content and cooling rate will also influence the relative amounts of the phases and their distribution throughout the microstructure. For example, high aluminum castings will exhibit much more and larger γ-2 phase than will lower aluminum or wrought alloys.

While all three phases exhibit some susceptibility to dealuminification, α is least susceptible, followed by β, then by γ-2, which is the phase that is most susceptible to dealuminification. When these alloys are exposed to solutions containing chloride ions or an oxidizing acid, the aluminum rich γ -2 phase will preferentially corrode (i.e., dissolve first; followed by some dissolution of β and possibly α) producing a loss of strength from the loss of the aluminum and the less than 100% dense copper that is left behind. It should also be noted that localized environments can be enriched in chlorides and are much more acidic than the bulk water leading to dealuminification locally. The primary concerns with dealuminification are its adverse effects on the ultimate tensile strength of components, potential for non-ductile failure, and loss of leak tightness. The key question becomes how the process can be effectively managed over time. Thus, dealuminification is a definite concern for nuclear power generation facilities that utilize aluminum-bronze alloy piping and piping components for the transport of brackish water or seawater.

When dealuminification is significant, it can be detected visually; identified by the presence of a deep copper color. The photographs in Figure 1 contain images of several samples where dealloying product has accumulated on the internal surface of an aluminum bronze alloy component. In addition, dealuminification can be observed visually with greater ease when ground or polished surfaces are etched, as is observed by the dark areas seen in the cross-section in the photograph on the right of Figure 1. Corrosion monitoring, using corrosion coupons or linear polarization resistance or electrical resistance probes, can provide useful information for the detection of dealuminification in plant systems. However, since dealuminification is a strong function of the initial microstructure, corrosion monitors may not be sufficiently typical of the actual system materials to be useful.

ULTRASONIC EVALUATION OF DEALUMINIFICATION

Recently, Structural Integrity began work on the development of an ultrasonic method for the characterization of dealuminification in aluminum bronze alloy samples. Very little previous work has been performed on the detection of dealloying in this material using ultrasonic methods. However, because the dealuminification process results in localized perturbations of the material's elastic properties and density, it is intuitive that dealuminification could be monitored by analyzing ultrasonic wave velocity trends, as this material characteristic is strictly dependent on the elastic moduli and density. Furthermore, the industry-wide acceptance of ultrasonic nondestructive evaluation methods for other types of material damage, such as cracking, pitting, and erosion, further motivated our investigation into the detection of dealuminification using ultrasonic methods.

In a laboratory environment, careful measurements of component thickness can be made; it therefore follows that determining the wave velocity of a material sample is a fairly trivial procedure. Unfortunately, this is not the case for the inspection of in-service components, where the internal surface of the component is not easily accessed and a precise ultrasonic thickness measurement cannot be made due to the unknown localized variations in wave velocity potentially caused by dealuminification. It is therefore not possible to determine absolutely the material wave velocity or material thickness. To circumvent this conundrum, Structural Integrity developed a technique that focuses on utilizing a ratio of the pulse-echo time-of-flights of shear and longitudinal waves. By utilizing the time-of-flight ratio method, a metric for characterizing the dealloyed state of the material has been developed that requires no specific knowledge of the material thickness or wave velocity.

In a demonstration study, a sample of an aluminum bronze alloy that had experienced varying amounts of dealuminification was diced into segments. An image of the internal surface of the test sample before dicing is shown in Figure 2 with the outlines and numbers corresponding to the resultant material coupons after dicing. A photograph of the diced material coupons is shown in the inset of Figure 3, (see page 28). Figure 2 shows that the frequency and overall volume of leached material deposits

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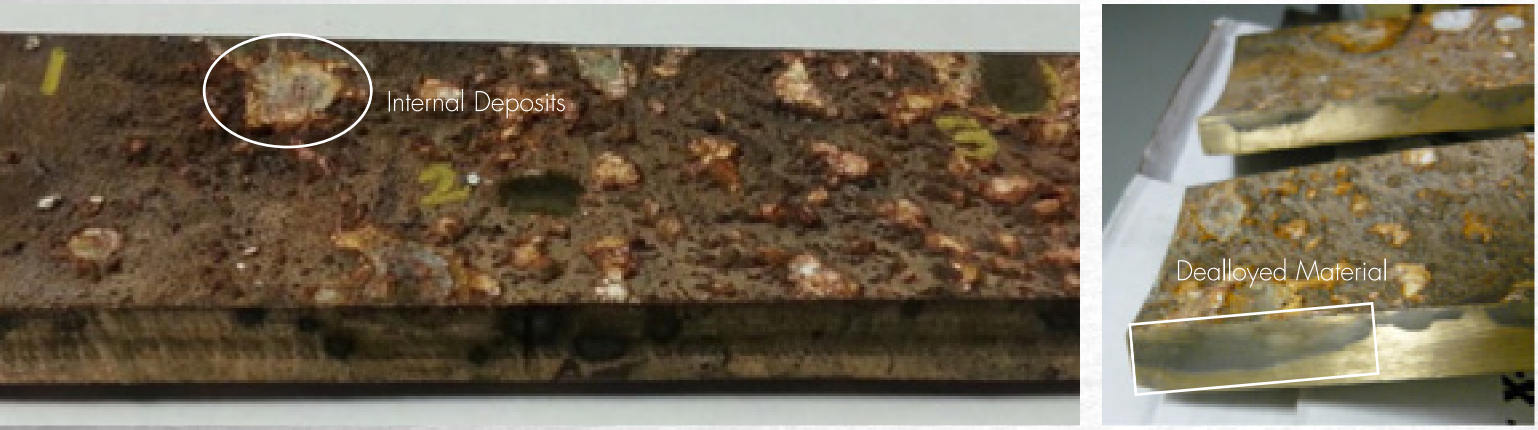


Figure 1 Material samples with indications of dealuminification.

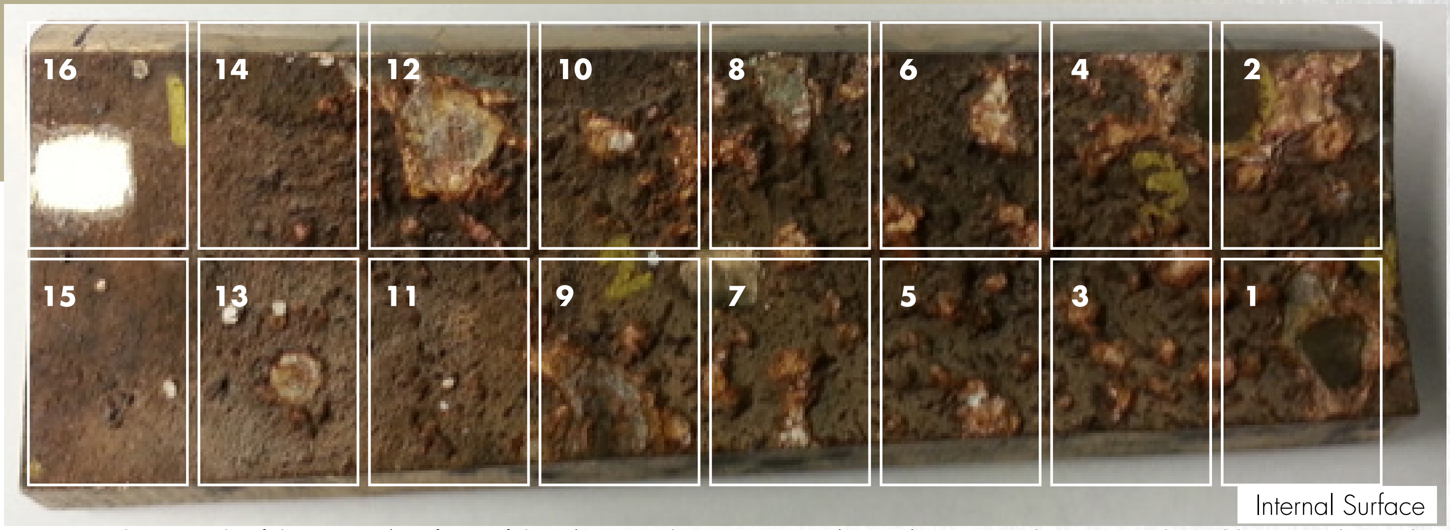


Figure 2 Photograph of the internal surface of the aluminum bronze material sample prior to dicing. Numbered boxes indicate the orientation of the material coupons that resulted from dicing.

increases from the higher numbered coupons to the lower numbered ones, suggesting that the dealloyed state is more severe in the lower numbered areas. This observation also agreed with a visual inspection of the etched sides of the material sample seen above.

A ratio of the recorded times (time-of-flight) for ultrasonic shear and longitudinal waves to propagate through the material thickness and back was recorded and compared for each material coupon. The results of this comparison are shown in Figure 3, which displays the ratios of the shear and longitudinal wave time-of-flights for each material coupon along with a color-coded map showing the location of the material coupon relative to the original material sample shown in Figure 2. Comparing the color coded map in Figure 3 with the photograph of the internal sample surface in Figure 2, it is seen that the time-of-flight ratio method has a positive correlation to the dealloyed condition of the material. Increasing ratio values correlate to increasing amounts of dealuminification, suggesting that the application of a tool based on measuring this ratio would be able to qualitatively characterize dealuminification.

STRUCTURAL INTEGRITY'S NEW PROCEDURE

Given this initial success, we are now working on the development of a procedure for the rapid location of dealloyed areas as well as to characterize the dealloyed material samples such that the developed time-of-flight ratio method may be applied for quantitative characterization. As the conceptual approach applied for the characterization of dealuminification in aluminum bronze is expected to have value for the characterization of dealloying in other materials, these methods are also being explored for the characterization of dealloying in other common power plant materials, such as gray cast iron, recognizing that the precise nature and distribution of selective leaching in other materials will be different.

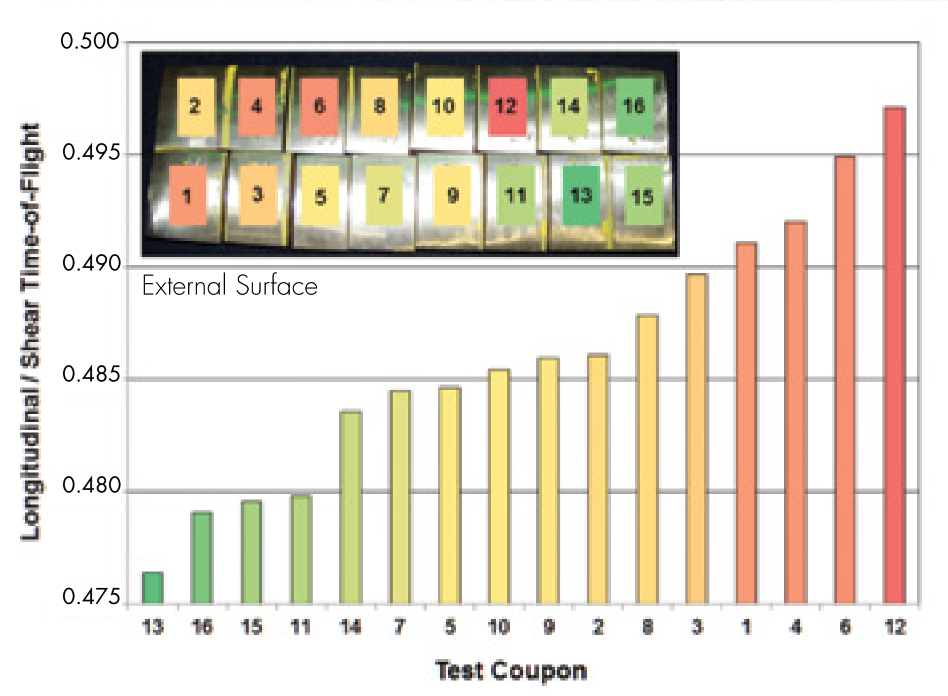
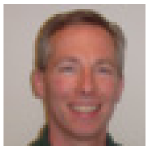


Figure 3 Longitudinal to shear wave time-of-flight ratio trend in an aluminum bronze alloy material sample containing varying amounts of dealuminification. The inset photograph shows the relative location of the test coupons to the original material sample, as shown in Figure 2.

LICENSE RENEWAL COMMITMENTS ARE COMING DUE



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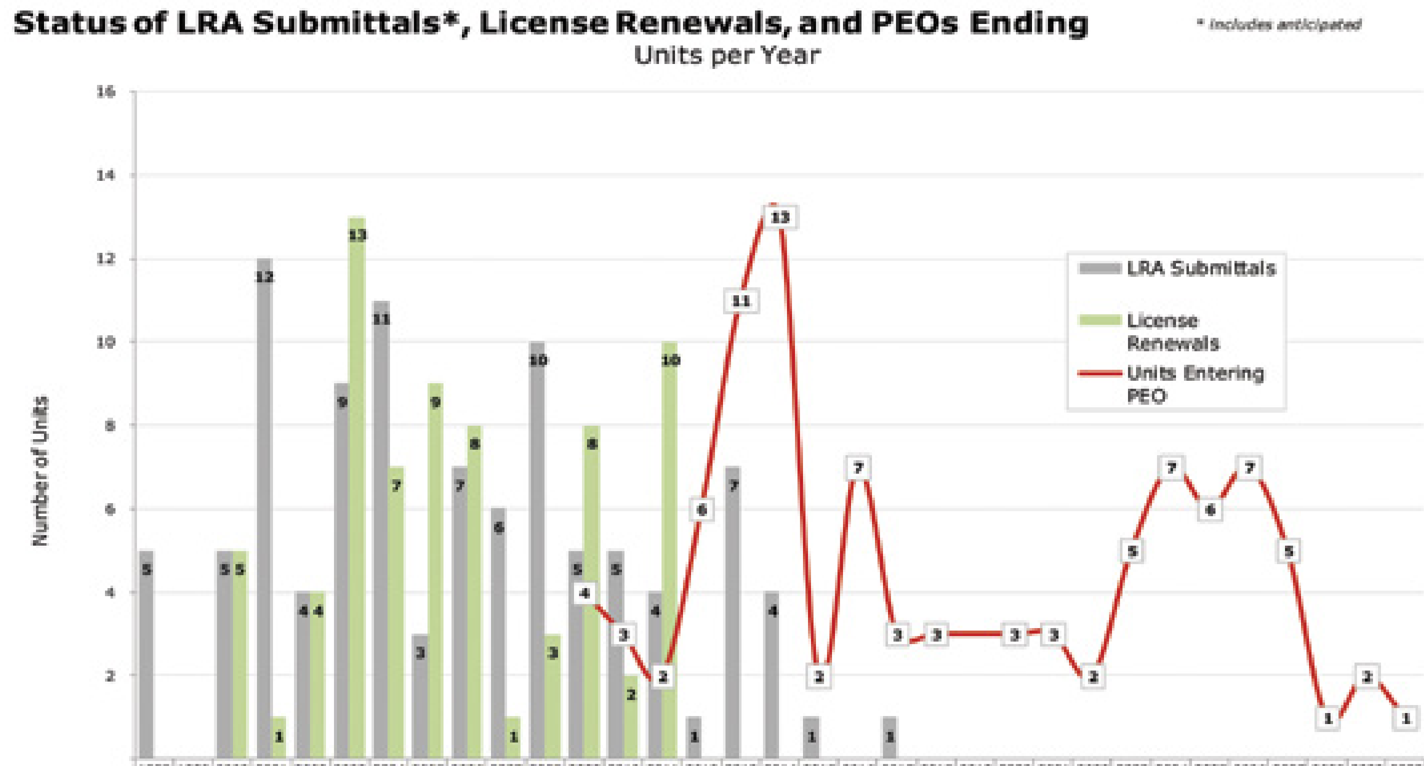
The good news is that most nuclear plants have received NRC approval for extending their operating life an additional 20 years. This can challenge those people charged with implementing the commitments made at the time the License Renewal Application (LRA) was approved. The graphic below shows the status of LRA submittals is tailing off, but the number of plants entering the period of extended operation (PEO) peaks over the next two years.

As commitments listed in the plant safety evaluation reports (SERs) and LRAs near their due date, readers should review various topics throughout this issue of News & Views that we've helped address; screening for environmentally assisted fatigue locations (page 21), less intrusive methods for evaluation of the potential for selective leaching (page 26), cathodic protection of buried assets (page 32), and corrosion management (page 34). Other items include evaluation of containment liners and other internal and external corrosion-related items (general corrosion of structures and components, flow-accelerated corrosion, microbiologically influenced corrosion, galvanic corrosion, etc.), as well as assistance with aging management of reactor vessel and internals (page 12), water chemistry programs, etc. In addition to the above, with our partners, we have added significant capabilities in the areas of cable aging management and concrete.



	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
LRA Submittals	5		5	12	4	9	11	3	7	6	10	5	5	4	1	7	4
License Renewals			5	1	4	13	7	9	8	1	3	8	2	10			
Units Entering PEO												4	3	2	6	11	13

	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
LRA Submittals	1		1													
License Renewals																
Units Entering PEO	2	7	3	3		3	3	2	5	7	6	7	5	1	2	1

NUCLEAR BURIED PIPING PROGRAM USED FOR ENHANCED GROUNDWATER PROTECTION

NEI 09-14 Support

By: STEVE BIAGIOTTI
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This summer the industry is reaching another NEI 09-14 milestone – completing the baseline inspections on buried high-risk piping and lines containing radiological materials. Structural Integrity has remained engaged with EPRI in this important nuclear industry initiative by completing the upgrade programming needs of BPWorks™ 2.1 in the fall of 2012 and continuing to aggregate the industry's inspection progress as reported into BPIRD (Buried Pipe Inspection Results Database).

SOME OTHER INTERESTING DEVELOPMENTS:

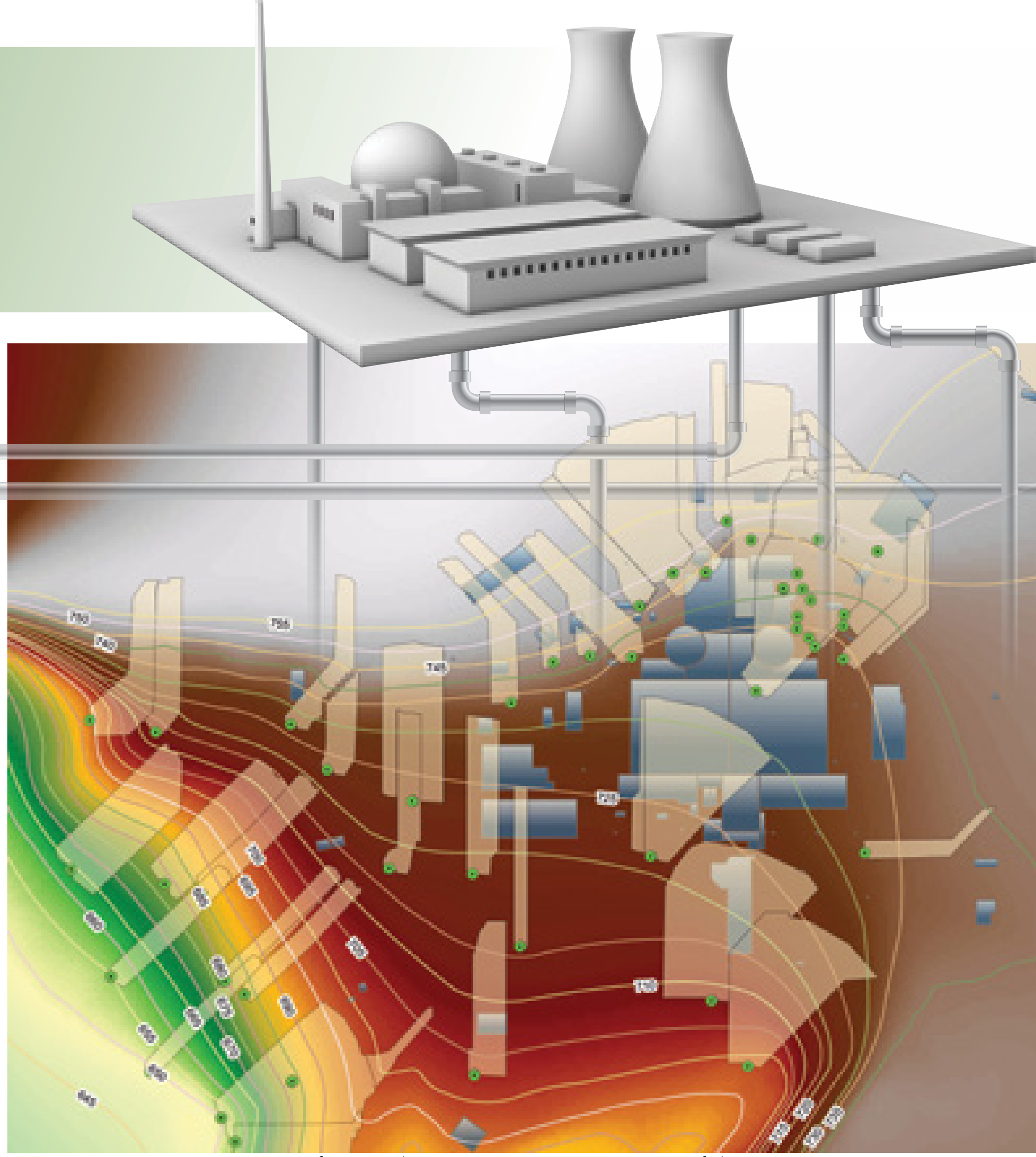
- Structural Integrity's MAPPro© User Community swelled from 18 to 24 member sites. Duke, Xcel Energy, Fermi and Palisades became new members in 2012. A total of 31 sites (half the U.S. nuclear market) have access to the MAPPro buried piping aging management tools. For more information on this community see www.structint.com/MAPProBrochure.

- A new version of MAPPro, was released in parallel to EPRI's announcement of BPWorks 2.1 in September 2012, some of which echo changes made in BPWorks. New and enhanced modules, as well as performance in dynamic segmentation and risk is significantly improved. Risk performance improvements are more pronounced as the amount of observational data increases (inspection results, leaks, repairs, and CP readings).

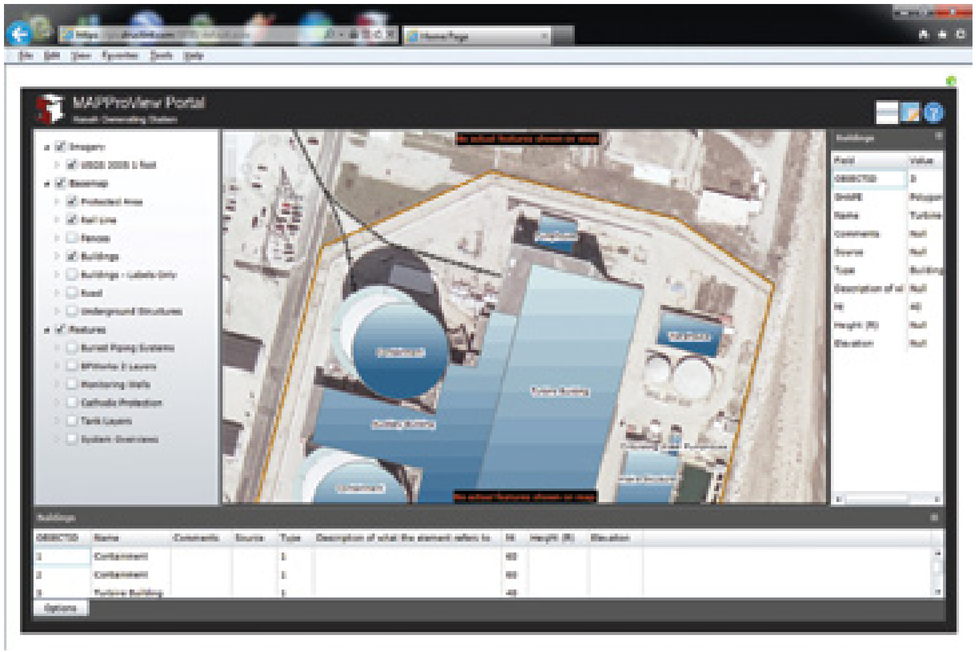
- We released internet (remote access) versions of our software tools – MAPProView Web, a remotely accessible platform for a site's BPWorks 2.1 and MAPPro tools. Instead of viewing MAPProView via ESRI ArcReader, the same GIS data can be viewed via a web page. The MAP GIS data is viewed on a map with a simple-to-use interface. The Client data is accessed via a login process. A key feature of MAPProView Portal is the accessibility of viewing of the MAP GIS data by anyone within a client company. These products are currently available in test environment for your site to evaluate. Both products can be fully deployed.

- We continue to integrate data used in support of the Ground Water Protection and UPTI initiatives into the MAPPro software. Ground water monitor wells in relation to buried piping and 3-D groundwater topology information are providing the rapid identification of upstream piping with the potential to be detected in monitoring wells.

- We also had a recent success with U.S. nuclear fleet in evaluating the long-term impact of internal and external corrosion on buried piping systems and developing Remediation Solutions that could be used in long range capital improvement planning. As other sites enter the Period of Extended Operation (PEO) and begin to consider what is needed for subsequent license renewals, technically based remediation engineering studies and strategies become critical. To meet this immerging need, Structural Integrity has teamed with Bechtel to offer a complete corrosion threat assessment, life cycle management and construction remediation solution.



MAPPro software data integration in support of the Ground Water Protection and UPTI initiatives



MAPProView Portal

ANALYZING THE NEED FOR CATHODIC PROTECTION THROUGH SOIL ANALYSIS

By: SHAWN MCFARLAND
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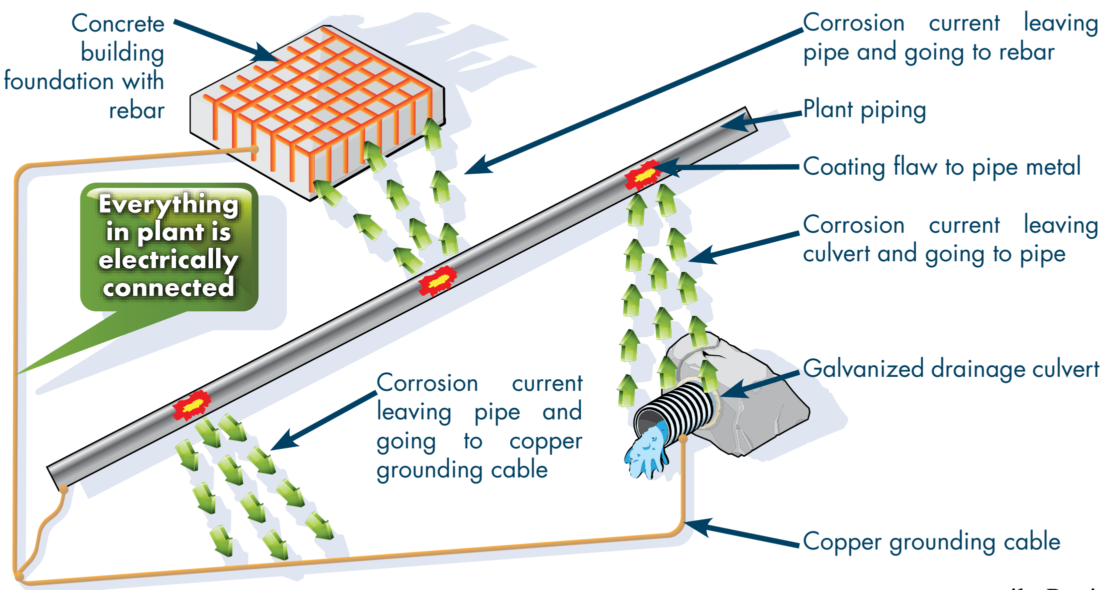


Buried piping at most nuclear power plant sites is nearing the end of the original 40 year design period. Buried piping coatings, considered the primary barrier to preventing external corrosion of piping in contact with the soil, are beginning to show signs of degradation. As coatings degrade, contact with the soil has the potential to support external corrosion on the pipe outer surface if the piping is not equipped with cathodic protection.

It is not uncommon for industry reported buried pipe degradation to be related to issues associated with coating failure. Recent events (e.g., tritium found in groundwater, 2008 and 2009) have dramatically increased pressures on the NRC to address buried piping degradation much more vigorously. As a consequence of coating failures and increased NRC oversight, utilities that operate nuclear power plants in the absence of effective cathodic protection systems are facing a challenging decisions regarding long-term aging management strategies for buried piping.

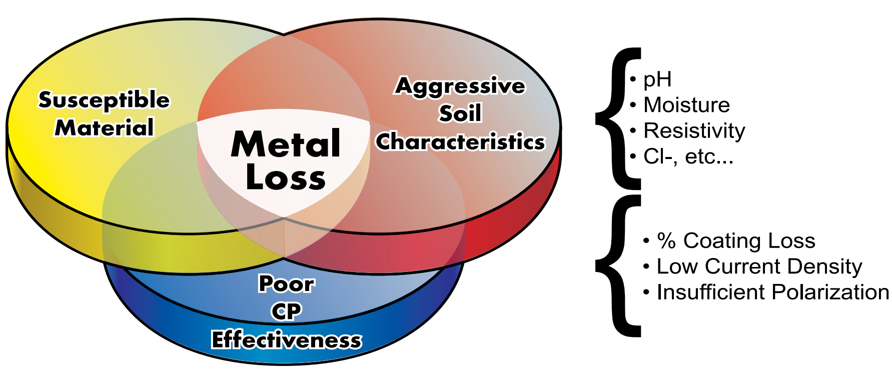
Development of long-term asset management strategies requires an intimate understanding of the variables contributing to the degradation threat mechanisms. For buried piping, the unknowns impacting aging management techniques can be broken into two generic categories;

- internal degradation mechanisms; and
- external degradation mechanism.

In general, knowledge of the effects of internal degradation mechanisms observed in accessible sections of piping (e.g., above grade) can be extrapolated to the buried portions. Unfortunately, the external degradation mechanisms affecting buried piping are significantly different than those typically affecting accessible piping.

Detailed site-specific soil analysis can quantify the corrosivity potential, which translates to estimated metal loss rates. Site-specific soil analyses evaluate cation and anion content of bedding soils. The results provide an understanding of the capacity of the soil to support ion transport and subsequently, the influence on corrosion rates. It is also important to understand the particle size distribution of soil. Particle size distribution influences the ability to support seasonal variations in moisture content around the piping. Piping subject to frequent wet-dry cycles can often be expected to have higher corrosion rates due to refreshed oxygen content.

Leveraging laboratory analyses with engineering corrosion modeling applications such as Structural Integrity's SoilPro© yields rate information that can be used



to forecast buried piping remaining life. Deterioration rates can then be applied to evaluate the required margin between the required minimum wall thickness for code of construction compliance and the nominal pipe wall thickness to meet the desired plant life.

This type of engineering analysis is key when evaluating the need to implement cathodic protection. The external corrosion potential for buried piping at nuclear facilities requires that a susceptible material (i.e., steel) is in contact with a a corrosive environment (i.e., soil). External coatings, by design, are applied as the primary barrier to isolate susceptible materials from corrosive environments. As coatings degrade, the potential for external corrosion for piping in direct contact with certain soil conditions increases in the absence of effective cathodic protection. However, if the environment (i.e., the soil) can be demonstrated to support a low corrosion potential, the application of cathodic protection may not be immediately beneficial until the indication of coating degradation is detected. Performing soil corrosivity analysis is also a key part of an aging management program as discussed in NUREG-1801, Generic Aging Lessons Learned (GALL) Report, XI.M41 for buried piping.

Utilities which pursue such studies, and are able to show basis for continued plant operation without the need for cathodic protection, can benefit from reduced costs, labor needs, and record keeping in contrast to plants operating cathodic protection systems. These reductions are influenced by eliminating the need to perform periodic test station readings to verify rectifier performance, periodic cathodic protection effectiveness surveys, system maintenance, and trending of system availability. In addition, utilities can also continue operating their plants without the need to increase the "house load" to supply electricity to cathodic protection rectifiers.

PG&E PROJECT BENEFITS FROM DEEPER WELL OF HYDRO EXPERIENCE

ANATECH Addition Brings Greater Hydro Capabilities

By: Jagannath Hiremagalur
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Structural Integrity (SI) was recently asked to help with a hydroelectric project for Pacific Gas & Electric (PG&E). It tapped into many of our areas of expertise.

Since 2010, we've helped PG&E define and implement a pressure boundary inspection program (covering items inside power houses) through the following activities:

1. Identification of program goals.
2. Identification of the components to be included in the program.
3. Identification of the inspection methods and acceptance criteria to be used.
4. Definition of the process to prioritize the power houses for inspection.

Subsequently, we participated in lessons-learned meetings to better define the items to be inspected and methods to define required corrective action. To address a deficiency in the design and installation of pressure boundary bolting, we provided a bolting program, based on ASME PCC-1 and EPRI recommended practices.

Though Structural Integrity has been involved in hydroelectric engineering consulting since its founding in 1983, a recent addition to the SI family expands our hydro capabilities, to the benefit of power plant clients like PG&E.

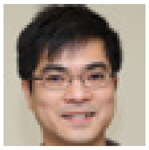
Earlier this month, we announced the acquisition of ANATECH Corporation, a leading engineering consulting firm for nuclear fuels and structures solutions. With the addition of ANATECH as a wholly owned subsidiary, we now have greater hydro facility analysis capabilities, including the following areas:

- Constructability of Massive Concrete Structures
- Durability of Degrading Structures
- Reliability of Hydraulic Steel Structures
- Risk from Internal Cracking in Dam Monoliths

By integrating all of our specialized engineering services, we are able to perform quantitative evaluations of a wide range of critical component aging problems. This integrated approach provides us with a sound basis for the analysis and control of failures in existing components and structures, as well as the prevention of failures in new designs. And with ANATECH on our side, we just got stronger.

STRUCTURAL INTEGRITY IN THE NEWS

ANSYS 2013 HALL OF FAME



By: *FRANCIS KU*
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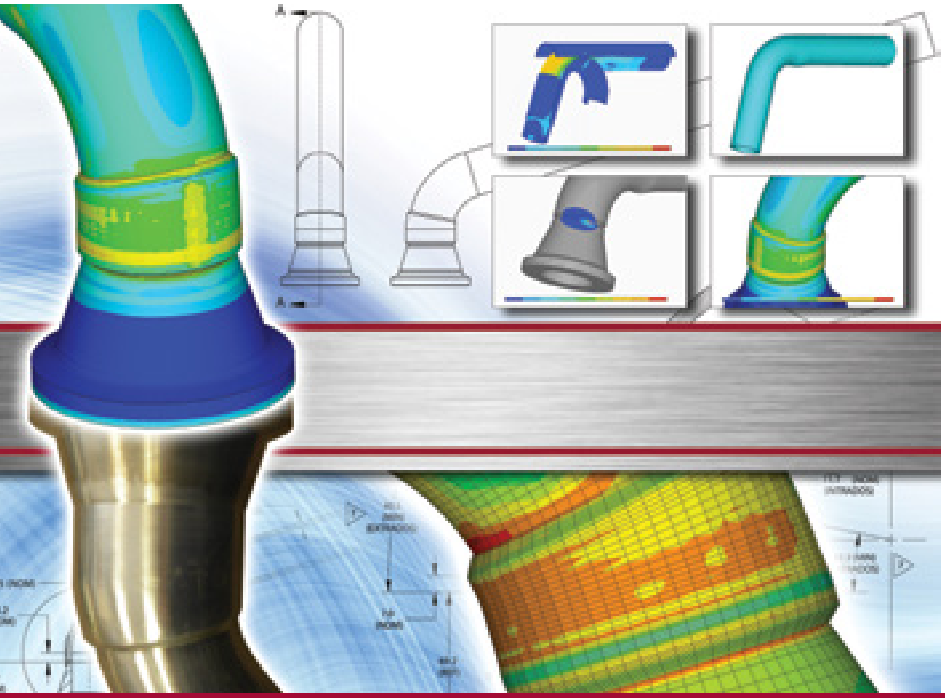
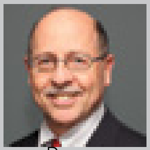
Structural Integrity designs and analyzes weld overlays on nuclear power plant piping to mitigate the effects of corrosion phenomenon or wall-loss mechanisms, such as stress corrosion cracking and flow-accelerated corrosion. Our engineering team developed a streamlined process in ANSYS to accurately simulate and predict residual stresses induced in piping from three distinct processes: forming an elbow by bending straight steel pipe, welding a straight/bent pipe to a pipe component, and applying a multi-pass weld overlay repair on an existing weld. Elastic–plastic forming and three-dimensional thermal–mechanical welding analysis is combined into a single continuous simulation to reliably and accurately predict residual stresses.

This technology has enabled researchers to more clearly understand the undesirable residual stresses and deformations. This has brought efficient evaluations for metal girth and butt weld simulations, weld overlay repair simulations, and forming simulations for clients in the nuclear power, fossil power, and civil sectors, as well as research activities to refine the development of weld residual stress related issues for the industry.

Our developed technology was selected as a runner up for the ANSYS 2013 Hall of Fame Competition, which can be viewed online under the Runners Up section at: www.ansys.com/Hall+of+Fame



BARRY GORDON BECOMES NACE FELLOW



Barry Gordon

Join us in congratulating Barry Gordon, an Associate at Structural Integrity, who has been named NACE Fellow. The honor of NACE Fellow is given in recognition of distinguished contributions in the fields of corrosion and corrosion prevention. As a NACE Fellow, Barry will serve as an advisor along with other NACE Fellows to the association.

The NACE Association made him a Fellow earlier this year at the NACE National Conference. Barry exemplifies the ongoing engineering expertise we provide our clients. Congratulations, Barry!

Structural Integrity Associates employees reached a new safety milestone in January safely working two million consecutive hours (four years and counting) without a lost-time injury. By making safety one of our core values and instilling a proactive approach to eliminate and control workplace hazards, this approach has led to the safe completion of over more than 3,500 projects within the United States and internationally. We could not have accomplished this goal without the dedication of our employees to working safely each and every day. Now that Structural Integrity has surpassed two million hours, the target for 2013 is 500,000 hours of safe work performance by continuously practicing ***Safety First: Every time. Every place. Every one.***

A Voyage Long and Strange

By: *ERIC HOUSTON*
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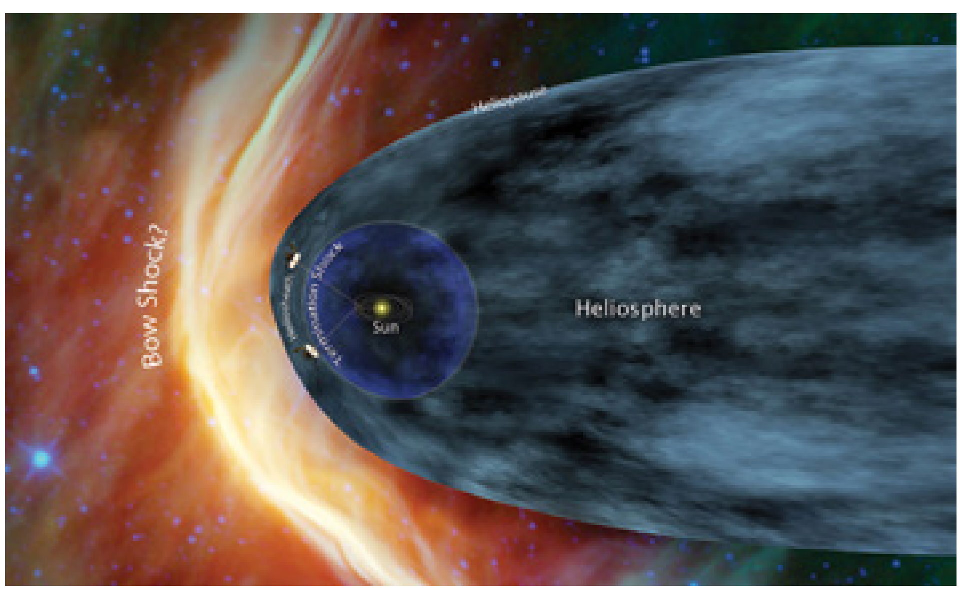
1977 was an important year; some say the greatest ever since Star Wars was introduced in May that year. But 1977 was also the year of another important launch: that of the Voyager space mission. Both Voyager 1 and Voyager 2 were launched in 1977, taking advantage of planetary alignment in the outer solar system that only occurs about every 175 years. The Voyager mission was originally intended to do intensive fly-bys of only Jupiter and Saturn. However, Voyager 1 and 2 were able to do fly by explorations of all the gas giant planets in our solar system. Voyager 1 and 2 both carry information about life on Earth should any other life forms encounter the space craft. The information includes sounds and images from life on Earth.

Because Voyager 1 and 2 were still sending back information 12 years after launch, the Voyager mission evolved into the Voyager Interstellar Mission (VIM). VIM is to explore the outer influences of the Sun in our solar system and the interstellar region beyond. Both spacecraft are now looking for the heliopause, the furthest reaches of the Sun's magnetic field and solar wind. As of December 2012, scientists believe Voyager 1 is in the final region of the Sun's influence before crossing into the interstellar region, which they presume Voyager 1 will reach in a couple months to a few years. Voyager travels too far from the sun to use solar panels, instead they are powered by radioisotope thermoelectric generators (RTGs). The RTGs convert heat produced from radioactive decay of plutonium into electricity. The Voyager spacecrafts each have enough fuel to be powered until 2020. After that they will drift through the Milky Way.

SOME INTERESTING FACTS FROM THE MISSION INCLUDE:

- Discovery of active volcanoes on Jupiter's moon Io
- Discovery of dark rings around Jupiter
- Discovery of geyser like eruptions of nitrogen gas on Triton, Neptune's largest moon
- Discovery of Proteus, Neptune's irregularly shaped moon believed to be just below the mass required to form a sphere
- Voyager 1 became the most distant manmade object from Earth 13 years after its launch and is likely retain this distinction for decades (at a minimum)
- Voyager 1 is traveling at about 38,000 miles per hour. Voyager 2 is on a more leisurely pace of 35,000 miles per hour. It will take until the year 41977 for either spacecraft to make a "close approach to another planetary system."

http://voyager.jpl.nasa.gov/index.html



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WEBINARS:
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Aging Management of PWR Vessel Internals
Presented by Tim Griesbach *April 24, 2013, 2:00 PM EDT*

Overall Approach to Boiler Tube Failure Reduction
Presented by Jeff Henry *May 7, 2013, 2:00 PM EDT*

Discussion of Boiler Tube Damage Mechanism
Presented by Wendy Weiss *May 21, 2013, 2:00 PM EDT*

Boiler Tube Inspection Techniques
Presented by Matt Dowling and Dave Overton *June 4, 2013, 2:00 PM EDT*

Gas Touch Length Analysis
Presented by Carl Skelonis *June 18, 2013, 2:00 PM EDT*

Data Management: A Key Part of Your Boiler Tube Failure Reduction Program
Presented by Nail Ozboya, Tube Track *July 24, 2013, 2:00 PM EDT*

TRADESHOWS:
API Pipeline Conference
San Diego, CA, *April 16-17* Exhibiting

HRSG Users Group, Booth #210
Tampa, FL, *April 29-May 1*
Presenting: Ian Perrin

International Conference Combined Cycles with HRSGs–Heat Recovery in the Industry Chemistry-Related Issues
Heidelberg, Germany, *May 6-8* Presenting: Barry Dooley

NAES O&M Managers Meeting
Nashville, TN, *May 7* Exhibiting

Nuclear Energy Assembly
Washington, DC, *May 13-15* Exhibiting

Nuclear Energy Insider Long Term Operations and Maintenance Conference
Charlotte, NC, *May 21-22*
Exhibiting and Presenting: Steve Biagiotti

TRADESHOWS CONTINUED:
AGA Operations Conference, Booth #200
Orlando, FL, *May 21-23*

FAC (Conference on Flow Accelerated Corrosion)
Avignon, France, *May 21-24*
Presenting: Barry Dooley

USA Nuclear Generator and Supplier Executive Summit
Hot Springs, VA, *June 4-7* Exhibiting

HPRCT Conference
Charlotte, NC, *June 11-14* Presenting: Terry Herrmann

EPRI Nondestructive Evaluation Technology Week
Hilton Head, SC, *June 17-20* Exhibiting

NACE Risk Management of Corrodible Systems
Washington, DC, *June 18-20* Exhibiting

EPRI Groundwater Protection Workshop (in collaboration with Nuclear Energy Institute)
Westminster, CO, *June 25-27*
Presenting: Eric Elder and Steve Biagiotti

EPRI Buried Pipe Integrity Group
Chicago, IL, *July 16-17* Exhibiting

Southern Gas Association Operating Conference
Houston, TX, *July 22-24* Exhibiting

AEP BRO Forum
Columbus, OH, *July 29-August 1* Exhibiting

EPRI Turbine Generator Users Group and Vendor Expo
Charlotte, NC, *August 12-14* Exhibiting

NACE Central Area Conference
Little Rock, AR, *August 26-28* Exhibiting

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