2014 VOLUME 37

Structural Integrity Associates, Inc.®

NEWS & VIEWS

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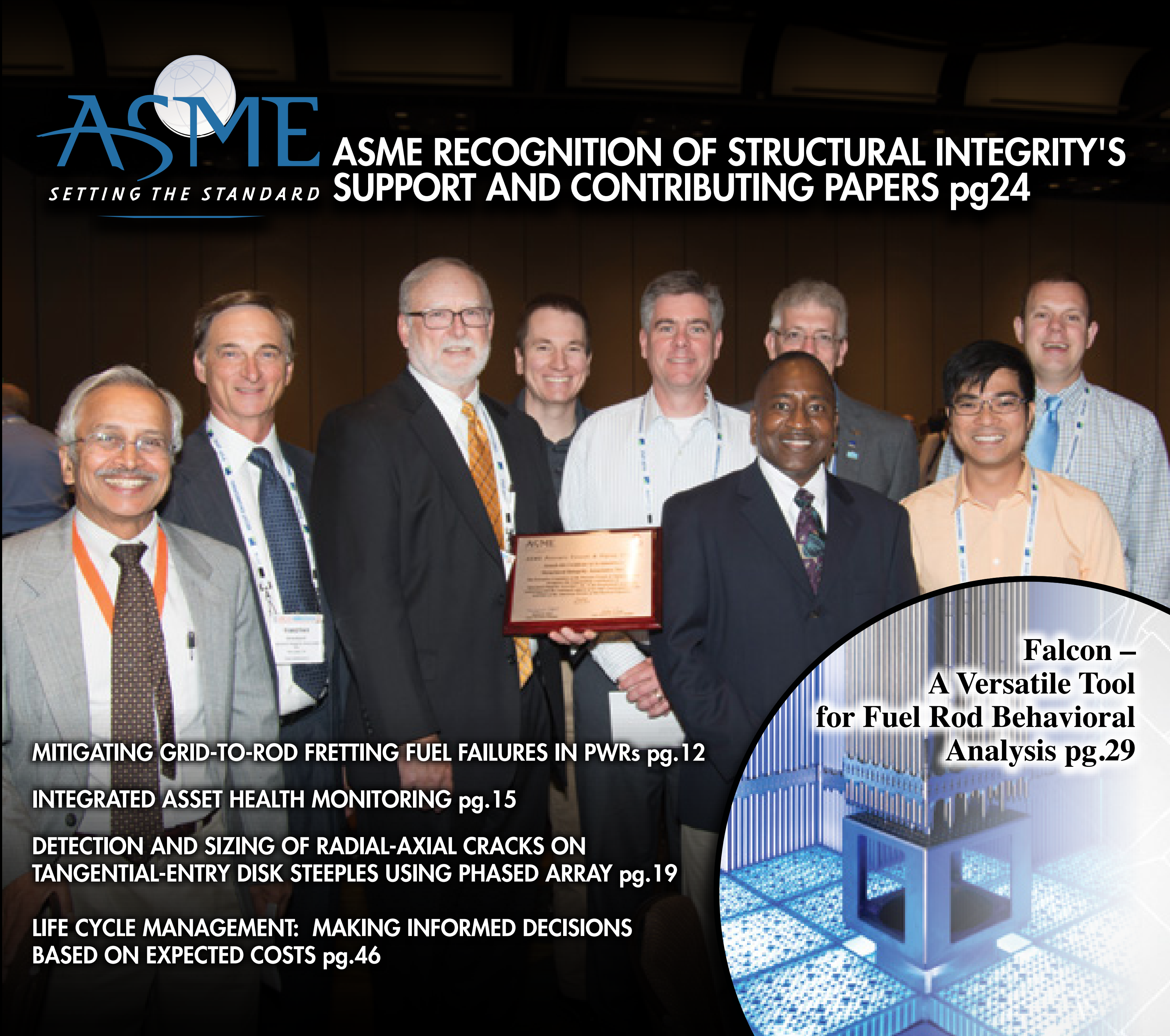

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Structural Integrity Associates, Inc.®

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So Many Welds, So Little Time

Structural Integrity Associates (SI) has always provided consulting services centered on pressure retaining components. And typically, they're big steel things – reactor pressure vessels, steam generators, main steam, hot reheat, cold reheat, and feedwater piping, turbine and generator rotors and casings, valves of all kinds, headers, drums, high pressure feedwater heaters, etc. As a materials guy with a love for NDE, I have always had a recurring thought as I drive past power plants, refineries and chemical plants – there are so many welds and so little time. Fortunately, with my career focused on fossil (and to a lesser degree, nuclear) power plants, I thought I just might have enough time to make it through all the welds out there.

Then, a few years ago, we added our pipeline services group, opening the doors to oil and gas transmission and distribution piping. Instead of a few hundred feet and a few dozen welds of high pressure steam piping in a nuclear or fossil plant, we now had literally thousands of miles of piping and welds that required assessment. I was excited just thinking of the potential, but quickly realized that there was an almost inconceivable number of welds and piping spools and the technologies I had always deployed would take far too long to get to them all. Fortunately, our pipeline consultants are industry leaders in the technologies applied to assessment of these critical assets – technologies that facilitate the risk-based assessment of all these welds and spools within an appropriate timeframe.

We continued to evolve, and in early 2013 added ANATECH, bringing new competencies, including the assessment of structures and nuclear fuel. The acquisition has proven to be perfectly complementary to our core competencies with little redundancy and added expertise for very different component types, materials and damage mechanisms. It was also the first time in quite a while that I didn't feel I had some basic level of understanding of what our staff did or was capable of doing – the ANATECH folks were that advanced. Always patient, the ANATECH team has helped educate me on the basics over the past year.

Always moving forward, Structural Integrity continues the hunt for the latest technologies and industry-leading solutions. Between the gems we find in the marketplace and the brilliant ideas coming out of our research, development and implementation group, we're bound to come up with new ways to evaluate and assess all of those components out there.

With each addition at Structural Integrity or each new industry issue and challenge, I'm always reminded – there are so many welds and so little time in a consultant's career.

Modular Blast and Wind-Generated Missile Barrier System

Tornadoes are one of many events that can unleash devastating destruction on even the sturdiest of structures, turning everyday objects into deadly missiles.

To protect the integrity of nuclear power plants, Nuclear Regulatory Commission guidelines state that systems, structures and components critical to safety must be designed to withstand tornadoes and other natural disasters without loss of safety function.

To help plant owners meet NRC requirements, Structural Integrity engineers have developed a new, patent-pending Modular Blast and Wind-Generated Missile Barrier system that offers a number of benefits over the standard approach.

STANDARD APPROACH: SOLID, BUT NOT SIMPLE

NRC Regulatory Guide 1.76 identifies a number of specific tornado-generated missiles that nuclear plants must protect against, including an airborne steel pipe traveling at 92 mph and measuring 15' long, 6" in diameter with a 0.28" wall thickness.

This is one of the most difficult threats to protect against because it requires plant owners to typically build a large barrier around the systems, structures and components in question. This solution presents several challenges:

- Massive concrete walls (> 12" thick) or extremely thick steel panels (> 2" thick) are typically required.
- The wall or panels must typically be constructed in a constricted space, while minimizing the impact to daily plant operations.
- When existing components are reclassified as safety-critical, or new systems or components important to safety are added, the wall must be expanded to protect them.

BUILDING A BETTER BARRIER

Many of these challenges are overcome with Structural Integrity's new patent-pending Modular Blast and Wind-Generated Missile Barrier system. This innovative solution consists of a concrete panel with a layer of ultra-high molecular weight polyethylene, along with a unique cabling and support system, which meets the requirements of NRC Regulatory Guide 1.76.

Our solution offers a number of advantages over the standard approach:

- The impact barrier is relatively thin and light.
- The modular design means the system can be constructed on-site and easily dismantled if plant staff need to access the area.
- The system can be easily installed within a constricted space.

In addition to nuclear power plants, this system offers a valuable solution to any industrial, commercial or military facility that requires protection of critical infrastructure, such as power transformers, tanks containing volatile chemicals, office complexes, equipment, electronic data centers, and emergency generators.

Building a better modular wall blast barrier is just one way Structural Integrity is generating innovative solutions to support the industry.

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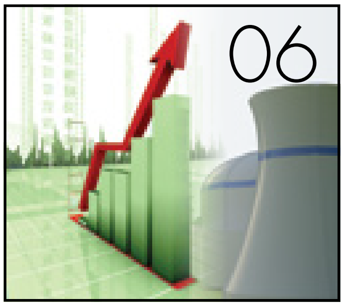

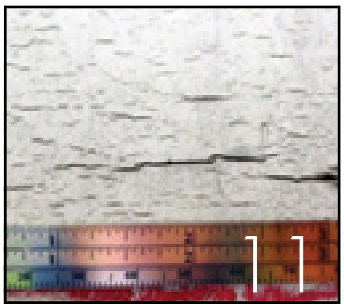

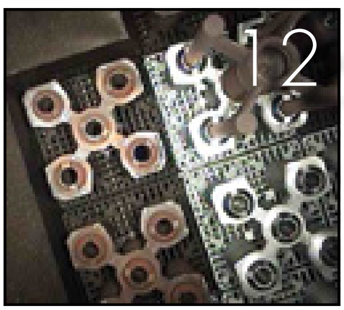

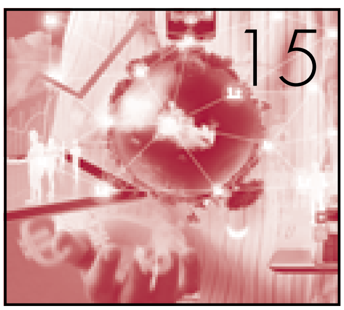

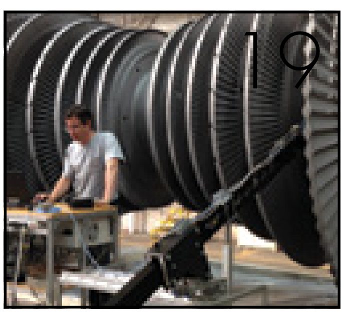

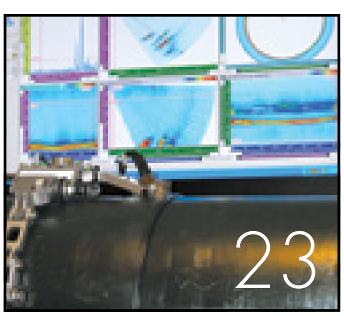

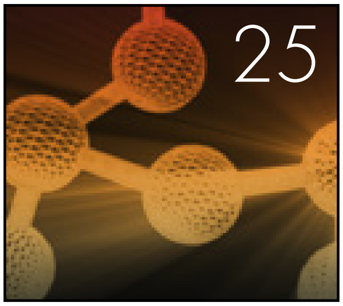
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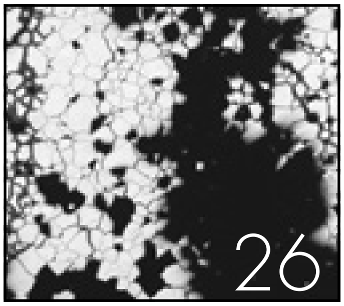
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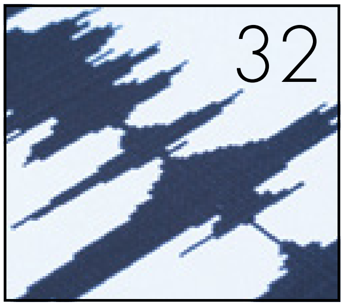
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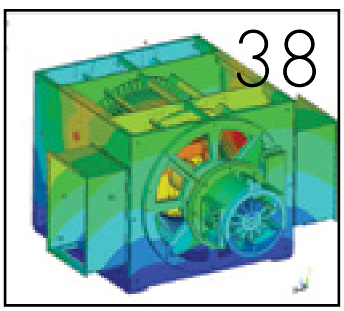
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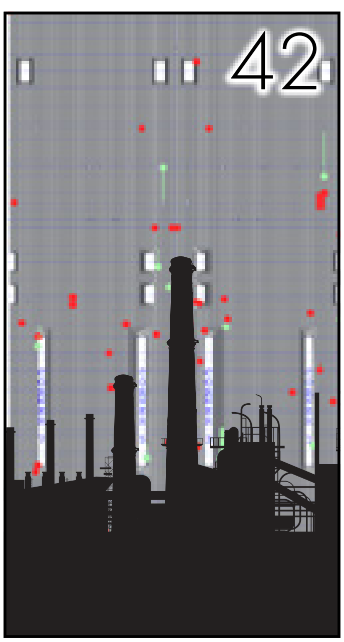
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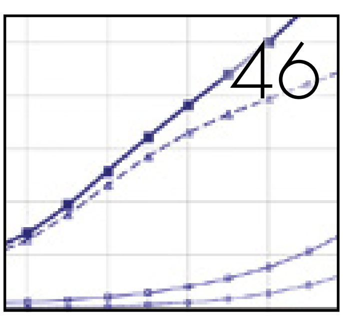
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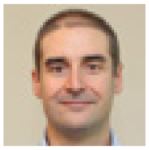
PROACTIVE DATA COLLECTION TO SUPPORT SUBSEQUENT LICENSE RENEWAL



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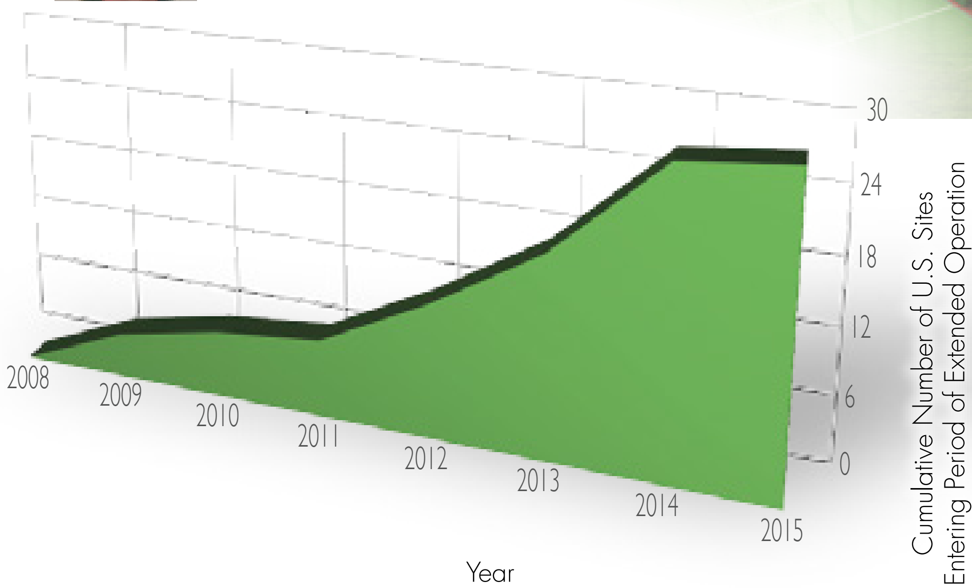
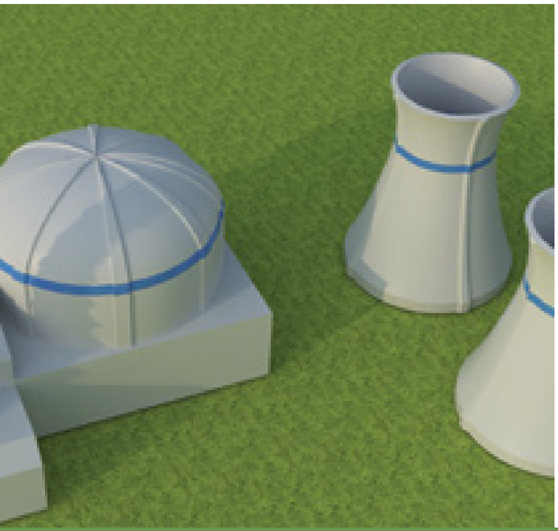
Today, most operating U.S. nuclear plants have received, or applied for, a renewed operating license from the NRC. The 10 CFR 54 license renewal process provides a 20-year operating license extension, which includes a comprehensive aging management review (AMR) process and implementation of aging management programs (AMPs) to address those AMRs.

To maximize returns on the significant capital investment that existing plants represent, utilities are now evaluating the possibility of seeking NRC approval for a second, or "subsequent", license renewal (SLR) addressing up to 80 years of plant operation. In contrast with the wave of initial license renewal applications, current economic forces make the benefits of pursuing SLR less clear. Nuclear power is an important contributor to a diversified U.S. energy portfolio, and utility owners need to have sufficient information to make decisions related to pursuing SLR. Furthermore, reasonable assurance is needed that the supporting technical basis is sufficient for NRC approval of subsequent license renewal applications.





Throughout our history, Structural Integrity Associates, Inc. (SI) has actively developed and implemented solutions that result in improved plant reliability for the long-term. Examples include adaptation of inspection programs based on data collection and advanced risk ranking to manage buried piping, as well as application of advanced analysis techniques to demonstrate the integrity of cast austenitic stainless steel piping. We also have initiatives underway to reduce or eliminate low-value inspection and maintenance activities while simultaneously ensuring that higher risk locations (sentinel locations) are inspected and evaluated at appropriate intervals.

These methods should enable utilities to reduce or eliminate unnecessary aging management commitments or modify those commitments to optimize long-term asset management approaches. While actual submittals of LRAs for subsequent license renewal are still a few years off, judicious attention to meaningful data collection and evaluation today can yield significant benefits tomorrow. For many initial license renewal applications, decisions regarding aging management commitments were necessarily made in the absence of supporting field data or with relatively limited operational data. Going forward, the opportunity exists to proactively identify, collect, and analyze data that will support subsequent license renewal and optimize the benefits associated with long-term operation. Field inspection data, if appropriately collected and analyzed, can be used to refine aging management programs to improve their effectiveness and lower implementation cost.

Operational data is also important. In many cases, analyses supporting initial license renewal margins were performed with relatively limited data regarding plant thermal transients and environmental conditions. In the context of a 60-year life, adequate margins could be demonstrated with these limited data. For SLR, there are cases where identification and collection of key data may represent the difference between a successful demonstration of

margin (fatigue margin or other) by less complex analysis methods or a need to resort to other alternatives. These supplemental examinations, advanced analysis methods or outright replacement of components may be time consuming and/or costly to implement. And, in the case of fatigue analyses, the need for data is further increased by the need to consider environmental effects and HELB fatigue screening criteria for ASME Class 1 locations.

We are committed to supporting the long-term operation of the U.S. nuclear fleet. A technical basis for SLR that provides reasonable assurance to regulators that aging mechanisms are being adequately managed is a key supporting element of a SLR application. Based on our extensive experience performing analyses and examinations to support initial license renewals, it is clear to us that proactive identification, collection, and analysis of key field inspection and operational data will be highly beneficial to plants considering SLR. As of 2015, more than half of U.S. nuclear plant sites with renewed licenses will have operated for 40 or more years and entered the "period of extended operation". For these sites, initial license renewal AMPs should be fully implemented. Although a first application for an SLR remains in the future, now is the time to capture additional margin through collection of data that reduces uncertainty and provides reasonable assurance of safe and reliable operation for many more years.

STRUCTURAL INTEGRITY HOSTED TRAINING

Future of Technology

Structural Integrity recently completed a successful one-day training and two-day workshop on the Future of Technology in Asset Management in Austin, Texas. Attendees learned about Condition Assessment; Metallurgical Fundamentals; Critical Component Data and Data Management; Predicting Material Behavior; Analytical Approaches and Computational Modeling; Run; Repair; Replace Strategies; and NDE technologies. They earned up to 17 hours of Professional Development Hours (PDHs).

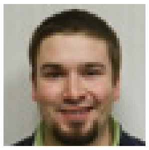
Two keynote presentations were made by Kent Coleman, EPRI, and Laney Bisbee, CEO of Structural Integrity Associates, Inc., focusing on Life Management for Grade 91 and the Future of Technology and how planned and unplanned changes affect utilities. The workshop also included hands on demonstrations. It was a busy but informational three days, concluding with a quick trip to the Circuit of the Americas F1 Track.

Utility attendees appreciated the quality of presentations by our industry experts and the ability to collaborate with their peers. We especially appreciated hearing from attendees: "I learned a lot and really enjoyed my time in Austin. I look forward to attending these events again in the future!" and "Thank you to everyone at Structural Integrity for putting together such an engaging workshop…All the presentations were clearly organized and informative."

"Structural Integrity's focus is to help our clients tackle the challenges they face on a daily basis through our engineering and inspection services as well as training, such as this workshop. We believe in continuous learning and we take pride in passing along knowledge and expertise to our colleagues in the power industry" said Ian Perrin, VP of Fossil Plant Services. "We enjoy the opportunity to interact with everyone and look forward to hosting future events."

If you would like to suggest a particular topic for future training, please call us at 1-877-4SI-POWER.

COMMON PROBLEMS WITH HIGH-ENERGY PIPING SUPPORTS



By: KEVIN HALEY
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For many years, poorly designed and degraded pipe supports have been a cause of significant problems in High- Energy Piping (Main Steam, Hot Reheat and Cold Reheat) systems. Complex support systems composed primarily of spring hangers, rigid supports, guides and vibration damping snubbers are engineered to allow for thermal expansion while providing support for the piping and insulation. This is done to ensure the piping systems operate within design code allowable stress limits. When performing as designed, these support systems result in reasonable stress levels throughout the piping. Dynamic loading events, improper installation, poor design and harsh environmental conditions, among other factors, can result in support system malfunction, which can lead to severe damage to the supports, structural steel, and most importantly, the piping itself. This damage can manifest as increased loads or movement restrictions on the piping system and therefore increase stress on welds and base metal, ultimately leading to shorter than anticipated useful lives.

Structural Integrity utilizes relative ranking and remaining life calculations to prioritize inspection locations as part of a comprehensive high energy piping (HEP) management program. Stress is the key input to these ranking and life calculation tools. Finite element stress analysis of piping systems with as-designed supports typically provide the stress inputs. Support problems can also be quantified with analysis. However, for Main Steam and Hot Reheat systems, where creep relaxation occurs, the amount of damage accrued when a support malfunctions (if that is known) becomes more difficult to pinpoint. This issue, along with adjustments made during the lifetime of the support, complicates the issue of ranking components for inspection and calculating remaining life.

A key aspect of maintaining these critical support systems is performing regular system walkdowns to observe and document support position and condition. Performing online or hot condition surveys annually, and offline or cold condition surveys at least once every three years or during major scheduled outages, allows for data trending that can help identify potential problems before significant damage is caused.
Conventional fossil plants consist of large boilers and steam turbines near each boiler. As a result, the HEP systems typically consist of long vertical runs and relatively short horizontal spans of piping. As such, the support systems consist mainly of large displacement spring hangers to account for large vertical thermal expansion movements, with relatively few rigid supports and guides.

Conversely, many combined cycle plants consist of relatively smaller heat recovery steam generators (HRSGs) and larger horizontal distances between the HRSG(s) and the steam turbine. While these systems also contain spring hangers to accommodate vertical displacement, there are many vertical rigid or shoe supports in areas with little to

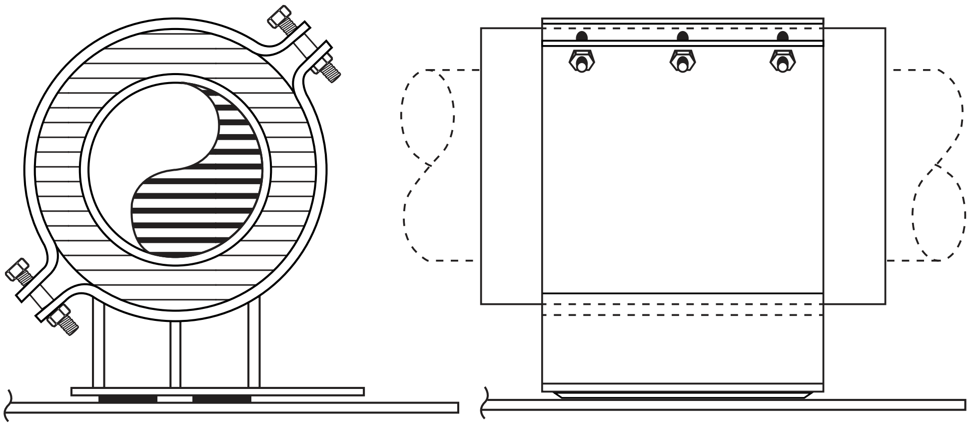


Figure 1 – Typical over-insulation type shoe support

no vertical movement and guides to control lateral displacements. Along with the added support types noted in these systems, unique support problems can be found. Following are some common issues Structural Integrity has encountered in both conventional and combined cycle plants.

OVER-INSULATION SHOE SUPPORT DAMAGE

Clamped on support shoes are used frequently in combined cycle HEP systems to supply simple downward vertical support for piping and allow for lateral displacements. For any support clamps that contact the piping, the clamp and shoe material must be able to withstand the high temperatures seen by the piping. In order to avoid the cost of high-temperature support clamps, shoes and friction plates, larger clamps are commonly placed over high density calcium-silicate insulation blocks (see Figure 1) to isolate the piping temperature from the support.

While these supports are designed to withstand static deadweight loading of the piping, loading from dynamic events such as water hammer during startup or overloading due to other malfunctioning supports can cause damage to the insulation blocks. The clamped on shoes may also eventually become loose against the pipe insulation (if tight originally) and allow the piping to slide inside the clamp rather than the shoe sliding on the guide plate. When this occurs, the clamps may visibly appear twisted or may slide off of the insulation blocks (see Figure 2). This condition can cause increased local stress in the piping, overloading of adjacent supports that now need to carry the load from the damaged support and/or sagging in the piping, potentially diminishing the effectiveness of the drainage system.

Figure 2 – Photograph of damaged over-insulation shoe support

SLIDE PLATE & GUIDE SUPPORT MALFUNCTION

Dynamic events, poor design, and incorrect installation can also cause support alignment issues with shoe supports and guides. Shoe supports typically rest on structural steel, and are offset from the centerline of the steel by half of the expected thermal displacement. If this offset is performed in the wrong direction, or if water hammer or a similar event causes large displacement, the shoes may fall off of the structural steel (see Figure 3). Such an event may also cause vertical movement of the piping and result in misalignment of a guide support (see Figure 4). Similar to the damaged shoe support condition noted above, these conditions can result in local stress increases, damage to surrounding supports and can adversely affect the slope of the piping relative to drains.

Figure 3 – Shoe support fallen off of structural steel

Figure 4 – Misalignment/malfunction of guide support

BUCKLING OF RIGID RODS

Rigid rod supports are typically used to support vertical dead weight loads in tension for conventional and combined cycle HEP systems. In compression, these rods tend to buckle under relatively small loads, causing a permanent bend in the rod (see Figure 5). When such damage occurs, the cause of the compressive load should be identified prior to replacement of the rod. If the compressive load was caused by a static load or a dynamic event that cannot be controlled or prevented from reoccurring, the rod may need to be replaced with a strut that can withstand both compressive and tensile loading.

While strut supports are better suited for compressive loading than thin cross-sectioned rods, overloading can also result in buckling. Figure 6 is an image of a bent strut caused by water hammer. In any case where a rod or strut has been damaged from piping loads or movement, it is important to not only evaluate the cause of the damage and replace the support, but also inspect the piping and structural steel attachments for damage. In the case of the bent strut in Figure 6, the trunnion attachment weld to the piping and the attachment hardware should be inspected for damage.

Figure 5 – Buckled rod due to compressive overloading

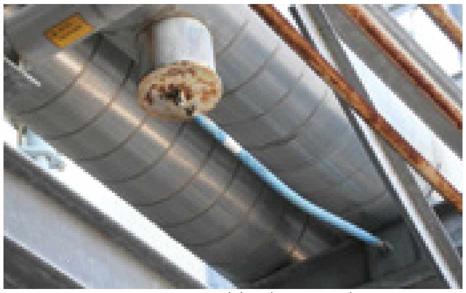


Figure 6 – Buckled strut due to compressive overloading

BOTTOM/TOPPED OUT SPRING SUPPORTS

An issue found commonly in HEP systems is spring supports operating outside of their design range. Typical variable spring and constant load spring hangers have travel scales with hot and cold setting stamps.

Continued on next page

COMMON PROBLEMS WITH HIGH-ENERGY PIPING SUPPORTS

CONTINUED

Over time, creep and other factors can cause movement in the piping, resulting in supports operating above or below their design positions. In general, this is not a significant concern with respect to piping stress, as long as the hangers are still within their operating range. In some cases, supports may bottom out – effectively acting as vertical rigids constraining additional downward movement, or top out – either constraining additional upward movement or providing no support/restraint, depending on hanger arrangement. Figure 7 is an example of a bottomed out constant load hanger.

Figure 7 – Bottomed out constant load hanger

For areas of large vertical thermal expansion, bottomed or topped out spring supports can significantly impact stress as they restrict the displacement of the piping. Figure 8 is a stress contour plot comparison showing the local effects of a bottomed out spring hanger at the base of a vertical run of Main Steam piping. In this example, constant load hanger was found to be bottomed out, constraining nearly 4" of downward design movement of the piping. As a result, maximum bending stress at the 30° elbow outlet girth weld increased from 3,000 psi to nearly 22,000 psi.

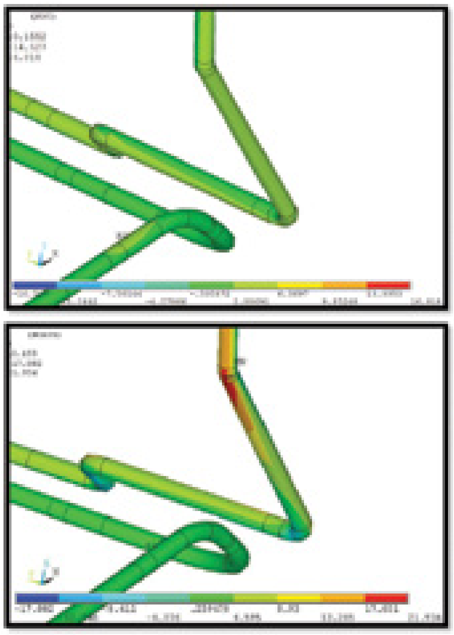


Figure 8 – Comparison of stress between normally functioning spring hanger (top) and bottomed out spring hanger (bottom)

INCORRECTLY INSTALLED/ MAINTAINED SUPPORTS

During original construction of piping systems, spring hangers are installed with locking mechanisms both for shipping and for hydrotesting purposes. These temporary devices are to be removed prior to putting the piping into service to allow for proper function of the supports. Figure 9 is an example of a spring hanger that had been in service for multiple years with the locking device in place. This support was designed to allow for vertical displacement, but instead acts as a vertical rigid.

These locking mechanisms or pins may also be installed in spring hangers during maintenance outages while other work is being performed on the piping systems. If load testing a nearby hanger or repairing a girth weld or replacing a fitting that requires parting the piping, one or more spring hangers may be pinned to maintain the position of the piping. It is important to remove the locking pins before returning the unit into service.

Other commonly omitted items either during original construction or maintenance outages are cotter pins, retaining rings and nuts. Figure 10 is an example of a hanger rod to structural steel attachment bolt with no nut. Regular support walkdowns can identify these issues before they become serious problems.

Figure 9 – Spring hanger with locking device in place

Figure 10 – Hanger to structural steel attachment bolt missing nut

PIPING/INSULATION INTERFERENCE WITH STRUCTURES

When performing support walkdowns, it is important to survey the entire piping system, not only the condition of supports. Items such as insulation damage and interference between the piping system and other systems or structures can be detrimental. Figures 11 and 12 are examples of piping insulation contacting grating at a floor penetration and a structural column. Such conditions can result in higher local stress in the piping due to the added restraint, damage to the structural component and damage to the piping insulation, exposing the piping to the ambient environment. This issue is commonly found at grating/wall penetrations and structural steel.

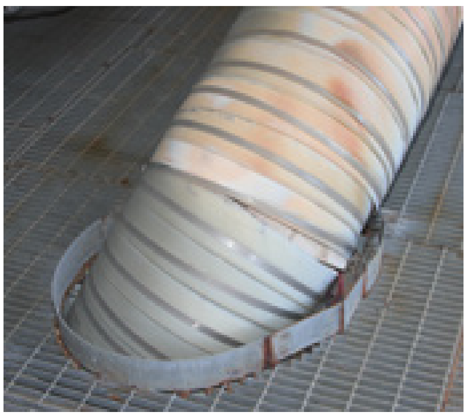


Figure 11 – Piping contacting grating at floor penetration

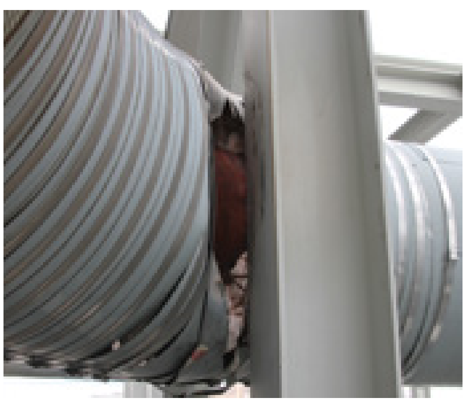


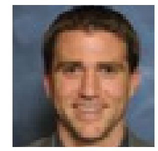
Figure 12 – Piping contacting structural steel

While the noted support deficiencies can cause significant problems with respect to serviceability of HEP systems, diligence in performing regular support walkdowns can identify many of the common problems before serious damage occurs. When included in a comprehensive piping management program, plants can mitigate the risk associated with these systems and understand what locations are most susceptible to damage.

PRCI STUDY OF NDE TECHNOLOGIES FOR SIZING CRACK-LIKE INDICATIONS

PRCI

LEADING PIPELINE RESEARCH



By: SCOTT RICCARDELLA

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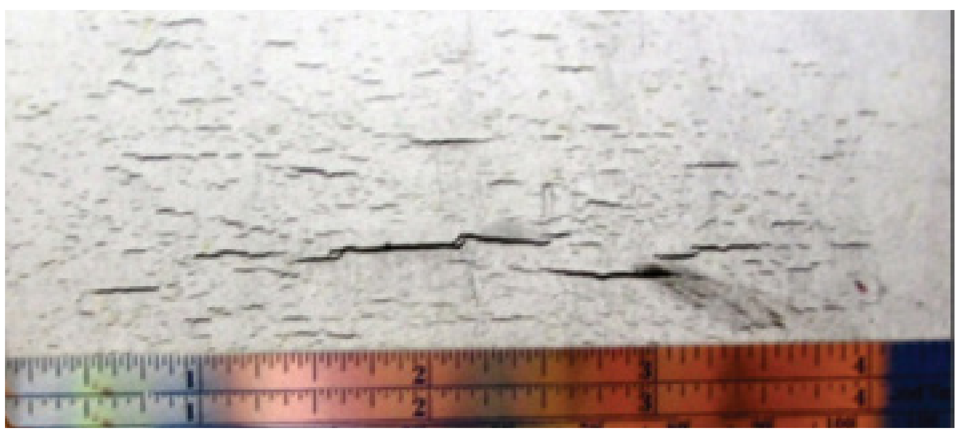
Pipeline operators are increasingly finding pipeline degradation in the form of crack-like defects from stress corrosion cracking (SCC), hook cracks and other seam defects in certain vintage pipelines among other mechanisms. Furthermore, operators are continuously challenged to identify and employ NDE techniques that can reliably determine the axial depth profile of these cracks. While magnetic particle testing (MT) provides a robust and inexpensive method of detection, it is unable to determine the through wall depth of the cracks. The geometry, location, and proximity of linear indications and other features can create a significant challenge and degree of variance in an NDE technologies' ability to size crack-like defects.



Structural Integrity is currently the prime contractor of a Pipeline Research Council International (PRCI) project to further investigate and define the capabilities and limitations of different NDE methodologies typically used and/or identified as feasible to size crack-like features. The project consists of developing and implementing a process to evaluate the applicability, accuracy, and sensitivity of different NDE methodologies in sizing crack-like defects. The primary task includes development and implementation of a test plan to support blind, round-robin NDE testing on selected PRCI crack-like defect samples and subsequent destructive testing to verify the crack depth size and accuracy of the different technologies used. As part of the final deliverable, we create a guidance document that provides the level of discrimination performance that can be expected from various in-ditch NDE technologies applied to sizing linear indications. We also document criteria for crack characteristics affecting performance.

MITIGATING GRID-TO-ROD FRETTING FUEL FAILURES IN PWRs

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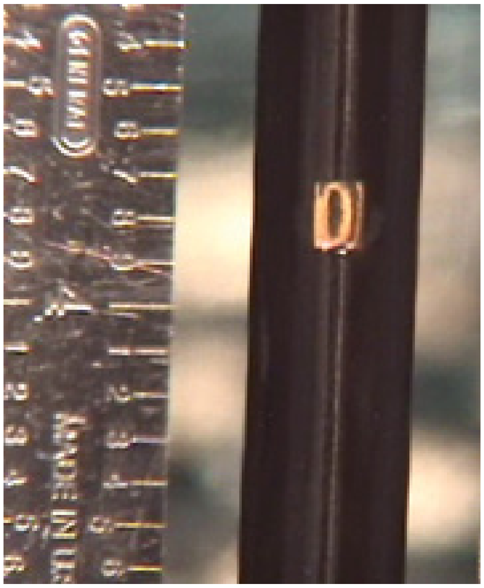


Grid-to-rod fretting (GTRF) has been the dominant fuel failure mechanism in PWRs. GTRF is the result of a fuel assembly design that does not provide sufficient resistance to vibration of the fuel rods against the assembly structure. Replacing a fuel design is often a lengthy process. Design to testing to implementation can take 10 to 15 years to completely remove the old design from use and eliminate GTRF fuel failures. Our ANATECH staff has a creative approach to implementation of new fuel design(s) and core designs that can eliminate fuel failures in a much shorter period.

In PWRs, the fuel assembly is comprised of a matrix of fuel rods. This matrix of fuel rods is held in place by a skeleton, with guide tubes providing the axial support, and 8 to 12 spacer grids welded to the guide tubes to hold the fuel rods in place. If the spacer grids do not provide adequate support, the fuel rod can vibrate against the supports, eventually creating a hole in the fuel cladding. This allows fission gasses to be released into the reactor coolant system. If the hole is severe enough, the uranium fuel and fission products can escape.

GTRF occurs when the fuel rod vibrates and a singular point on the rod continues to contact a spot on the grid. Several factors impact this wear rate:

- Amount of crossflow-induced vibration
- Amount of contact area between rod and grid
- Amount of time under full flow conditions (similarly, burnup of the fuel)
- Hardness of fuel cladding compared to grid material, if different

Failed fuel has many impacts:

- Radioactivity in the reactor coolant system (RCS) increases, creating an increased dose hazard to the plant workers
- If the failed fuel assembly was planned for use in subsequent fuel cycles, additional work is required to repair the fuel and dispose of the damaged fuel rod(s)
- If the failed fuel assembly cannot be repaired, the core design must be reanalyzed using a replacement assembly
- If the failed fuel assembly has finished its useful life, it still needs to be repaired before dry cask storage, or additional storage requirements are necessary to put failed fuel in dry cask storage

Unfortunately, if failed fuel occurs during plant operation in PWRs, there is little that can be done to mitigate the impact during that fuel cycle mitigating GTRF fuel failures in PWRs usually involves a design change to the fuel. If the design change needed is substantial, then the time frame to implement that change can be lengthy. It can take up to two years or more to design and test the new design. Once the design is ready, a lead test program using a small set of typically eight assemblies may be needed to test the design in real plant conditions. Since GTRF occurs over long lengths of time, this test program may require two or three fuel cycles (3-5 years) to test performance. If the design proves successful, then the transition to the new design can begin, although it can take two to three more fuel cycles before the entire core is replaced with GTRF resistant fuel. The result is, for significant design changes, it can take as much as 10 to 15 years to fully design and implement a new GTRF-resistant fuel design.

Plant "X", a two-unit site, had been experiencing GTRF fuel failures for much of its operating life. While the failures were not a significant impact to plant operation, there was an impact a outage dose to the plant workers, and a financial impact in dealing with the failed fuel. Almost all of these failures were GTRF on the outer row of assemblies against the core shroud.

For the Plant "X" design, the inlet flow at the bottom of the core was greater at the center of the core due to the lower internals design. This resulted in a outflow of water to the outside of the core. This high crossflow resulted in greater fuel rod vibration on the outer row of assemblies. This failure mechanism was prevalent in high burnup fuel, as the fuel grid relaxes at high burnup and fails to hold the rod tightly in place.

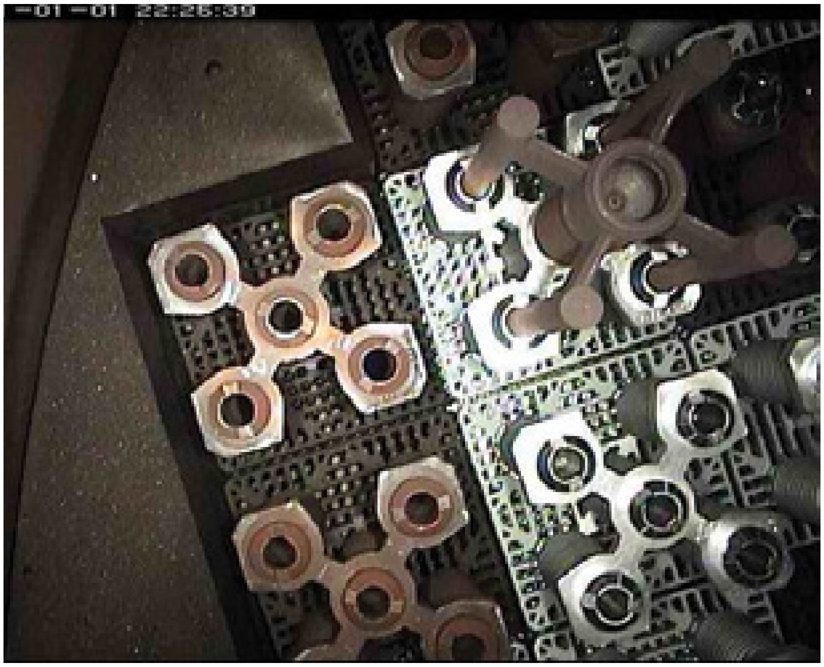
In 2006, an initiative was launched at Plant "X" to replace the susceptible fuel design with a GTRF resistant fuel design. Several alternatives were considered, and a two-tier approach was implemented to eliminate GTRF failures:

1. Short Term Mitigation Strategies
2. Long Term Fuel Design Replacement/Improvement

SHORT TERM MITIGATION STRATEGIES

In order to reduce the short-term impact of fuel failures, three programs were implemented:

1. Core design strategies were used to try to reduce and/or eliminate the practice of putting high burnup fuel assemblies on the core periphery.
2. Rather than replace ~1/3 of the core each reload, Plant "X" switched to a ½ core replacement to reduce the number of highly burned assemblies.
3. Plant "X" also reduced cycle length from ~600 effective full power days (EFPDs) to 530 EFPDs, again reducing the amount of time the fuel stayed in the reactor.



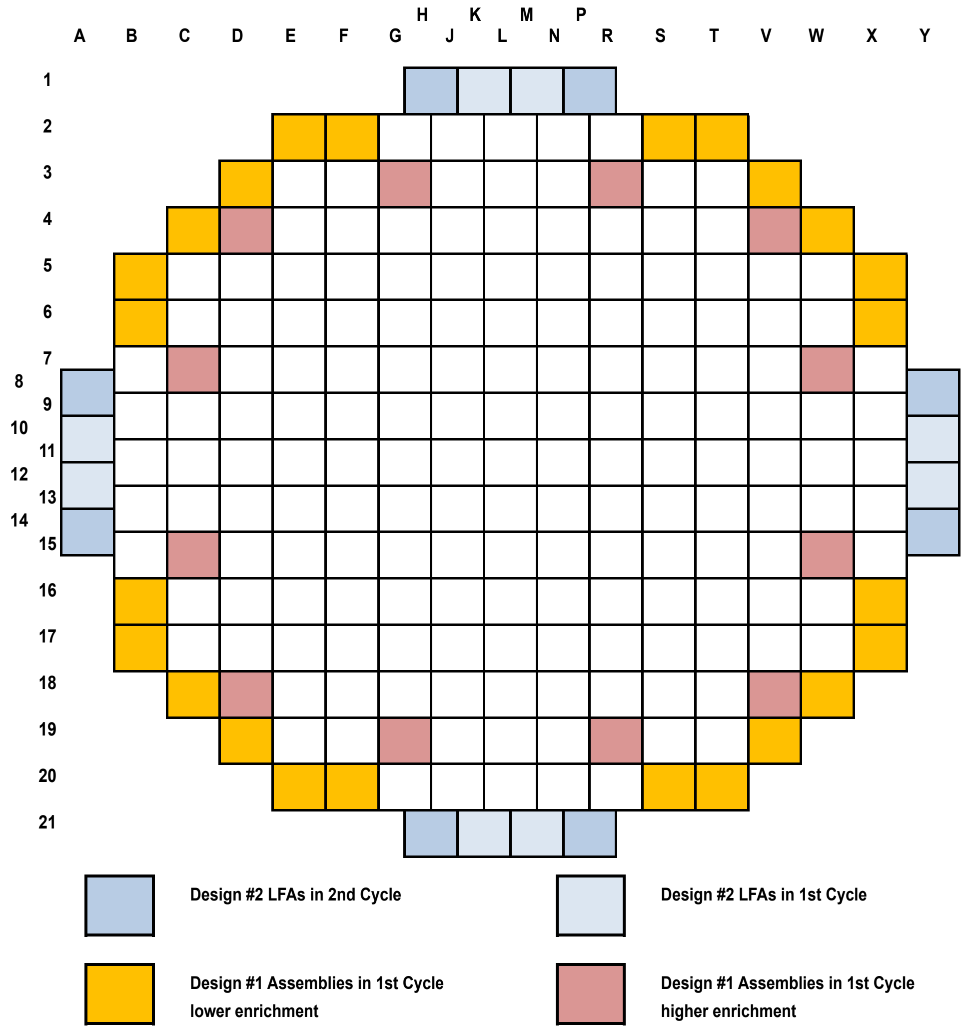
LONG TERM FUEL DESIGN IMPROVEMENT

Numerous options were considered to improve GTRF performance at Plant "X" (e.g., fuel design changes, lower internals changes, lower core flow plate redesign). Several improved fuel designs were considered, and two GTRF-resistant designs were selected for implementation. Design #1 design was implemented via a lead test assembly program of 8 assemblies in Plant "X", Unit 1. Design #2 was implemented via a lead test assembly program of 8 assemblies in Plant "X", Unit 2 the following year. In discussions with the NRC at the time, Plant "X" staff stated that full testing and implementation of the GTRF resistant design would not be complete until 2018 (i.e., fuel failures would continue).

Continued on next page

After one fuel cycle with design #1, two things became apparent: (1) Plant "X" needed an accelerated schedule to eliminate fuel failures, and (2) design #1 was showing significant GTRF resistance compared to the existing design. This allowed Plant "X" to implement a creative approach to mitigate GTRF during the fuel transition.

Originally, the lead fuel assembly (LFA) program planned for 8 assemblies to be tested over 3 fuel cycles to confirm their GTRF performance. Once the Design #1 LFAs were deemed acceptable for batch implementation, the staff began to look for ways to utilize that design in the other Unit that was currently using the design #2 LFAs. By having independent in-house core design staff, Plant "X" was able to analyze and utilize fuel from different vendors in the same core.



This innovative core design strategy included utilization of a mini-batch of 36 assemblies of the new fuel design #1 that would be placed in susceptible locations. This would allow Plant "X" to put those susceptible assemblies in internal locations where GTRF failures did not occur, while getting an early start in transitioning to the improved fuel design.

As a result, Plant "X" Unit 2 was expected to have no fuel failures. This core design strategy would be followed with future fuel batch replacements in the new fuel designs, effectively eliminating GTRF failures at Plant "X" well before the full core implementation of a new design.

RESULTS OF GTRF MITIGATION STRATEGIES

We were able to evaluate new GTRF resistant fuel designs while also providing creative solutions to core designs during the transition from the old design to the new designs. Under the old approach to fuel design improvements, Plant "X" was not expected to be free of fuel failures until 2020. By increasing use of the new fuel designs through creative and innovative core designs, we created a plan which could allow Plant "X" to actually be free of fuel failures in 2015.

While we are focusing on the strategies applied to eliminate GTRF failures at Plant "X" in this article, the creative approach to core design and fuel transition discussed here can be applied to all nuclear plants. The benefits can be performance related (as in this case), or even financial related in implementing designs from different fuel vendors, allowing utilities to select the most cost-effective and robust fuel design. By using non-vendor produced independent core designs, the utility can make more fuel decisions that are in the best interest of the rate player.

INTEGRATED ASSET HEALTH MONITORING

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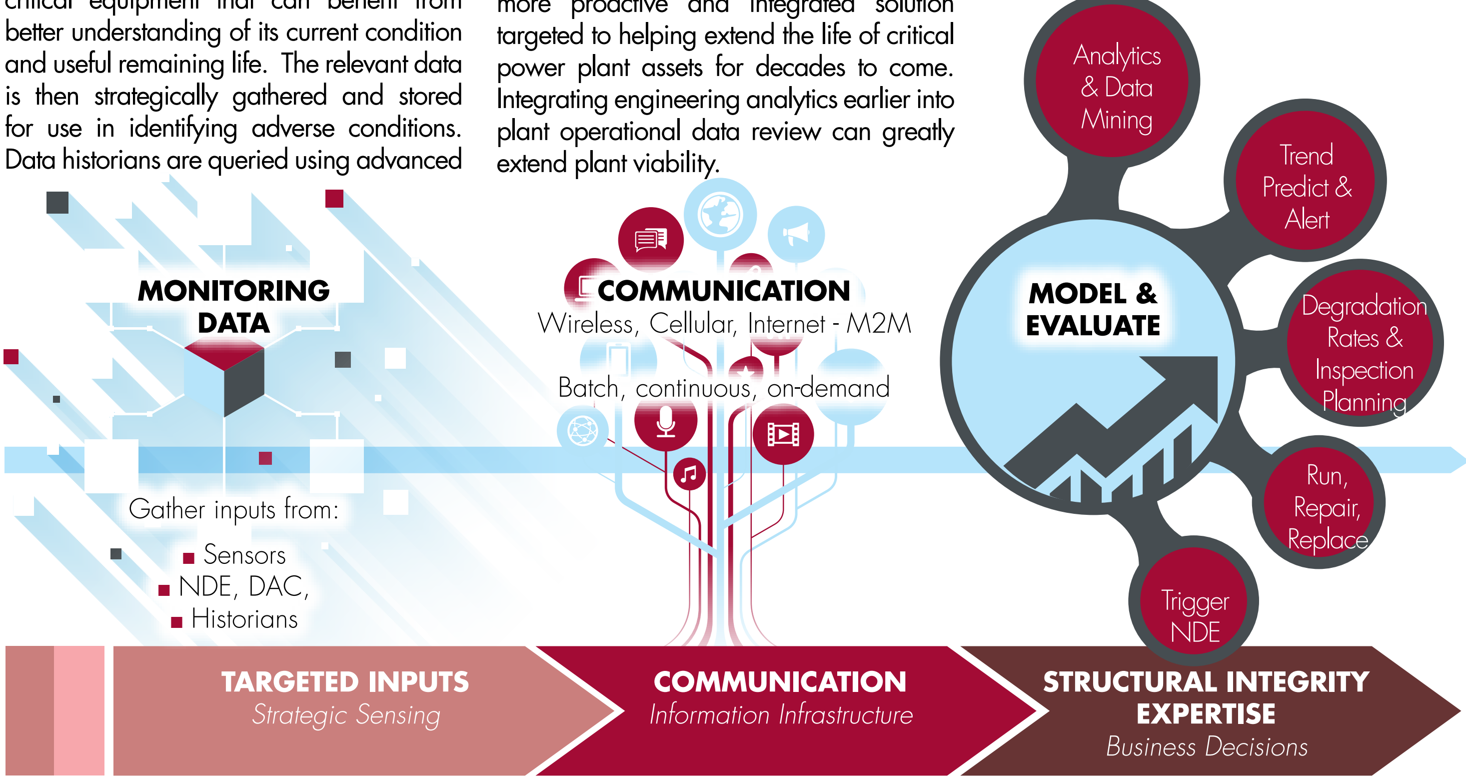
WHAT IS INTEGRATED ASSET HEALTH MONITORING?

The concept has been around for a while and has been successfully used in industries ranging from aerospace to microelectronics. In a nutshell, integrated asset health monitoring looks to leverage online condition monitoring technologies by providing information that can be used to proactively detect the early onset of adverse conditions. This enables operators to better optimize asset life, performance, integrity and reliability.

Power plants are rapidly transitioning to instrumented sensors for monitoring everything from pressures, temperatures, vibration, and movement in structures, to more complicated NDE information in real time. The first step in the process is to identify critical equipment that can benefit from better understanding of its current condition and useful remaining life. The relevant data is then strategically gathered and stored for use in identifying adverse conditions. Data historians are queried using advanced pattern recognition systems for trends and other susceptibility patterns. Recognizing and properly characterizing anomalous conditions early has the potential for significant cost savings by avoiding forced outages and properly staging the right parts needed for maintenance on your schedule.

For decades, companies have come to count on Structural Integrity to help with the inspection and characterization of critical assets through our innovative NDE solutions. By applying our world class analytical capabilities and ASME Code experience, we've helped avoid unnecessary and costly loss of production. We are now applying our strengths in condition assessment and anomaly disposition capabilities to a new, more proactive and integrated solution targeted to helping extend the life of critical power plant assets for decades to come. Integrating engineering analytics earlier into plant operational data review can greatly extend plant viability.

Structural Integrity has been doing asset health monitoring for many years using tools we have developed such as SI:FatiguePro4 and EPRI's CreepFatiguePro for Nuclear and Fossil plants, respectively. You're going to hear more from us on this topic as we apply new technologies and approaches, such as EPRI's Fleet Wide Prognostics and Health Monitoring application and modular, in-situ sensors for damage detection and real-time monitoring of pressure boundary internal components, to support license renewal and flexible operation at nuclear plants, and to track damage due to increased cycling at fossil and combined cycle plants.



SIPEC PULSED EDDY CURRENT SENSOR FOR ROBOTIC IN-LINE INSPECTION OF LINED PIPING

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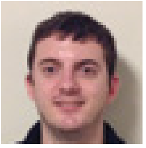

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Pulsed eddy current (PEC) is a nondestructive testing (NDT) technology traditionally used to inspect for corrosion under insulation (CUI). Unlike traditional Eddy Current Testing (ECT), PEC uses a transient excitation pulse induced in the conductive test material by a driver coil. As the magnetic pulse is injected, transient eddy-currents diffuse inward into the material and result in a time-lag in the response of the material to the induced magnetic field. The duration of the time-lag is related to the material properties and thickness of the metal, thus providing a method for estimating the remaining wall thickness. Inspectors using existing PEC systems traditionally acquire point-by-point measurements by manually scanning the sensor over the insulation jacket, with each point measurement requiring several seconds of stationary data acquisition.

Structural Integrity Associates recently completed the development of a new dynamic PEC sensor, electronics, and data processing and analysis algorithms that enable PEC data to be acquired while the sensor is in motion. Utilizing the high measurement frequency and dynamic data acquisition capabilities of Structural Integrity's Pulsed Eddy Current (SIPEC™) technology, along with Diakont Advanced Technology's RODIS robotic in-line inspection (R-ILI) delivery system, the industry's first SIPEC in-line inspection was successfully completed on an internally-lined 42-inch diameter pipe. Subsequent scans were acquired on an unlined 36-inch diameter pipe; in this case, spacers were used to simulate the presence of a liner. The data and results of this novel application of SIPEC are presented herein.

The patent-pending SIPEC™ sensor design and data processing algorithms enable detection and approximate sizing of flaws at up to 0.625 inches of sensor lift off. The SIPEC™ inspection system currently offers the following advantages:

- Inspection through internal liners (up to 0.625 inches of lift off).
- Rapid data acquisition (up to 20 measurements per second).
- Dynamic data acquisition (scanning speeds up to six inches per second).
- Differentiation between inner diameter (ID) and outer diameter (OD) flaws.
- Approximate spatial sizing (axial, circumferential, remaining wall thickness).
- Measurement of approximate liner thickness.

BACKGROUND

The test spool on which the inspection was performed consisted of a carbon steel pipe, with a 42-inch diameter, 0.500-inch nominal wall thickness, half-inch thick internal fiberglass liner. This piping configuration is representative of that used to transport seawater from oil tankers' ballast water tanks to water treatment facilities as the tankers are loaded with crude oil. The test spool was fabricated with flaws of various morphologies, including concavities and flat-bottom holes representative of general corrosion. In addition, the liner was fabricated with several repairs where rectangular portions of the liner had been removed to fabricate flaws and subsequently replaced and sealed, resulting in an irregular ID surface for scanning.

DATA ANALYSIS

The SIPEC™ acquisition software displays an unrolled pipe C-scan data image in real-time, indicating the axial and circumferential locations of any indications (i.e. potential flaws). The software also features a real-time cross-section view that indicates the circumferential position of lowest remaining wall thickness reading. The SIPEC™ post-processing software adds an interactive rolled pipe display that includes a three-dimensional rendering of the data overlaid on the pipe, as well as a zoomed view for analyzing indications. Multiple scans were recorded on both the 42-inch and 36-inch diameter test spools.

Two flaws on the 42-inch diameter test spool were targeted for scanning. The first was a 6.375-inch by 6.875-inch ID concavity with a maximum depth corresponding to 0.140-inch (28%) remaining wall thickness. Figure 1 shows a real-time unrolled pipe C-scan display of the ID flaw. From left to right, Figure 2 shows zoomed C-scan, rolled pipe C-scan, and cross-section displays of the ID flaw. The second flaw was a 7.750-inch by 8.125-inch OD concavity with a maximum depth corresponding to 0.133-inch (27%) remaining wall thickness. Figure 3 shows a real-time unrolled pipe C-scan display of the OD flaw. From left to right, Figure 4 shows zoomed C-scan, rolled pipe display, and cross-section displays of the ID flaw.

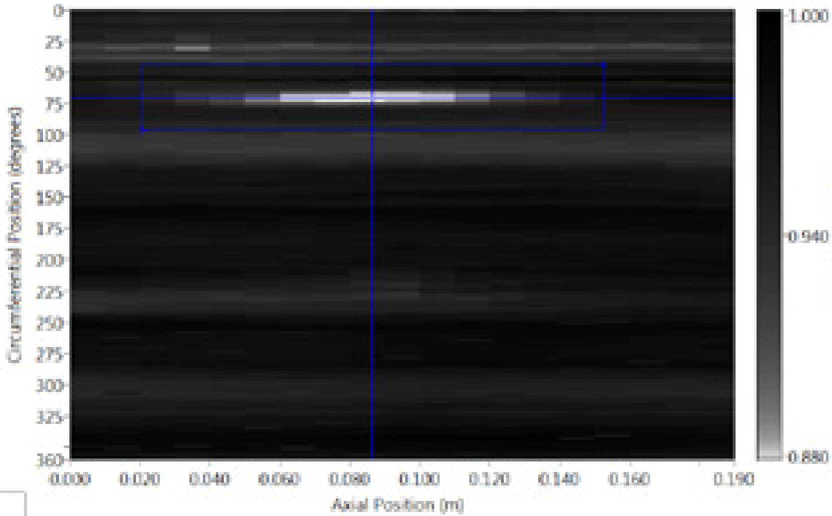

Figure 1 Real-time unrolled pipe C-scan display identifying the location of the 42-inch diameter pipe ID flaw and the seam weld.

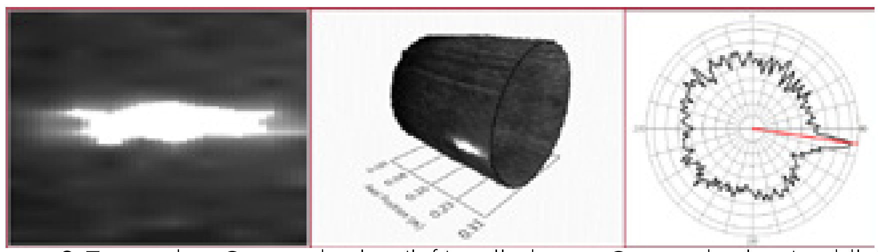

Figure 2 Zoomed in C-scan display (left), rolled pipe C-scan display (middle), and cross-section view (right) of the 42-inch diameter pipe ID flaw.

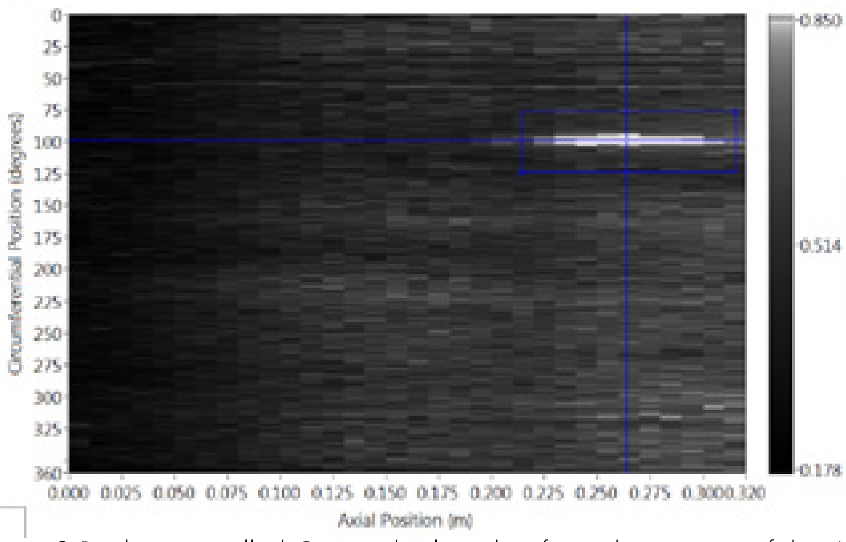

Figure 3 Real-time unrolled C-scan display identifying the position of the 42-inch diameter pipe OD flaw.

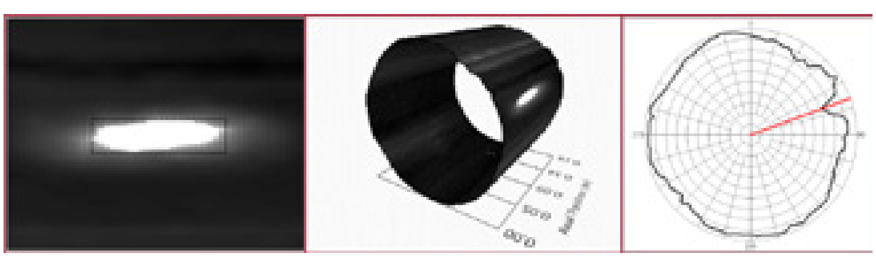

Figure 4 Zoomed in C-scan display (left), rolled pipe C-scan display (middle), and cross-section view (right) of the 42-inch diameter pipe OD flaw.

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SIPEC PULSED EDDY CURRENT
CONTINUED

RESULTS

Consolidated results from the 42-inch and 36-inch test spool are shown below in Table 1. All of the flaws that were targeted for scanning were detected and depth-sized to within a maximum error in measured defect depth of 0.056-inches. The average error in defect depth estimation was 0.029-inches.

It is important to note, especially as it pertains to flaw depth sizing, that data acquisition was completed at lift-off distances between the sensor face and ID surface of the pipe of 0.625-inches and 0.600-inches for the 42-inch diameter and 36-inch diameter pipes, respectively. Furthermore, each flaw was auto-scanned only once in a high-speed scan mode. Typical R-ILI protocol consists of a high-speed detection scan after which the detected indications are investigated with a low-speed, high-resolution scan for each indication in the data in order to facilitate classification and sizing.

				Remaining Wall Thickness		
Flaw Identifier	Flaw Type	Lift Off	Detected	Measured	Actual	Error
42"-ID-1	Concavity	0.625"	Yes	0.375"	0.360"	-0.015"
42"-OD-1	Concavity	0.625"	Yes	TBD	0.133"	TBD
36"-ID-1	Flat-Bottom Hole	0.600"	Yes	0.156"	0.100"	-0.056"
36"-ID-2	Flat-Bottom Hole	0.600"	Yes	0.187"	0.180"	-0.007"
36"-ID-3	Flat-Bottom Hole	0.600"	Yes	0.126"	0.165"	0.039"

Table 1 Consolidated detection and depth sizing results.

The results of the industry's first PEC R-ILI indicate that the SIPEC sensor is capable of flaw detection and depth estimation at high scan speeds and appreciable sensor lift off. A unity plot displaying our measurement of ID defect depth is shown in Figure 5. The novel SIPEC™ sensor design and data acquisition and processing algorithms represent an evolution from static, point-by-point data acquisition schemes employed by traditional PEC technology to rapid, dynamic data acquisition. These evolutionary developments have enabled the SIPEC™ sensor to meet the requirements for R-ILI deployment.

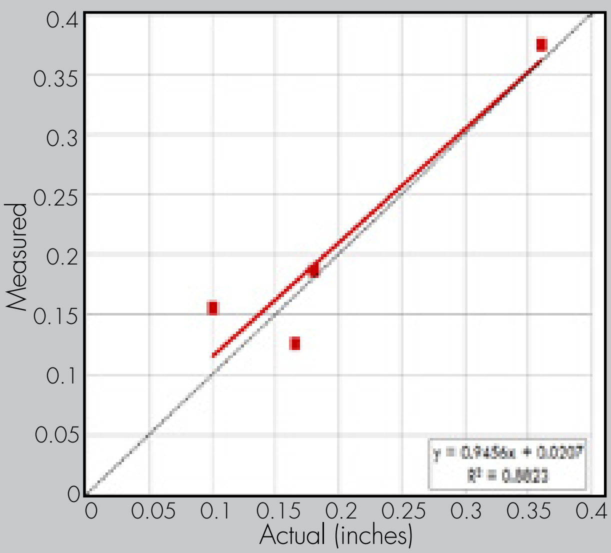

Figure 5 Unity plot for depth measurements of the ID defects listed in Table 1.

DETECTION AND SIZING OF RADIAL-AXIAL CRACKS ON TANGENTIAL-ENTRY DISK STEEPLES USING PHASED ARRAY

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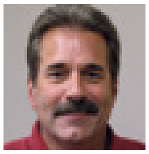

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INTRODUCTION

Turbine disk steeples on low-pressure turbines are among the highest stressed components of a generator train. Due in part to centrifugal loading stresses, potentially catastrophic cracking may initiate at the disk steeple and propagate in a Radial-Circumferential (RC) or Radial-Axial (RA) plane. Structural Integrity Associates currently offers inspection of turbine disk steeples, with blades installed on the disk, for detection and sizing of Radial – Circumferential Cracking. SI has recently completed a performance demonstration at EPRI for inspection of turbine disk steeples for radial-axial cracking without the need for blade removal.

Because of its occurrence rate and the potential for failure if left undetected, RC cracking today is well-studied and well understood. The mechanism driving RC crack initiation is stress corrosion cracking, and propagation is from radial stresses caused by centrifugal loading. Cracks are often branched and intergrannular and always oriented transverse, or near transverse, to the long axis of the rotor. NDE techniques developed years ago, typically involving phased array ultrasonics and automated scanners, are still widely used today to reliably detect and size these flaws, and NDE results feed directly into a fracture mechanics analysis to effectively mitigate and manage this risk.

Radial-Axial cracking on the other hand is also not new, but unlike its counterpart, little is known about this failure mechanism. Perhaps a result of lower stresses in the axial plane and/or a lower occurrence rate, RA cracking has largely been ignored, until relatively recently, even though numerous RA cracks have been documented over the years, primarily occurring on L-2 and L-3 stages of tangential-entry turbine disks.

Ironically, a failure from an undetected RA crack can be just as catastrophic as one caused by a radial-circumferential crack. Add to this today's ever aging fleet, with some units running well beyond their design service life, and plant managers and engineers, support organizations like EPRI (the Electric Power Research Institute) have recently taken an interest in RA cracking.

RADIAL-AXIAL CRACK MORPHOLOGY

What is known about radial-axial cracking is that it likely originates at regions of surface pitting, and crack morphology suggests that propagation is fatigue driven, i.e., cracks are typically not branched and in some cases are quite planar. What is currently not known about RA cracking is the initiation site, i.e., is it the disk-rim or the underside of the top hook? Given the understanding that the top hook is more highly stressed, and barring any blade fit-up issues, the underside of the top hook should be the likely candidate site for initiation, but not enough disks have been studied to make this a forgone conclusion.

What is also not known is how small an RA crack (if any) can be tolerated. To date, little is known about RA crack growth rates, so determining a critical flaw size is difficult and would likely be different from disk to disk as numerous factors, including disk type,

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THE DETECTION AND SIZING OF RADIAL-AXIAL CRACKS ON TANGENTIAL-ENTRY DISK STEEPLES USING PHASED ARRAY CONTINUED

flaw location/orientation, plant operating conditions, number of starts/stops, etc., would all have to be considered. But regardless of flaw size, RA cracks are not self-arresting, so the only effective way to mitigate propagation is by defect removal. And to minimize the extent of repair and have the greatest disposition flexibility possible, early detection is necessary, yet no reliable nondestructive technique existed short of removing blades for visual or magnetic particle inspections.

Once initiated, cracks tend to propagate through the rim, and left undetected, work their way into the shank and to the lower hooks. Some crack depths of one, to one and a half inches from the rim have been measured.

Radial-Axial Crack on a Disk Rim
Note the crack morphology, i.e. un-branched and planar, and skewed in the shank

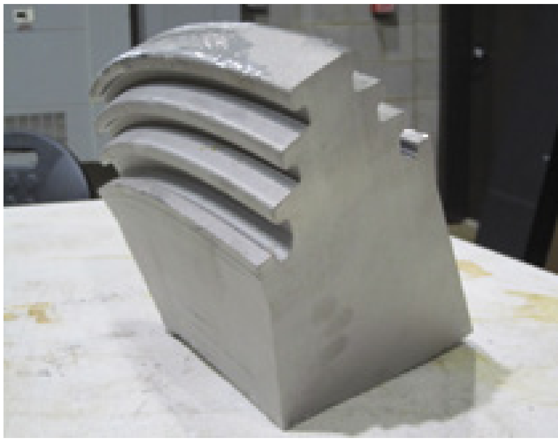
PHASED ARRAY TECHNIQUE DEVELOPMENT & BLIND TRIAL

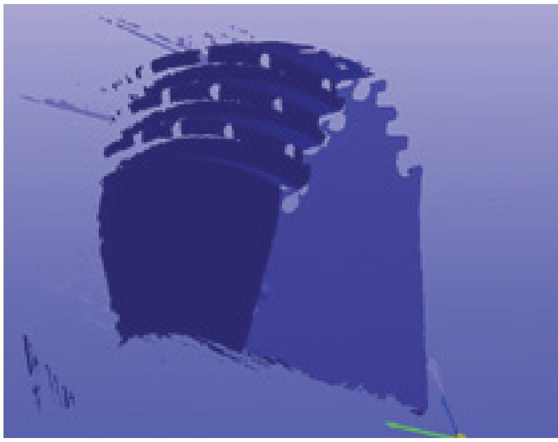
Although cracking begins in the radial-axial plane, RA cracks tend not to remain truly axial. Once they propagate into the shank, they typically grow at a skewed angle of approximately 45° through the shank. Current radial-circumferential inspection techniques should detect the skewed portion of the flaws once larger, more developed cracks reach this point. But an early stage crack (where the crack is confined to the top hook or outer rim) is still missed because the long axis of the flaw is parallel to the UT beam.

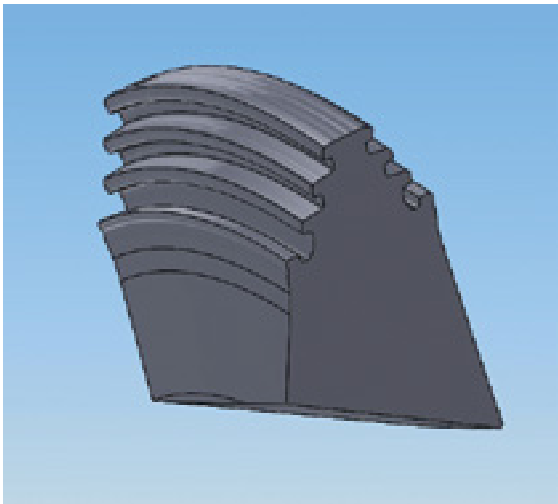
In anticipation of client needs, and with a renewed interest in early detection of radial-axial cracking, Structural Integrity began work on the development of a Linear Phased Array (LPA) ultrasonic technique in mid-2013, with the goal of reliably detecting and sizing early stage RA cracking without requiring dissassembly or blade removal.

Development efforts were supported by advanced technologies including a laser profilometry scanner and CIVA UT modelling software. Zetec's Zircon® phased array data acquisition system was selected for data collection for its superior signal quality and high data throughput; and analysis would be performed off-line using UltraVision 3 software.

We obtained sectioned GE disk steeple and created a 3D model of the specimen using the laser profilometry scanner. We machined a simulated notch-opening into the top hook of the specimen and several axially-aligned EDM notches embedded in the upper and middle hooks to simulate radial-axial flaws. A probe positioner with wheel encoder was designed and fabricated for purposes of collecting data during the development phase. This provided encoded data for offline analysis. Subsequent field deployment of this technique will use our existing steeple inspection scanners.







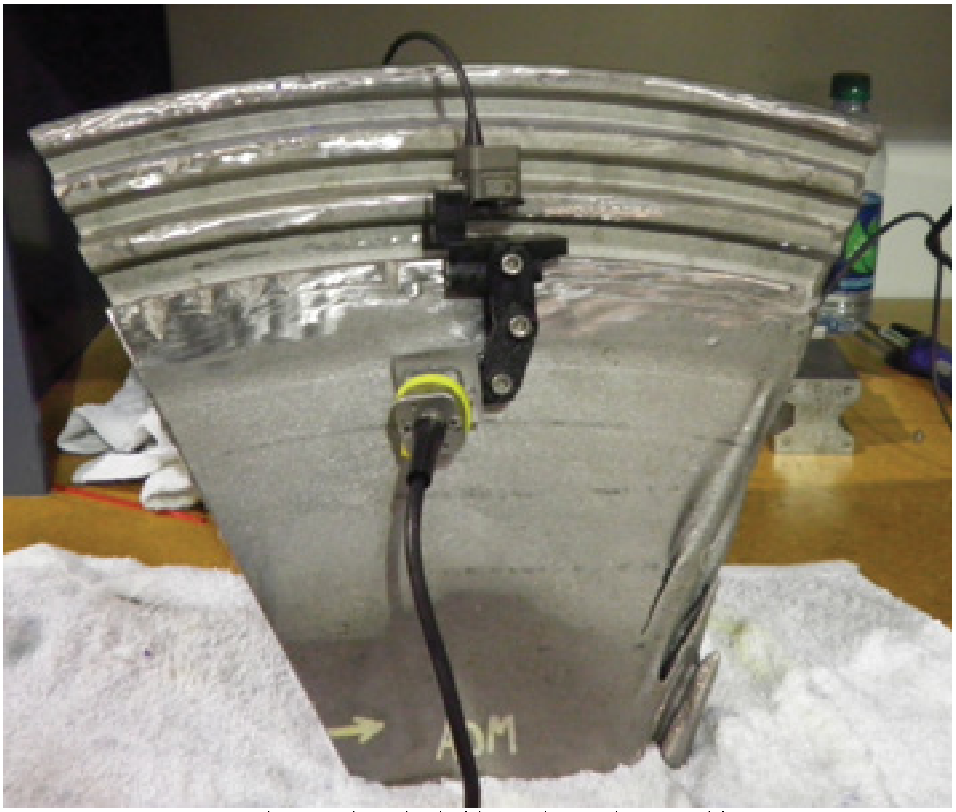
Model Generation
Sample disk piece modeled using laser profilometry scanner to create 3D model of the complex geometry

Laser profilometer

The 3D model we created from the laser scanner was imported into CIVA simulation software and simulations were run to assist in selecting appropriate probe frequencies, probe placement, and wedge angle(s). The UT ray tracing capabilities within CIVA also helped predict flaw sensitivity and defect response expectations.

Various arrangements of viable search-units, software parameters, and probe positions were then demonstrated on the specimen to determine the best combination. This process was repeated until optimum results were achieved. And finally, full-length scan data was collected from both sides of the specimen and analyzed.

Our resultant LPA technique utilizes a high frequency, 32 element phased array probe and compound wedge combination. A nominal wedge incident angle was selected to produce refracted shear waves over the desired range within the disk, and a secondary, squint angle, was calculated to direct the sound beam in a near-perpendicular axis to maximize sound energy in the radial-circumferential plane. The ultrasonic beam is steered from 50°-80° in half-degree increments.



Search-unit with probe holder and encoder assembly

Following development and initial trials on the in-house specimen, we partnered with EPRI to test the technique's capabilities through a blind trial exercise. EPRI secured an out-of-service LP disk of a design susceptible to RA cracking and induced flaws in the radial-axial direction on the disk-rim over an area of approximately thirty inches. During the blind trial, we to scan a length of approximately 45 inches, this included the entire 30 inch 'blind' area, as well as the nearby notch opening, which could be used for sensitivity verification and positional reference.

Data was collected on the inlet and exhaust faces of the EPRI disk, in both the clockwise and counter-clockwise directions to ensure full volumetric interrogation of the rim, and to maximize flaw detection potential regardless of orientation.

The blind trial was performed in late January 2014, and a detailed report submitted to EPRI in May. We detected and sized numerous indications thought to be the result of induced or existing radial-axial flaws. Flaw depths ranged from just a few ten-thousandths of an inch to greater than one-eighth inch.

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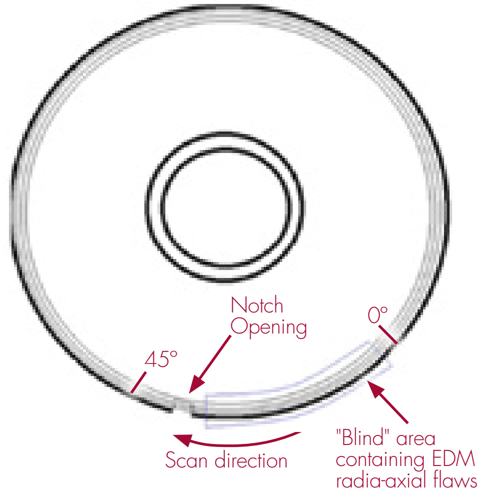
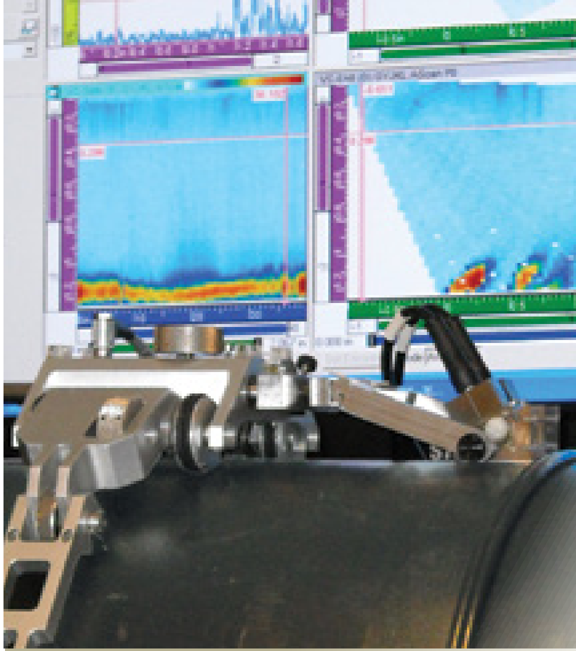


EPRI Disk used for Blind Trial Exercise

DETECTION AND SIZING OF RADIAL-AXIAL CRACKS… CONTINUED



Although a full review and analysis of the results is still ongoing as of the date of this writing, preliminary verbal feedback from EPRI staff to date has been positive.

For field inspections, the RA search-unit was modified to fit into our existing automated disk-rim scanners to ensure reliable, repeatable and effective field examinations. As with our RC crack inspection technique, inspection for RA cracking will be done with the blades installed on the disk.

On a side note, one interesting discovery was that with careful hardware selection and parameter setups, a single ultrasonic technique is possible for the detection and sizing of both, RA and RC flaws within a disk steeple. Current radial-circumferential inspection techniques require only two circumferential scans per disk, one on either side, to obtain full coverage; while RA flaw detection will require two scans per side, one facing clockwise and one counter clockwise. So although additional scans will be required, a single-technique approach would still save valuable time and money for clients. However, this dual technique still needs to be thoroughly evaluated and validated to ensure that it provides accurate detection, characterization and sizing for all flaw orientations.

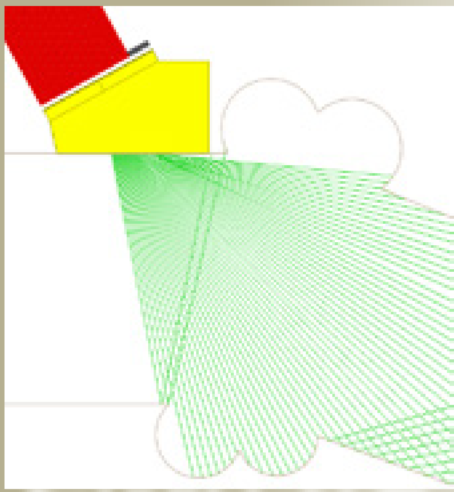


Figure 1. Model developed in the CIVA software package demonstrating full volumetric coverage of a miter joint configuration.

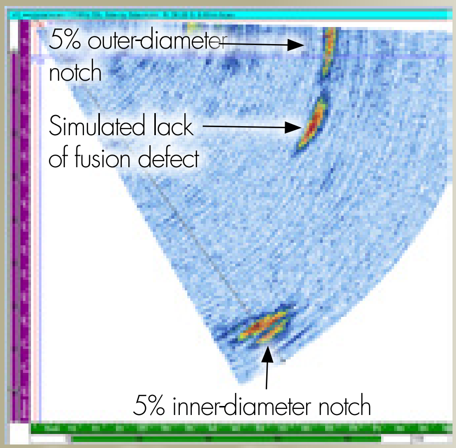


Figure 2. Image of the inspection method successfully detecting a 5% (0.12") inner-diameter defect, simulated lack of fusion defect, and a 5% outer-diameter notch implanted in a 2.5" thick HDPE miter joint sample.

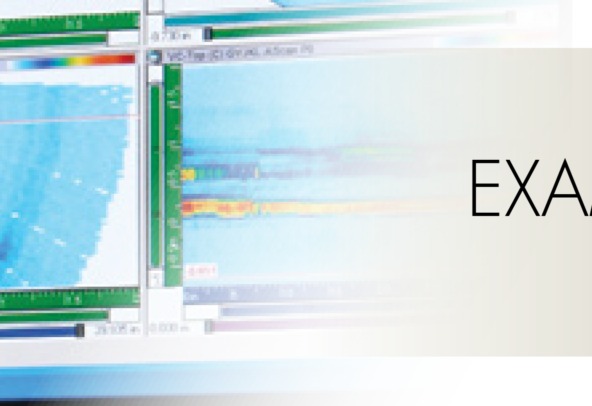
MOVING FORWARD

Once results from the blind trial are thoroughly evaluated by EPRI staff, adjustments, if any, to either the technique and/or analysis approach can be made, in cooperation with EPRI staff, to continue the pursuit of developing the best possible nondestructive test for early-stage RA cracking.

Aside from continued technical improvements, other possible steps to better understand RA cracking have been suggested:

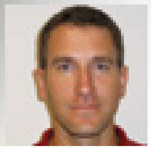
- Conducting an industry survey to identify and characterize occurrences of RA cracking
- Obtaining samples of RA cracking for forensic examination
- Performing stress and life assessment calculations to assist in the establishment of inspection criteria and dispositioning of defects

Disclosure: Although the current LPA technique is promising, and is expected to perform well on a majority of affected disks, geometric constraints on some disk types may not be suitable for this technique in its current form. Some disk width-to-steeple height ratios and blade-shank lengths (i.e., tall, thin steeples) may inhibit the introduction of ultrasound at the area of interest (the disk-rim). Much of this could be mitigated however by having access to drawings in advance. Then disk geometry and steeple dimensions could be better understood, and inspection personnel could assess coverage and sensitivity before ever mobilizing for an examination. Modifications, if necessary, could also be modelled and demonstrated in a shop environment to ensure the best possible outcome once in the field.



ULTRASONIC PHASED ARRAY EXAMINATION OF HIGH DENSITY POLYETHYLENE (HDPE)

Butt-Fusion Joints



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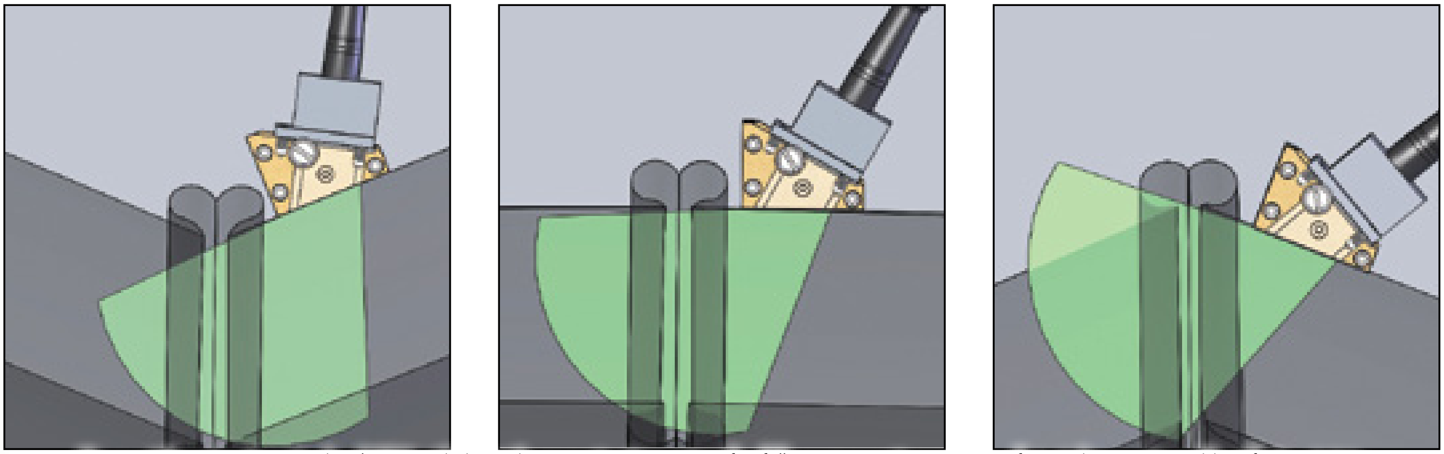
High-density polyethylene (HDPE) has become a common piping material for many industries, including gas distribution, sewer and wastewater, oil and gas production, industrial, chemical and mining. The broad use of HDPE is due to its advantages over traditional metal piping as it does not rust, rot, corrode, or support biological growth. It also provides a lower material cost, is easier to transport and handle, and is relatively easy to join, as compared to metallic pipe systems.

The nuclear power industry has selectively used HDPE piping for non-safety and safety-related applications, and there is significant ongoing ASME Code activity regarding the construction, design, fabrication, utilization, and examination of high-density polyethylene. Specifically the industry is developing ASME Boiler and Pressure Vessel Code rules for HDPE application in Class 3 buried piping systems. In addition, ASME has begun developing a new standard for capturing all the B31 Code for Pressure Piping rules for Thermoplastic Piping. Structural Integrity has been very active in both processes.

Structural Integrity has been developing and implementing ultrasonic phased array examination techniques for HDPE butt-fusion joints for over five years. Our NDE development has led to US Patent Number 8,438,928, "Apparatus and Method for Non-Destructive Testing Using Ultrasonic Phased Array." This patented wedge design and technique allows for full volumetric inspection of HDPE butt-fusion welds in both straight and mitered joint configurations. Figure 1 is a model of the inspection method developed in the CIVA software package applied to a mitered joint configuration. The green lines are ray traces of the refracted ultrasonic waves, thus demonstrating the full volumetric inspection capability of the patented wedge design and inspection technique. Figure 2 shows an image of the technique detecting a 5% inner-diameter notch (0.12"), a 5% outer-diameter notch, and a lack of fusion defect which were implanted in a 2.5" thick test sample of HDPE. Furthermore, these methods have been developed in order to compensate for temperature variations and gradients, and are highly sensitive to volumetric and planar flaws.

SI's use of advanced ultrasonic phased array acquisition and encoding equipment allow for fully automated, or semi-automated, inspection techniques that provide a 100% digital record of examination for off-line analysis, independent review, and historical comparison. These volumetric inspection techniques are field-proven and have been successfully employed during examination jobs for nuclear power utilities, EPRI, and the U.S. Army.



Transmit-Receive Longitudinal (TRL) side-by-side examination setup for full coverage inspection of straight or mitered butt-fusion joints

ASME RECOGNITION OF STRUCTURAL INTEGRITY'S SUPPORT AND CONTRIBUTING PAPERS

Structural Integrity was recently presented with the ASME Corporate Appreciation Award by J. Robert Sims, Jr., the President of American Society of Mechanical Engineers (ASME), at the annual ASME Pressure Vessels and Piping Conference on July. This is only the third Corporate Appreciation Award given in the ASME's 48 year history. The ASME selected Structural Integrity due to our significant leadership in the ASME and industry since our founding in 1983.

We have a significant amount of participation in the PVP Conference and contribute in many ways including:

- Authored or co-authored over 55 papers in the last five years
- Supported over 50 attendees to the Conference in the last five years, including 16 this year
- Worked in developing multiple sessions in the areas of high pressure technology, materials and fabrication, Design Analysis, and Codes and Standards
- Participated in both the Software and NDE forums many times, including this year
- Two Technical Committee Chairs and supporter of the current PVP2014 Conference Chair
- Authored or Co-Authored three tutorials in the PVP Tutorial Series over the years.
- Multiple year sponsor of this Division including a Silver Sponsor for the last three years
- Laney Bisbee, the company CEO, was a plenary speaker at PVP 2011

Structural Integrity currently supports approximately 20 employees as active participants in ASME activities including Codes and Standards, in addition to PVP. We are currently involved with approximately 40 ASME Codes and Standards Committees. Several are members of ASME Standards Committees, Committee Chairmen, and they have one member on the Board of Pressure Technology Codes and Standards.

Our long standing support is valuable to ASME and PVP achieving its long term mission and goals.

PAPER BY STRUCTURAL INTEGRITY AUTHORS SETS HIGH STANDARD AT ASME CONFERENCE

Several Structural Integrity employees also were recognized by the ASME. A paper exploring the use of linear elastic fracture mechanics (LEFM) for BWR core plate bolt life evaluation written by a trio of Structural Integrity engineers was noted as being a standout from the 2013 ASME Pressure Vessels & Piping (PVP) Conference.

In June 2014, ASME's PVP Division selected "Comparison of Handbook and 3-D Finite Element Analysis LEFM Solutions for a Threaded Fastener" as Outstanding Technical Paper for the 2013 PVP Conference. The paper was co-authored by Daniel Sommerville, Minghao Qin, and Matthew Walter.

The paper explores the current state of LEFM technology for performing accurate flaw tolerance evaluations of bolted joints. The authors summarize and compare results of a plant-specific 3-D finite element analysis (FEA) versus readily available handbook-style LEFM solutions.

Findings presented in the paper will be particularly useful to BWR owners assessing the integrity of bolted components within the reactor pressure vessel as part of license renewal activities.

The authors received a Certificate of Appreciation at the Computer Technology & Bolted Joints Technical Committee meeting at the 2014 PVP Conference in Anaheim, California.

This honor speaks to the quality of technical knowledge, technical writing and industry involvement among the Structural Integrity team. Congratulations to Daniel, Ming and Matt for their outstanding work!

RECENT CHANGES TO ASME CODE CASE N-513

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ASME recently approved revision 4 of Code Case N-513, Evaluation Criteria for Temporary Acceptance of Flaws in Moderate Energy Class 2 or 3 Piping (N-513-4), with publication scheduled later this year. The changes in Code Case N-513-4 address the current condition on acceptance by the NRC, including clarification of the applicability limits and expansion of Code Case scope to additional piping components. New flaw evaluation procedures are given for through-wall flaws in elbows, bent pipe, reducers, expanders and branch tees.

Code Case N-513-3 (current NRC accepted revision) provides evaluation rules and criteria for the temporary acceptance of flaws, including through-wall flaws, in moderate energy piping. The provisions of this Code Case are focused on preventing gross failure of the affected pipe for a temporary period. However, it also requires the piping system and adjacent equipment functionality be demonstrated for lost fluid inventory, spraying and flooding caused by the leakage. The Code Case provides rules for the evaluation of degraded pipe and tube for a temporary operating period, with inspection and monitoring requirements of the degraded condition as part of the overall integrity assessment. The application of the Code Case is restricted to moderate energy Class 2 and Class 3 systems, so that the safety issues regarding short-term system operation are minimized. Moderate energy piping is defined as those piping systems where the maximum operating pressure and temperature do not exceed 275 psig and 200°F, respectively.

THE CHANGES IN CODE CASE N-513-4 ARE GIVEN BELOW, ALONG WITH A BRIEF REASON FOR EACH CHANGE:

- Temporary acceptance period redefined (addresses NRC condition given in the current Regulatory Guide 1.147)
- Flaw evaluation criteria included for elbows, bent pipe, reducers, expanders and branch tees (scope expansion)
- Allow flaw evaluation of heat exchanger tubing if the flaw can be characterized and leakage monitored (scope expansion)
- Daily walkdown requirement for through-wall leaks provides additional flexibility for user implementation (scope expansion)
- Limit scope to only liquid systems (scope clarification)
- Treatment of Service Level load combinations (scope clarification)
- Treatment of flaws in austenitic pipe flux welds (scope clarification)
- Minimum wall thickness acceptance criteria to consider longitudinal stresses in addition to hoop stress (scope clarification)

A 2014 ASME Pressure Vessel and Piping (PVP) paper, *PVPV2014-28355 Technical Basis for Proposed Fourth Revision to ASME Code Case N-513,* contains a more detailed discussion of each of these changes.

Featured Damage Mechanism: Overheating in Waterwall Tubes

By: WENDY WEISS

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Short-term overheating occurs in water wall tubes because of lowered coolant flow, excessive combustion gas temperature, or a combination of both. Once the cooling flow is interrupted, failures can occur within a matter of minutes.

Damage by short-term overheating will display distinctive characteristics depending upon the temperatures experienced by the tube. The most often observed features for short term overheating include swelling and a thin edged "fish mouth" appearance (Figures 1 and 2). These features occur both in subcritical and intercritical failures. Subcritical failure occurs with temperatures that are above design but below the lower critical temperature, exhibit a microstructure of ferrite and pearlite, and hardness values consistent with original material (Figure 3). The intercritical failure also has swelling, occurs between the lower and upper critical temperatures; it has transformational microstructural products consistent with the temperature at the time of failure resulting in higher hardness values at the failure site (Figure 4).

Failures can occur anywhere in the water walls, but are usually located in the high heat flux areas near or above the burners and the bottom of the nose arch, even if there is flow disruption lower in the furnace. There are three primary causes of short-term overheating in waterwall tubes 1) partial blockage due to maintenance activities, 2) feed water corrosion product deposition on orifices, and 3) improper drum level control.

Figure 1. Waterwall tube showing swelling, and a thin-lipped, fish-mouth rupture.

Figure 2. Cross-section through rupture.

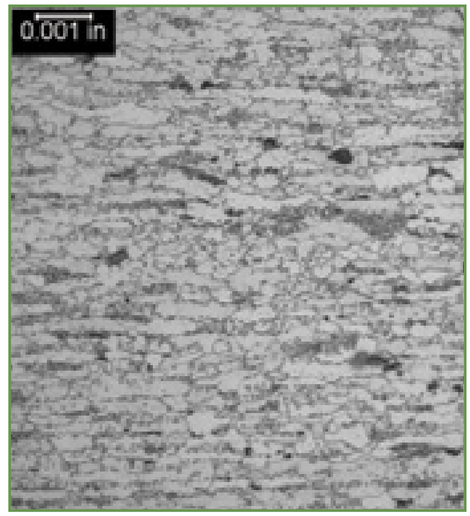


Figure 3. Microstructure showing exposure to subcritical temperatures, consisting of spheroidized pearlite in a ferrite matrix with grain boundary voids scattered throughout.

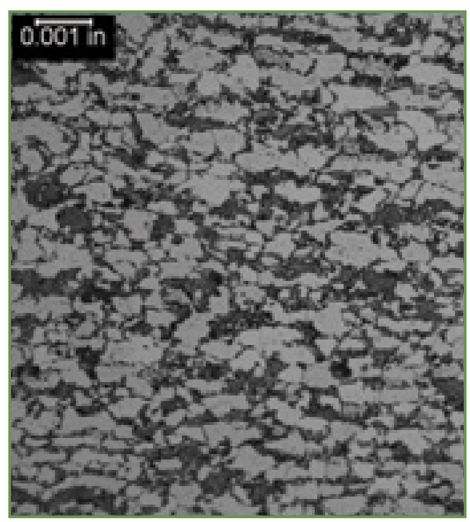
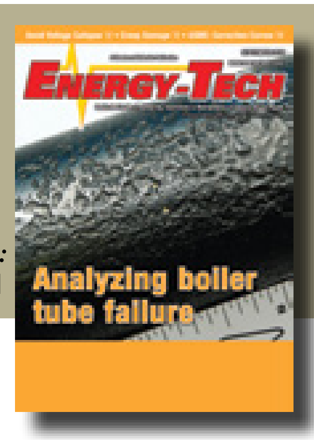


Figure 4. Microstructure showing exposure to intercritical temperatures, consisting of transformed pearlite in a ferrite matrix with a few grain boundary voids scattered throughout.

Check out our article in the September issue of *Energy Tech:*
http://issuu.com/energy-techmag/docs/1409_et_digital/1



Polythonic SCC

Structural Integrity Associates, Inc. (SI) was asked to examine a section of a burner gas ring from a boiler located at a chemical plant (Figure 1) and determine the cause of the corrosion and cracking. The approximately 10-year old burner ring was manufactured with Type 304 austenitic stainless steel. Reportedly, the corroded side of the burner ring was exposed to flue gas and the other side was exposed to methane gas. The outlet flue gas temperature was reported to be between 250 and 300°F.

Figure 1. The OD surface of the burner ring sample showing corrosion and cracking.

Cross-sectional samples were cut through the cracking, mounted and prepared for evaluation of the damage morphology. The damage consisted of intergranular attack and oxidation, intergranular (around grain) cracking and grain "fall out". (Figures 2 and 3). In addition to the intergranular cracking, a few areas with transgranular (through grain) cracking were also observed (Figure 4).

We removed another cross-section from the burner ring and prepared for examination in a scanning electron microscope (SEM) so that the crack deposits could be analyzed using energy dispersive X-ray spectroscopy (EDS) to identify the elements present. Various cracks in the sample were analyzed and the deposits in all areas were similar. All of the areas analyzed contained iron, chromium, nickel and silicon from the base metal as well as significant amounts of oxygen, indicating oxides were present, and a moderate amount of sulfur (Figure 5). Additionally, chlorine was present in a few areas, but it was not widespread.

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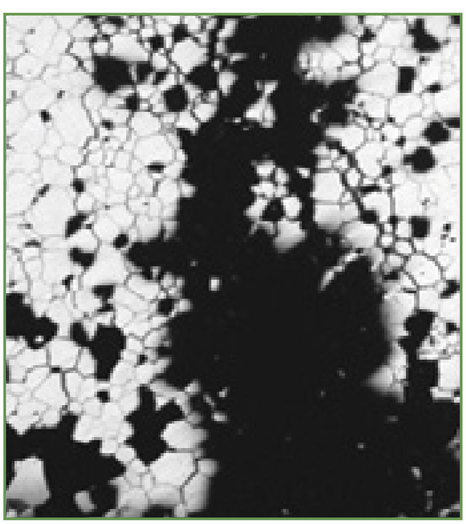

Figure 2. Image from a through-wall crack showing intergranular attack and grain fallout. (original magnification: 100X)

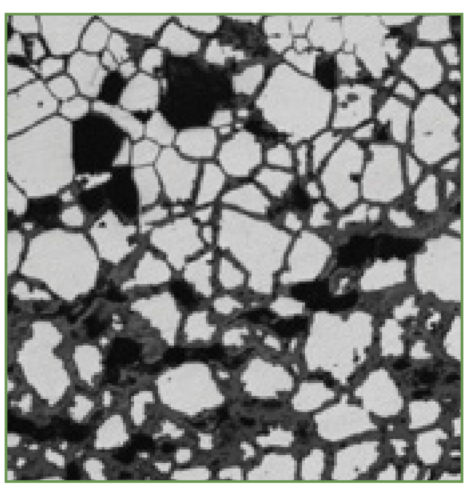

Figure 3. Images showing the intergranular attack and oxide-lined grain boundaries, as well as areas of grain fallout. (original magnification: 200X and 400X)

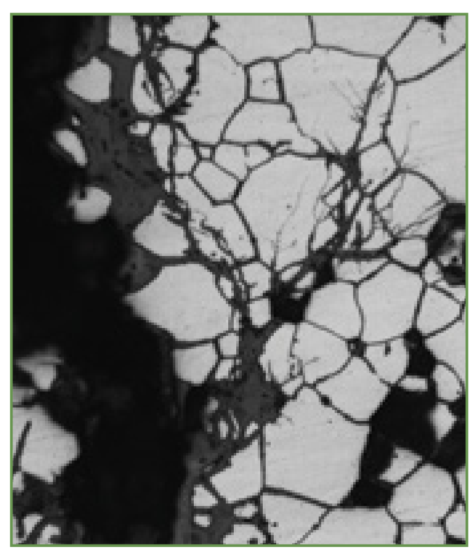

Figure 4. Area of transgranular cracking. (original magnification: 400X)

Metallurgical Lab Corner

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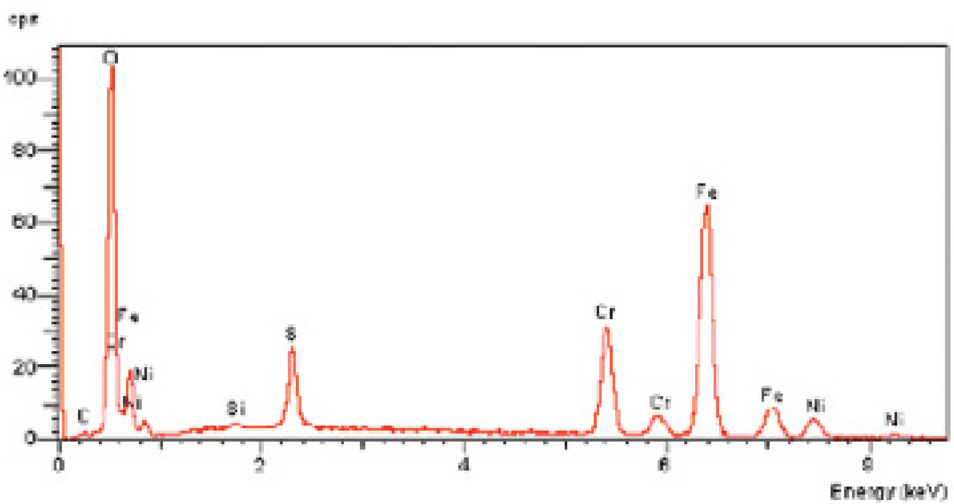

Figure 5. EDS spectrum is typical of the crack deposits that were analyzed, with more oxygen than sulfur.

The intergranular attack, intergranular cracking and grain fall out are all characteristics of stress corrosion cracking due to polythionic acid in sensitized austenitic stainless steels. This type of stress corrosion cracking occurs when sulfur-containing deposits mix with oxygen and moisture to form polythionic acids of the type H2SxOy. In this case, sulfur in the deposits from the flue gas was plentiful. Polythionic acid SCC requires the presence of moisture, and therefore occurs during downtime or at dew point temperatures when moisture can form during operation.

Sensitization, which is the condition when chromium carbides form on the grain boundaries resulting in a chromium-depleted region immediately adjacent to the grain boundaries, of Type 304 stainless steel normally occurs at temperatures between 750 and 1500°F (400 - 815°C). The transgranular cracking, which is indicative of chloride-induced SCC, which was observed in the sample, was less abundant than the intergranular cracking and in some cases the transgranular cracking was emanating from the intergranular corrosion, suggesting the polythionic acid attack had occurred first. Though it is not possible to determine if the chloride SCC was secondary to the polythionic acid attack, it is clear that the polythionic acid attack is the major damage mechanism.

Because the burner gas ring reportedly operates at temperatures in the 250 to 300°F range, the component was not sensitized during normal operation unless the metal temperature is substantially higher than the gas temperature. Because the damage in the burner ring section was not localized to the weld, the sensitization cannot be attributed to welding. It is possible that the material was heat-treated improperly and has been in the sensitized condition since construction. Another, more likely possibility is that the sensitization occurred during operation, perhaps during upset conditions when the burner gas ring metal condition could have been above 750°F.

Ensuring that the Type 304 stainless steel burner gas ring is not exposed to temperatures that can cause sensitization will help mitigate the polythionic acid attack, as it only occurs in sensitized material. Chloride-induced SCC can occur in Type 304 stainless steel whether it is sensitized or not. Keeping the burner gas ring dry and as free from deposits as possible will help prevent both the polythionic acid and chloride SCC from recurring.

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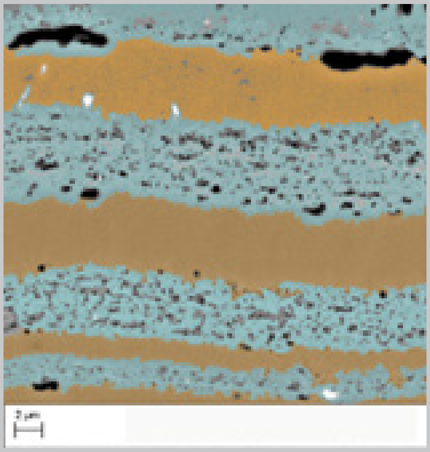
WHAT AM I?

- I can take the heat; it only makes me grow.
- I can cause damage to my neighbor.
- Parts of me can break when I get too large.

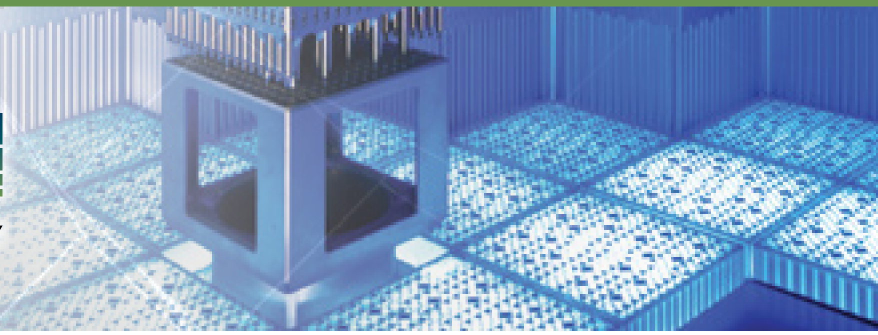


Answer: T23 Secondary Superheater tube oxide at 7300X – EDS map of inner region consisting of alternating chromium-rich (blue) and iron-rich (orange) layers

FALCON – A VERSATILE TOOL FOR FUEL ROD BEHAVIORAL ANALYSIS

ANATECH CORP.

A Structural Integrity Associates, Inc.® COMPANY



Falcon is a fully-coupled, thermo-mechanical computer code designed to provide best-estimate light water reactor (LWR) fuel rod performance analyses. ANATECH originally developed the Falcon code under EPRI sponsorship and continues to improve the code by expanding the code's applicability through enhancements and additions to the code's numerous material property and behavioral models.

Unlike traditional fuel performance codes, Falcon is based on a two-dimensional finite element (FEM) computational framework that provides for a fully coupled thermo-mechanical solution capable of both steady state and transient analyses. This allows for computation of fuel and cladding deformation, up to and including extreme conditions such as cladding ballooning, to be computed as integral aspects of the thermo-mechanical FEM solution. Other key features include:

- A unique and effective implementation of fuel pellet smeared cracking and pellet/cladding contact logic,
- An integrated coolant channel model with full representation of the boiling regimes as well as an option for sodium coolant,
- An R-Θ plane, two-dimensional geometric modeling capability that permits detailed simulation of pellet-cladding interfacial forces including the effects of discrete pellet cracks, fuel pellet surface defects, cladding mechanical defects, etc.
- Three cladding failure models implemented to address:
  1. Pellet cladding interaction (PCI) related to the intergranular stress corrosion cracking (ISCC) failure mechanism under power ramp conditions,
  2. Cladding failure by ballooning and rupture under high temperature conditions associated with a loss-of coolant accident (LOCA), and
  3. Mechanical fracture and cladding failure resulting from pellet cladding mechanical interaction (PCMI) during rapid power ramps or power pulses associated with reactivity initiated accidents (RIA).

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As an integral part of our development program, we routinely use a large verification and validation (V&V) database (currently at ~200 distinct cases) consisting of commercial, test, and instrumented fuel rods out to rod average burnups of ~70 GWd/tU to evaluate the code. This database also includes analytical and separate effects simulations designed to verify specific behavioral submodels. Results from evaluations by the developers, user community, and from the V&V program are used to demonstrate and verify the broad range of Falcon analytical capability and to provide guidance for future code development work.

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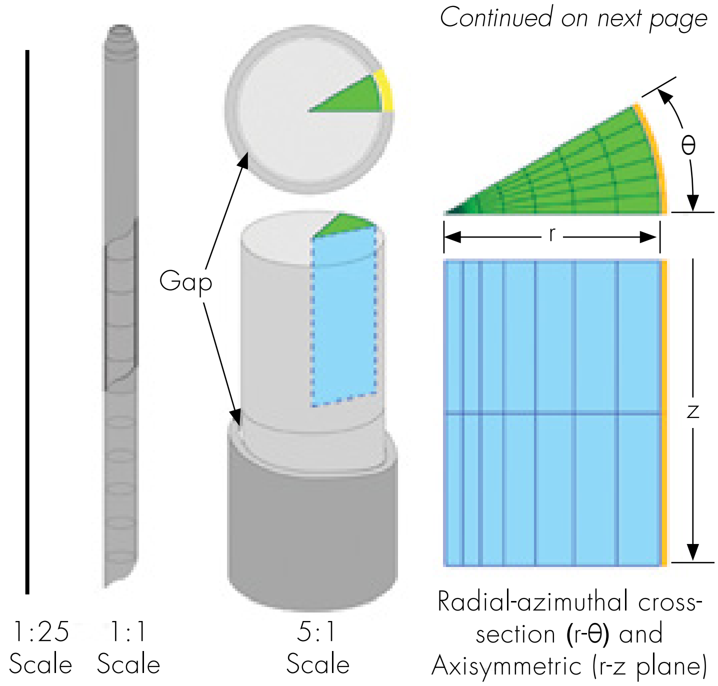
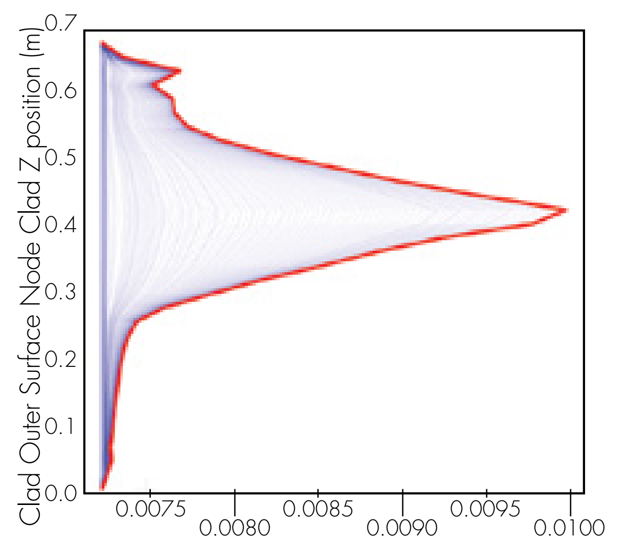


Fundamental geometric modeling approach applied in Falcon[2]

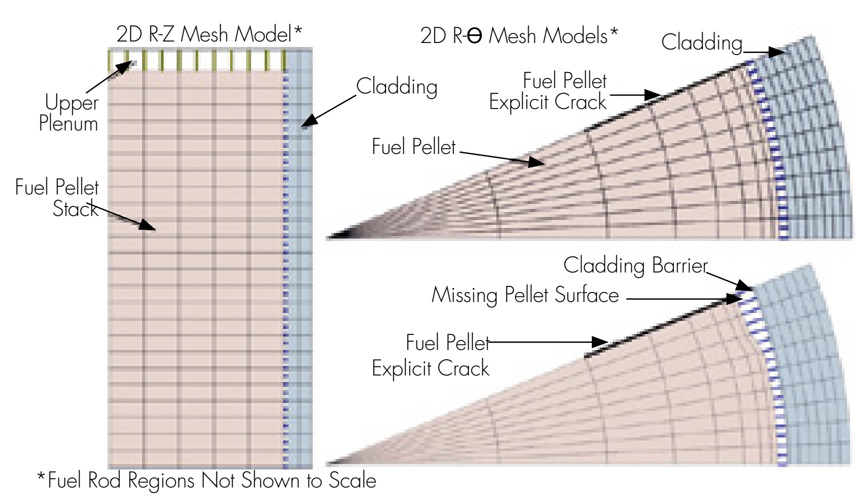
APPLICATIONS

Developers and users around the world have applied Falcon extensively in the last 10 years for numerous commercial and test fuel rod analyses, as well as supporting computations for spent fuel rod assessments. In many of these cases, Falcon has provided an enabling and unique capability to address a specific modeling requirement. Examples of Falcon applications are listed below.



LOCA analysis showing cladding ballooning computed by Falcon

- Fuel rod research and development program evaluations
  - Numerous Halden Instrumented Fuel Assembly (IFA) experiment analyses. Recent examples include:
    - IFA-650 – LOCA analyses
    - IFA-742 – utilizing Falcon's unique post primary defect analysis capability
  - Analysis of Studsvik Cladding Integrity Project (SCIP) test rod experiments
  - Evaluation of proposed accident tolerant fuel rod designs
    - SiC and TZM molybdenum composite cladding materials
    - Doped-pellet cladding hour-glassing and ridging evaluations
- Regulatory support focusing on postulated accident analysis (RIA and LOCA)
  - Analytical support to the EPRI Fuel Reliability Program Fuel Safety Licensing Working Group
  - Development of the technical bases for the fuel acceptance criteria for RIAs
  - Analysis and design support for the NRC-ANL LOCA test program
  - Assessment of experimental data for evaluation of the impact of burnup on the cladding embrittlement criteria (10 CFR 50.46) for LOCA events
  - Support for the topical report for NRC submittal for Safety and Licensing for Burnup Extension
- PCI risk reduction
  - Analytical support for the development of EPRI's Fuel Reliability Guidelines: PCI[1] (PCI-GL) to provide utility operating guidance for the reduction of fuel rod failures due to PCI across the entire US PWR and BWR nuclear fleet
  - Fuel rod analyses for multiple commercial utilities
    - plant and cycle specific PCI failure margin evaluations
- Post fuel rod failure forensic analysis
  - Falcon has been applied for numerous post failure fuel rod analyses to determine root cause and develop mitigating strategies to limit or eliminate fuel rod failures
    - Example: evaluation of Braidwood and Byron mid-cycle fuel rod failures determined by post irradiation examination (PIE) to be due to Missing Pellet Surface (MPS) manufacturing defects
- Spent fuel analysis
  - Analysis support for characterization of failure mechanisms, associated failure criteria, and response analysis of spent fuel systems subjected to normal and hypothetical transport accident conditions (10 CFR 71)
  - Support for the development of technical bases for high burnup spent fuel rod dry storage acceptance criteria
- Support for development of next generation 2D and 3D nuclear fuel behavior codes
  - Model development, benchmarking, and evaluation supporting Department of Energy (DOE) research programs
    - Consortium for Advanced Simulation of Light Water Reactors (CASL)
    - Nuclear Energy Advanced Modeling and Simulation (NEAMS) development program

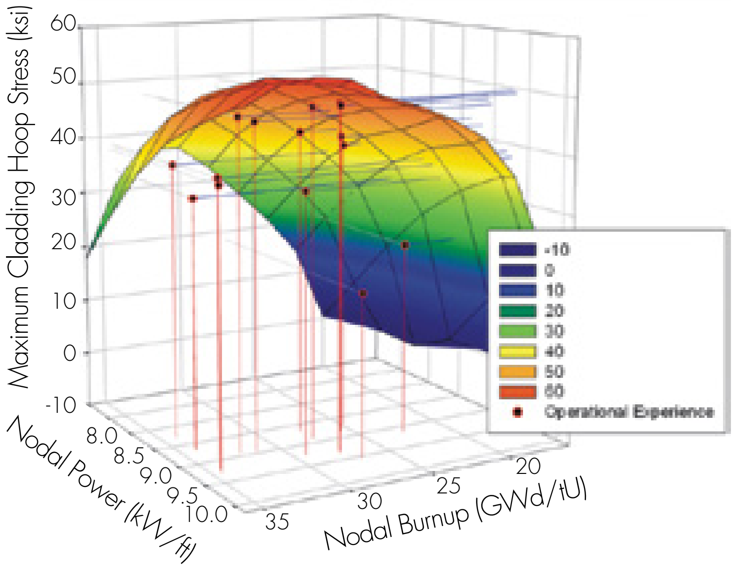


Typical Falcon Fuel Rod Models

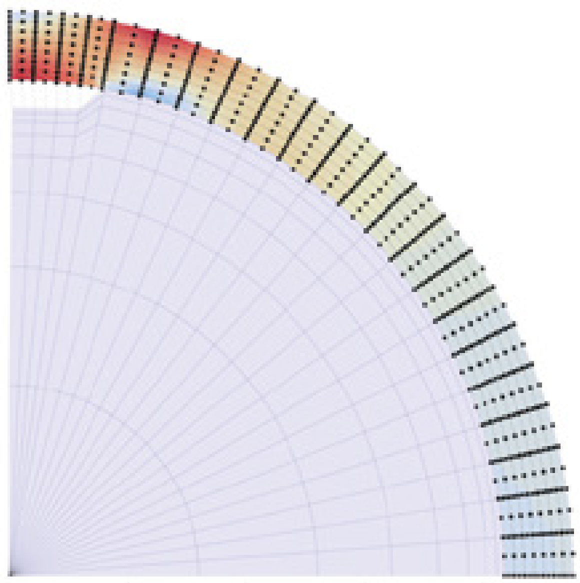
UNIQUE AND ENABLING CAPABILITY

One area of special significance that highlights Falcon's unique and enabling capabilities is fuel rod analysis for mitigation of fuel rod failure due to PCI. As noted in addition to being the analytical tool used to develop the PCI guidelines, Falcon has been used by ANATECH for direct support to a number of nuclear utilities to provide operational guidance for increasing fuel reliability and reducing or mitigating the potential for fuel rod failures due to PCI. These analyses have included plant and cycle-specific analyses applied to the following areas:

- Alternative cycle start-up strategies to limit cladding stresses during reactor start-up
  - For example, revised power ramping strategies, insertion of constant power holds, reduced extent of prior cycle coastdown, and reducing the extent of power increase on startup,
- Evaluation of changes in plant operation on PCI failure margin from unanticipated plant operational events, varying coast down strategies, and different fuel vendor/utility power ascension strategies, and
- Evaluation of fuel design changes on PCI failure margin
  - For example, new or improved fuel design features, advanced lead test assemblies, alternate vendor fuel designs, etc.



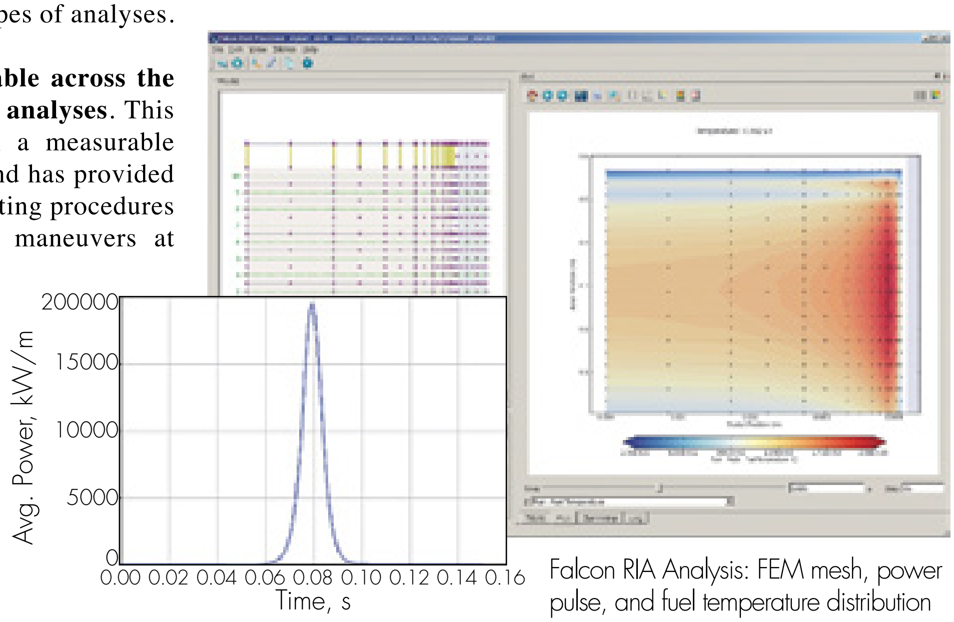
Power and burnup dependent bounding analysis



MPS model showing grid deformation and cladding hoop stress distribution

Recent notable examples of the application of Falcon by ANATECH for utility support in this area include cycle-specific and start up strategies for Exelon (Braidwood and Byron), Southern Nuclear Company (Farley and Vogtle), Progress Energy (Shearon Harris and H. B. Robinson), Xcel Energy (Prairie Island), and Constellation Energy Nuclear Group (Calvert Cliffs ramp rate evaluation for a new fuel supplier). In terms of successes, all of these utilities have benefited from the insight Falcon provides. Exelon, who has contracted ANATECH for over 10 years, has not experienced any PCI-related fuel failure issues at either Braidwood or Byron since employing Falcon for these types of analyses.

Falcon is the only analytical tool available across the industry that can perform these type of analyses. This "real world" application has resulted in a measurable reduction in fuel rod failures due to PCI and has provided sound technical bases for revision of operating procedures for startups and other power ascension maneuvers at nuclear utilities throughout the country.



Falcon RIA Analysis: FEM mesh, power pulse, and fuel temperature distribution

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1. Fuel Reliability Guidelines: Pellet Cladding Interaction, EPRI, 1015453, Final Report, November 2008
2. Fuel Reliability Program: Falcon Fuel Performance Code, Version 1.2, EPRI, 1022711, User Guide, September 2012

GENERATION OF IN-STRUCTURE CABINET SPECTRA

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As part of the process in the seismic qualification of control cabinets which house various Seismic Category I equipment, plant owners must demonstrate that the various electrical devices supported inside the cabinet enclosures remain functional during and after a seismic event, including an Operating Basis Earthquake (OBE) and a Safe Shutdown Earthquake (SSE). One way of determining the functionality of equipment integrated inside a cabinet is by testing of the fully integrated cabinet using the available building Floor Response Spectrum (FRS). This method is not always practical ,particularly in cases where the cabinets are of different designs and the placement of the equipment inside each different cabinet varies significantly. An alternative approach to testing a fully integrated cabinet is to test each device individually by developing in-cabinet amplified Required Response Spectrum (RRS), which takes into account the amplified response of the cabinet structure and the localized amplified response at equipment attachment points. Recently, Structural Integrity Associates, Inc, (SI) used a finite element time history analysis approach in determining the in-cabinet amplified RRS for planned testing of cabinet electrical equipment.

APPROACH

Testing and analysis of electrical cabinets is described in IEEE-344, which provides guidance on the analytical methods as well as requirements for RRS. The finite element time history analysis method is one of the methods recommended in IEEE-344 and is used in determining the dynamic response of a cabinet. The ANSYS software package is used for the time history analysis. The process of computing the RRS involves the generation of synthetic acceleration time histories which envelope existing floor response spectra. Smoothed and broadened floor acceleration spectra are typically provided for damping values ranging from 2% through 10% for building locations where the cabinets are placed. For time history analysis of cabinet enclosures, the appropriate structural damping values for input time history generation are 2% for OBE and 3% for SSE. The synthetic acceleration time histories corresponding to the floor spectra are then used as input in a finite element time history analysis of the cabinet assembly to obtain responses at various equipment mounting locations. A modal analysis is used to extract mode shapes and frequencies, followed by a modal time history analysis. The analysis method used is applicable to linear systems. Time history responses are extracted from the analysis and are used as input to calculate response spectra at the different equipment attachment locations. The raw acceleration spectra are enveloped to represent all equipment mounting locations in the cabinet. The enveloped spectra are then broadened, smoothened, and the required margins applied to obtain the RRS. Two sets of RRS for two horizontal directions and one vertical direction are considered: one for OBE and another for SSE. The RRS are then used in seismic testing of the equipment.

FINITE ELEMENT MODEL

The cabinets are constructed from cold-formed steel sheet panels and frame members and are either floor-mounted or wall-mounted. Floor-mounted cabinets are anchored to the floor at the base at four corners. Wall-mounted cabinets are anchored to the wall at four corners. A cost-effective approach to limit the number of analytical models is used by analyzing bounding cabinet configurations. In general, two bounding cases, based on cabinet total weights, are sufficient to represent a group of similar cabinets. In cases where there are only small differences in weight between the individual cabinets, only one bounding case is sufficient for analysis.

Beams and shell elements are used to model the cabinet enclosure (Figure 1). Individual equipment pieces are represented as eccentric lumped masses at their attached locations. Non-structural items are not modeled explicitly, however, their masses are included in the model. The analysis is performed for one isolated cabinet. Sufficient clearance is provided to prevent impact between adjacent cabinets.

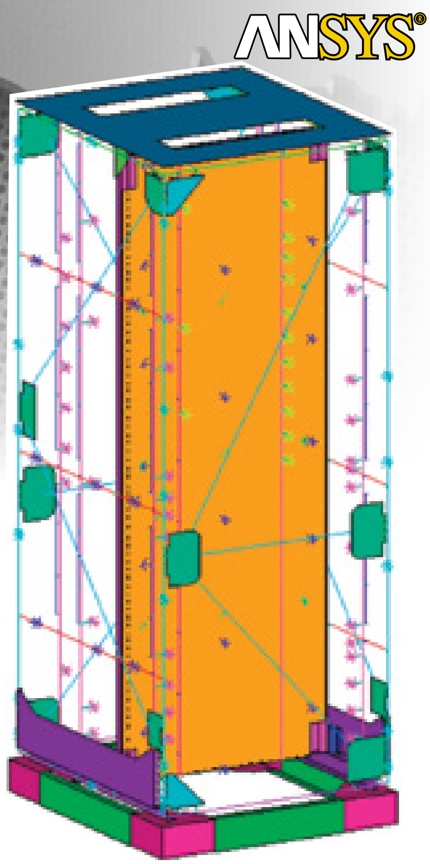

Figure 1. Typical Floor-mounted Cabinet Finite Element Model

GENERATION OF FLOOR ACCELERATION TIME HISTORIES

Synthetic acceleration time histories corresponding to the enveloped floor spectra are generated for two horizontal directions and one vertical direction. Separate sets of acceleration time histories are required for OBE and SSE since the floor spectra and associated spectral damping values are different for each of these earthquake levels (i.e. 2% damping for OBE and 3% damping for SSE). The synthetic acceleration time histories meet several requirements outlined in NRC NUREG-0800 Standard Review Plan, Section 3.7.1. In addition, they also satisfy the industry guidelines and standard procedures provided by IEEE-344 and ASCE-4-98 associated with the characteristics of seismic input motions. The generation of the acceleration time history has been performed using SI proprietary software called GENTIME. The algorithm involves the summation of sinusoidal signals so that a computed response spectrum from the generated time history data closely matching the target floor response spectrum in the frequency range of 0.2 Hz to 100 Hz is obtained. The synthesized acceleration time history (Figure 2) is generated iteratively so that its response spectrum matches the target floor response spectrum (Figure 3). The total duration of each acceleration time history is 20 seconds, containing strong motion duration of 15 seconds, a time interval of 0.0005 seconds and adequate to capture structural responses up is to a frequency of 100 Hz.

All the generated acceleration time histories in different directions are independent and meet the required cross correlation requirements (i.e., that the absolute maximum correlation is below 0.30 over the entire delay time of 15 seconds, corresponding to the strong motion period, and the absolute correlation is not greater than 0.16 with no time delays). In all cases, the computed Power Spectral Density (PSD) amplitudes satisfy the required PSD amplitudes over the entire frequency band of interest (Figure 4 and Figure 5).

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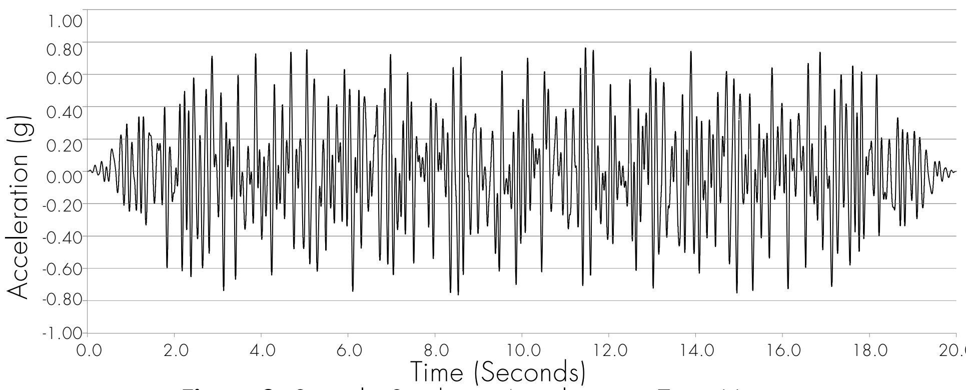

Figure 2. Sample Synthetic Acceleration Time History

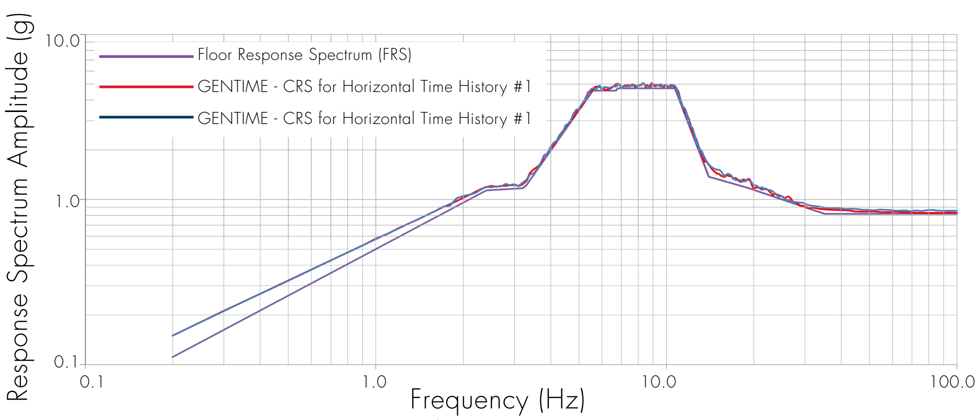

Figure 3. Sample Comparison of Target Floor Spectrum and Computed Synthetic Time History Spectrum

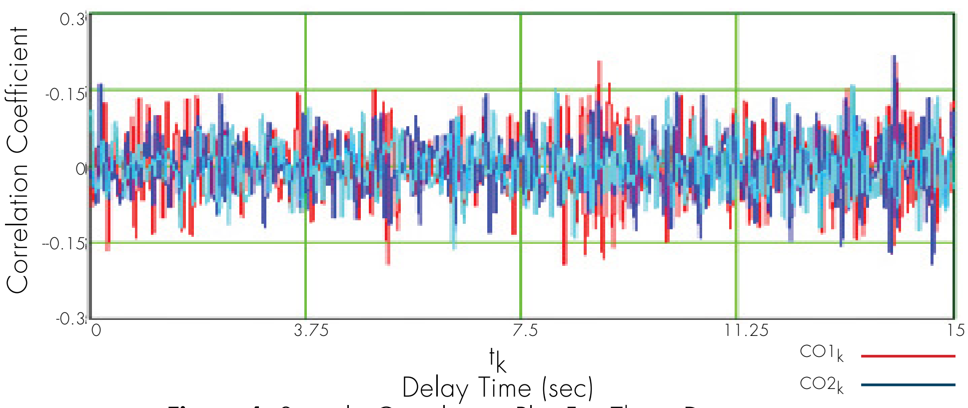

Figure 4. Sample Correlation Plot For Three Directions

GENERATION OF IN-STRUCTURE CABINET SPECTRA
CONTINUED

AMPLIFIED REQUIRED RESPONSE SPECTRA

Using the ANSYS software, a modal analysis is first performed to determine cabinet mode shapes and frequencies up to 100 Hz. The finite element model is then subjected to seismic acceleration input at the cabinet supports simultaneously in three directions for the entire 20-second duration of the input motion. Separate analyses are performed for OBE and SSE, with appropriate structural damping values for each case. The integration time step chosen is sufficient to capture responses up to 100 Hz. The analyses produce displacement time histories at all locations where the various equipment are attached (i.e., the equipment base). The output displacement time histories relative to the cabinet supports are superimposed with corresponding input support motion displacements to determine the absolute displacement time histories. These are then used to compute raw response spectra at each equipment attachment location in three orthogonal directions. Raw spectra are generated for 5% damping from 0.2Hz to 100Hz. From all the output locations, one horizontal envelope spectrum is obtained that is applicable to both horizontal directions (Figure 6). Similarly, one envelope vertical response spectrum is obtained. Spectral ordinates are increased to account for additional desired margins (10% per guidelines and 10% additional margin) and are peak-broadened by 15% (Figure 7). Final smoothed and broadened RRS are obtained for both OBE and SSE.

CONCLUSIONS

A time history analysis has been used to develop in-cabinet amplified RRS enveloping all equipment attachment locations in the cabinet. The process includes development of synthetic acceleration time history input motions, a time history analysis, as well as generation of envelope broadened amplified acceleration RRS. The RRS developed by analysis are used for seismic testing and qualification of electrical equipment mounted inside the cabinet.

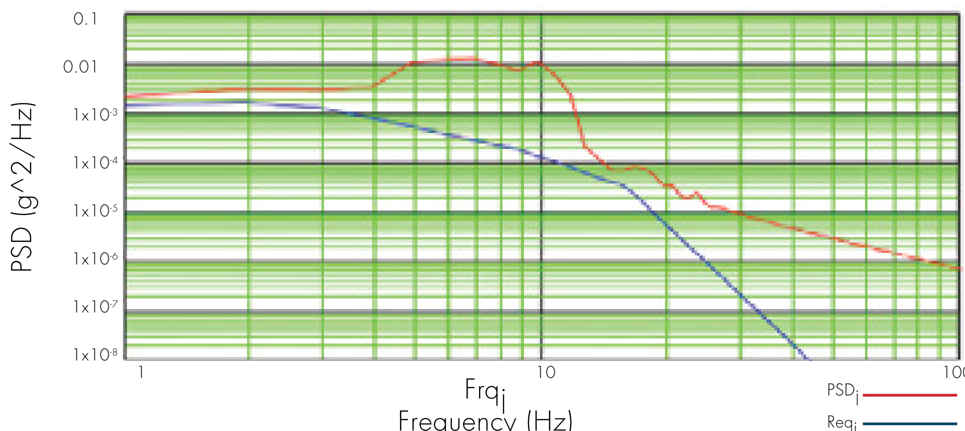

Figure 5. Sample PSD Plot of a Horizontal Direction Acceleration Time History

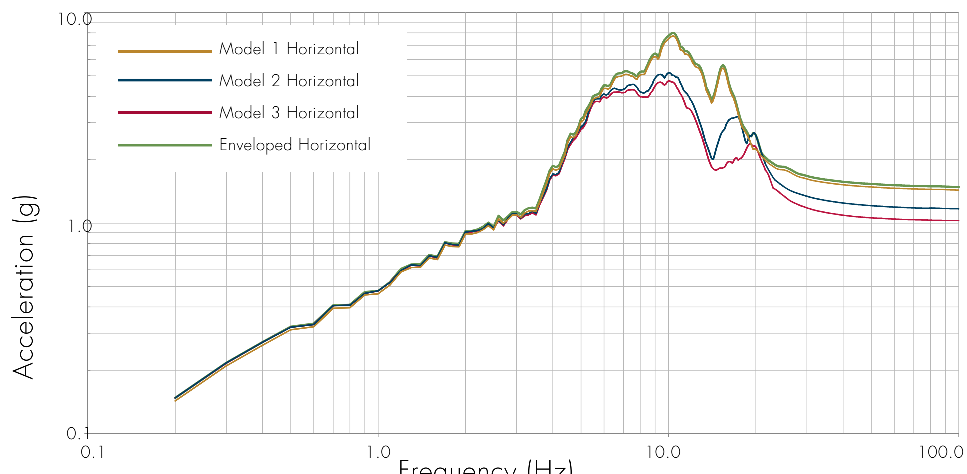

Figure 6. Sample Envelope Raw Response Spectra From Three Cabinet Models

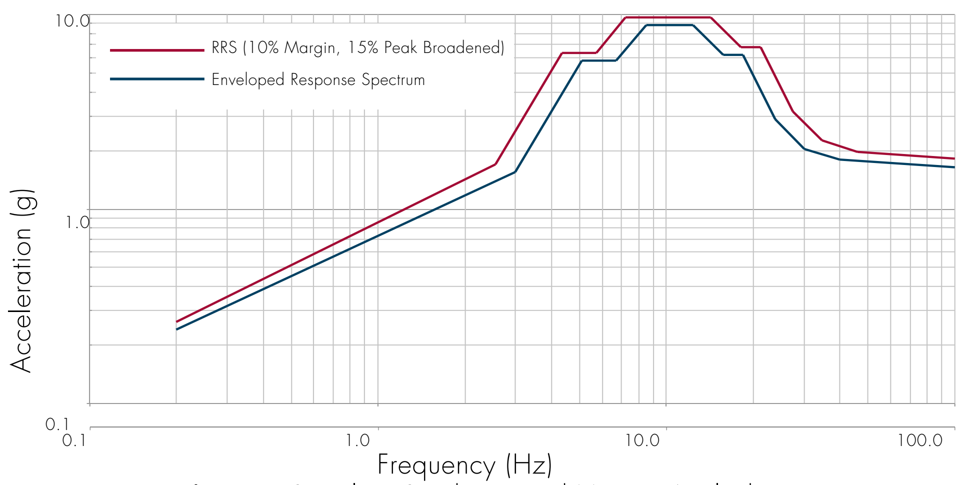

Figure 7. Sample RRS with Required Margins Applied

Gravitational Waves

By: ERIC HOUSTON
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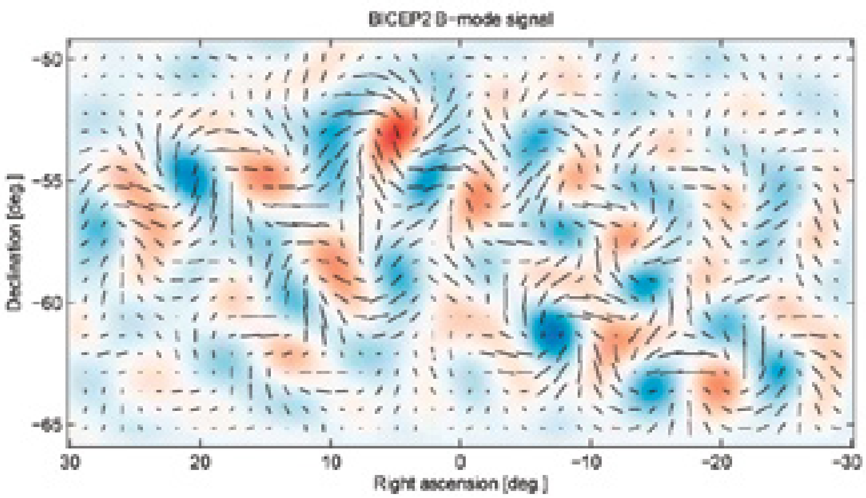

Red and blue indicate clockwise and counterclockwise twisting of B-mode CMB

BICEP2 telescope shown at left

Note: all pictures are from bicepkeck.org

REFERENCES:
http://bicepkeck.org/
http://www.cnn.com/2014/03/17/tech/innovation/big-bang-gravitational-waves/
http://www.scientificamerican.com/article/gravity-waves-cmb-b-mode-polarization/
http://www.nytimes.com/2014/06/20/science/space/scientists-debate-gravity-wave-detection-claim.html?_r=0

Albert Einstein's theory of general relativity predicted the existence of gravitational waves, and nearly 100 years later scientists are finding the first possible proof of such waves.

Small ripples in space-time (known as quantum fluctuations) were perturbed by the Big Bang, creating gravitational waves. These waves cannot currently be directly detected. Instead scientists looked to the effect on the cosmic microwave background (CMB), which was created when the universe was only 380,000 years old. Gravitational waves should refract the CMB, which could then be detected through polarized sensors. Specifically, scientists are looking for B-mode polarization which indicates twisting of the light. When scientists with the Background Imaging of Cosmic Extragalactic Polarization 2 (BICEP2), located ¾ of a mile from the geographic South Pole, looked for B-mode polarization of the CMB that is exactly what they found.

Gravitational waves help explain the rapid expansion of the universe that occurred during the first 10^{-32} second in the history of the universe. The distortion of space-time caused by gravitational waves not only helps explain the uniform distribution of mass in the universe, but also how expansion of the universe could have significantly exceeded the speed of light (a theory known as cosmic inflation).

A number of other groups searching for gravitational waves, and the results of the BICEP2 study have yet to be confirmed. One possible explanation for the extraordinary results is that interstellar dust, not gravitational waves, is responsible for the B-mode polarization. Although the authors stand by their results as evidence of gravitational waves, they acknowledge that the discovery requires independent verification.

ULTRASONIC EXAMINATION OF LARGE-DIAMETER DISSIMILAR METAL WELDS

By: PAUL SULLIVAN
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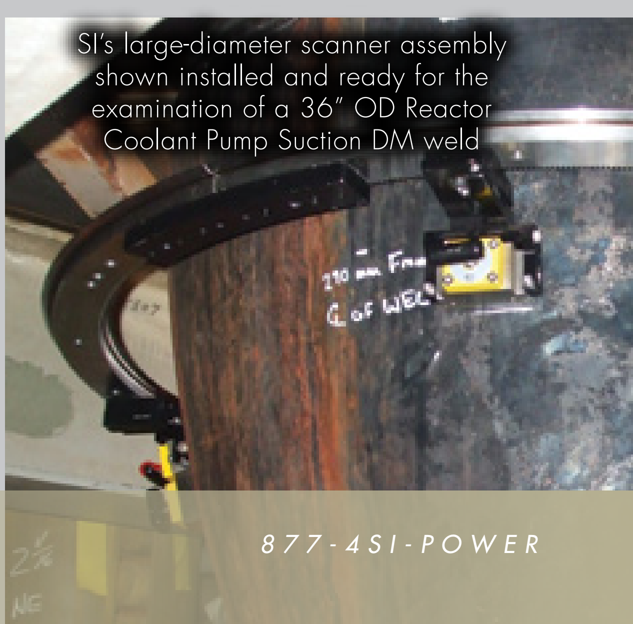
SI's Safety Injection scanner assembly (centered in photo) is shown installed in proximity to the small-diameter scanner and ready for the examination of a Safety Injection DM weld.

Structural Integrity Associates, Inc. (SI) continued the trend of providing innovative examination solutions to the nuclear industry by completing an aggressive spring 2014 work scope that involved the automated, encoded, phased array ultrasonic examination of large-diameter dissimilar metal (DM) piping welds. This included the examination of eight Reactor Coolant Pump (RCP) DM welds (36 inch outside diameter) and four Safety Injection DM welds (12 inch outside diameter) at each of two U.S. nuclear facilities. In addition to the RCP and Safety Injection welds, the work scope at one plant included three small-diameter (4 inch OD), tapered surface Cold Leg Spray and Charging DM welds.

SI utilized the Procedure for Encoded, Phased Array Ultrasonic Examination of Dissimilar Metal Piping Welds (Zetec OMNISCAN Raster-03) for the subject examinations. In support of these projects, SI expanded the Zetec OmniScan Raster-03 procedure to permit the use of a smaller wedge, which provides increased examination coverage during axial scanning for the detection of circumferentially-oriented flaws for the large-diameter RCP DM welds.

Pre-outage preparations required the development and fabrication of specialized ultrasonic scanning device for the Cold Leg Spray and Charging DM welds due to the associated tapers and limited access. Additionally, SI designed and fabricated scanning for the Safety Injection and RCP DM welds specifically for these projects. The specialized delivery tooling was designed and modeled by Structural Integrity to identify any plant-specific clearance issues or limitations to examination coverage during field implementation. All specialized tooling subcomponents were designed and assembled by SI's engineers and machinists and tested in-house on full-scale component mockups. The flexibility designed into the tooling allows for their easy adaptation to unique weld configurations and field interferences associated with DM welds in US plants.

SI's small-diameter scanner assembly (centered in photo) is shown installed and ready for the examination of$" OD RCS Spray DM weld.



SI's large-diameter scanner assembly shown installed and ready for the examination of a 36" OD Reactor Coolant Pump Suction DM weld

As an important part of the project preparations and in support of mobilization to site, integrated crew training was conducted by SI NDE and project supervisory staff for SI's ultrasonic scanner and data acquisition personnel. The training included repeated assembly and installation of scanner components onto full-scale mockups in the SI facility in Huntersville, NC. Client representatives witnessed the training and provided feedback on our scanner training and practice sessions. Client feedback was then incorporated into the examination process which benefited the onsite examination performance.

Working closely with the client site personnel, along with the benefits of the well-designed, tested, and custom-packaged SI equipment, resulted in the need for only two shifts from the receipt of protected area badges for SI personnel,to moving equipment into containment, setup and the beginning actual component scanning. The flexible equipment design, coupled with the pre-outage training, resulted in the efficient initial setup, transition among the various DM welds within each RCP pump bay and movement between each separate pump bay.

Structural Integrity's experience in performing automated, encoded DM weld examinations, ranging from small-diameter to large-diameter welds with complex geometries with limited access, allows us to provide innovative examination solutions to allow our clients to meet regulatory requirements. Our experience and in-house ability to design, manufacture and test specialized tooling to adapt for tight clearances and examination limitations uniquely positions SI as a preferred provider of DM weld examination services.

CONTRIBUTIONS TO TSUNAMI SCIENCE

ROBERT SEWELL, PhD
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Dr. Rob T. Sewell was presented with an award of Tsunami Society International in conjunction with the 6th International Tsunami Symposium in Nicoya, Costa Rica, Mexico for Original and Significant Contributions to Tsunami Science.

STRUCTURAL INTEGRITY SUPPORTS INTERNATIONAL CONFERENCE

Structural Integrity frequently supports and presents at key industry conferences. EPRI's Boiler Tube and HRSG Tube Failure and Inspection International Conference is one example, because boiler tube failures (BTF) are the leading cause of forced outages in the conventional fossil plant utility industry, accounting for almost 3% of availability loss in the U.S. HRSG tube failures (HTF) are also the major cause of damage in the multiple-pressure combined-cycle plants and result from many of the same tube failure mechanisms as conventional plants.

Please join us at this important industry event.

ABSTRACT SUBMISSION

To produce timely reports and publications, the following deadlines have been set:

150–250 Word Abstract..January 16, 2015
Speaker Notification..March 4, 2015
Final Paper/Presentation..May 20, 2015

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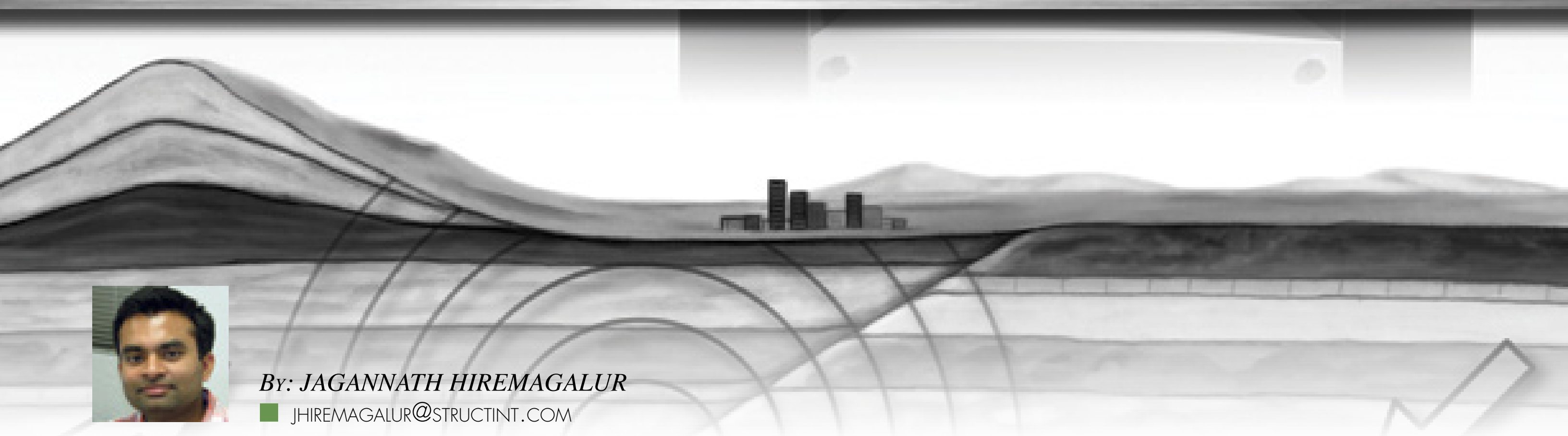
SEISMIC QUALIFICATION ANALYSES OF A SYNCHRONOUS GENERATOR



By: JAGANNATH HIREMAGALUR
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Structural Integrity Associates, Inc. (SI) recently completed a seismic qualification analysis of a Gas Turbine Generator (GTG) set enclosure and related components and piping to provide emergency power to PWR. One of the components qualified by analysis was the synchronous generator, which consisted of the following subcomponents:

- Frame
- Bolting to Skid
- Bolts
- Exciter & Permanent Magnet Generator (PMG) support structure
- Gaps specified for housing & rotating components (rotor, exciter & PMG)
- RENK bearing
- Bearings and housings (floating and thrust bearings)

ANALYSIS PROCESS

The seismic qualification analysis is performed in two steps. First, a three-dimensional (3-D) finite element model of the generator is developed and a modal analysis is performed to determine all mode shapes within the frequency range from 0.1 Hz to 100 Hz in order to capture modes within the zero period acceleration (ZPA) frequency. An acceleration of 1g is applied in the vertical direction to simulate gravity. This load case, along with its respective results, are then used.

The second step is to perform a finite element analysis (FEA) of the generator finite element model by applying a single point response spectrum, representing the input floor response spectra for the safe shutdown earthquake (SSE), and combining these results with the gravity (deadweight) analysis results discussed above. The results of these two analyses are added on an absolute sum basis and compared to the stress allowable values in the applicable acceptance criteria provided by the Steel Construction Manual, American Institute of Steel Construction (AISC).

The inputs to a single point response spectrum analysis are mode shapes (eigenvalues) corresponding to different modal frequencies. The bounding safe shutdown earthquakes (SSE) seismic response spectra for the horizontal and vertical directions are used to determine stresses due to seismic excitation. In addition, the maximum horizontal seismic response spectrum is used as the horizontal

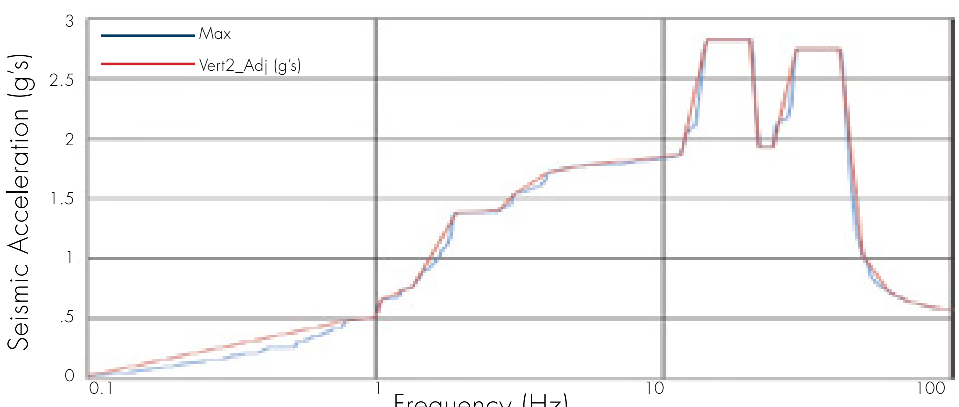


Figure 1. Bounding and Adjusted Seismic Input Response Spectrum Curve for Horizontal Direction, 3% Damping Curve
(Vert2_Adj is the bounding seismic accelerations in the vertical direction)

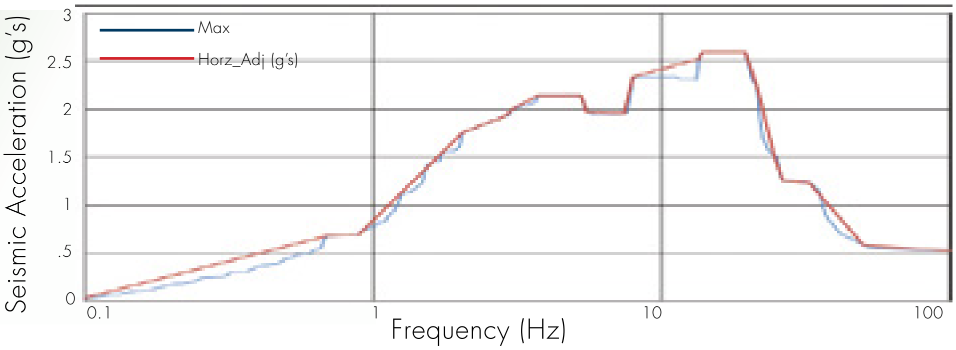


Figure 2. Bounding and Adjusted Seismic Input Response Spectrum Curve for Vertical Direction, 3% Damping Curve *(Horz_Adj is the bounding seismic accelerations in the horizontal direction)*

spectra for both directions. The spectra used are as shown in Figures 1 and 2.

FINITE ELEMENT MODEL

The finite element model (as shown in Figure 3) is developed and the modal analysis is performed using the ANSYS finite element analysis software package. The Computer Aided Design (CAD) geometry for the synchronous generator was provided by the client and SI imported the model into ANSYS for analysis.

The total weight of the synchronous generator was maintained and the structural stiffness of the un-modeled components was ignored in the analysis. By ignoring the structural stiffness of the un-modeled components, the analysis does not take credit for potential increase in eigen frequency, which is conservative for the seismic analysis.

TECHNICAL APPROACH

Operating and deadweight stresses and seismic acceleration induced stresses were calculated using analysis FEA methods. The resulting stresses due to operating conditions and the combined stresses of operation and seismic conditions are then compared to the allowable stress criteria for the component materials. The acceptance criteria for these evaluations are in accordance with the Steel Construction Manual.

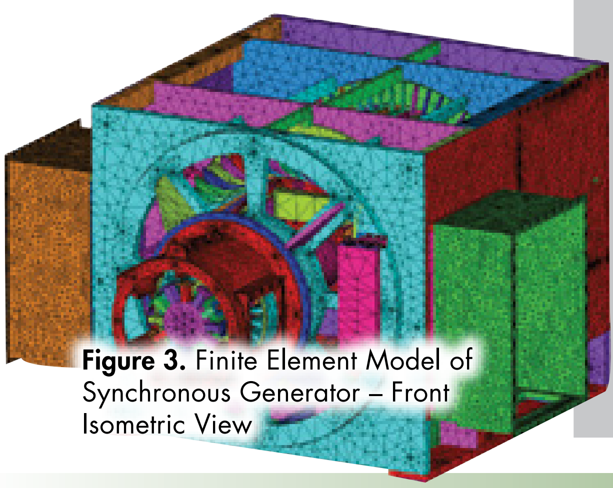


Figure 3. Finite Element Model of Synchronous Generator – Front Isometric View

OPERATING STRESS CRITERIA

For operating and deadweight conditions, the allowable stresses are as follows:

- The allowable stress in tension under operating loads is 60% of the specified minimum yield strength of the most limiting stressed component within the synchronous generator.
- The Steel Construction Manual acceptance criteria is to be applied to average stresses on a member basis and is not intended to provide limits on detailed stress results from numerical analyses. Regardless, maximum stresses at hot spots (peak nodal stresses) are conservatively compared to the allowable stress limits in this evaluation to minimize the need for summing member forces across many sections.
- For those situations where peak stresses cannot be conservatively qualified, through-wall normal stresses are linearized. According to the Steel Construction Manual, combined bending and axial stresses are limited by the interaction formula given below.

$$\left| \frac{f_{ra}}{F_{ca}} + \frac{f_{rbw}}{F_{cbw}} + \frac{f_{rbz}}{F_{cbz}} \right| \leq 1.0$$

where,

f_{ra} = required axial stress at the point of consideration using Allowable Stress Design (ASD) load combinations, ksi

F_{ca} = available axial stress at the point of consideration, ksi

f_{rbw}, f_{rbz} = required flexural stress at the point of consideration using ASD load combinations, ksi

F_{cbw}, F_{cbz} = available flexural stress at the point of consideration, ksi

W = subscript relating symbol to major principal axis bending

z = subscript relating symbol to minor principal axis bending

For those situations where peak stresses cannot be conservatively qualified, the interaction formula can be incorporated in the operating stress evaluation. For the linearized stress case, the allowable bending stress is 0.9*specified minimum yield strength, Fy for a flat plate bending about its minor axis. According to the Steel Construction Manual, the allowable flexural strength is Mn/Ωb, where Mn is the nominal flexural strength and Ωb = 1.67. The allowable flexural strength is (1.5/1.67)*Fy. The 1.5 factor is for converting the plastic section modulus to the elastic section modulus; the section is capable of developing full plastic moment before failing.

- The allowable maximum shear stress for operating loads is 40% of the specified minimum yield strength of the most limiting stressed component within the synchronous generator. The Steel Construction Manual defines the allowable shear strength as Vn/Ω where, Ω =1.67 and Vn is the nominal shear strength. According to the Steel Construction manual, ASD traditionally has used two-thirds of the yield stress as the allowable value (2/3 of 0.6*Fy); thus, the allowable shear stress is equal to 0.4*Fy. Only the membrane (average) component of shear stress is considered for comparison against the stress criteria when it is necessary to extract linearized through-wall shear stresses.

Continued on next page

OPERATING-PLUS-SEISMIC STRESS CRITERIA

For the purpose of the synchronous generator qualification by analysis, the load combinations and stress limit coefficients are obtained from Supplement No. 2 to the Specification for the Design, Fabrication, and Erection of Steel Safety-Related Structures for Nuclear Facilities," (ANSI/AISC N690-1994(R2004).

For operating-plus-seismic loads, the stress limit coefficient for members in tension (normal) shall not exceed 1.6 in members, i.e., allowable tensile stresses are 1.6 times the operating condition allowable stresses. For operating-plus-seismic, the stress limit coefficient in shear shall not exceed 1.4.

ACCEPTANCE RESULTS

Figure 4 shows the exaggerated mode shape (eigenvalue) of the model due to structural modes at the corresponding natural frequency. Figure 5 provides the sum-total of displacements in one of the three orthogonal directions due to the bounding input response spectrum seismic loads (horizontal spectral loading). The stress states in each load direction were then combined by taking the square root of the sum of squares (SRSS) to generate one resultant stress state for seismic. The resulting stresses are used as input for the total stress evaluation. The stress results for the operating loads and the input response spectrum seismic loads were combined by addition on an absolute sum basis.

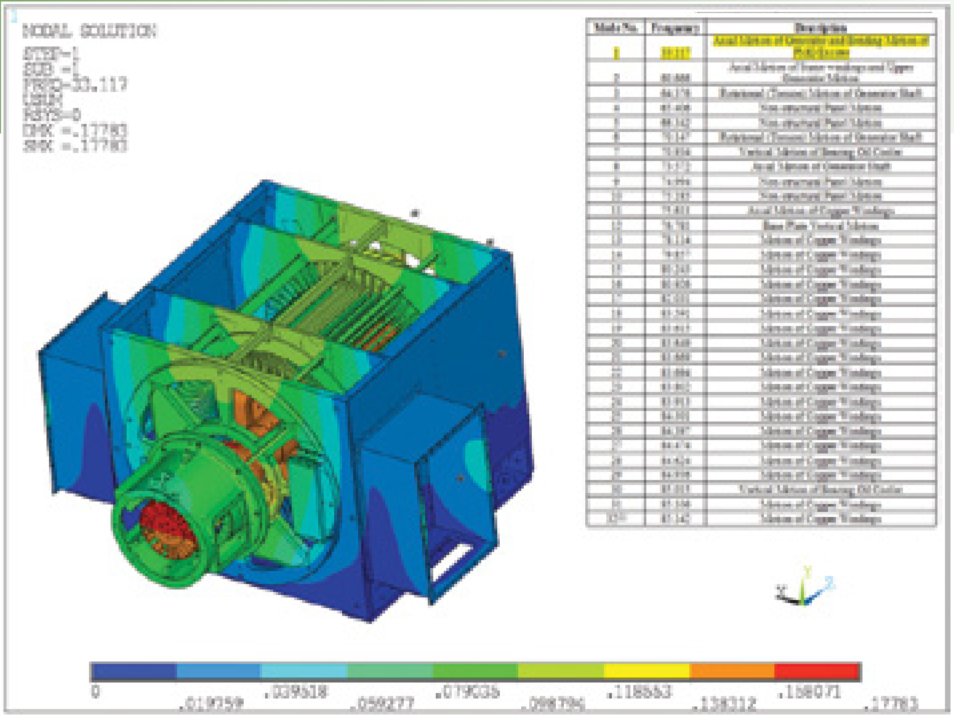


Figure 4. Exaggerated Mode Shape Plot at Natural Frequency of 33.117 Hz

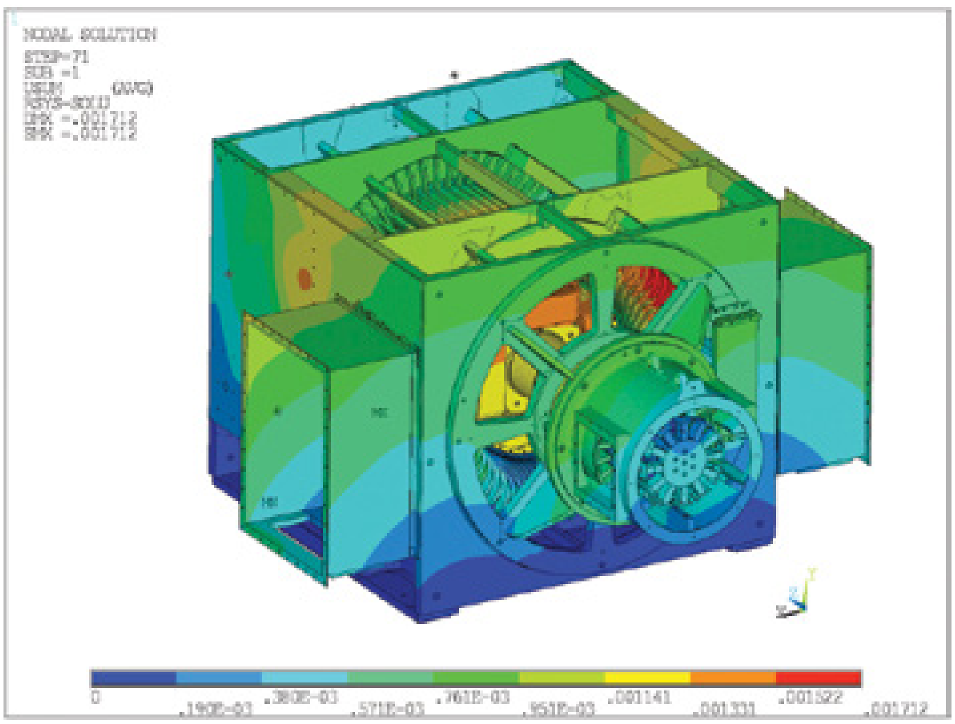
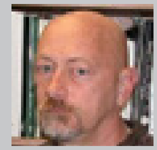


Figure 5. Total Displacement Contour Plot – Horizontal Spectrum Analysis

CONCLUSIONS

The maximum operating stresses, as well as the maximum operating-plus-input response spectrum seismic normal and shear stresses, for the synchronous generator were mathematically shown to meet the allowable stress criteria per the Steel Construction Manual.

THE DANIEL CUBICCIOTTI STUDENT AWARD



By: GEORGE LICINA
glicina@structint.com

Dr. Nian Liu of Stanford University is the 2014 recipient of the Daniel Cubicciotti Student Award, presented by the San Francisco Section of the Electrochemical Society and sponsored by Structural Integrity Associates. Since I was unable to present Dr. Liu the award at the ECS April chapter meeting, he came to SI's San Jose office to receive the award and give us the same presentation he gave at the chapter meeting: "Structural Design of Silicon Anodes for High Energy Lithium Batteries".

From our inception, Dan Cubicciotti had been a good friend to the company. He was also a great friend and mentor to Tony Giannuzzi and me. We felt that it was only proper to honor his memory in some way and that was standard 20 years ago.

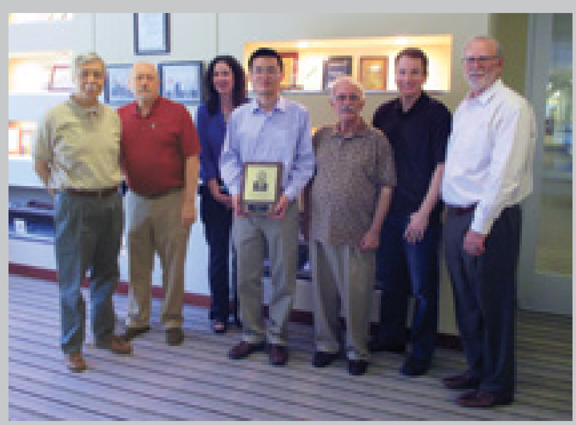
The DANIEL CUBICCIOTTI STUDENT AWARD was established in 1994 to help deserving students in Northern California to pursue a career in the physical sciences or engineering. The award honors the memory of Daniel Cubicciotti, for his dedication and expertise in the application of electrochemical principles to the understanding and control of materials deterioration in nuclear power plants. The award is presented to a student based on academic excellence, a demonstrated interest in the study or application of electrochemistry, and personal characteristics that reflect Dan Cubicciotti's integrity and cheerful enjoyment of life.

Daniel Cubicciotti was born in Philadelphia in 1921 but spent most of his life in northern California. He graduated from the University of California with a BS in chemistry in 1942 and a PhD in physical-inorganic chemistry in 1946. In his 47-year professional career as a researcher, including 20 years at SRI International and 13 at the Electric Power Research Institute, Dan worked in all aspects of the nuclear fuel cycle, from nuclear fuel to cooling water systems for the removal of heat from power generation and auxiliary equipment. The spectrum of problems addressed by Dan's work included developing an understanding of the thermodynamics and kinetics of chemical processes in fuel pellets, the interaction of fission products with fuel cladding, prediction of stable phases in complex systems, stress corrosion cracking of reactor structural materials, and microbiologically-influenced corrosion of reactor materials. His expertise in the areas of high temperature chemistry and corrosion were well known, documented by more than 200 scientific papers. His scientific knowledge, experimental skills, and ability to grasp the overall importance of such problems were coupled with a remarkable ability to transfer his expertise and the technology developed by others to people in the field so that solutions could be applied to real life problems. Dan continued to delve into new and exciting technical areas until his death in 1993.

Dan Cubicciotti left a legacy to the nuclear industry replete with innovation and usable information in the areas of fuel cladding materials, stress corrosion cracking, Pourbaix diagrams, and microbiologically influenced corrosion. He also helped numerous non-experts in corrosion to appreciate the importance of corrosion processes, and, more importantly, provided them with valuable tools to predict where or how attack might occur, and how to mitigate or prevent such problems. In addition to his roles as high temperature electrochemist and corrosion expert, Dan served as a husband, father, grandfather, part-time musician, and friend; always with an obvious joy for life. He showed many scientists and engineers the joy inherent in finding the truth. He served as a mentor to many and an example of a gentleman of the highest integrity to all.

The initial concept of this award was that each year Tony Giannuzzi and I and anyone else who wanted to contribute would send a deserving kid to band camp, in honor of Dan and his love for music. Unfortunately, neither of us knew how to find a band camp, how to set up a fund, or any of the necessities. Since Dan was an outstanding electrochemist, our next choice was The Electrochemical Society. Fortunately, several of the local chapter's members did know how to put us in contact with the proper people and they and the ECS corporate staff helped to establish the first award. Over the years, Dan's family and friends have contributed generously to the award fund, transforming the award itself from its initial concept as an immediate memorial to his legacy into one that can now be awarded perpetually. The award currently consists of a $2,000 cash award and commemorative metal plaque to the winner.

Over the years, the Cubicciotti award has permitted us to meet some absolutely brilliant and extremely interesting young people. Being a part of the award and meeting those young people gives me great confidence that the world is going to be all right.



Focus on PlantTrack: Boiler Module

By: NAIL OZBOYA
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Structural Integrity has developed the PlantTrack program as a state-of-the-art, complete data management system for conventional fossil power plants. During the lifetime of a power plant, a vast amount of data is generated included:

- Design drawings / specifications / fabrication records
- Replacements and modifications
- Failures (what failed, where, why and when)
- Repairs (where, why, how)
- Inspections (data, reports)
- Key operating events (chemical cleans, fuel switches, hanger resets)

Unfortunately, most of this data is usually scattered between many different systems, such as hard copy documents in file cabinets, spreadsheets, operating logs, etc. Even with a decent document management system, it is very difficult and often impossible to detect any patterns or trends in problems areas, and causes.

PlantTrack provides the tools necessary for a successful asset data management system:

- a centralized source of drawings, specifications, and related data,
- detailed drawings of the systems and boiler parts with two way interaction with records,
- an easy way of interfacing with other programs, and
- a fast and user-friendly method of extracting and reporting data.

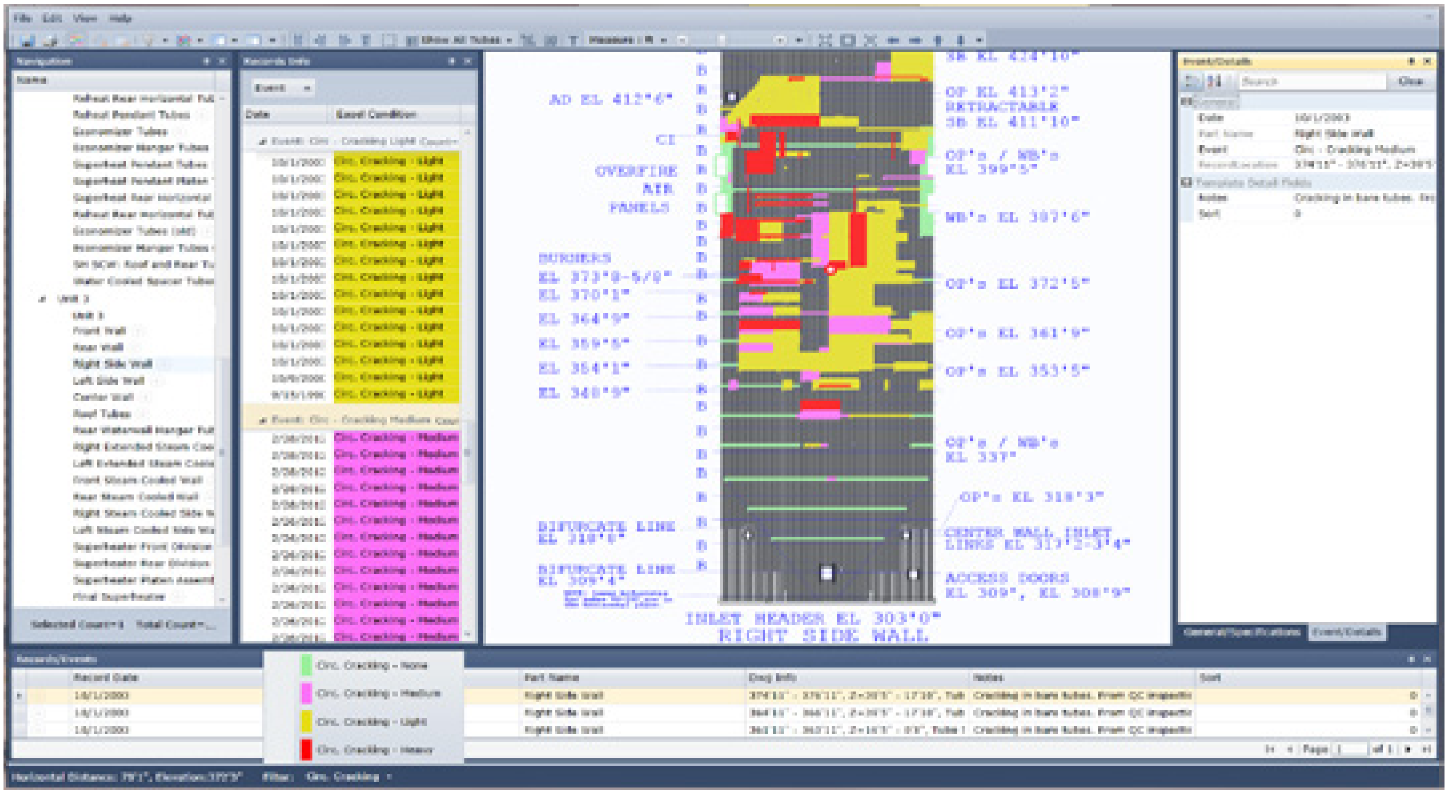

Figure 1 Display of Circ. Cracking records on a Waterwall

The boiler module can track an extensive variety of record types associated with boiler tubing. This makes PlantTrack an invaluable part of an overall boiler tube life Management Program to pro-actively reduce Boiler Tube Failures. Some examples of records that can be tracked include:

- Boiler tube failures: failure mechanisms, root causes, locations, analysis/metallurgical reports, photos, etc.
- Tube repairs: due to failures or for preventive maintenance reasons, repair method, procedure, welders, photos, etc.
- Tube replacements: due to failure, diagnostic purposes, access to other tubes, eliminate pad welds, etc.
- Tube specifications: material type, outside diameter, minimum wall thickness, weld procedure,
- Weld locations: Dissimilar welds, field/shop welds, weld procedures
- Weld overlays, cladding, metal spray, tube shields: Method, material, applied thickness, applied by, etc.
- Inspections: NDE/UT wall thickness, oxide/internal deposit thickness, cladding/ metal spray thickness, etc.
- Tube orifice sizes, flow rates
- Analysis results: thinning rates, wall thickness projections, remaining useful lives
- Chemical cleaning: solvent, material composition
- Inspection planning records to define upcoming outage efforts, such as sand blasting, NDE, etc.

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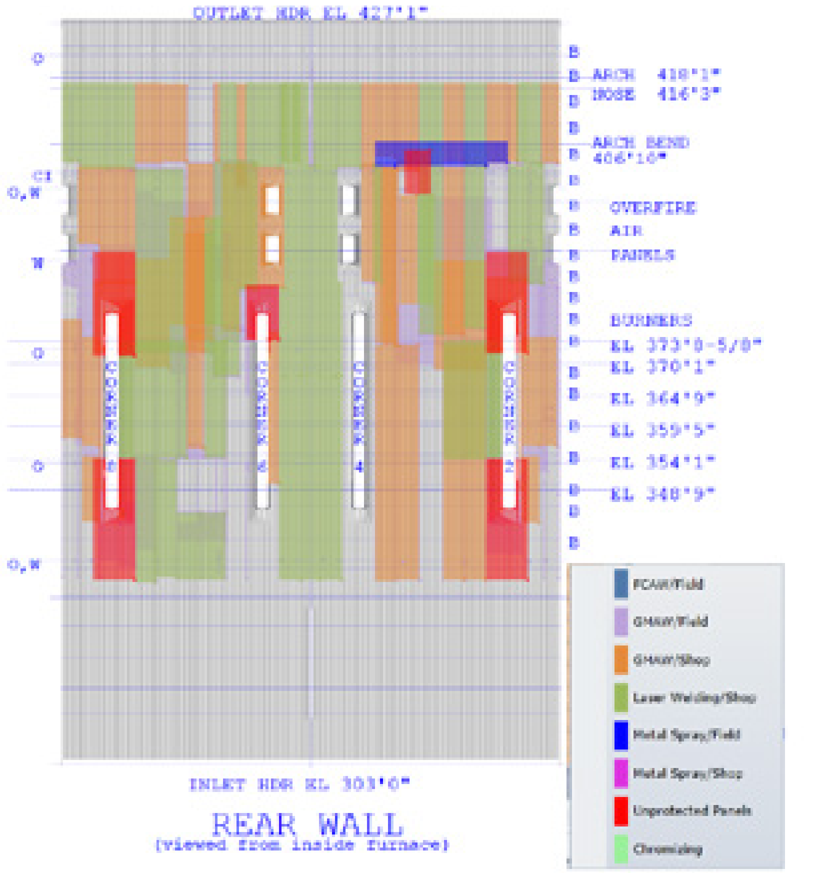

Figure 2 Wastage Protection Methods displayed on a waterwall

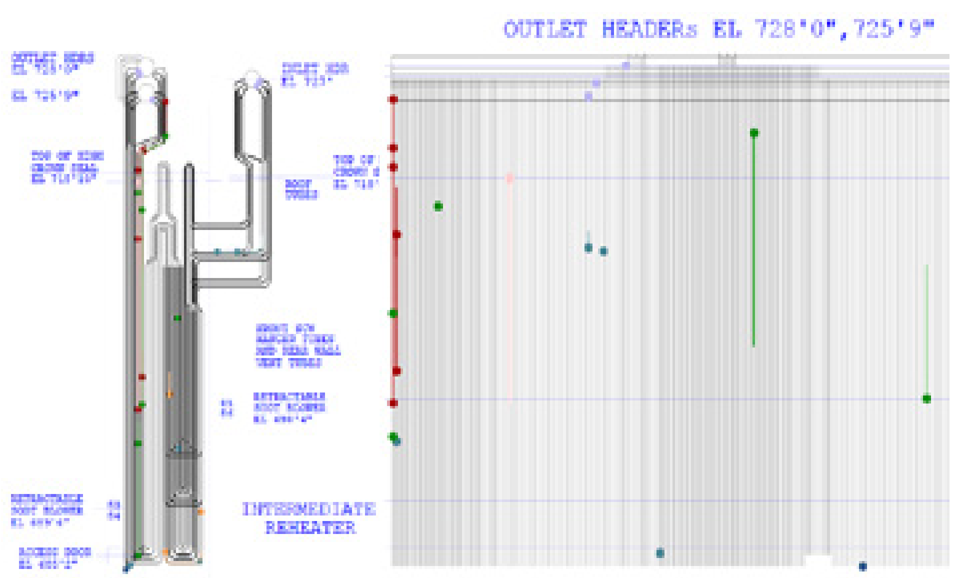

Figure 3 Tube Failures displayed on a reheater

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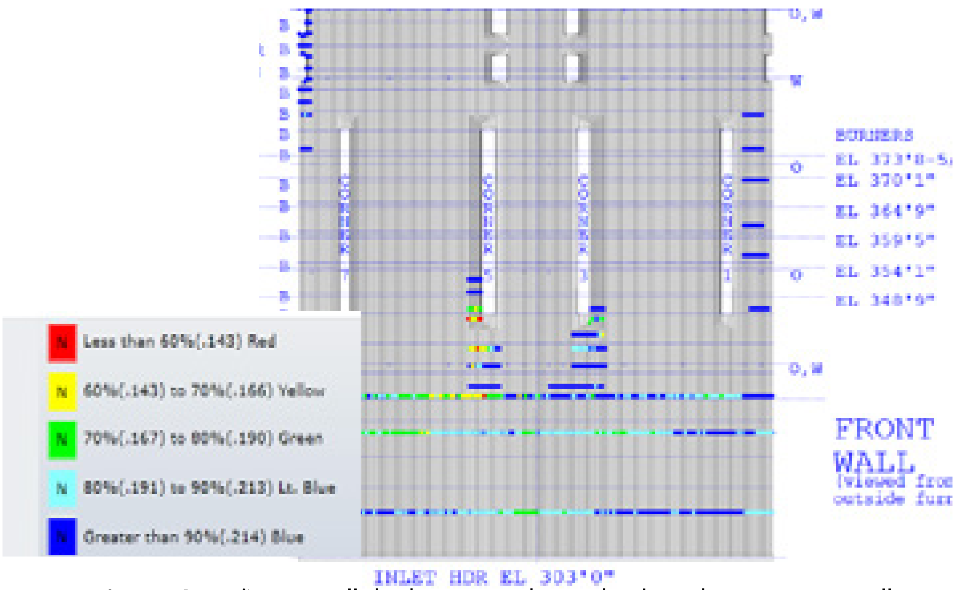

Figure 4 UT/NDE wall thickness readings displayed on a waterwall

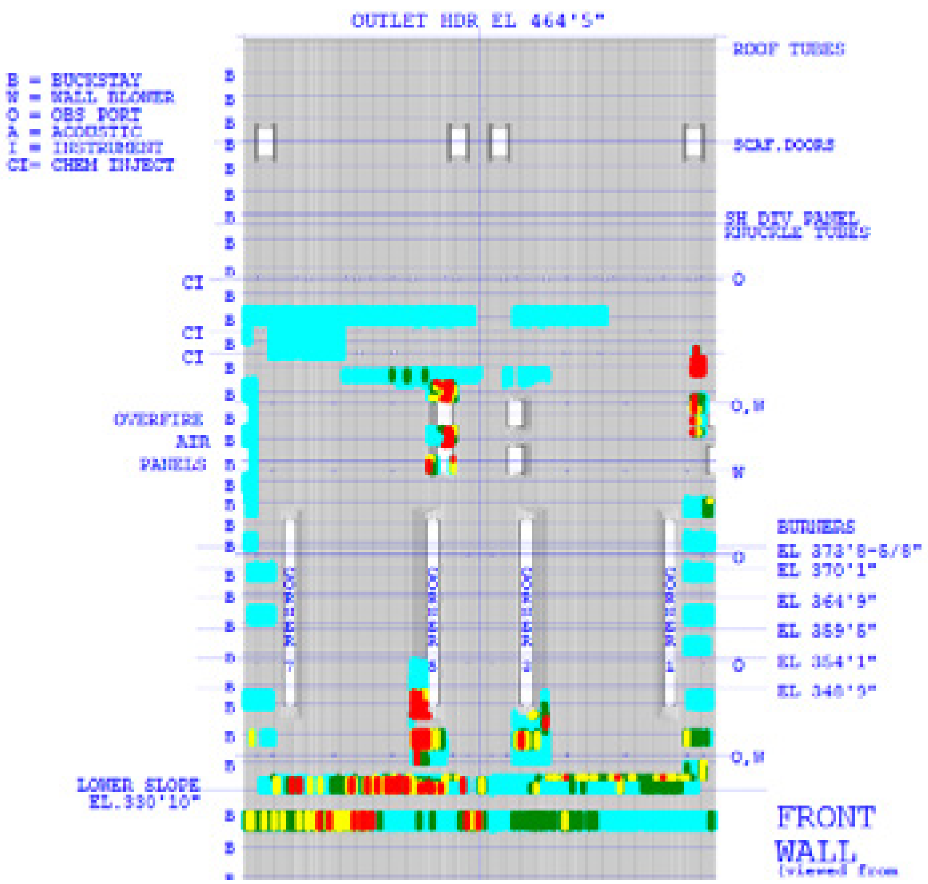

Figure 5 Projected wall thickness values based on existing wall thickness readings.

The graphical filter (easel) feature of PlantTrack allows display of the records as color-coded on the boiler part drawing. The user can select the type of records to display, and assign different colors based on the types, dates, or any detailed field value. These filters can be saved for future uses, as well as made available for other users.

The flexible filter module has enabled the users to come up with methods to visualize any patterns, trends, or to measure effectiveness of tube wastage protection methods. For example, tube failures, or wall thickness readings can be superimposed on the graphics displaying various methods of wastage protection methods applied.

Also a display of padweld locations can be displayed together with the tube replacements already performed.

The records can be graphically entered, or for most boiler parts, multiple records can be entered or edited by using copy/paste feature between PlantTrack and MS Excel. For offline data entry, a PlantTrack plug-in to Excel is available. The user can quickly develop a record entry template in Excel by selecting the boiler part and record type. The template can be filled off-line, and then uploaded to the PlantTrack database. We have optimized the speed of uploading these records. This is necessary as thousands of NDE/UT Wall Thickness readings need to be entered promptly to identify any problem areas.

PlantTrack also allows a quick way to create lists and trend charts using the Quick List and Chart feature. The lists can be created for a boiler part, or at the fleet level. This feature will form the basis of mining the existing records to identify correlations between problem areas and design and maintenance data. Samples of some lists and charts are shown in the figures.

PlantTrack has introduced advanced tools to effectively manage boiler tubing related data. We will be working with our clients to identify areas where we can improve it even further, while adding other PlantTrack modules.

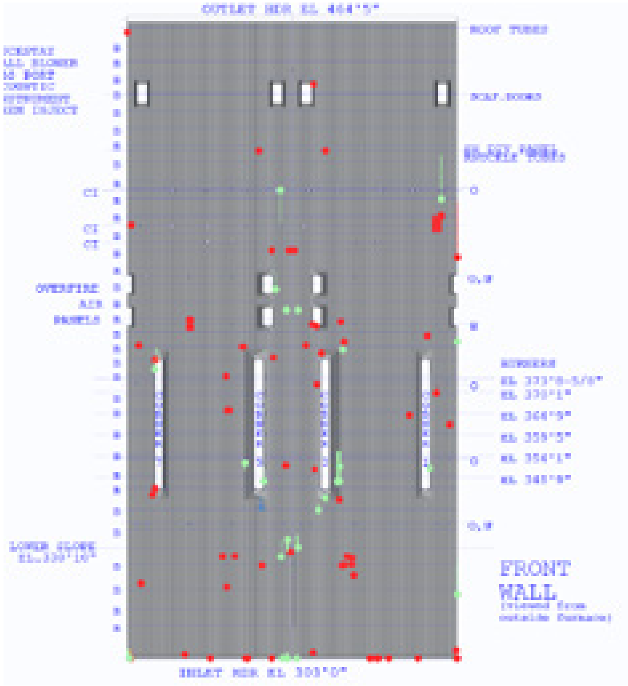

Figure 6 Location of existing padwelds and replaced tubes

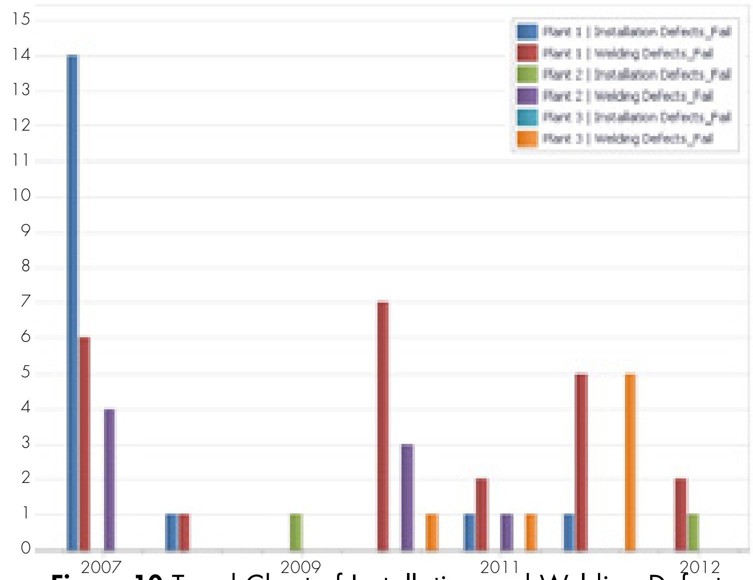

Figure 10 Trend Chart of Installation and Welding Defects Failures

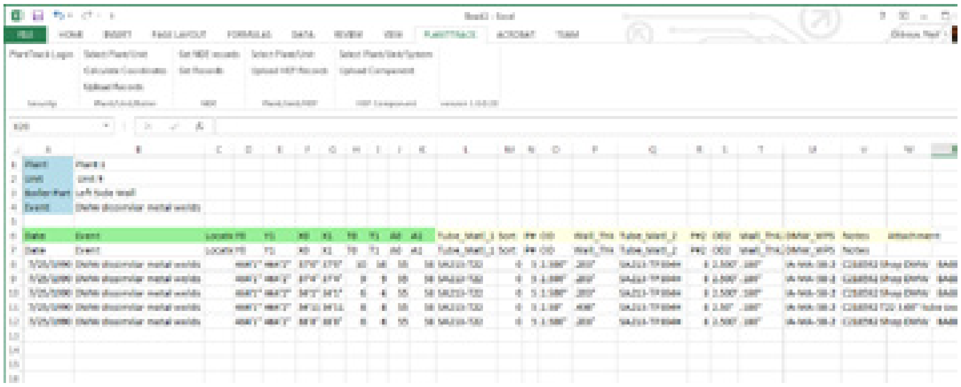

Figure 7 Use of PlantTrack Excel plug-in to enter multiple records

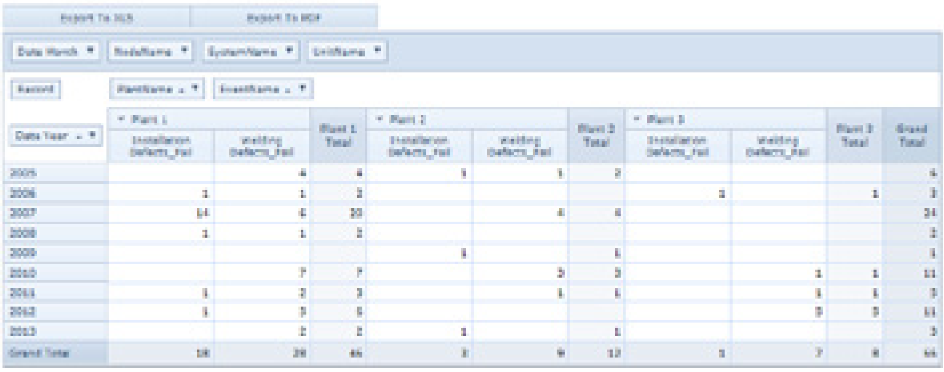

Figure 8 List of Installation and Welding Defects Failures

Figure 9 Pivot Grid of Installation and Welding Defects Failures

LIFE CYCLE MANAGEMENT: MAKING INFORMED DECISIONS BASED ON EXPECTED COSTS

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Historically, nuclear plants have had many decisions on primary system components made for them by NRC directive, by INPO guidance, or by operating experience elsewhere in the industry. For systems like service water, including safety related service water, such directives often do not exist. In addition the size of such systems, often representing the greatest footage of piping, number of pumps, and valves, etc. makes inspections daunting. Buried or otherwise inaccessible portions of such systems further confound the issue. As a result, plant actions have often been reactive and sometimes have been overly reactive to issues where system condition is difficult to characterize or predict. The results have often been that plants continue to experience leaks, at ever increasing rates, or that plants have expended millions of dollars for replacements that may or may not improve performance.

Exelon and Peach Bottom Atomic Power Station (PBAPS) felt that there was a better way.

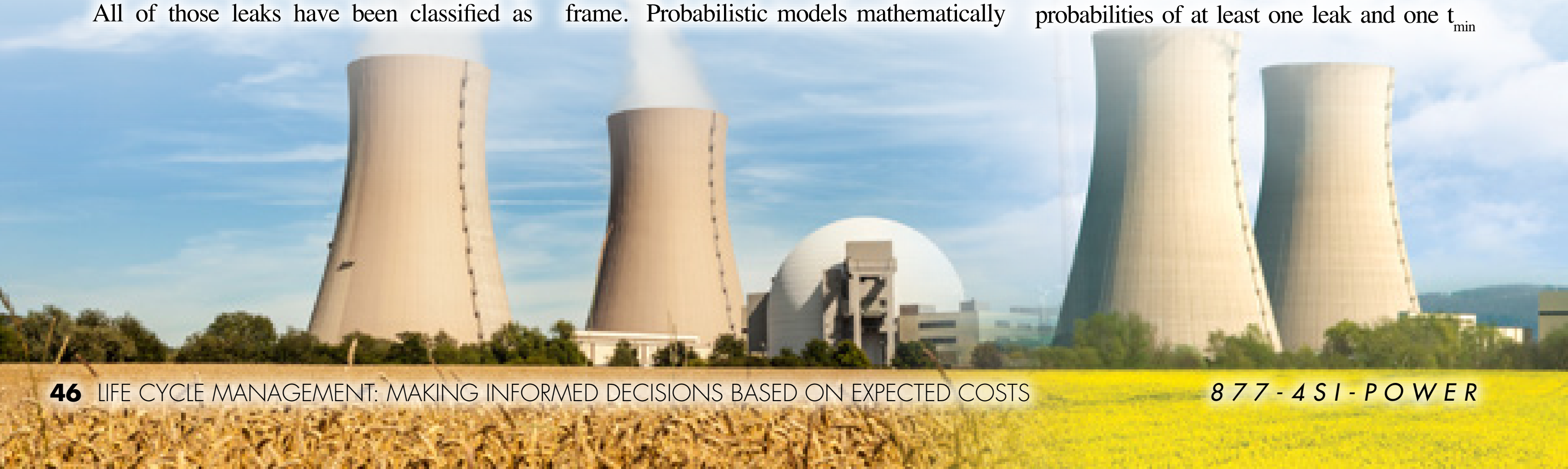
PBAPS is currently inspecting buried safety related piping as part of the station's response to NEI-09-14, the nuclear industry's Buried and Underground Piping and Tank Integrity initiative. A small number of pinhole leaks have been observed in above ground and in some excavated buried service water piping. All of those leaks have been classified as weepers, and all of those leaks appear to be ID-initiated, suggesting that a large majority of issues with the buried safety related piping is and will continue to be ID-initiated.

Exelon and PBAPS commissioned Structural Integrity to provide a Life Cycle Management (LCM) assessment of the three buried safety-related service water systems to provide a method for quantitatively defining leaks, thinning, probability of at least one leak, etc. as a function of time to plan for inspections, repairs, and refurbishments based upon where the plant is in its life cycle, based upon ID degradation (ID degradation only). This study identifies and prioritizes segments based on their degradation, provides an approach that can be used to evaluate candidate alternatives for mitigation of degradation in select safety related systems, and define the optimum timing for the implementation of candidate methods.

Because of the complexity and random nature of corrosion processes, it is difficult to develop mathematically deterministic models to predict corrosion rates incorporating all of the relevant environmental and system variables. However, probabilistic models can be used to closely estimate the distribution of possible thinning and to define the most probable number and distribution of leaks (or other measures of metal loss) in a given time frame. Probabilistic models mathematically integrate statistical distributions describing the various corrosion processes and iterate possible combinations of those distributions a sufficient number of times to achieve confidence in the results. Structural Integrity developed ACCORDION™, a probabilistic model that predicts the spatial and temporal distribution of internal corrosion for water-filled systems based upon system materials, water chemistry, water treatments, flow and flow history (including periods of stagnation), and temperature, using established distributions for the corrosion rates of carbon steel in contact with various water chemistries.

Those corrosion rate distributions are applied to lines and segments of similar size that have exposures to similar environmental histories to produce predicted metal loss vs. time histories for those lines and segments, thus producing inputs to an overall assessment of the condition of a system (large or small) by addressing the corrosion history of segments of the system. The model breaks the overall time of the analysis into time steps that are specified by the analyst to address changes in operating history or changes in the water chemistry/chemical treatment. All pipe sizes, differences in orientation that can be significant to corrosion and deposition, flows, flow histories, temperatures, and line/segment/system length are addressed to treat variables that will affect the overall corrosion response.

Figure 1 shows the type of output that is generated by ACCODIAN for each segment. Each plot shows the remaining wall thickness at the 5th, 50th, and 95th percentiles, the probabilities of at least one leak and one t_{min}



violation, and the numbers of leaks and t_{min} violations over time. Figure 2 and Figure 3 show the compilations of the results from all of the segments.

The LCM evaluation readily identified the segments that will be the greatest contributors to leaks. The evaluation also showed which segments, most prominently several high pressure service water lines to the Turbine Building, will be the primary contributors to t_{min} violations. The relative ranking of segments both for numbers of leaks and for t_{min} violations was the same at 60 years as for 40 years. The results predict that the cumulative number of leaks will increase from approximately 15 (in reasonable agreement with the number of known leaks that have occurred in those systems to date) to approximately 25 by 2023, 41 by 2033, and then increase by nearly 40 per decade for a total of approximately 120 leaks by 2053, assuming no change to operation, chemistry, or treatments. Similarly, the number of t_{min} violations will increase, but at a slower rate than the number of leaks. Therefore, the ratio of t_{min} violations to leaks will decrease from about 20 at present to 11 by 2053 (i.e., >1300 t_{min} violations by 2053).

As would be expected, full implementation of the lining mitigation option was predicted to completely stop the increase in number of leaks and t_{min} violations, upon completion of the lining installation. Other mitigation approaches that leave the piping in place and attempt to decrease degradation by corrosion control measures, such as water treatment, are predicted to significantly decrease, but not eliminate, the number of leaks and t_{min} violations. The methodology used in the LCM evaluation provides the platform upon which these various mitigation options can be compared to the base case (continue the current operations, unchanged), allowing for decisions as to the best approach (e.g., lining vs. water treatment vs. cleaning & water treatment) and the determination of the most appropriate timing for the chosen mitigation approach.

The quantitative results from the LCM evaluation permitted Exelon to apply known or projected costs associated with leaks, t_{min} violations, and costs for mitigation approaches using Net Present Value determination methods to evaluate any selected cases, including "Do Nothing", Install Liners (as a function of time); or Add Corrosion Mitigation Approaches (also as a function of time).

Computed values shown are the 5th, 50th, and 95th percentile for remaining wall, the probability of at least one leak, the probability of at least one t_{min} violation (all read to the left) and the expected numbers of leaks and t_{min} violations (read to the right).

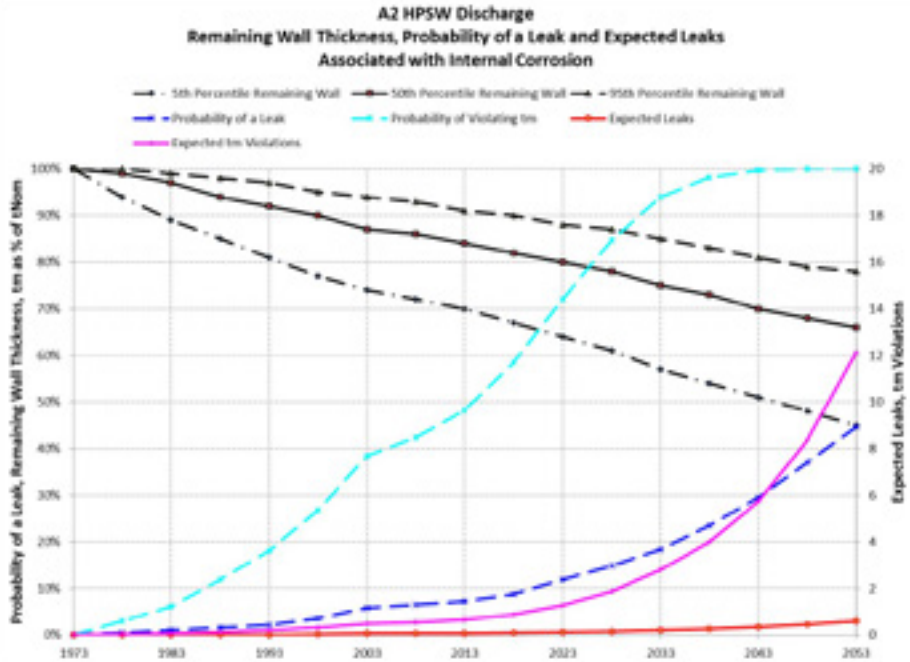


Figure 1. Plot for a typical segment with a relatively small number of leaks at end of life.

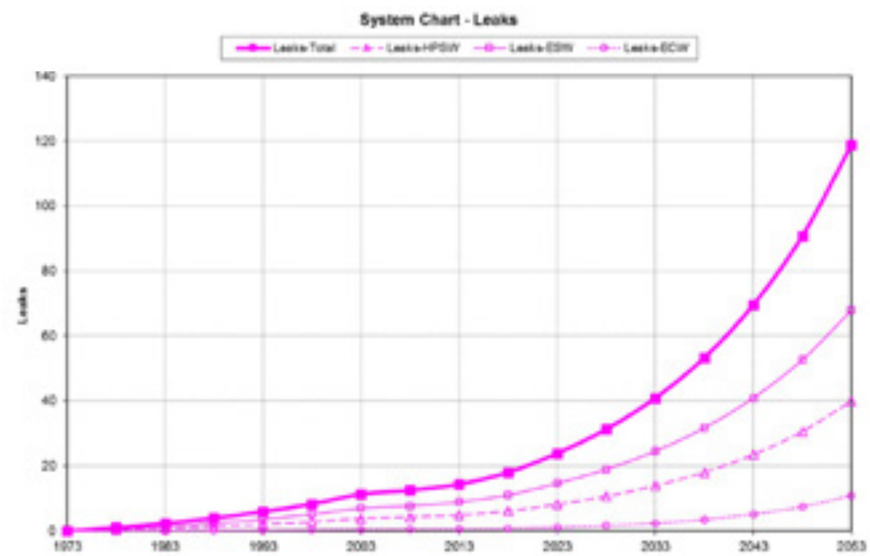


Figure 2. Leak Evolution Diagram for All Segments in Scope

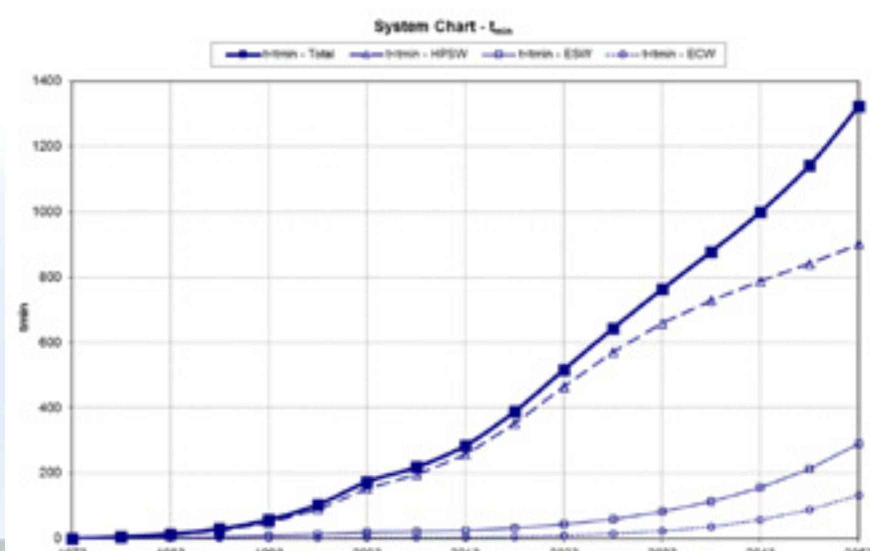


Figure 3. Evolution Diagram for t_{min} Violations for All Segments

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JOE AGNEW
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Please join us in welcoming Bruce Paskett to our Oil & Gas Transmission and Distribution team.

Please join us in welcoming Joe Agnew, Director of NDE Services

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Presenting: Andy Jensen, Structural Integrity

RI Fall Fleetwide Monitoring Interest Group
Albuquerque, NM, *October 28-30, 2014* Exhibiting

ANS Nuclear Plants Current Issues Symposium
Charlotte, NC, *December 7-10, 2014* Exhibiting and Sponsoring

EPRI Turbine Generator Users Group (TGUG) Winter
Amelia Island, FL, *January 19-20, 2015* Exhibiting

EnergyGen Conference
Bismarck, ND, *January 27-29, 2015* Exhibiting

Buried Piping Integrity Group
Palm Coast, FL *February 16-20, 2015* Exhibiting

HRSG Users Group Annual Conference
Orlando, FL, *March 9-11, 2015* Exhibiting (Booth 309)

NACE Corrosion 2015
Dallas, TX, *March 15-16, 2015* Exhibiting (Booth 23056)

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