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NEWS & VIEWS

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ROBOTIC ENCODED PHASED ARRAY pg.6
Ultrasonic Examination of Dissimilar Metal Welds

3D LASER PROFILOMETRY pg.20
External Corrosion Assessment and Modeling Using a 3D Laser Scanner

DIVERSITY IN GUIDED WAVE TECHNOLOGY pg.22
Improving Transmission Pipeline Assessments

FULL SERVICE SEISMIC RISK ASSESSMENTS pg.41
Update on Fukushima Initiatives

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New Generation Technology and the Light Switch

While I'm a supporter of renewables (primarily wind and solar) as a contributor in the overall mix of power generation, I'm unabashed advocate for coal, gas and nuclear power along with renewables. My hesitancy in fully advocating solely renewables is well known – availability, (or more accurately, the potential lack of it) owing to the natural daily fluctuations in weather conditions that serve as the fuel for this generating source. However, my concern could be addressed by advancements in storage. My advocacy for coal, gas and nuclear generation is derived from a strong belief in the science, technology, economics and proven performance of fossil and nuclear power generation. I have observed over my 50+ years that, regardless of the time of day or weather conditions, when I flip that wall switch, my lights always come on and I'm comforted by that long, established correlation. But, there is now a 'new' technology that in time could tempt my advocacy – Small Modular Reactors (SMRs).

I think of coal as the older brother of gas combined cycle plants in the fossil family and liken SMRs to the little brother of conventional units in the nuclear family. If you're not familiar with SMRs, there are several companies around the world currently designing small scale reactors and, in general, they all share a number of similar characteristics. Specifically, they are "modular" in design and are planned to be manufactured completely in a factory and delivered and installed at the site in modules, giving them the name "small modular reactors". The designs are essentially much smaller conventional reactors – 300MW or less – with fewer support systems and a greater reliance on passive safety systems. The goal of the designs is higher safety and simplicity. In addition, many designs are introducing no new technology so there's nothing different in water chemistry, alloys, reactor technologies and fuel storage.

Construction costs are anticipated to be comparable to those for a conventional nuclear plant on a $/kW basis, largely due to the ability to manufacture major components and assemblies, including the entire reactor, in a quality-controlled factory. Operating costs may also be lower but will be highly dependent on the imposed nuclear regulations. Projected costs are likely to increase because the technical development work is not yet complete and because the U.S. regulators appear to have made little progress in determining how regulations should be modified to accommodate SMRs.

The primary U.S. opportunity for SMRs is in distributed generation; i.e., locating a plant near the electrical load to avoid large-scale transmission, locations where cooling water is restricted and for repowering existing facilities of a moderate scale. Although several units could be grouped together to replicate the size of an existing large nuclear facility, that is generally not the intended purpose of the SMR and doing so limits some of the advantages of the design. Additional opportunities for SMRs are self-contained and non-electricity production facilities. With a relatively self-contained design (up to 10-year refueling, modular construction), the SMR can be installed in remote locations that do not have easy access to conventional fuels (oil, natural gas or coal) or a large network of transmission lines. Those advantages could also be used to provide steam for industrial purposes, desalination, oil extraction, etc.

Why are SMRs tempting me even though the technical development, design, cost and regulatory issues have yet to be finalized and, it could be argued, no operating experience exists? First, I believe in the science and technology of nuclear power for generating electricity. Even with the highly publicized events in the nuclear industry -- TMI, Chernobyl and most recently Fukushima – I believe nuclear power might well be the safest, most reliable and available electric power generation technologies available to us and to future generations.

Second, I appreciate the scalability and flexibility offered by SMRs – not one size or purpose has to fit all – take one SMR if you need it and add more as the demand or need dictates.

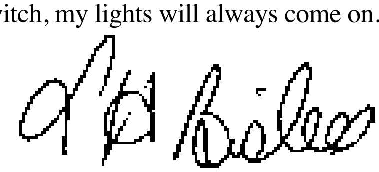
SMRs seem almost ideal (nothing is perfectly ideal) for repowering retired coal plants – the required infrastructure is already there (siting, transmission, water, etc.) so all that's needed is a safe, economical, environmentally friendly, reliable technology to produce steam – technology that's available to produce steam at any time of the day or night and any day of the year. Current repowering is almost exclusively limited to gas. While I strongly support gas, I can really get behind a diversified generation base.

SMRs could also be a local and committed power source for isolated facilities like military bases, large manufacturing complexes, universities, or municipalities and replace some of the out-dated generation currently being used (e.g., diesel generators).

As an engineer and consumer, what do I need to see to become a bona fide advocate of SMRs?

- First and foremost, a national energy policy endorsed and supported by all branches and departments of government. It's way past time that our country had one to guide our decisions in the decades ahead.
- Second, a realistic solution to long term spent nuclear fuel, whether it be storage, re-use or the alchemy to turn it to gold.
- Third, an accelerated SMR design qualification and approval process, followed by prototype build and testing. While there's excess capacity today, starting new builds soon will ensure the required capacity is available when needed. In addition, designing, manufacturing, constructing and operating new plants based on new technologies create jobs – lots of them – especially if you build lots of plants, not just one or two every few decades.
- Finally, support of a rigorous, unbiased, comparative financial analysis with all other power generation technologies. I believe certain regulatory and governmental agencies don't fully appreciate the impact of their decisions, but maybe they'll understand financial analysis if they can't grasp the technical realities.

My hopes are high that SMR technology, founded on 50+ years of highly successful nuclear power experience, will become another cornerstone of reliable power for the U.S., taking a place of prominence alongside gas, coal, and conventional nuclear plants. If that happens, I know that when I flip that wall switch, my lights will always come on.



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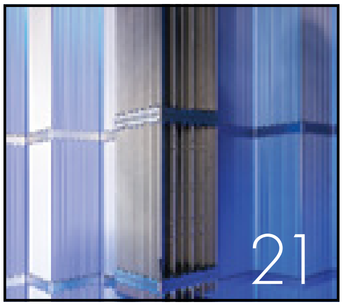
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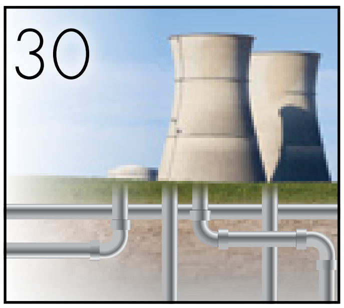
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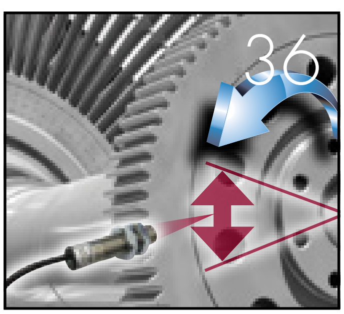
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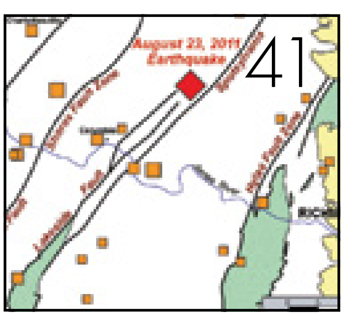
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43

ROBOTIC ENCODED PHASED ARRAY

Ultrasonic Examination of Dissimilar Metal Welds


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Structural Integrity (SI) recently completed robotic encoded phased array ultrasonic examinations of seven dissimilar metal welds (DMWs), which included piping welds in the Reactor Coolant System (RCS) Cold Leg Drain, Spray and Charging systems, in response to the requirements of Code Case N-770-1. Code Case N-770-1, approved by the NRC for use on November 15, 2011, requires the examination of DMWs in piping that was previously exempted from examination based on its small nominal pipe size (NPS). The subject DMW configurations all have an NPS smaller than the previous size exemption threshold of 4” NPS and are all now required to be examined, based on the new NPS and operating temperature (≥ 525˚F) parameters of N-770-1.

We completed these DMW examinations utilizing the Procedure for Encoded, Phased Array Ultrasonic Examination of Dissimilar Metal Piping Welds (Zetec OMNISCAN Raster 03), which was developed by the Electric Power Research Institute (EPRI) NDE Center and qualified through the Performance Demonstration Initiative (PDI) to provide a raster scan technique for the acquisition of circumferential flaw data instead of the electronic line scan technique previously used in the procedure. The raster scanning technique allows for the use of a smaller search unit footprint and may potentially provide improved examination coverage for configurations with limited access or components containing tapered surface geometries.

The tapers and limited access associated with the Cold Leg Drain, Spray and Charging DMWs, and the associated interferences with the run piping, the surrounding structures, and the outboard piping configuration, required a specialized ultrasonic scanning device to be developed.

We designed and modeled the specialized delivery tooling to ensure that there were no clearance issues or coverage limitations during field implementation. Additionally, all specialized tooling subcomponents were fabricated and assembled by our machinists at Structural Integrity and tested on full-scale component mockups.

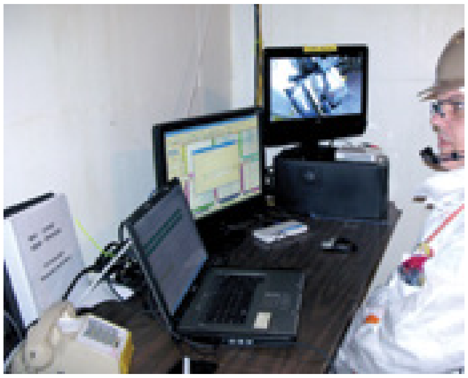
The use of a mechanical raster scan technique required additional personnel training. Training was conducted by EPRI NDE and our project supervisory staff for SI’s ultrasonic scanner personnel, data acquisition and data analysis personnel. The training employed both open DMW samples at EPRI and full-scale component mockups with the complete ultrasonic system at our Huntersville, NC facility. The development effort included fabrication of a mockup stand with full-size nozzles to support equipment assembly and check out.

EPRI involvement was required for procedure expansion to address the smaller and tapered cold leg nozzles. In support of this expansion, we expended significant effort to support the EPRI qualification, including providing equipment and personnel to maintain the necessary schedule.

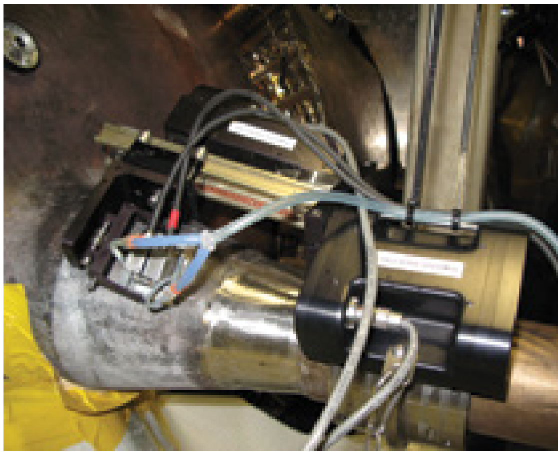
Given the late start for procedure expansion, the accelerated schedule that was required to support the implementation in Spring of 2012 included the following:

- Issuance of the EPRI procedure and PDQs as late as three weeks before actual production use of the procedure.
- Training of SI personnel at EPRI on the procedure as late as 4 weeks before actual production use of the procedure
- Performance of the Client Readiness Review 2 weeks prior to mobilization to site for actual implementation.

We worked closely with the client site personnel. Combining that with the use of the well-designed, well-tested, and pre-packaged SI equipment, only one day was needed to move equipment into containment and set up, and begin actual scanning inside. Shown to the right are pictures of the test configurations including the portable data acquisition set up inside containment.



Portable Containment Data Acquisition Control Station

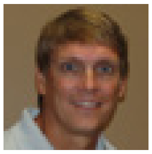


Once examinations began, the production rate for the first-time use of the equipment was sufficient to complete equipment setup, examination, and equipment teardown for all seven nozzles in seven single-shift days.

Of greatest importance in these exams, and the rationale for the encoded exams themselves, was the resulting ability to carefully evaluate any potential indication using the encoded phased array data. As a result of this data, our on-site Level III was able to disposition several "areas of interest" in the seven welds as non-reportable indications. Using the reviewable encoded phased array data, this evaluation was done in concert with client NDE personnel and therefore avoided the need for flaw evaluation, and potential weld overlay repairs.

The same equipment will be utilized in Fall of 2012 and Spring of 2013 to complete similar exams for the remaining units at this three-unit site.

DETAILS OF UNUSUAL GRAPHITIZATION IN P1 (C-1/2MO) SH INLET PIPE



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[Note: Results discussed in the article are presented in detail in the ASME 2012 PVP Proceedings.]

After a series of failures in SA-335, Grade P1 (C-½Mo) piping in a superheater inlet system, Structural Integrity conducted an investigation into the failures that revealed that cracking in the extrados regions of the bend sections occurred due to an unusual form of graphitization. The failures occurred over a period of several years, with the most significant failure occurring in 2011, after approximately 275,000 hours of operation at an average operating temperature of approximately 830˚F.

Graphitization in P1 steel is by no means uncommon. However, the graphitization in the subject piping developed in a manner that had not previously been observed, with the individual graphite particles forming as small (micro) nodules preferentially concentrated within grain boundaries oriented normal to the hoop stress. This alignment of the damage resulted in significant degradation of the material toughness in the tangential (hoop) direction. The damage was also unusual in that, although it resulted in the creation of distinct planes of weakness through the material, it was not associated with welds or distinct planar regions of shear strain (common locations for graphitization damage to occur).

As part of the analysis of this unique form of graphitization, testing was performed using cryo-cracking, scanning electron microscopy, energy dispersive spectroscopy, and X-ray diffraction; in addition, mechanical tests were carried out to quantify the extent of the material degradation. Due to the range of damage levels observed, a five-level damage ranking system was developed, similar to that used for creep damage evaluations. Although details regarding the original manufacture of the P1 piping, and in particular, the bending process, were not available, the testing results indicated that cold forming was a key factor in the observed damage morphology.

The failed piping was fabricated from 6-5/8" OD x 0.935" nominal wall thickness, seamless C–½Mo steel produced in the late 1960's. The material had been installed as primary superheater (PSH) inlet piping in a once-through, supercritical, balanced draft steam generator firing Eastern bituminous coal. The reported average operating temperature was 830°F at an operating pressure that ranged from 3,400 to 3,800 psig (below the design pressure of 4,180 psig). A number of prior failures had also been reported, dating back almost 20 years, but only the failures in 2009 and 2011 could be confirmed as graphitization-related (after the damage mechanism was identified in 2011). The most recent failure occurred along the extrados of a 90° bend with a 24-inch bend radius (Figure 1). The longitudinal fracture was about two feet in length, OD-initiated, and thick-lipped, with no evidence of macro-ductility.

Figure 1. View of the Thick-Lipped Extrados Rupture

GRAPHITIZATION BACKGROUND

Graphitization is generally defined as the formation of free carbon, or graphite, in steel. When graphite forms, it can exist in several different forms at different locations in a component. "Secondary" graphitization (in which graphite forms subsequent to the solidification process) is considered as a degradation mechanism and has been studied extensively since prior to WWII. It is typically categorized by type (nodular or chain graphitization) and by location ("weld-related", i.e., within the weld/HAZ, or "non-weld-related"). A common location for graphitization to occur is in the coarse-grained region of the Heat Affected Zone (HAZ) of welds. In this case, the graphite is often present as clusters of "nodules" in or near the weld. Nodular graphite can also occur volumetrically within carbon and carbon-moly steels, and is often termed "non-weld-related" graphitization. Because of the approximately "round" shape of the nodular graphite and its random distribution throughout the material, mechanical properties are not significantly affected in steels with limited amounts of random nodular graphitization.

"Chain" graphitization, which is another form of secondary graphitization, occurs when individual nodules of graphite link together along a favored metallurgical path within the steel, thereby creating a plane of weakness. Research in the early

1930's identified this form of damage along HAZs, including in locations along grain boundaries. Chain graphitization can also involve the localized formation of clusters of graphite nodules along planar regions of prior cold work, or slip bands.

A general industry rule of thumb has been that graphitization in carbon and carbon-moly steels becomes significant only at temperatures greater than about 800°F, with spheroidization (a competing damage mechanism) occurring at higher temperatures (around 900°F or above). There is also an increased potential for shorter formation times as the exposure temperature is increased. Because predicting graphitization is difficult, we take a conservative approach to dealing with in-service management of graphitization through well-prepared planning and inspection programs.

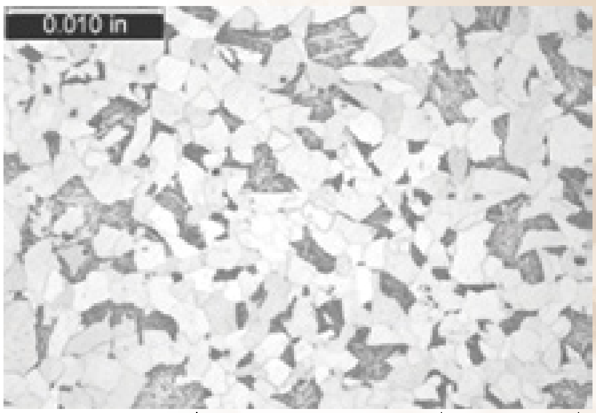

Figure 2. Typical P1 Microstructure in the Examined Samples (Etchant: Nital)

SAMPLE TESTING

After the rupture of the PSH inlet piping bend, a total of 19 pipe samples were destructively tested, with a total of 140 metallographic samples prepared from the bend and straight regions of submitted pipe sections. Of the 19 pipe samples, 11 were subjected to mechanical testing and a detailed chemical analysis was performed on 15 of the samples. Multiple locations on bend and straight sections of piping were examined, but emphasis was placed on the extrados region of bends, which is the location where OD initiated cracks had been occurring in the pipe.

Metallographic mounts were prepared to allow for examination of the transverse microstructure. The typical P1 microstructure observed in all pipe samples consisted of bainite colonies in a ferrite matrix with scattered non-metallic inclusions, with no evidence of advanced spheroidization of the original carbides (Figure 2). Representative images of the identified grain boundary graphitization, which was more easily detectable in unetched samples, are shown in Figures 3 and 4. Examination of samples in various orientations revealed that the damage was generally planar in nature, and aligned in the radial and longitudinal directions. We observed variations in the extent of damage present, which necessitated a ranking system, and defined damage levels between 1 (no observed damage) and 5 (microcracking and/or cracking present). A summary of the observed maximum damage level for each region (bend/straight) of each pipe sample analyzed is provided in Table 1. Note that virtually all significant damage was observed in the bend regions of the tested pipe, indicating that the original bending process strongly influenced the formation of graphite in these samples.

Charpy impact testing performed on samples removed transverse to the pipe axis were performed at room

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Figure 3. Grain Boundary Graphitization within the Base Metal (Bend Region, Unetched, Transverse Orientation

Figure 4. Same as Figure 2, Higher Magnification View of Graphite Along Grain Boundaries

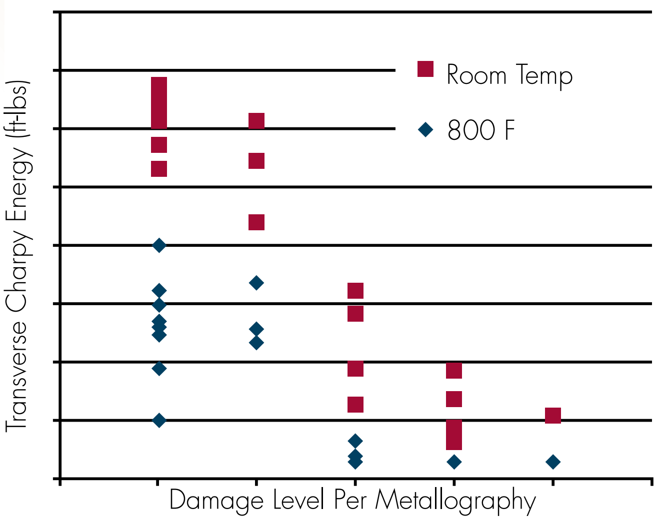


Figure 5. Transverse (Hoop Direction) Charpy Impact Energy as a Function of Volumetric Grain Boundary Graphitization in SA-335 Grade P1 Steel

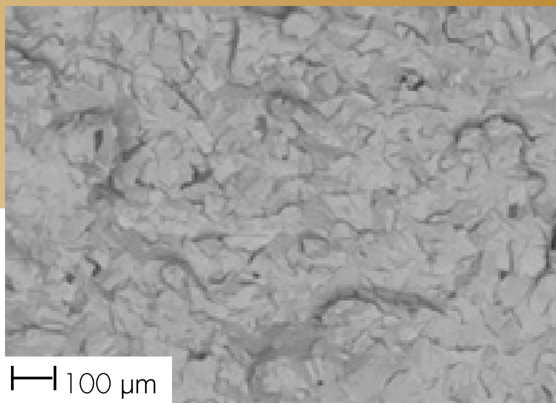


Figure 6. SEM Image of Cryo-Cracked Fracture-Small Dark Patches are Regions of High Carbon Exposed via Intergranular Fracture

temperature and at 800°F. Due to the orientation of the damage, we considered the transverse Charpy data as the best indication of loss of toughness in the hoop stress direction. The results from this testing, when plotted versus the observed damage level (from the metallographic samples), shows a strong correlation between the degree of damage and a loss of toughness within the P1 material (Figure 5). In addition to the Charpy testing, we performed hardness testing on multiple locations on seven pipe sections. The average bend region hardness was 184 Vickers, while the average straight region hardness was 162 Vickers, with the difference being attributed to the bends having been formed "cold" with no subsequent post-forming heat treatment, a common practice at the time these bends were fabricated.

Of the 19 pipe samples we evaluated, 15 were analyzed to determine the materials' chemical composition. The identified compositions indicated that all materials met the requirements for P1 steel. Of particular interest were relatively high levels of aluminum, which were found to range from about 0.025 to 0.055 weight percent. The potential influence, if any, of the aluminum content on the observed damage morphology has not been evaluated, although previous studies have suggested a strong link between the aluminum content and the time-to-initiation of graphitization in carbon and carbon-moly steels.

Scanning electron microscopy (SEM) and energy dispersive spectroscopy (EDS) were used to evaluate the elemental composition of the material identified along the grain boundaries, with the dark grain boundary regions repeatedly exhibiting very strong carbon peaks with no detectable traces of any other elements that might be associated with carbide formation, oxidation product, contaminants, etc. These results were consistent with graphitization of the steel.

To further evaluate the damage, we machined small bars from the damaged P1 pipe with the long axis oriented in the hoop direction of the pipe. The bars were cooled to 77 Kelvin, and fractured to expose a fresh surface oriented parallel to the orientation of the fracture plane in the ruptured pipe. SEM examination of these "cryo-cracked" samples with high damage levels (determined by optical metallography) revealed patches of dark material on grain boundary surfaces exposed by intergranular cracking (Figures 6 and 7). EDS analysis revealed high carbon levels in the dark regions and no evidence of other elements not associated with the base metal. Even in a sample with no identified damage identified via optical metallography, light (incipient) damage was present in the cryo-cracked sample (Figure 8). This damage consisted of relatively light specks of carbon in scattered patches that were more dispersed in comparison to severely damaged material.

We also used x-ra diffraction (XRD) to analyze an exposed fracture in a cryo-cracked specimen. An XRD scan was performed on the fracture surface, and on a machined

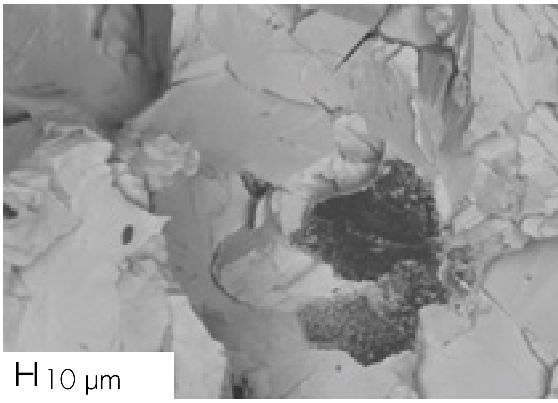


Figure 7. SEM Image Showing Concentrated Carbon at an Exposed Grain Boundary (Bend Region)

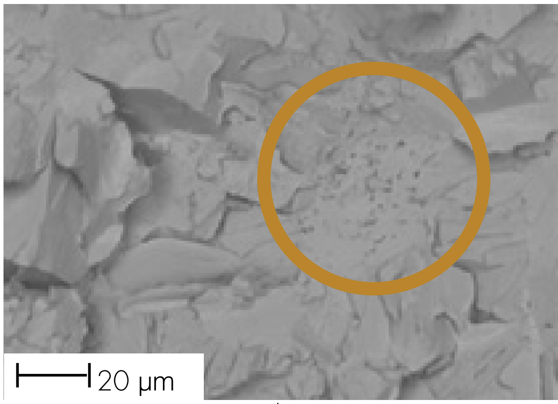


Figure 8. SEM Image Showing Incipient Grain Boundary Graphitization (Specks) not Detectable with Metallography

surface of the same bar. Comparison of the results from each location revealed a local peak that corresponded to graphite in the fracture surface scan, thereby confirming the nature of the material located within the grain boundaries.

TABLE 1 SUMMARY OF GRAIN BOUNDARY GRAPHITIZATION DAMAGE LEVELS1 AND MECHANICAL TEST RESULTS2 FOR P1 PIPE SAMPLES

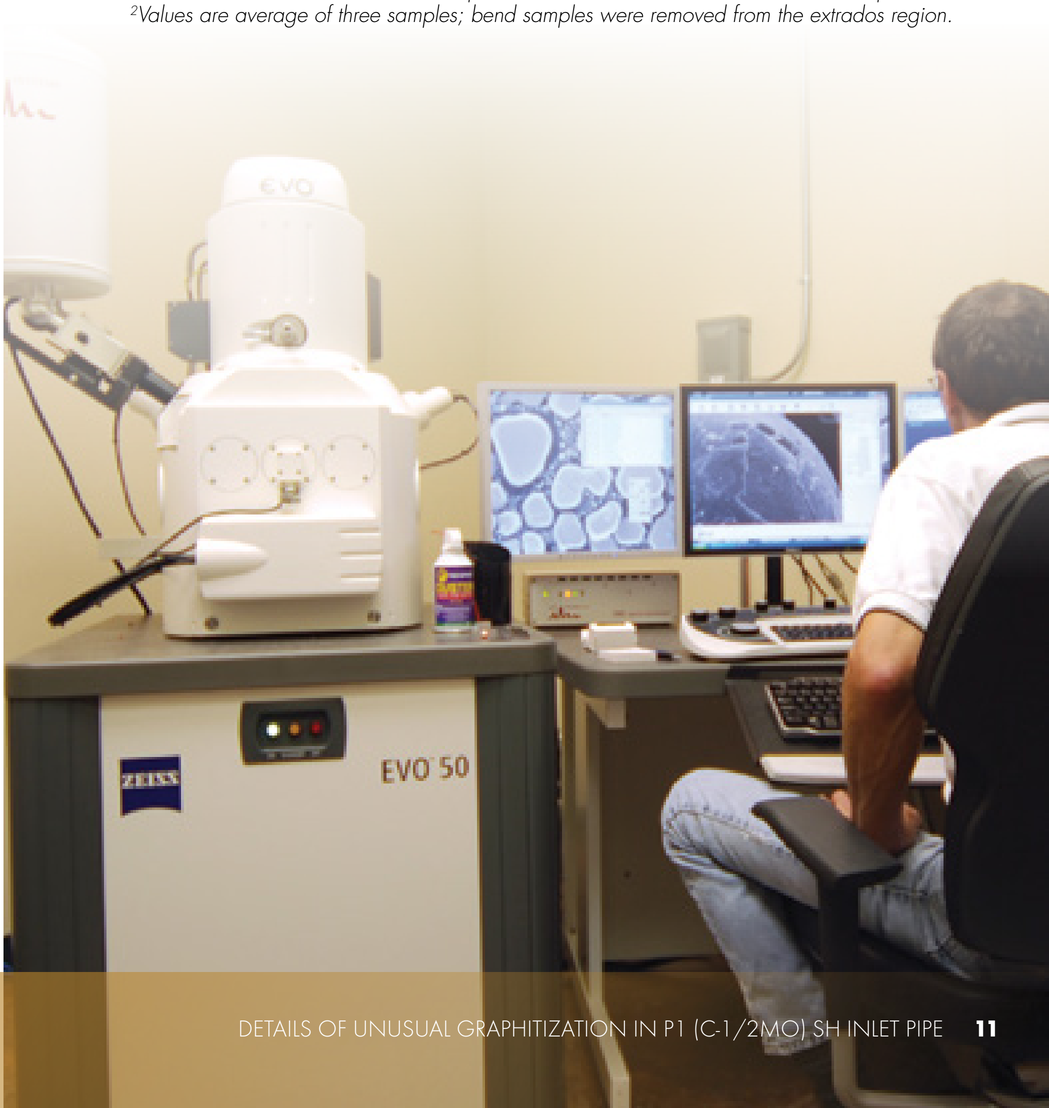
PIPE SAMPLE ID	OBSERVED DAMAGE LEVEL (BEND)	OBSERVED DAMAGE LEVEL (STRAIGHT)	ROOM TEMP TRANSVERSE CHARPY ENERGY IN FT-LBS (BEND)	ROOM TEMP TRANSVERSE CHARPY ENERGY IN FT-LBS (STRAIGHT)	800 F TRANSVERSE CHARPY ENERGY IN FT-LBS (BEND)	800 F TRANSVERSE CHARPY ENERGY IN FT-LBS (STRAIGHT)
1	5	2	3	34	11	44
2	5	-	-	-	-	-
3	4	2	3	26	8	61
4	4	1	-	-	-	-
5	2	-	-	-	-	-
6	3	2	-	-	-	-
7	3	2	-	-	-	-
8	1	1	-	-	-	-
9	1	1	10	27	53	68
10	1	1	-	-	-	-
11	3	1	3	19	13	62
12	3	1	4	25	19	63
13	4	1	3	40	14	66
14	4	2	3	24	19	55
15	3	2	-	-	-	-
16	4	1	3	30	9	57
17	4	1	3	26	6	61
18	3	1	6	32	28	64
19	3	1	3	19	32	57

[1]For bulk metal; value reported is maximum level observed at all clock positions
[2]Values are average of three samples; bend samples were removed from the extrados region.

CONCLUSIONS

The influence of plastic deformation on the graphitization process is clearly supported by the distinct relationship between the degree of damage observed, the hardness measurements, and the location of damage within the bend regions of the pipe. Aside from the appearance of similar graphitization features near a weld evaluated by Emerson in the early 1940's, the observed form of volumetric grain boundary graphitization does not appear to have been documented within the open literature. Further, the aligned grain boundary graphitization identified in these samples promotes anisotropy in the pipe and causes embrittlement of the steel, particularly in the hoop stress direction, and this effect is present at operating temperatures as well as at room temperature. We recommend that owners of plants using similar materials under similar operating conditions be aware of the potential for graphitization damage to occur, and consider implementing appropriate testing if the potential for grain boundary graphitization exists, based on operating history.

For more information, review the ASME PVP 2012 Technical Paper at www.structint.com/technical-papers



North Anna Weld Overlay Project is Seamless Success

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Earlier this year, Structural Integrity Associates and Aquilex WSI – in a partnership known as W(SI)^2 – completed the nuclear industry's largest weld overlays to date. The goal of the project was to mitigate Alloy 600 SCC risk at the steam generator (SG) hot leg nozzle welds at Dominion Virginia Power's North Anna Unit 1.

Despite challenges with a late design change, discovery of leaking flaws, and the sheer size of the weld overlays, W(SI)^2 and the utility team were able to successfully complete the job safely and on schedule.

BACKGROUND

The North Anna plant is unique in the U.S. nuclear fleet in that the dissimilar metal (DM) welds joining the steam generator hot and cold leg low alloy nozzles to the stainless steel primary piping contain Alloy 82/182 (600). These materials are susceptible to SCC in PWRs.

The base nozzle configuration included a 41" outside diameter carbon steel nozzle (approximately 5" thick) joined to a stainless steel safe end which, is joined to the cast stainless steel primary piping. The weld between the nozzle and safe end consists of Alloy 82/182 filler metal. The weld between the safe end and cast stainless primary loop pipe contains stainless steel filler metal. The nozzle, DM weld, and safe-end have an 11° as-built taper.

Previous nondestructive examination of the hot leg and cold leg nozzles found no indications of flaws or cracking in any of the six nozzles. However, as part of its Alloy 600 Program, Dominion Virginia Power chose to proactively mitigate Unit 1's three hot leg nozzle DM welds.

After considering several mitigation options, the utility selected W(SI)^2 to implement a full structural weld overlay (FSWOL) approach during the plant's April 2012 refueling outage. The original schedule called for approximately 25 days from set up to final UT.

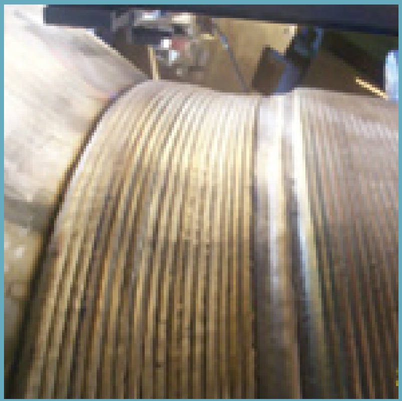
PLANNED MITIGATION APPROACH

The project presented several significant challenges to the W(SI)^2 team:

- Large nozzle geometry
- Severely restricted access for equipment operations
- 6G orientation (45-degree angle)
- Thick overlay design
- Limited time window for application

Full-Scale Mockup at Aquilex WSI

W(SI)^2 overcame these challenges by designing an overlay that met all ASME Code requirements and could be applied to the tapered nozzle and inspected using a Performance Demonstration Initiative (PDI) qualified procedure. Our team also modified welding and machining equipment to fit within the restricted access envelope (eliminating the need for significant interference removal) and to accommodate the 6G weld orientation.



In-Process Welding on MockUp

For this project, WSI developed advanced techniques to increase the weld deposition rate by an expected two to three times historic rates, while maintaining first-time quality.

In light of the scale and complexity of the project, the team used three full-scale mockups, including simulated DM welds, to test and demonstrate the process and verify equipment fit and function.

DESIGN CHANGE

Due to the 11° as-built taper of the configuration, Dominion Virginia Power required an NDE 'demonstration' to provide added confidence that the PDI qualified procedure for post-WOL examination was suitable. A number of issues occurred with the related NDE demonstration block fabricated by a third party – issues not fully resolved even with rework of the block. Due to the time constraints, Dominion Virginia Power and W(SI)^2 decided to change to a standard (or flat) WOL design that would not require NDE demonstration. The team expedited the re-design effort, completing it within five weeks.

The revised design reduced the thickness of the nozzle and safe-end base material over the DM weld by approximately 20% of its original thickness allowing for a thinner overlay (~1.6") than the previous design with a flat profile. To reduce WOL length, the stainless steel weld would not be covered by the WOL as it was in the original design.

Despite the need to remove approximately eight times more material than initially planned for the revised design via machining, the baseline schedule was marginally increased.

IMPLEMENTATION

Our crew and equipment mobilization began approximately two weeks prior to plant shutdown. Our team arrived at the site with four complete welding systems to allow work on the three nozzles to take place simultaneously (with the remaining system held as a spare).

Prior to commencing the WOL activities, all three SG Hot Leg DM welds were UT examined by a Dominion Virginia Power contractor. This was intended to allow the new FSWOL to be classified as Inspection Item C, "Uncracked butt weld reinforced by full structural weld overlay of Alloy 52/152 material" per ASME Section XI Code Case N-770-1. Like prior examinations performed at these locations, no flaws were identified by the pre-WOL examinations.

However after the machining preparation of the 'B' nozzle (i.e., machining the OD contour flat), two through-wall leaking indications were discovered. With this discovery, Dominion Virginia Power performed additional examinations of this nozzle using both conventional and phased array techniques. These iexaminations found three additional axial flaws that were approximately 50% through wall. (No flaws were found on the 'A' or 'C' SG Hot Leg or within any of the three SG Cold Leg DM welds).

Additional SI analysis of the FSWOL design was required to accommodate the as-found flaws (i.e., 100% or through-wall flaws). Although the re-analysis resulted in a decrease in the design life, it still met the desired 10-year re-inspection frequency.

Leak Location

Upon evaluation of the flaws in the B-nozzle, it was decided that the two through-wall defects would be addressed by excavating the base metal of the flaw area to a depth of 0.25 to 0.30 inches, then mechanically peening the affected area to seal the leaks. Following the excavation and mechanical peening, pre-weld heat treatment was applied and the cavity was filled with weld filler material. A manual

Continued on next page

ALLOY 600 UPDATE

CONTINUED

temperbead SMAW base metal repair was chosen utilizing Alloy 152 and 182 filler metal. After the weld repair, a four-hour post-weld soak was required prior to grinding the repair flush with the existing base metal. Liquid penetrant examination was performed and found no remaining surface indications. An intermediate localized examination of the area was also planned and executed after completion of five (5) layers of WOL application.

The team completed FSWOL on all three nozzles using a double-up welding technique to minimize potential for fusion defects and low dilution welding parameters to minimize welding defects. A fully automatic dual head machine gas tungsten arc welding (GTAW) process was used to complete the FSWOL. The application included two stainless steel buffer layers, Alloy 82 bridge beads, three Alloy 52M ambient temperature temperbead layers, and approximately 12 Alloy 52M overlay fill layers. Overlay thicknesses were approximately 1.6 to 1.7 inches thick and the overlay lengths were between 11.5 to 14.5 inches, depending on the nozzle-specific geometry. The crew worked on all three nozzles in parallel to meet an aggressive 25-day overall schedule.

The final configuration of the 'B' FSWOL was consistent with 'A' and 'C' and stayed within the design drawing, with one minor deviation that was deemed acceptable. As a result of the 'B' leg nozzle weld flaws, it is now classified as Inspection Item F "Cracked butt weld reinforced by full structural weld overlay of Alloy 52/152 material". Dominion Virginia Power will perform a re-inspection during the first or second refueling outage following the April 2012 outage before reverting to a 10-year inspection interval.

After WSI completed the required surface conditioning and surface examination of the weld overlays, SI's PDI-qualified fully-automated (encoded) phased array ultrasonic examination system was employed to provide volumetric examination of each weld-overlaid component. SI's ultrasonic system was able to readily detect and provide length and through-wall sizing dimensions of all five of the base material flaws that were found prior to the application of the weld overlay material of SG "B".

Separately, a Dominion Virginia Power root cause team investigated why the flaws found in the B-nozzle were missed during previous examinations in 2009, as well as the inspection just prior to installation of the weld overlay.

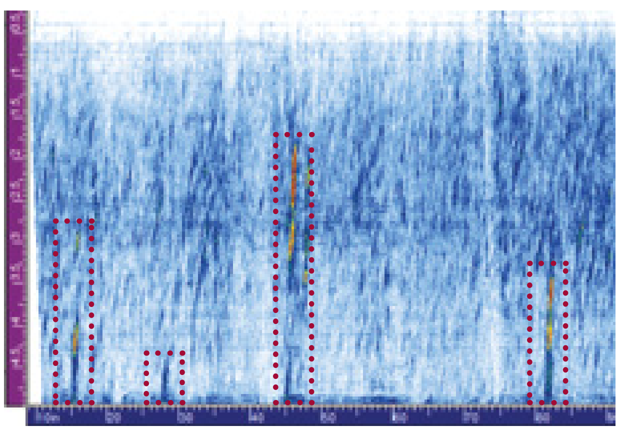
RESULTS

The North Anna FSWOL project was a success, meeting all safety, quality and schedule goals. The project team was able to overcome challenges to meet management expectations and finished within 1.5 shifts of the 25-day schedule.

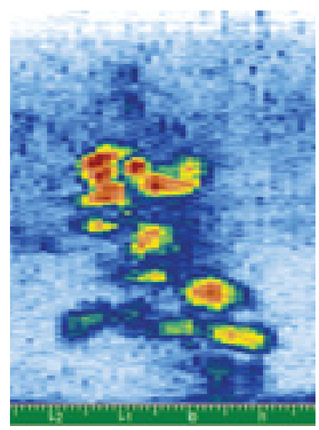
Overall safety performance on the project was excellent. With more than 25,000 man-hours in the field, there were no reportable safety incidents and just one minor safety first-aid.

ALARA performance was also strong, thanks to extensive training and support from Dominion Virginia Power personnel during the project planning and training phases. The final radiation dose for the project was 31.5 man-rem, including 2.3 man-rem related to the additional repairs on the 'B' DM weld. No personnel contamination events occurred on the project.

With the North Anna FSWOL project, the W(SI)^2 and Dominion Virginia Power team successfully completed the industry's largest weld overlays to date. Despite significant and unexpected challenges, our project team worked safely and on schedule, proving that unique situations – like dissimilar metal Alloy 600 welds – call for innovative solutions and flexible teams.

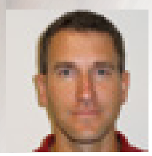


B-Scan (Side-View) image depicts the azimuthal locations and through-wall dimensions of the axial PWSCC cracks as detected through 1.70" thick alloy 52M weld overlay material of "B" SG inlet nozzle



D-Scan (End-View) shows reflective facets along with the length and through-wall dimensions of the crack seen at 45" in the image above

Examining Boiler Tubing Dissimilar Metal Welds



By: JEFF MILLIGAN
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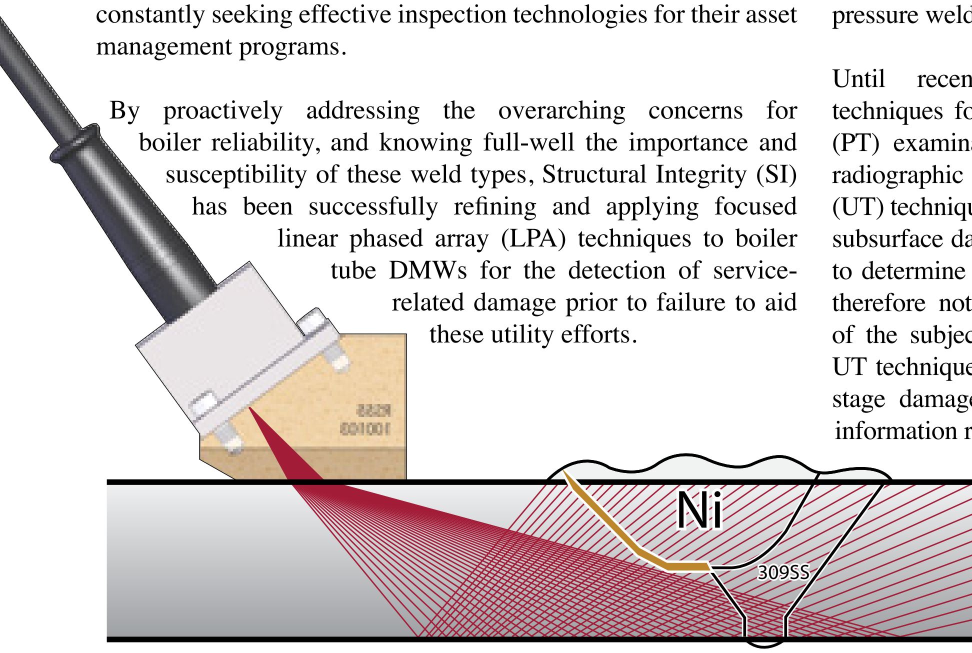
As the power plant fleet in the U.S. continues to age, failures of tube dissimilar metal welds (DMWs) in fossil-fuel-fired boilers continue to increase and produce a significant number of forced outages for utilities. As a result, plant owners are constantly seeking effective inspection technologies for their asset management programs.

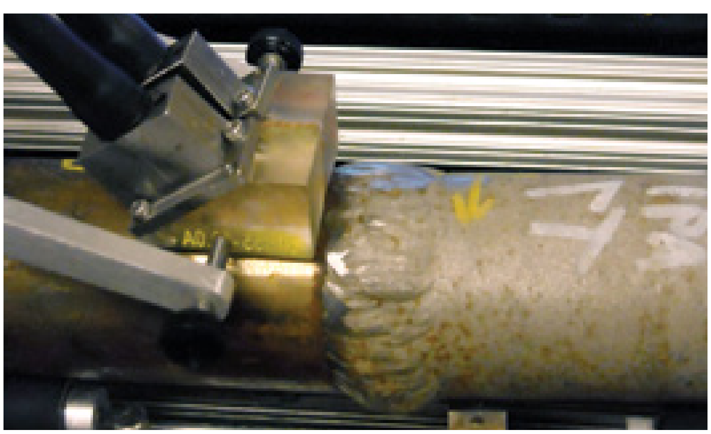
By proactively addressing the overarching concerns for boiler reliability, and knowing full-well the importance and susceptibility of these weld types, Structural Integrity (SI) has been successfully refining and applying focused linear phased array (LPA) techniques to boiler tube DMWs for the detection of service-related damage prior to failure to aid these utility efforts.

BACKGROUND

Generally speaking, there are three types of boiler tube DMWs: those fabricated with austenitic filler metal, those joined with a nickel-based filler metal, and welds fabricated by the induction pressure welding process (no filler material).

Until recently, typical nondestructive evaluation (NDE) techniques for these welds have been limited to liquid penetrant (PT) examinations for the detection of surface cracking, while radiographic (RT) and conventional single-element ultrasound (UT) techniques have been the primary methods for the detection of subsurface damage. In the case of the PT exams, it is not possible to determine the through-wall extent of any detected damage and therefore not possible to determine the remaining serviceability of the subject weldment. Meanwhile, the PT and conventional UT techniques, although proven effective in the detection of later stage damage (macro-cracking), have previously provided little information regarding early stage damage in these components.





Nickel metal weld repair on austenitic filler metal weld

Recently, Structural Integrity completed an EPRI research project that compared different UT inspection techniques for examining boiler tubing dissimilar metal welds. The ultrasonic technologies compared in this project included conventional pulse-echo, conventional pulse-echo with focused water wedge, linear phased array, passive focus linear phased array, two-dimensional linear phased array, two-dimensional linear phased array with pitch-catch setup, and time-of-flight diffraction.

Recent field projects have highlighted the benefits of phased array ultrasonics and its ability to detect service damage in austenitic (stainless steel) filler metal DMW tubes, and nickel (Inconel) metal weld repaired stainless steel DMW tubes.

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ULTRASONIC TECHNOLOGIES

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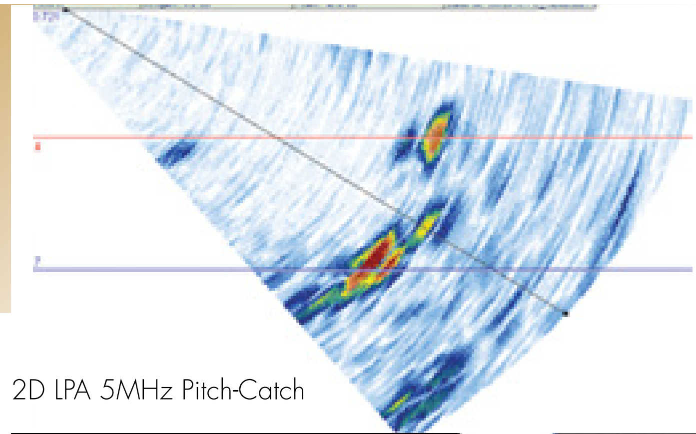
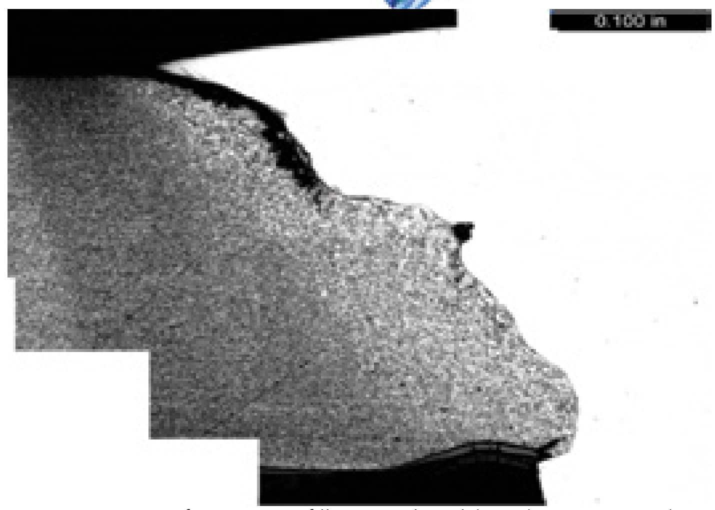


2D LPA 5MHz Pitch-Catch



Cross Section of austenitic filler metal weld and inspection data

FOCUSED LINEAR PHASED ARRAY ULTRASONIC APPROACH

When comparing focused LPA technologies to the aforementioned traditional techniques (PT, RT, conventional UT), the performance of linear phased array (LPA) testing far exceeds the capabilities of the previous test methods. While, conventional single-element UT can only introduce a single beam at a single trajectory into the part, the focused phased array approach can incorporate numerous elements to produce a sectored range of angles to be swept into an exam location. Therefore, this technique reduces the amount of time needed to provide a comprehensive inspection, as it is no longer necessary to change wedges in order to introduce different angles,and still provide a volumetric inspection. When utilizing a multi-element phased array probe mounted to a fixed angle wedge, this beam angulation sweeping also provides enhanced improvements in the detection of both subsurface and near-surface indications. In addition to beam-sweeping and increased detection capabilities, the probes utilized for this technique allow for electronic beam focusing on the active (primary) axis and sometimes the passive (secondary) axis, depending on the phased array probe type. This specific feature allows for greater indication resolution as well as increased accuracy in through-wall and length sizing. In general, the smaller the beam size produced by the technique at the depth of the target, the smaller the detectable flaw at that depth and the better the sizing, all other variables being equal. An example of calculated or measured incident beam size dimensions are shown in Table 1.

Technique	Incident Beam Size (inch)	Incident Beam Size (mm)
Conventional Pulse-Echo	0.200	5.0
Con. Focus Water Wedge	0.100	2.5
LPA 5 MHz	0.071	1.8
2-D LPA Pitch-Catch	0.071	1.8
LPA 7.5 MHz (passive focus)	0.067	1.7

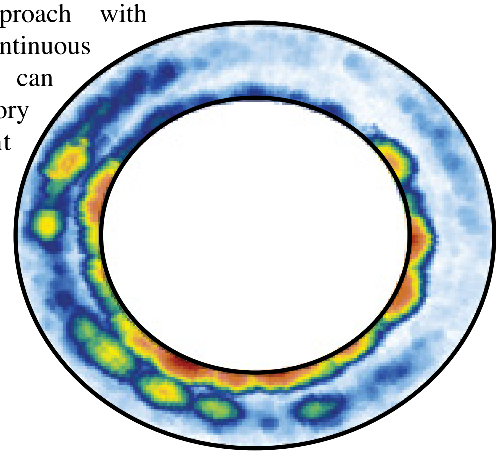
Table 1

TECHNIQUE

In addition to enhanced resolution and detection capabilities, the LPA evaluation techniques are capable of collecting ultrasonic imaging data at very rapid rates and can be coupled with encoding technologies to provide full results around the entire circumference of the tubing welds. This is a significant advantage over typical manual, conventional UT techniques and is also less time-consuming. With the ability to encode the examination data, more test locations can be inspected in a prescribed time frame while allowing the examination results to be independently reviewed and stored to perform data comparisons for growth analysis with any subsequent inspection results.

SUMMARY

In numerous field projects and the recently completed EPRI report, (*Technology for the Examination of Boiler Tubing Dissimilar Metal Welds,*.EPRI, Palo Alto, CA: 2011. 1022013) Structural Integrity's advancements in phased array inspection techniques for boiler tube dissimilar metal welds have shown significant advantages over the traditional examination methods. In numerous field projects and the recently completed EPRI report, Structural Integrity's advancements in phased array inspection techniques for boiler tube dissimilar metal welds has shown significant improvements over the traditional examination methods. By providing a means to characterize damage severity and growth over time, SI can make available to utilities an option that will provide earlier detection of damage and a greater degree of advance notice. Simultaneously aligning this approach with a plant's continuous evaluation efforts can allow for anticipatory repair/replacement strategies prior to a forced shutdown.



Encoded scan Polar View

FRACTURE MECHANICS FOR A COMPREHENSIVE INSPECTION PLAN

By: MATTHEW WALTER
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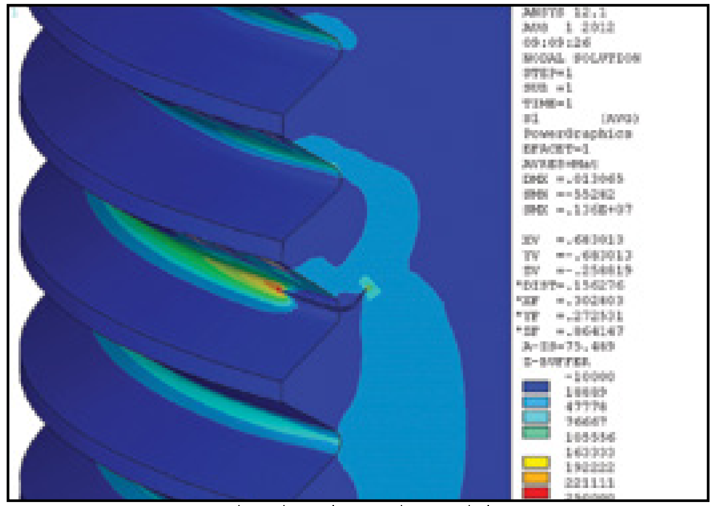
Structural Integrity (SI) recently performed a Boiling Water Reactor (BWR) plant-specific fracture mechanics evaluation of core plate bolting to support development of a boiling water reactor core plate bolt inspection plan. We performed finite element analysis using ANSYS® and other computer software tools.

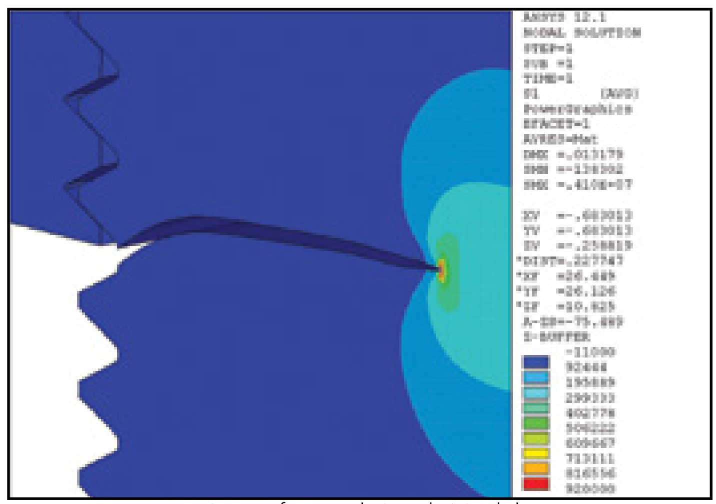
Non-planar crack growth can be calculated for complex geometry with various crack growth mechanisms. For this project, stress corrosion cracking (SCC) was considered for cracks postulated to occur at the root of the first engaged thread. Crack growth is determined by the direction of maximum energy release rate at the crack front, which allows the crack to grow in any direction in the model as would be expected to occur in actual service. SI used plant water chemistry information to develop time-dependent crack growth curves based on varying initiation times. We analyzed both thumbnail and circumferential cracks at different locations and with different initial depths.

CONCLUSION

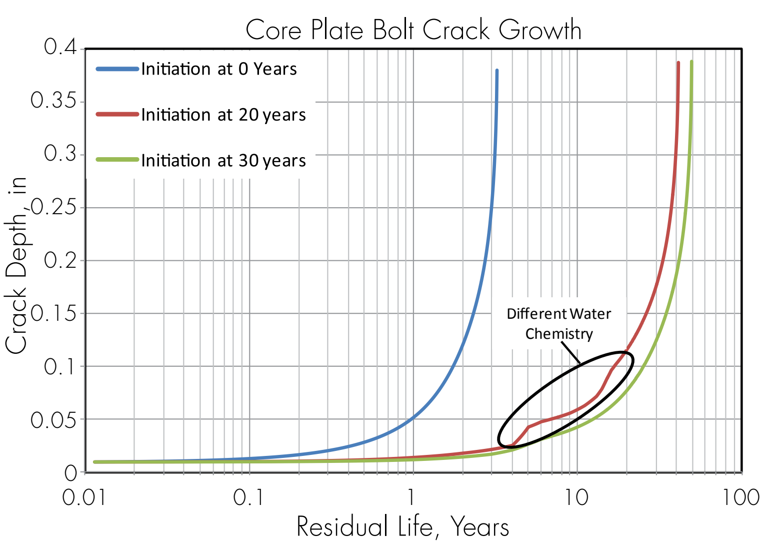
Through the use of this refined fracture mechanics approach, the client was provided with a more realistic crack growth model for a variety of geometry and driving mechanisms. Combined with materials, water chemistry and other expertise, a comprehensive inspection plan can be outlined to meet plant-specific conditions.

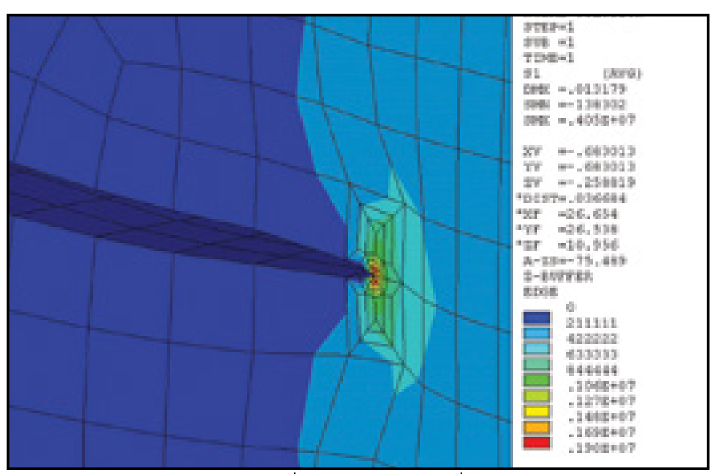


Thumbnail Crack Model



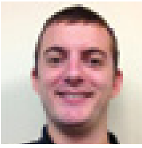
Circumferential Crack Model





Principal Stress at Crack Tip

GUIDED WAVE MONITORING: A NEW TREND FOR IMPROVED SENSITIVITY AND COVERAGE IN BURIED AND CASED PIPING



By: OWEN MALINOWSKI
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Guided Wave Testing (GWT) is a relatively young and rapidly evolving Non-Destructive Evaluation (NDE) method primarily used for the inspection of piping. In its infancy, the results from a guided wave test were displayed in a very basic amplitude versus distance plot that allowed the inspector to extract qualitative information about the relative size and axial location of potential areas of corrosion. The advent of the guided wave focusing technique brought with it the ability to determine the approximate circumferential location of these areas of corrosion and even to generate a three-dimensional image of the inspected area of the pipe, showing amplitude and axial and circumferential positions, all on a single display. This provided a new means for determining the criticality of detected corrosion indications.

More recently, a new guided wave technology and trend is emerging for the long-term condition monitoring of piping, referred to as Guided Wave Monitoring (GWM). GWM represents a paradigm shift in the way we apply guided wave technology and is characterized by the use of permanently installed guided wave sensors for continuous monitoring or cyclical re-inspection of a component. Among other significant benefits, this technology will allow for improved penetration power and sensitivity over traditional GWT for buried and cased piping applications. These benefits are discussed next, along with a description of several of the available technologies and potential applications for GWM.

GUIDED WAVE MONITORING

GWM differs from GWT in that a guided wave transducer collar is permanently installed on the piping segment of interest. A baseline data set is acquired at the time of installation to which all subsequent data sets may be compared and analyzed for changes in the component. The permanently-installed sensors are ideal for installation on piping in excavations, high-radiation areas, difficult-to-access areas, or on critical components.

SEVERAL OF THE PRIMARY BENEFITS OF GWM OVER GWT INCLUDE:

- Ability to re-inspect as often as desired without direct access to the component.
- Improved sensitivity/ coverage through the removal of coherent noise.
- Improved sensitivity to corrosion at structural features (e.g. supports, welds, flanges).
- Increased productivity as there is no need to apply/ remove the transducer collar.
- Simplified interpretation through time-progression processing of data.
- Added prognostic capabilities through data trending.
- Conducive to condition-based, rather than time-based, maintenance.

MEF COLLARS

Magnetoelastic Focusing (MeF) collars, developed by FBS, Inc., utilize the magnetostrictive effect to efficiently generate and receive guided waves. The MeF collar is the first commercially-available collar of its kind to incorporate phased-array and passive focusing capabilities. The magnetostrictive effect is a property of ferromagnetic materials by which the material changes shape in the presence of an applied magnetic field and vice versa. MeF collars are well-suited for permanently-installed applications as they have a low profile and operate most efficiently when permanently bonded to the pipe prior to use.

gPIMS COLLARS

Guided Ultrasonics, Ltd. (GUL) currently offers permanently-installed monitoring systems (PIMS), consisting of piezoelectric guided wave testing collars that are permanently installed on the piping segment of interest. After installation of the collar, the tool leads can be located in a convenient location where the inspector can return to the site and recollect data at will without the need for direct access to the piping segment.

OPTIMIZING PERMANENT INSTALLATIONS

Piping segments are routinely excavated for External Corrosion Direct Assessment (ECDA) and Internal Corrosion Direct Assessment (ICDA) examinations. This is an opportune time to install a GWM collar.

GWM is a form of Structural Health Monitoring (SHM). SHM, in many cases, is easier to execute than NDT and can often provide more information. The essence of this advantage lies in the fact that GWM produces multiple data sets that represent a timeline of the condition of the piping segment. In contrast, GWT requires that the assessment of the piping segment be done from a single data set. Furthermore, GWM provides enhanced sensitivity because it is possible to isolate a particular indication in the data and monitor its progression over time. This data trending approach facilitates the estimation of indication growth rates, subsequently enabling a condition-based maintenance approach in place of a time-based approach.

Coherent noise, often resulting from the inspection process itself, is problematic in GWT because it can produce false indications; however, GWM enables the use of signal processing techniques, such as the simple subtraction of successive data sets, that make it possible to remove this coherent noise and subsequently highlight changes in the piping segment of interest. This time-lapse inspection approach is advantageous as flaws, such as corrosion and cracks, tend to grow over time, while structural features, such as welds and supports, tend to provide a stable response. GWM can therefore be utilized as a simple means to identify areas of active corrosion at or near structural features such as welds, flanges, and supports.

The adoption of GWM and permanently-installed collars has the potential to drastically increase productivity and minimize future inspection costs. As an example, GWT of buried piping is time-consuming and costly as the component must be excavated, protective coatings usually must be removed, the excavation must be made safe for entry, GWT personnel that are trained in excavation safety and entry must travel to the site (with a considerable amount of equipment) and perform the GWT examination, and finally, the component must be recoated and reburied after the inspections. The placement of permanently-installed collars in this situation would facilitate future guided wave inspections of the buried component without the need to re-excavate, thus significantly reducing the time and cost associated with the inspection process.

In comparison to that of GWT, data interpretation with GWM has the potential to be much simpler. With GWM, the existence of baseline data and subsequent data sets enables the statistical and feature-based analysis of the data sets, data-trending, and prognostic capabilities, which may potentially allow for the estimation of the remaining useful life of a structure or component. For example, indications from cracks or corrosion can be isolated and analyzed with each subsequent data acquisition, allowing valuable information about the size and/or growth of the indication to be extracted for more reliable failure analysis and prognostics.

Currently, NDT and maintenance activities are most commonly planned on a time-based recurring schedule with pre-determined inspection intervals that may not take into consideration the actual condition of the specific component of interest. GWM can initiate a transition from time-based maintenance to condition-based maintenance, which can provide more substantive information for making decisions regarding the re-inspection and/or replacement of a specific component and can raise early warning signs that a structure or component is nearing failure. A condition-based maintenance approach can also provide a means to obtain the maximum usable life of a specific component prior to its replacement.

CONCLUSIONS

The imminent paradigm shift from GWT to GWM has the potential to reduce the complexity, cost, and time associated with guided wave inspection of buried and/or cased piping. Furthermore, the added signal processing capabilities afforded by the GWM approach provide significant potential for improved sensitivity and penetration power in these applications.

External Corrosion Assessment and 3D Modeling Using a 3D Laser Scanner

By: MICHAEL GREVELING
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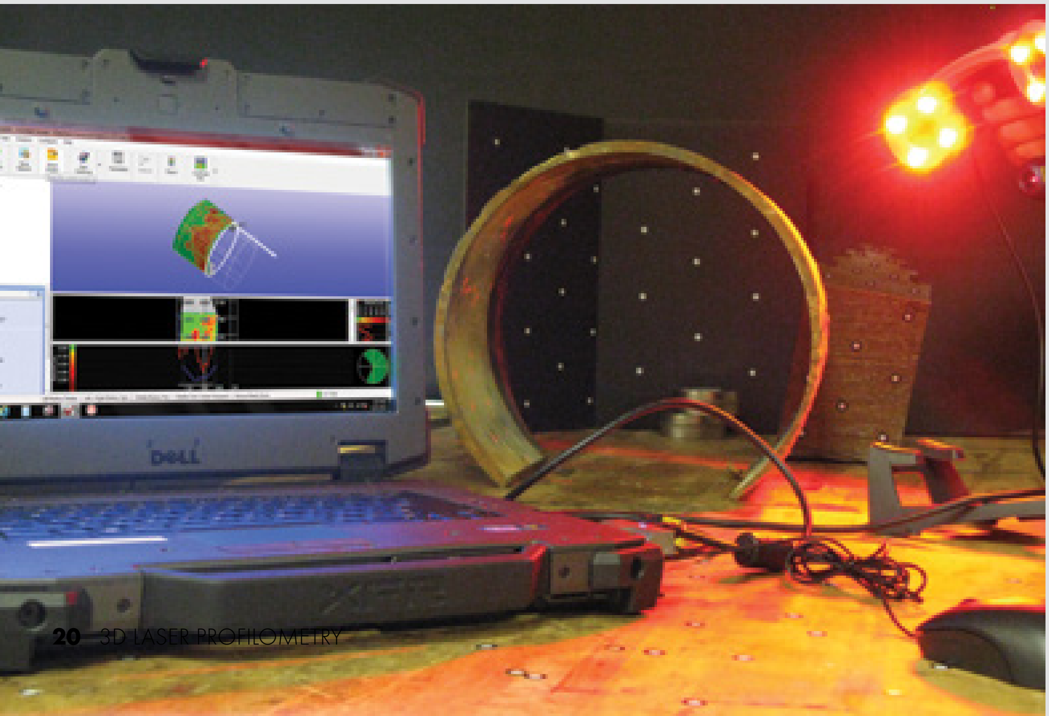
Conventional pit gauge measurement of external corrosion on pipe surfaces can be a time-consuming and inaccurate process. The results rely heavily on the experience of the technician, as well as the surrounding surface condition. An alternate method is to create an exact image of the surface using a profilometry device for analysis. However, most profilometry devices are suited for use in a lab, not in the field or remote locations.

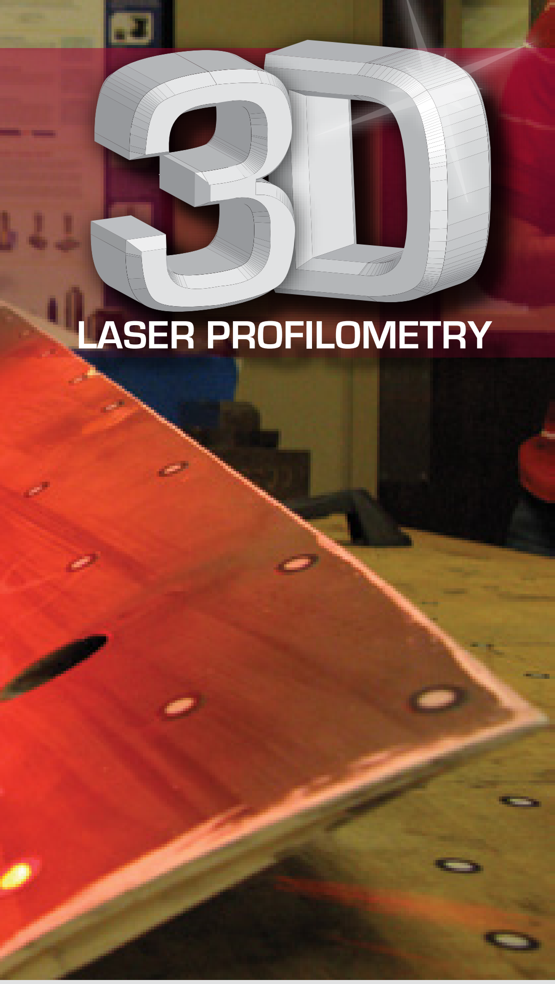
To address this problem, Structural Integrity recently purchased a Creaform HandyScan 3D™ laser scanner and accompanying Pipecheck® software to perform surface modeling and analysis. The scanner has two cameras and utilizes retro-reflective targets placed on the inspection piece for positioning. Having the targets fixed to the work piece allows both the scanner and work piece to move freely making it ideal for vibrating environments. The surface information is collected by measuring the variation of a laser crosshair projected onto the exterior of the scanned part. The scanner has a resolution of 0.004 in. (0.1 mm) and an accuracy of 0.002 in. (0.05 mm). It is very portable and can operate on battery power for field use.

VIEWS FROM A 3D LASER SCANNER

The data analysis software quickly performs post processing on the acquired surface scan. The results can be displayed as a 3D surface or unrolled to a 2D view. A river bottom path view can be selected to show the representative worst case profile. The pit gauge feature applies a virtual gauge at any selected point to correlate the scanned results with traditional measuring methods. The software can also provide estimated burst pressure using calculations based on ASME B31G code determining remaining strength in corroded pipelines. Once the analysis has been completed, the results can be exported into an Excel workbook for reporting.



Another function of the laser scanner is its ability to create accurate 3D models of parts with complex geometries. Components of power plants rarely have accurate drawings to create 3D CAD models for analysis. Many of these parts were sand cast and ground by hand, creating surfaces that are difficult to model using manual gauging techniques (calipers, micrometers, profile gauges, pi tapes, etc.). The process for creating the model begins with the same positioning targets used for the external corrosion function. The acquisition software creates a polygonal model of the scanned surface. The raw polygonal model will most likely have additional undesirable geometry from surrounding components, interferences, or noise (if the part is shiny). 3D metrology software, Polyworks™, takes the polygonal model and allows the user to edit the mesh to remove unwanted triangles and clean up the model. Smooth, ideal surfaces are fit



to the model which can be exported as an IGES or STEP file to be imported into a 3D CAD program, Finite Element Analysis (FEA) program, or ultrasonic modeling program. The Polyworks software also has the ability to import CAD files, which can then be compared to the scanned model.

MAPPING CAPABILITIES

The corrosion mapping capabilities of the 3D laser scanner is a valuable tool for our Pipeline Services, Fossil Plant Services, and Nuclear Plant Services divisions at Structural Integrity Associates. The 3D modeling capability of the laser scanner is currently being used on an EPRI project to create a CAD model of a turbine casing for the purpose of importing the file into an ultrasonic simulation program. The UT simulation requires a precise model due to the varied external surface contours and the complexity of the interior surface, and the 3D laser scanner is the perfect tool for this job.

Overall, the 3D laser scanner improves accuracy, greatly reduces the amount of time spent gathering data for external corrosion on piping, and creates accurate 3D models of difficult-to-measure parts.

BOILING WATER REACTOR STEAM DRYER SUPPORT

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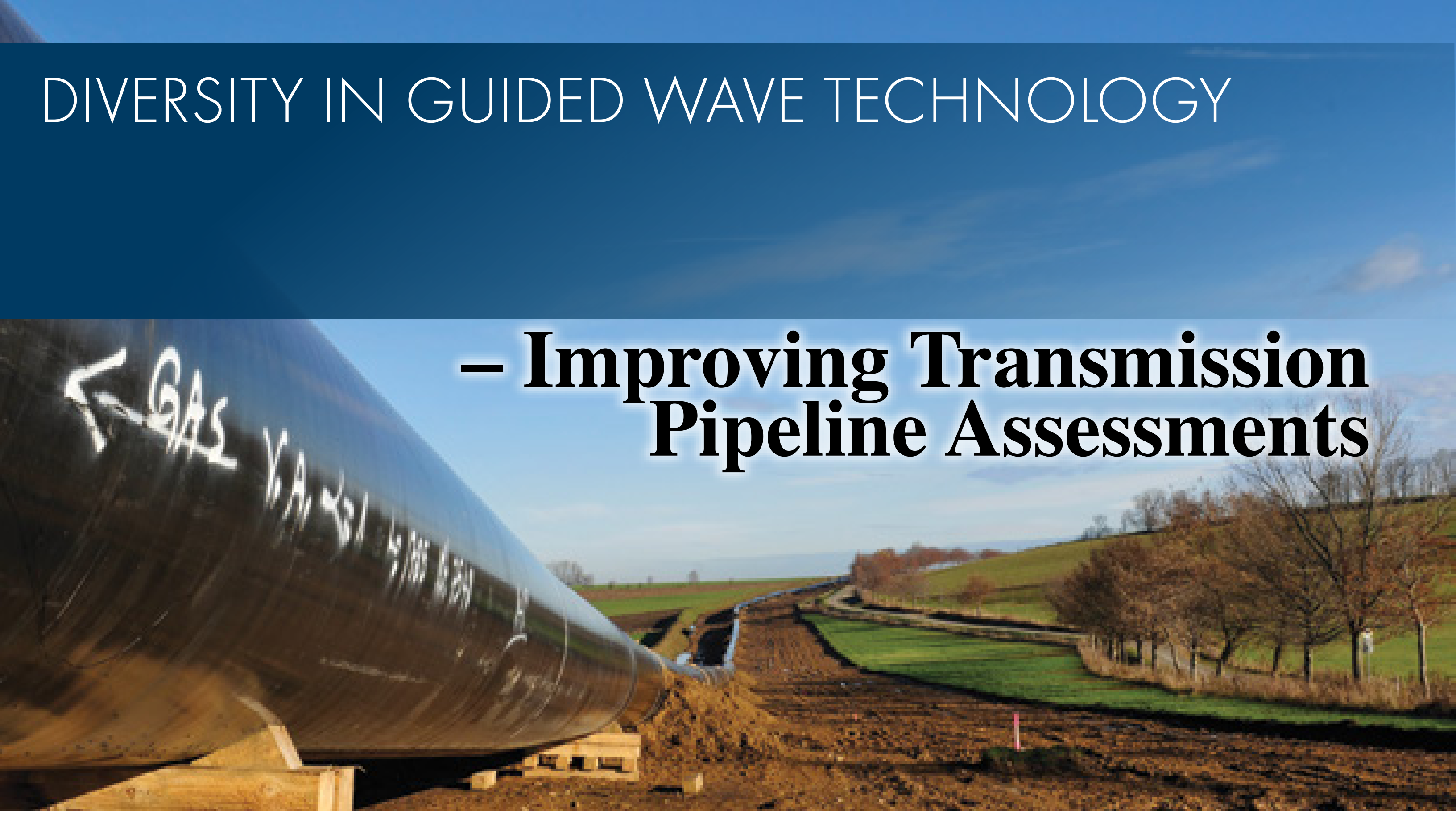
Structural Integrity Associates, Inc. (SI) continues to provide responsive support to the industry regarding integrity of boiling water reactor steam dryers. We are often asked to participate on engineering teams tasked with assessing the integrity of the steam dryer as part of a larger power uprate project. Depending on the need-of our clients, SI has either performed stand-alone work or augmented our clients' engineering teams to perform independent reviews of work performed by other organizations. Since SI staff have been continuously involved in steam dryer integrity since the 2002 industry operating experience that resulted in the current industry requirements for steam dryer integrity evaluations, SI provides a continuity of experience and perspective that provides a substantial benefit to our clients. The scope of our typical support includes, global steam dryer finite element analysis, submodel analysis, ASME Boiler and Pressure Vessel Code Section III stress analysis, high cycle fatigue stress analysis, flaw evaluations of in-service detected cracking, main steam line and steam dryer instrumentation and data acquisition and analysis, experimental modal analysis, safety and relief valve testing and mitigation support, and support of regulatory authority comment resolution. The only aspects SI does not support are steam dryer design, fabrication, and installation and acoustic load development.



DIVERSITY IN GUIDED WAVE TECHNOLOGY

– Improving Transmission Pipeline Assessments

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A key requirement of an Integrity Management Program is that gas and hazardous liquid pipeline operators identify transmission pipeline segments lying within High Consequence Areas (HCAs), known as a covered segments, and perform a "PHMSA approved" integrity assessment method for all known threats on these pipeline segments by December 17th, 2012 (for gas pipelines), and then periodically reassess these segments at least every seven years thereafter.

PHMSA Approved Methodologies include:

1. Hydrostatic Pressure Testing per Subpart J of Part 192
2. In-line inspection (ILI) or "smart-pigging"
3. Direct Assessment (DA)
4. Other Technology (OTN)

A subset of pipelines located in HCAs includes difficult-to-access pipelines installed within facilities, inaccessible rack piping, through-wall penetrations (inside station buildings or vaults), piping inside casing pipe (casings) beneath roadways, railroads and other locations. Operators have faced significant challenges in trying to implement approved integrity assessment methods for these segments as the typical methods adopted for assessing these segments have proven either not-applicable or difficult and cost-prohibitive to implement; however, recent developments in guided wave technology are showing great potential in these situations.

Guided Wave Testing (GWT) is a relatively new and rapidly evolving nondestructive evaluation (NDE) method that has been used over the past several years to help transmission pipeline operators perform assessments of their assets. However, just as there are many different kinds of hammers, the selection of which depends on the task to be completed, there are many variations and configurations of guided wave equipment that may be better suited for a specific application. Outlined next are two examples of how SI's GWT assessment process has utilized the technological advantage offered by diversity in testing equipment.

LONG-RANGE GWT

Acquiring the equipment needed to operate a long-range GWT inspection service business requires a significant capital investment. Growing and maintaining a pool of highly skilled GWT inspectors to operate the equipment adds cost and complexity to such an endeavor. For these reasons, most service providers often become attached to a particular brand or equipment platform despite the breadth in technical capabilities that is offered by operating multiple brands of GWT equipment. SI has adopted the approach of technological diversity and maintains a GWT equipment reserve consisting of GUL Wavemaker, Teletest Focus, and FBS PowerFocus inspection systems and a versatile inspection crew trained on the fundamental operating concepts of the methodology and not just on the operation of a particular piece of equipment.

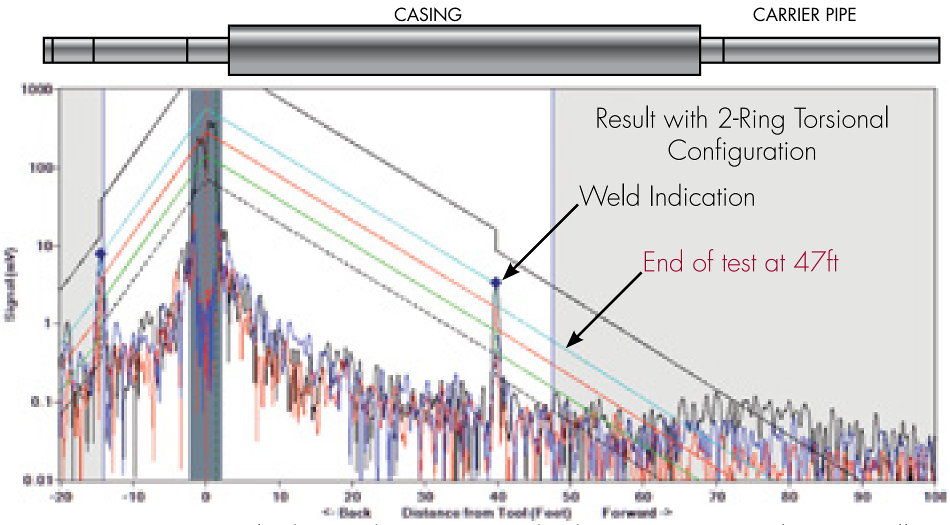

Figure 1 A-Scan result obtained using a standard two-ring torsional GWT collar configuration. Approximately 47ft of diagnostic length was achieved using PHMSA's guidelines.

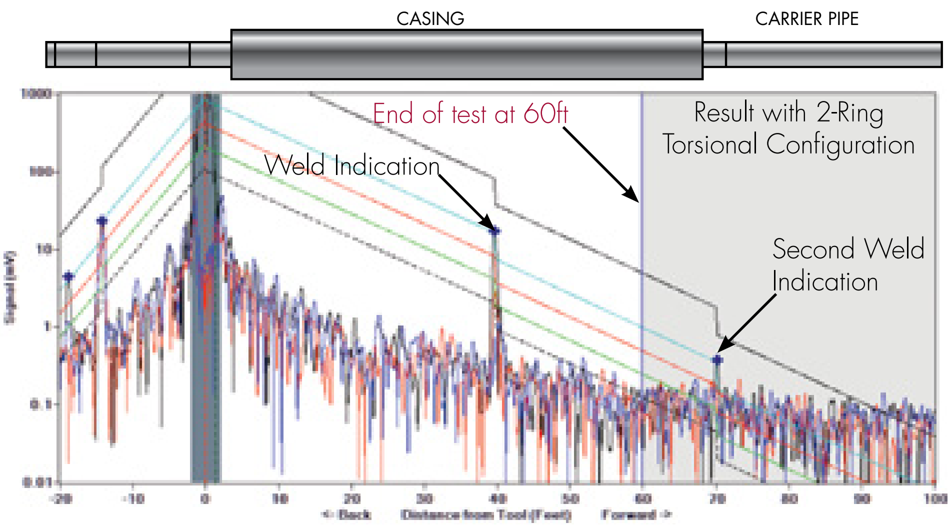

Figure 2 A-Scan result obtained using a non-standard three-ring torsional GWT collar configuration. A 13ft improvement in coverage of the cased segment is obtained per PHMSA's guidelines.

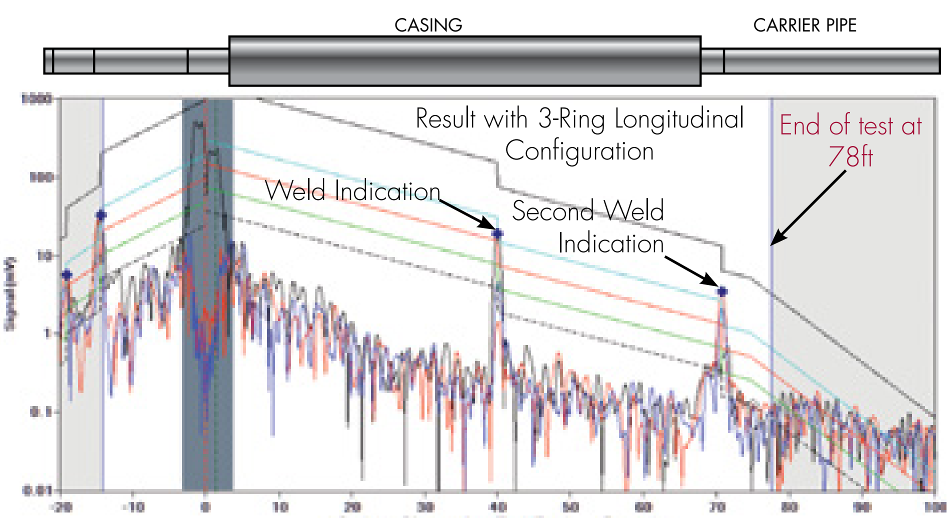

Figure 3 A-Scan result obtained using a non-standard three-ring longitudinal GWT collar configuration. A 31ft improvement in coverage of the cased segment is obtained per PHMSA's guidelines.

As a testament to this approach, SI recently completed an assessment of a cased gas transmission line using multiple GWT collar configurations, including the standard two-ring torsional configuration as well as non-standard three-ring torsional and longitudinal configurations. This particular casing was approximately 60 feet in length and was filled with wax and the carrier pipe was coated with Fusion Bonded Epoxy (FBE). The minimum criteria provided in PHMSA's 18-point guidelines for the GWT of cased road crossings only require the use of torsional guided waves and, accordingly, a vast majority of all GWT inspections of road crossings are performed with a standard two-ring torsional guided wave transducer collar.

Figure 1 shows the result obtained on the cased crossing with this standard collar configuration. Approximately 47 feet of diagnostic length was achieved using the PHMSA criteria. The results displayed in Figure 1 were obtained with the Teletest Focus+ system; however, the same results were also obtained with the GUL Wavemaker system.

Figure 2 and Figure 3 show the results obtained with the non-standard three-ring torsional and longitudinal collar configurations, respectively. For this particular cased pipe, applying a non-standard three-ring torsional wave configuration resulted in approximately 13 feet of improvement in coverage, while switching to the three-ring longitudinal wave configuration resulted in approximately 31 feet of improvement in coverage. Essentially, the entire cased segment was inspected from only one side of the crossing using the three-ring longitudinal configuration.

This result is not entirely surprising as longitudinal waves have a theoretically lower attenuation rate than torsional waves in the frequency ranges used by typical long-range GWT equipment. Furthermore, gas transmission lines present a unique opportunity to utilize this type of guided wave as it cannot be applied to liquid-filled lines due to leakage of the longitudinal energy from the pipe wall into the liquid.

Continued on next page

DIVERSITY IN GUIDED WAVE TECHNOLOGY

CONTINUED

SHORT-RANGE GWT WITH ELECTROMAGNETIC ACOUSTIC TRANSDUCERS (EMATS)

Conventional long-range GWT, as previously discussed, was initially developed to screen long lengths (sometimes >100ft) of pipe for corrosion; however, areas where other structures contact the pipe, such as supports, are particularly difficult to assess with traditional GWT as their mere presence will often produce an indication in the GWT data, making it difficult to differentiate between a support and an area on the pipeline with corrosion under the support. Accordingly, a market need has developed for the ability to accurately detect and characterize potential flaws in these applications. To address this assessment gap, SI has recently added a new short-range guided-wave Electromagnetic Acoustic Transducer (EMAT) inspection system to its toolbox of inspection technologies.

EMATs generate ultrasonic waves in electrically conducting materials by employing a physical principle known as the Lorentz force. When a current-carrying wire is placed in a magnetic field, the magnetic field created by the current flow interacts with the surrounding magnetic field, resulting in a force that attempts to move the wire. This phenomenon is utilized in many everyday objects, such as doorbells, audio speakers, and electric motors. If the current-carrying wire is placed near the surface of an electrically conducting material, such as a steel pipe, an eddy current is formed in the material. The Lorentz force generated by the interaction of the eddy current and magnetic field causes a microscopic displacement of the electrically conducting material. This is the fundamental operating principle of a Lorentz-type EMAT. By carefully controlling the orientation of the magnetic field as well as the time-varying properties and orientation of the eddy currents, many different kinds of ultrasonic waves can be generated with EMATs, including guided waves.

The temate® PowerBox H, pictured in Figure 4, coupled with a horizontal shear-wave EMAT, is capable of generating high-frequency torsional waves in piping components. High-frequency guided waves are useful in situations where the area of interest falls within the dead-zone or near-field of traditional GWT tools or where external structures contact the pipe, creating high-potential areas for crevice corrosion. EMATs also have several practical advantages in that they do not require any ultrasonic couplant, can be used in a non-contact configuration (or through coatings), work on rough and pitted surfaces, and work on both ferromagnetic and non-ferromagnetic metals.

Figure 4 The temate® PowerBox H ultrasonic pulser (top) and an assortment of EMAT sensors and dry- and air-coupled sensors (bottom).

Potential applications for the short-range EMAT system include:

- Assessment for corrosion at supports
- Assessment for corrosion in cased wall penetrations
- Assessment for corrosion in concrete encased wall penetrations
- Assessment for corrosion at pipe anchors
- Assessment for corrosion at soil penetrations
- Assessment of Dead-Zone and Near-Field areas of conventional GWT equipment
- When access for traditional UT is limited

SUCCESSFUL WELD REPAIR/REPLACEMENT OF GRADE 91 STEEL

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The successful weld repair or replacement of a damaged component, pipe, or sub-assembly fabricated from one of the Creep Strength Enhanced Ferritic (CSEF) steels, such as Grade 91, requires uncompromising attention to every detail. In addition, it is necessary that the execution of the repair or replacement in no way compromise the serviceability of any other component or sub-assembly in the system of which the damaged component/sub-assembly is a part. For this reason, any contractor undertaking a repair/replacement of a Grade 91 component should demonstrate a comprehensive understanding of 91's unique metallurgy, and this understanding should be reflected in every aspect of the contractor's repair/replacement procedure. This means that the procedure will cover not only the initial planning of the repair to insure that the appropriate equipment and personnel are available to execute the repair within the appointed time, but that it will address the procurement of replacement material to the appropriate technical requirements and that it will take account of all possible contingencies that may occur during the actual execution of the repair or replacement.

The repair/replacement procedure should include factors such as the detection of damaged material that extends beyond the repair area, the influence of induced magnetism on welding, the establishment of an effective purge, modifying heat treatment procedures to deal with unanticipated cooling effects, etc. In addition, the procedure must include a rigorous quality control plan that, at the project's end, will provide to the equipment/plant owner full documentation of the final condition of all material directly or indirectly affected by the repair or replacement.

The difference between a CSEF steel, like Grade 91, and a standard Cr-Mo steel is not unlike the difference between the engine in a '32 Plymouth and a 2012 Cadillac CTS Coupe: the basic elements – the block, the pistons, the spark plugs, etc. - are the same in both, but in the Cadillac those elements have been re-designed to function in ways that make the operation of the engine far more efficient. With regard to the steels, new efficiencies have been achieved through a re-design of the microstructure. The CSEF steels require that a specific condition of microstructure be developed during an initial austenitizing and tempering operation – a condition of microstructure characterized by the initial formation of a lower transformation product, such as martensite or lower bainite, which then is stabilized for operation at elevated temperatures by the formation of temper-resistant precipitates at favored defect sites. Once this essential condition

Continued on next page

of microstructure is created, all subsequent thermal and mechanical processing must be carried out in a way that preserves that structure, or the material will lose the enhanced creep strength that is its reason for being. This requirement for rigorous control of all processing steps is a distinct departure from the notoriously lax processing practices that have developed over the years in the course of working with the relatively stable Cr-Mo steels, and it is a lesson that all too many material producers, manufacturers, constructors, and end users have failed to absorb fully. As a result, all parties involved have borne substantial unscheduled costs associated with unexpected repairs or replacements of grade 91 material that have been required due to improper processing of the materials, and these costs will mount as more defective material is uncovered either through grade 91 High Energy Piping programs, inspections or as a result of component failures.

The issue of the repair or replacement of operating components fabricated from Grade 91 steels assumes particular importance, because for end users the reliability of their equipment depends on the materials of construction performing in reasonable conformity to the expectations of the designers.

If, when a grade 91 component is repaired or replaced, the appropriate processing controls and weld procedures are not maintained throughout the entire repair/replacement cycle, then there is a substantial risk that the essential structural condition of the material will be compromised and will not perform as expected in service.

The most important elements of a successful repair or replacement project involving 91 materials are summarized here. In order to provide guidance to equipment owners who may be faced with carrying out such a repair or replacement project on their own, or who will hire a contractor to execute the project, please contact Fred DeGrooth or Kim Bezzant directly to discuss project specifics.

PRE-REPAIR REQUIREMENTS

In preparing for the repair or replacement of a CSEF component (or, for that matter, any component) there is a certain logical progression to the planning and execution of the project that, if followed, will greatly improve the likelihood of success. In the most general terms, four phases of such a project can be identified:

1. Defining the project objective,
2. Creating a repair/replacement plan,
3. Executing that plan,
4. Fully documenting all results.

THE PROJECT OBJECTIVE

The first step in any repair/replacement project is to clearly define the equipment operator's objective in carrying out the project, since that will determine not only what type of repair/replacement is undertaken but also how the repair/replacement is executed.

There are certain cases in which the most prudent engineering decision is to defer a repair until some later date when all necessary resources can be assembled to accomplish the repair in an orderly and controlled manner. For example, during a routine inspection significant sub-surface indications are discovered in a girth weld in a Grade 91 main steam piping system. Ultrasonic testing data indicates that the indications are concentrated along the fusion boundary on one side of the weld and likely are original welding-related flaws, which may have begun to grow in service. Although a repair of this weld ultimately will be required if the plant is to continue to operate reliably, it may not be necessary to perform the repair immediately. A determination of how quickly the repair must be carried out may be warranted if available resources to accomplish the repair are limited or if, in executing the repair, the scheduled return date of the unit is compromised to the detriment of the operator's commercial objectives. In this case, a detailed engineering analysis could be conducted to determine whether and for how long the weld could continue to operate under either "normal" operating conditions or under operating conditions modified to reduce the rate of damage accumulation in the area of the indications.

Of course, in dealing with the CSEF steels, an important part of any such engineering analysis is a determination of the existing condition of the material for which the analysis is being conducted. For example, if there is evidence that the structure of the material has been compromised in some way (e.g., low hardness values, an anomalous optical microstructure); an account of the deficiency must be factored into the analysis, since this could have a significant effect on the analysis results. Failure to make an appropriate adjustment could result in a non-conservative conclusion with regard to a decision to continue to operate.

THE REPAIR/REPLACEMENT PLAN

Once the objective of the repair or replacement has been established, including the final scope of the repair/replacement, then our next step is to develop a detailed plan for the repair/replacement that clearly defines both the sequence of the actions that will be taken to complete the repair and the specific content of each action. At a minimum, the plan should include the following:

1. A purchasing specification to cover the procurement of any base or weld metals required for the repair/replacement.
2. A repair procedure covering the execution of the repair. This procedure should provide detailed guidance on the controls required for preheats, weld bake-outs, when necessary, and post-weld heat treatments (PWHTs), including the number and placement of thermocouples during any heating of the material.
3. A schedule indicating the dates by which key pre-repair activities must be completed to support the execution of the repair.
4. A determination of the NDE capabilities that will be required on site during the repair to insure Code compliance and the specification of any acceptance requirements more restrictive than those of the Code.
5. A strategy for properly supporting and restraining all components that will be affected by the repair/replacement. This strategy should be developed based on an engineering review that takes into consideration the major loads to which the components are subject, as well as stresses that will be generated during the PWHT cycle

EXECUTION OF THE REPAIR/REPLACEMENT

SELECTION OF A CONTRACTOR

As discussed above, the relatively complex metallurgy of the CSEF steels requires that the thermal and mechanical processing of the material be controlled within much tighter limits than is the case with the standard Cr-Mo steels. Since the consistent implementation of those controls is more likely to occur with a contractor whose technical and quality managers have been effectively educated in the details of the metallurgy of these alloys and, therefore, understand the technical basis for the more restrictive processing requirements, the importance of selecting a contractor with extensive prior experience with these alloys should be readily apparent. The fact that a particular contractor holds an National Board "R" stamp, has been in business for many years provides no assurance that the contactor will be capable of successfully executing a project involving these materials. These are minimum requirements that must be supplemented by a reference list that describes successful experience in the execution of projects involving the CSEF steels.

In addition, a contractor's Quality Procedures and Welding Documents should specifically reference the internal requirements that exceed Code requirements in relation to the welding and heat treatment of these alloys. Key indicators of a contractor's overall competence with these alloys would include controls on the 9Cr and 12Cr materials to prevent stress-corrosion cracking when they are in the as-welded condition and specific requirements pertaining to the number and location of thermocouples required during any preheating or post weld heat treating of the CSEF steels. If the contractor intends to augment his/her staff from a local union hall or from other sources, then there must be a demonstrated commitment to the proper training of the temporary staff in the unique requirements that apply when dealing with the CSEF alloys.

DOCUMENTATION

A successful repair/replacement project should conclude with the submission to the owner of a comprehensive data package that documents the results of all activities related to material procurement, welding, heat treatment, and inspection. The value of this package is twofold: first, it provides confirmation to the operator that the key technical requirements by which the repair/replacement activity was controlled were fully satisfied. On this basis the operator can have confidence that the fitness-for-service of the repaired or replaced components is satisfactory. Second, the data package provides the baseline information pertaining to the condition of the repaired or replaced material that is essential for any subsequent condition assessments that are conducted as the unit continues to operate.

CONCLUSIONS

Repairs to CSEF material can be successfully performed if:

- There is uncompromising attention to detail.
- The unique metallurgy of the material is fully understood.
- The current condition of the material is fully understood.
- The reason for the repair is clearly understood.
- A detailed repair plan is developed by a competent technical specialist and all aspects of the plan are successfully executed by the end user or by the mechanical contractor acting on the end user's behalf.

Vulnerabilities, Risk-Informed "Smart" Walkdowns

By: TERRY HERRMANN
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License renewal and industry issues have resulted in greater focus on nuclear plant cables. Structural Integrity, in cooperation with Kinectrics, Inc., offers Low Voltage (LV) and Medium Voltage (MV) cable aging management solutions. We have collaborated with multiple utilities regarding availability of cable information and the methods companies have used to prioritize and risk rank the condition of cables. Structural Integrity and Kinectrics optimize plant walkdown activities in what we call a "Smart Walkdown" using a risk-informed approach. (SMART – Systematic Minimization of Actions related to Radiation and Temperature)

The most recent EPRI sponsored Cable Users Group meeting was held in Raleigh, NC in May of this year. Structural Integrity and Kinectrics made presentations on cable risk assessment and testing to the utility engineers, cable manufacturers, NRC and INPO representatives in attendance. A key topic of discussion was the need for utility engineers to "understand your vulnerabilities."

More recently, Dominion hosted a two-day nuclear cable workshop at its Innsbrook Technical Center near Richmond, VA in August, where we teamed with Kinectrics to provide training on technologies and methods to develop practical, comprehensive, cable aging management programs. Topics included risk ranking of cables, aging mechanisms and selection of condition assessment methods (inspection and testing) for low and medium voltage

KINECTRICS

cables, walkdown inspections, interface with equipment qualification programs, and trending.

There was good discussion both at the EPRI meeting and the Dominion workshop regarding utilities' experience from NRC inspections and INPO evaluations related to cable aging management.

What's clear from these discussions is that the approach to cable aging management needs to be more proactive and risk-informed than in the past.

Walkdowns are often time-consuming, expensive and result in undesirable increases to station collective radiation exposure. This lends itself well to a risk-informed approach that incorporates risk, temperature, and material insights into the program. This method focuses on the areas with the most severe environmental conditions based on risk ranking of the components, improved understanding of the environments, and relative susceptibility of the cable materials to environmental aging. In other areas cable and raceways can be assigned less rigorous walkdowns, thereby reducing the level of effort required and time spent in the radiologically controlled area (RCA).

STRUCTURAL INTEGRITY'S MAPPRO CABLE

Structural Integrity has created MAPPro© Cable. This application tool includes cable data tables consistent with EPRI's BPWorks™ 2.0 database, a product currently installed and in use at the majority of U.S. nuclear plants for buried and underground piping and tanks. In utilizing this approach, the cable solution leverages the functionality within the MAPPro suite of tools: reporting, risk analysis, exporting to MS Excel©, and the data visualization and mapping tools of the MAPProView© application.

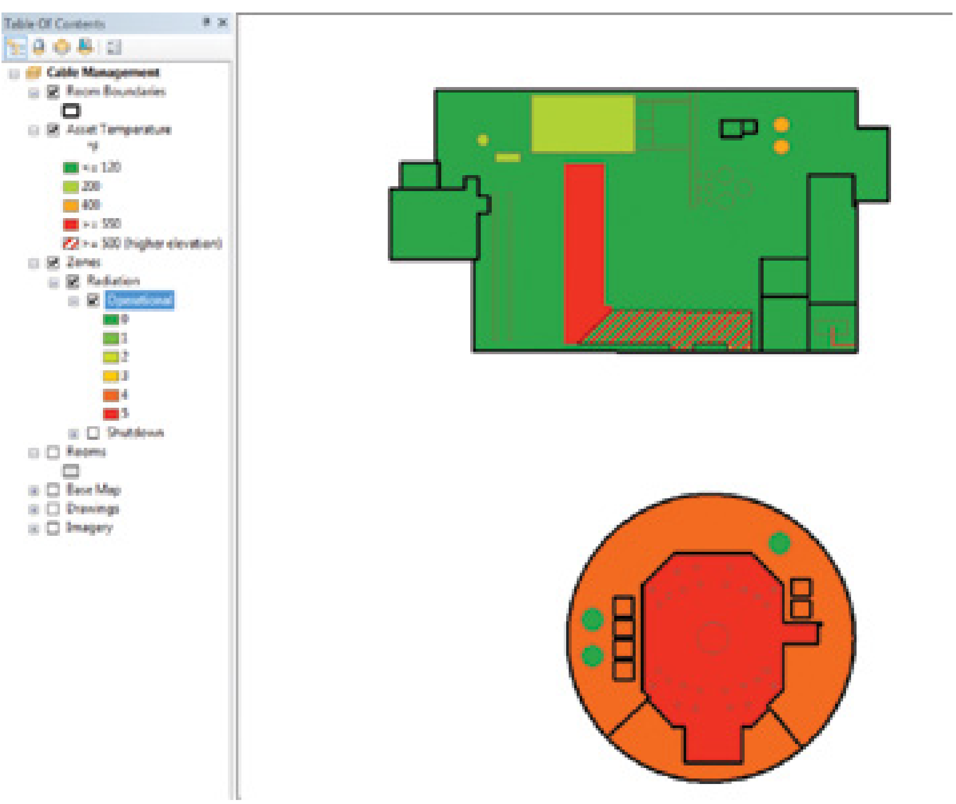

Figure 1 Temperature and Radiation Zones (at power)

Figure 1 depicts a typical PWR plant and provides an indication of how plant temperature zones vary and can be used to reflect the key areas of concern, illustrating how the walkdown can be focused. This figure shows representative temperature zones at a specific elevation (Reactor Containment Building and Turbine Generator Building). As an example, the focus areas for the plant outside of the RCA will be those areas in the vicinity of equipment operating at temperatures in excess of 200°F. Areas shaded in red exceed 550°F, areas in orange experience temperatures between 400°F and 550°F, and the light green areas operate at temperatures between 200°F and 400°F. Cable trays and conduits having cables associated with higher risk components will be identified in these areas for walkdown to validate that no adverse localized environments exist; or, if they are found, that they are documented for corrective action and/or future trending.

In addition to evaluating operating conditions, we factor shutdown conditions into the MAPProView© output, since plant conditions change when not in operation. While these conditions normally provide less severe aging conditions, such is not always the case. For example, the valve gallery in the Reactor Containment Building has general area dose rates less than 100mR/hr, but exceeds 100mR/hr when the plant is shut down.

Our team can provide the field crews and technical expertise to perform walk-downs, and as follow up activities, cable aging nondestructive examination and electrical testing. Input from the walkdowns and testing can be used to further improve the MAPPro Cable risk algorithms, making them the most technically superior in the industry.

2012 CHANGES TO UNDERGROUND PIPE AND TANK INTEGRITY (UPTI) PROGRAM TOOLS

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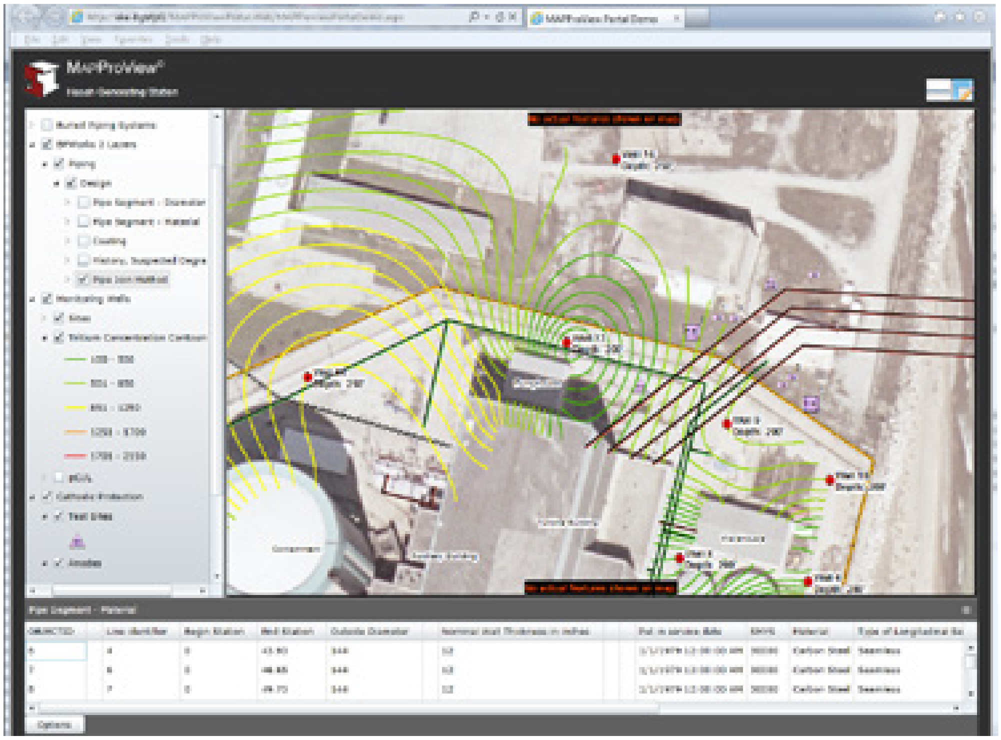
Underground Pipe and Tank Integrity (UPTI) programs at nuclear sites have significantly matured since their inception in 2008. Utilities are now actively performing excavations and inspections needed to meet the next NEI 09-14 milestone on June 30, 2012. The process requires the integration of to new inspection results within their buried pipe inspection results database. Learning from inspection results will enhance the risk prioritization capabilities and improve the selection and monitoring of future inspection sites.

Throughout this evolving process, Structural Integrity has worked extensively with EPRI on the management of Buried Pipe database projects. In 2010, we developed BPWorks™ 2.0 with EPRI, which included the Dynamic Segmentation engine to segment piping based on changes in characteristics and provided more than 200 data fields for storing a wide variety of design, operating and inspection characteristics about piping systems. As a companion to BPWorks 2.0, we introduced MAPPro© 2.0 to leverage the same database information and provide additional functionality and analysis tools for buried pipe program owners. Both software tools have been upgraded and will be released this fall as Versions 2.1, incorporating new and modified functionality to meet the ever-changing needs and lessons learned in this industry.



MAJOR ENHANCEMENTS

Users will appreciate these two major changes to BPWorks in v. 2.1:

1. Removing the Administrator rights requirement and including an export for BPIRD data. Removing the Admin rights constraint will improve IT reception and improve users separation, enabling simple configuration of remote/ multi-user access. Compiling new inspection results for submission into the Buried Pipe Inspection Results Database (BPIRD) is required per NEI 09-14, but can be a time intensive activity. Assuming inspection data exists within the site's BPWorks database; a new BPIRD export tool will auto-populate the template and streamline the semi-annual data submission requirements to EPRI under NEI 09-14.

2. We also implemented improvements in MAPPro to support all new BPWorks v2.1 database changes and additions. Similar to BPWorks v2.1, the new release of MAPPro will no longer require Administrator access to run properly. MAPPro Risk algorithms have been adapted to use the updated database fields and to assess some risk factors in a better manner. Modifications to the algorithm logic address lessons learned over the last few years to better reveal potential issues.

MAPPro USER COMMUNITY

The MAPPro© User Community has grown to almost 20 members (about one-third of the industry). These members have directed additional changes that will be available with MAPPro v2.1. Updates to the BPWorks v2.1 user interface have allowed the BPWorks Percent Complete tool to be updated and to be more accurate and meaningful for users wishing to run a secondary risk algorithm.

In MAPPro 2.0.8, a Ground Water Priority Index calculation, per NEI 07-07, was added using pipe data from the BPWorks data structure. A major shortcoming of this feature was the lack of numeric data for radiation exposure/radioactive compound concentrations. Tables changes in BPWorks v2.1 now pave the way to a much improved Priority Index calculation.

MAPPro User Community members will soon be testing remote access to BPWorks/MAPPro services and Web access to MAPProView© services (see image on page 30). Remote access to BPWorks/MAPPro will provide multi-user access for each site, significantly decreasing processing times for Dynamic Segmentation and the Risk Algorithm calculations. The web hosted version of MAPProView provides clients an easier way to access their GIS data. Accessing MAPProView is now performed through a web browser. This web-enabled version removes the requirement of having ESRI ArcReader software installed locally and also allows for easier multi-user access to the MAPProView data. A key function now available is an attribute table display, which was not available with prior ArcReader versions of MAPProView. The web hosted version continues to have the same tools users have come to expect, such as measure and identify tools.

STRUCTURAL INTEGRITY'S GWT CERTIFICATION PROGRAM

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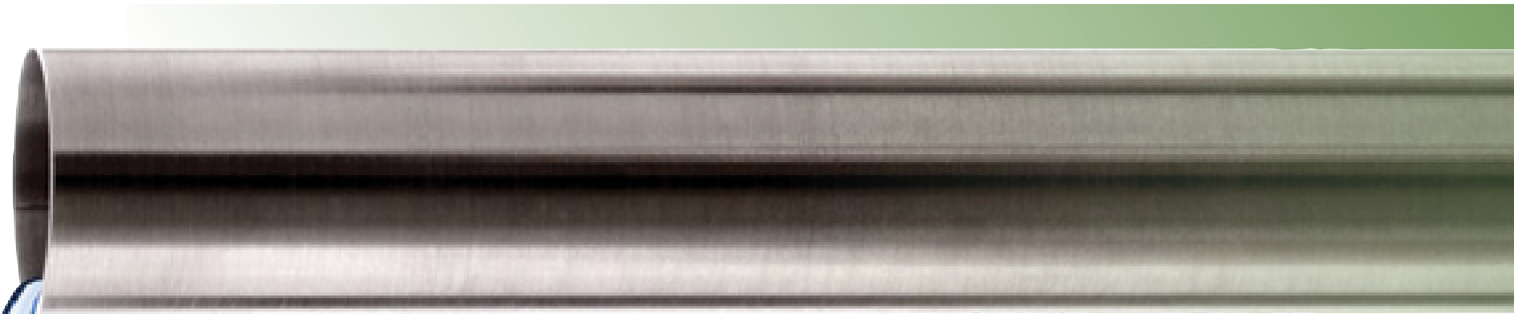
Two critical components of a successful Guided Wave Testing (GWT) assessment include having well trained and qualified GWT specialists on-site to perform the assessment and having every GWT examination reviewed by a second certified GWT specialist as a quality control checkpoint.

A thorough certification program is critical to a successful inspection as it helps ensure:

1. A level of proficiency on the equipment being utilized (which may vary depending on the application)
2. A fundamental understanding of GWT technology and experience in multiple applications and industries
3. An understanding of regulatory requirements as they pertain to specific applications of GWT
4. Assurance that the GWT specialists have maintained a level of proficiency and are current on the latest advancements in the technology

SI has recognized an industry need for GWT technician qualification and certification programs that are consistent with the processes and standards that are used for other NDE techniques in the industry. SI has found that while OEM qualification processes are good in quality, they are too equipment-centric to assure consistent, versatile, defensible certified inspectors. Thus, SI has developed a GWT certification program that documents the qualifications, and experience of SI GWT specialists that is specifically targeted for meeting the documentation and project requirements of the industry.

This program not only requires in-depth guided wave training and experience, but requires specific qualification in assessment strategies, operations, and trouble shooting. The program also requires periodic requalification, test-specific qualifications, and continual oversight of inspectors' performance. The program is consistent with the American Society of Nondestructive Testing (ASNT) SNT-TC-1A standard. In addition, to assist the industry as a whole, SI actively participates in new committees to establish the GWT Method within ASNT and to develop specific GWT standards within ASME and NACE.



Assessing Internal Corrosion Trends for Nuclear Power Stations

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Essential service water (ESW) piping systems in nuclear power plants are critical to plant operability and safety, as their primary purpose is to provide cooling capability to essential equipment and components in the event of an accident. Recent trends in the industry indicate that one of the dominant degradation mechanisms for these systems is internal corrosion. Typical ESW systems can be prone to internal corrosion degradation depending on the quality of the water being run through them, the water treatment regime, and if the presence of stagnant water for prolonged periods of time. Periodic assessments to determine the condition of these lines are required to assure safe plant operability. Once it has been decided to perform an assessment of the system, it is then necessary to select an appropriate assessment strategy, including selecting the inspection technology, determining how to manage the data collected, and what actions are to be taken in the event that degradation is found during the examinations.

1. INSPECTION TECHNOLOGY SELECTION

Many different technologies and strategies can be employed to assess the condition of piping systems, including ultrasonic testing (UT), radiography, visual inspections, ultrasonic guided wave testing (GWT), and others. Most of these techniques offer only a localized inspection capability and require direct access to the pipe to perform the inspection. Considering that most ESW systems contain thousands of feet of piping, which requires insulation removal and scaffolding for direct access, it is clear that performing a comprehensive assessment of the entire system with localized inspection technologies is impractical. GWT, alternatively, provides a cost-effective means to screen long sections of the piping system from only one access point in order to identify areas of potential degradation where conventional inspection approaches, such as UT, can be focused to provide quantitative data of the remaining wall thickness of the pipe.

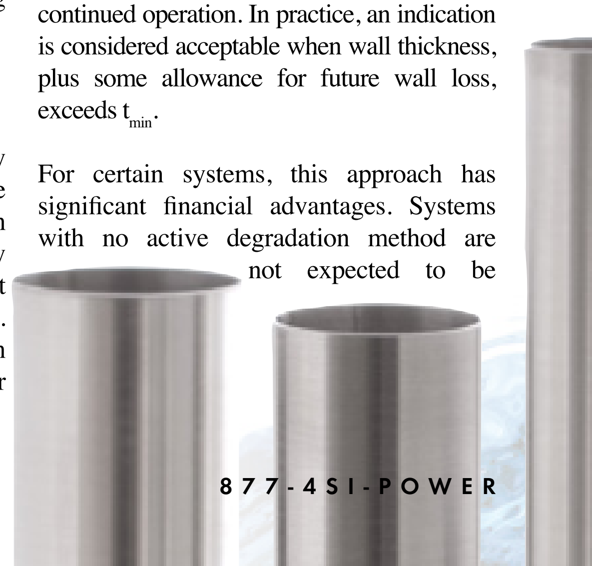
2. PLANNING FOR DEGRADATION DETECTION AND REMEDIATION

There are two approaches for any comprehensive system evaluation. One approach is a plan with evaluation criteria established prior to starting any inspections and methodology development to disposition the inspection findings. The other approach is the post-inspection evaluation methodology or the "cross your fingers and hope" methodology. Both approaches will be discussed but since preventative measures provide the certainty and quality we recommend, this article will focus mainly on the comprehensive pre-inspection evaluation methodology.

NO PRE-INSPECTION METHODOLOGY

We typically begin this approach with the selection of a number of inspection locations for detailed examination. Plant engineering usually has limited input at this point in the process, with that input being guidance on inspection locations and gathering of system design basis documents. The minimum allowable wall thickness, t_{min}, is either obtained from design basis documents or calculated in accordance with the Code of Construction. For Class III and B31.1 components, such as the ESW system, the Code of Construction does not consider local thinning in piping. Therefore, the calculated t_{min} value is not limited in the axial or circumferential extent. This makes applying this limit relatively straightforward. Any indication with wall thickness greater than t_{min} is acceptable for continued operation. In practice, an indication is considered acceptable when wall thickness, plus some allowance for future wall loss, exceeds t_{min}.

For certain systems, this approach has significant financial advantages. Systems with no active degradation method are not expected to be



ESSENTIAL SERVICE WATER PIPING

challenged in maintaining the structural integrity of the piping, making pre-inspection evaluations of limited value. For systems in which the anticipated degradation mechanism is highly variable, the likelihood that pre-inspection evaluations bound discovered indications is low.

Without planning, an outage can be forced. This can happen in a number of ways. In some situations, the design basis stress report may have used a limiting location to bound large portions of the system or assumed unrealistically high loading. Although conservative, this can unnecessarily restrict the allowable flaw size for the entire system. It is unlikely that a design basis stress report could be recreated to eliminate the overly conservative aspects in the time frame of a typical Limiting Condition for Operation (LCO). Another situation that could cause an LCO to expire is if the number of indications exceeds engineering's ability to process them. Both of the above scenarios have the potential to cycle the plant into and out of an LCO. This can be unpleasant and also has the potential to move the decision to shut down from an engineering decision to a political decision.

PRE-INSPECTION PLANNING

We recommend an integrated approach to planning with all the appropriate stakeholders at the site, including operations, design engineering, systems engineering, NDE personnel, along with the maintenance teams to make required repairs in a timely fashion and to prevent an unnecessary plant shutdown. The remainder of this article will concentrate on the interaction between the engineering and NDE personnel.

We start the planning for this integrated approach well in advance of the actual inspection activities. To increase the efficiency of the inspections, the engineering teams need to understand the inspection methodology and the NDE personnel need to know how to apply the engineering evaluations. Some level of pre-inspection engineering evaluations are recommended prior to inspection activities.

> For safety-related piping, pre-evaluations are considered critical. The purpose of the evaluations is threefold:
> 1. Establish flaw tolerance of piping
> 2. Determination of inspection technique
> 3. Rapid disposition

The first purpose, establishing the flaw tolerance of the piping, reveals the margin between the design basis stresses and the ASME Code allowable stresses. This can identify situations in which the design basis stress report may be overly conservative, which can unnecessarily restrict the allowable flaw size. By establishing the margin prior to receiving inspection results, actions can be taken to reduce overly restrictive assumptions and increase margin without the added pressure of being in an LCO. Once the flaw tolerance of the piping is established, the second purpose of the pre-inspection evaluations is to determine the appropriate inspection technique and sensitivity requirements. The final purpose of the pre-inspection evaluations is the compilation of a group of flaw parameters for which the safety margins in the ASME Code are met; aka a flaw handbook.

3. WOLF CREEK EXAMPLE

Structural Integrity recently completed a project at the Wolf Creek Generating Station (Wolf Creek) to comprehensively assess the condition of the ESW system. An extensive pre-project planning phase was conducted by a multi-disciplined team of NDE specialists, engineers, and project managers in order to select the proper inspection technologies to meet Wolf Creek's objectives, determine the proper dispositioning and remediation actions to be taken if and when degradation was found, and develop a plan for organizing and managing the large amounts of inspection data created. The goal of the assessment was to perform a comprehensive evaluation of the system, not just local inspection of select areas.

Based on Wolf Creek's objectives, we selected GWT as a key driver of the inspection phase of the project in order to screen long lengths of piping to intelligently select areas for conventional ultrasonic testing (UT). The use of GWT allowed the plant to screen long sections of pipe, including inaccessible regions such as wall and floor penetrations, as well as areas which were easily accessible. Our approach resulted in tremendous cost savings by not having to remove insulation in areas other than the areas where the GWT was performed and/or where areas of interest further localized examination. Further, test locations could be selected to minimize the amount of scaffolding required to access the piping. Piping

Continued on next page

geometries which were not suitable for GWT, such as short lengths of pipe, elbows, tee-pieces, etc., were 100% screened with conventional UT and select welds throughout the system were inspected using Phased Array UT (PAUT).

The assessments identified multiple areas of internal wall thinning from under deposit corrosion and pitting, which violated the minimum allowable wall thickness criteria identified in design basis documents. Wolf Creek established administrative limits (T_{admin}) which provided additional margin above the t_{min} requirements to account for ESW system configurations and the potential for degradation. The t_{admin} limits provided allowed the station to disposition flaws well above the t_{min} limits. Individual and ASME Code Case N-513 flaw evaluations for class 3 piping were invoked, resulting in repair or replacement of piping throughout the plant. Because the flaw evaluations and code case calculations were conducted prior to the inspections, the plant could continue to operate and conduct repair activities while on-line and defer replacements until the next refueling outage. In the event that a wall thickness was detected less than t_{min}, a typical approach to dispositioning the flaw would be to first size the flaw and then grid out the entire circumference of the pipe at the flaw location to gather thickness measurements to be used as inputs into the calculations as shown in Figures 1-3.

Figure 1 shows a typical sizing and banding pattern for dispositioning an internal flaw. Figure 2 shows a typical repair encapsulation applied to maintain structural integrity of a flawed region. Figure 3 shows a photograph of the internal degradation from a section of pipe which was cut out and replaced.

We examined a total of 5,000+ ft. of pipe resulting in the replacement of ~180 ft. of piping to date and numerous repairs throughout the system. In order to manage the massive amounts of GWT and UT inspection data collected during the assessment, Structural Integrity is digitizing the ESW system and storing the data in BPWorks/MapPro View. By doing so, Wolf Creek will be able to easily review the assessment findings and identify and monitor areas where wall thinning was detected but didn't violate t_{admin} or t_{min} limits. An aerial overview of the ESW system in MapProView is depicted in Figure 4. showing areas where piping was replaced, while also highlighting the vault and pump-house locations where piping was repaired. The assessment approach was not applied to the buried ESW piping as Wolf Creek has plans to replace and re-route this piping starting in late 2012.

Figure 1. Sizing of flaws and full circumferential grid for flaw dispositioning

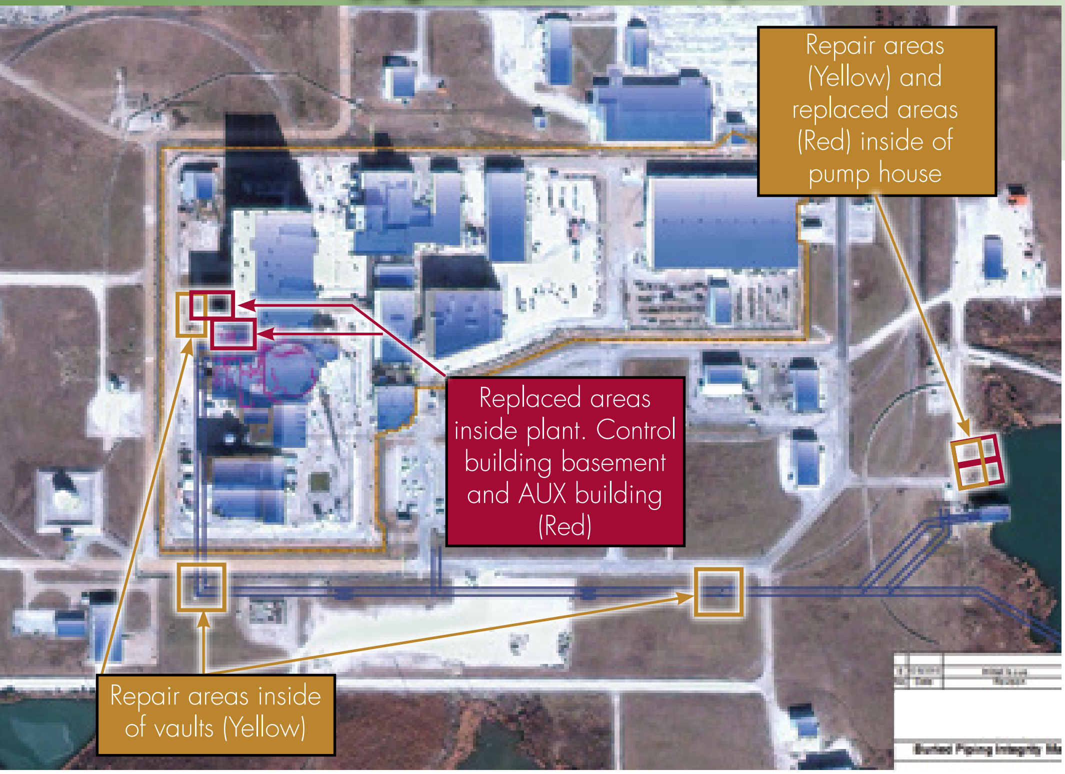
Figure 2. Typical encapsulation repair

4. SUMMARY

Presented here is a comprehensive approach to assessing the condition of the ESW system, something which is not simple

Figure 3. (Left) Internal build-up on a section of piping replaced. (Right) Close-up of an internal pit.

Figure 4. Aerial overview of the plant in MAPProView showing the ESW system and piping components which were replaced



given that such systems can have thousands of feet of piping that twists and turns throughout the plant and creates challenges for inspection due to many regions which are not accessible or very difficult to access. Key to the success of such an assessment is the pre-project planning and coordination to review the objectives, select the appropriate inspection technologies, determine how flaws will be dispositioned while remaining on-line, and how the large amounts of data will be captured and managed. This approach was successfully applied at Wolf Creek to assess the ESW piping system, whereas areas of piping degradation were detected, dispositioned, and remediated without affecting plant operations. Wolf Creek realized an estimated $1M+ savings from the use of GWT vs. manual scanning of the piping, as well as additional savings from proper planning of the assessments, allowing the plant to continue operations and not shut down when degraded areas were detected that violated code of constructions limits. We are currently working with Wolf Creek to integrate new advanced monitoring solutions for on-line monitoring for degradation growth on piping where degradation was detected but did not exceed t_{admin} or t_{min} limits. Solutions being considered include the use of permanently installed guided wave sensors s.

We are also integrating new inspection technologies such as PAUT roller probes (see Figures 5 and 6) into our service offering to continue to improve our inspection processes and capabilities. These portable wheel probes provide the capability to quickly scan an area of piping to obtain thousands of UT thickness measurements per square foot. These devices are equipped with an encoder which allows these measurements to be stored and referenced for further analysis, thus providing the capability to quickly detect and size internal corrosion.


Figure 6. PAUT Corrosion Wheelprobe manufactured by Sonatest.

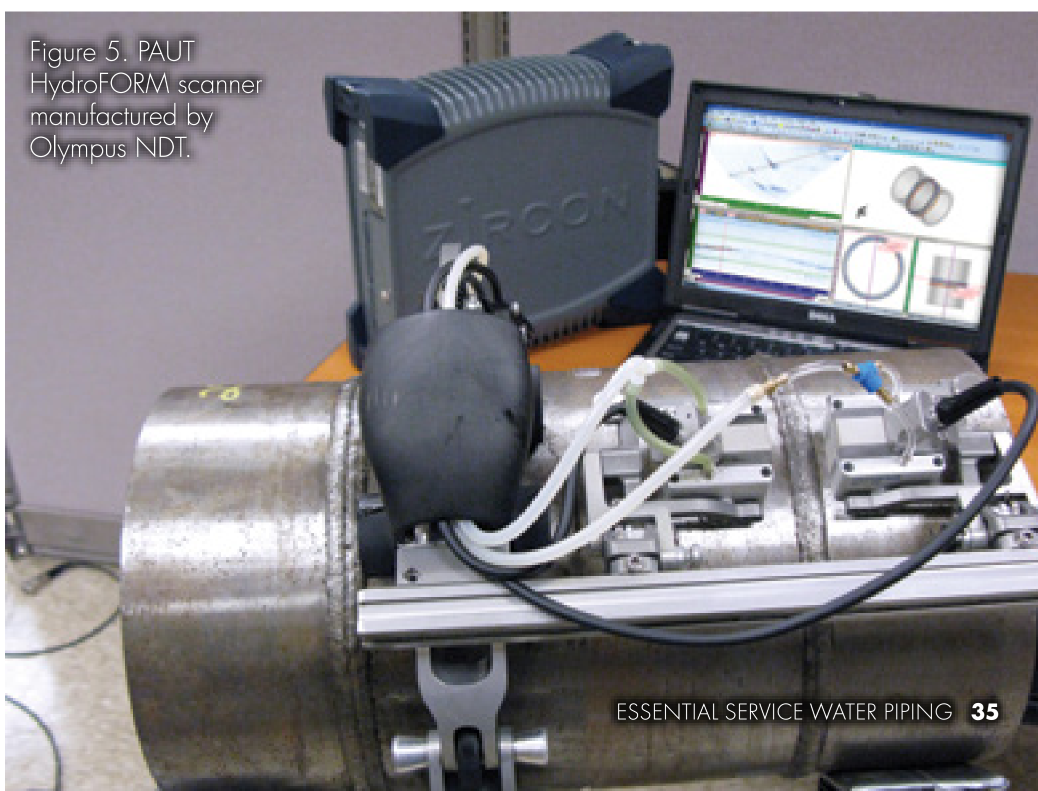
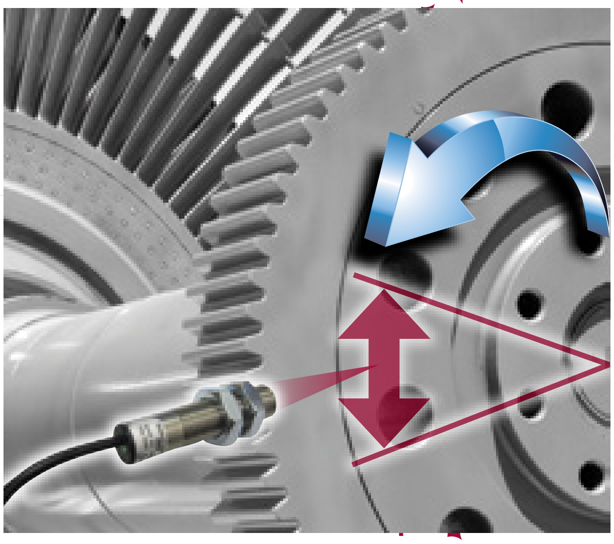
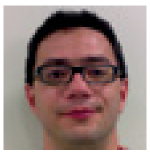


Figure 5. PAUT HydroFORM scanner manufactured by Olympus NDT.



Transient Torsional Vibration Monitoring System



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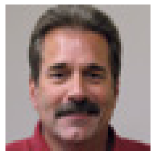

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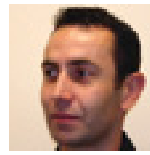

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Historically, failures of Turbine Generator (TG) rotor components due to torsionally induced high cycle vibration fatigue (retaining rings, shaft cracks, blade root cracks) have been catastrophic and with little warning. Torsional vibration of rotors, leading to fatigue failure, is generally a sporadic, transient phenomenon provoked by sudden load changes on the grid and/or inter-harmonic loading, which lasts from seconds to minutes. Most of the time these transient events do not overly excite the TG shaft torsional resonances. But occasionally there is a coincidence of the transient's wave form characteristics and torsional resonances resulting in several cycles of high stress. The accumulation of these cycles may lead to crack initiation and fatigue failure. In addition, modification to the TG rotor i.e., exciter or turbine replacement, may move the torsional resonances into a range of susceptibility.

Structural Integrity's Transient Torsional Vibration Monitoring System (TTVMS) is used for characterization of torsional resonance of a TG set and the influence of transient torsional events from turbine perturbations or electrical grid events. TTVMS can be used for characterization of a TG set or for continuous monitoring of transient torsional events.

Figure 1. Catastrophic failure of Retaining Ring

Examples of damage resulting from torsional vibration include fatigue cracks on the rotor shaft, cracks in retaining rings and cracks in turbine blade roots. The failures ranged from cracks found during inspection to complete failures. These failures can cause severe damage to the TG and are a potential human safety concern. The expense of downtime and repair may be in the millions of dollars. The cause of these failures are vibrational fatigue initiated and driven by TG rotor torsional vibration.

In a typical TG set, steam energy is converted to rotational motion of the shaft through the turbine which drives the generator rotor. The rotor windings, with excitation from the exciter, create current flow through the three phase generator stator windings. The stator is connected to the grid through transformers and associated equipment. The generator mass and the grid load coupled through the stator to the rotor create a torsional resistance to the turbine driven shaft's rotational motion. Ideally, under steady state conditions (constant rotational speed and constant electrical load), the torque remains essentially constant.

Two types of changes in the TG system can cause torsional variation: (a) turbine perturbations and (b) electrical grid perturbations. The electrical perturbations are due to sudden changes on the grid, such as very large motor starts and arc furnace operation. In general, there are always relatively small perturbations that create a sort of broadband background noise. But with large equipment, such as arc furnaces, the perturbations may be in the order of 20 to 100 MWs with similar instantaneous reactive power (VAR) changes. These transients may cause phase imbalance and negative sequence currents. All the sources of perturbations have time, frequency and amplitude characteristics that will uniquely affect the shaft rotation and manifest as torsional vibration. Fast transients will excite higher vibration modes. Negative sequence currents will cause excitation forces near 120 Hz. Inter-harmonic currents may cause excitation at any frequency, not just the harmonics. The coincidence of any of these transient forces with a torsional resonance will increase vibration amplitudes significantly. The torsional forcing functions can have both a pseudo-steady state and transient characteristics where the power amplitude changes over many seconds (large motor starts, grid frequency) to relatively instantaneous changes (several milliseconds) furnace arcing and line faults. The effect of the speed of power change (rise time) or the frequency composition of the perturbation will determine the amplitude and frequency of the response. The number of occurrences and durations the various forcing functions will determine the fatigue usage of the shaft components vulnerable to this type of failure.

CUSTOM DATA ACQUISITION SYSTEM IMPLEMENTATION

Structural Integrity successfully implemented a custom data acquisition system at two fossil power plants. With both applications, the goal was to identify torsional modes going through the generator. These vibrations can damage the retaining rings of a generator. Multiple torsional probes were placed along the TG set to measure small angular velocity changes.

As an example, TTVMS captured short transients associated with synchronizing the generator to the Grid (Figure 2). This procedure will induce a short period of torsional disturbance to the TG set. Later, we analyzed this transient and the natural frequencies and mode shapes were identified (Figure 3).

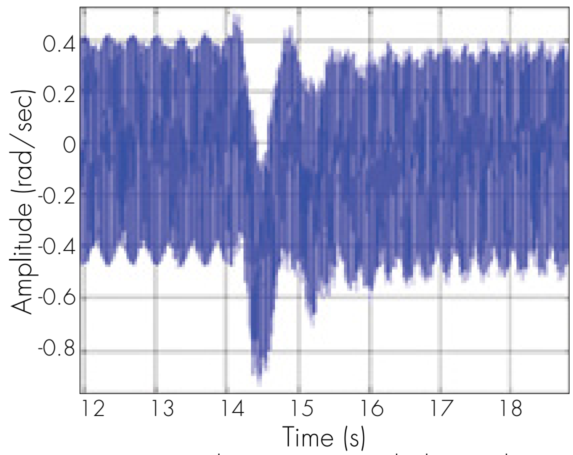

Figure 2. Synchronization with the grid at time 14 seconds.

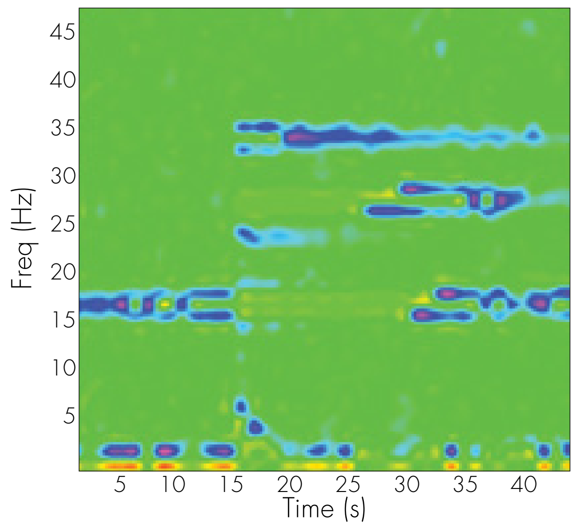

Figure 3: Transient Frequencies at 2.5,17, 27, and 33Hz.

CONCLUSION

Turbine generator rotor failures due to torsional induced vibration fatigue may be catastrophic and costly. The relatively long length of time from onset of the torsional mechanism to failure allows the opportunity to detect, analyze and safely shut down the TG set. This incipient failure detection is possible with adequately designed data acquisition monitoring systems, such as TTVMS. When applied either as a continuous or periodic monitor, transient, sporadic torsional vibration indications that differ from the baseline can be recognized.

DIRECT EXAMINATIONS FOR NUCLEAR AND TRANSMISSION PIPELINE OPERATORS

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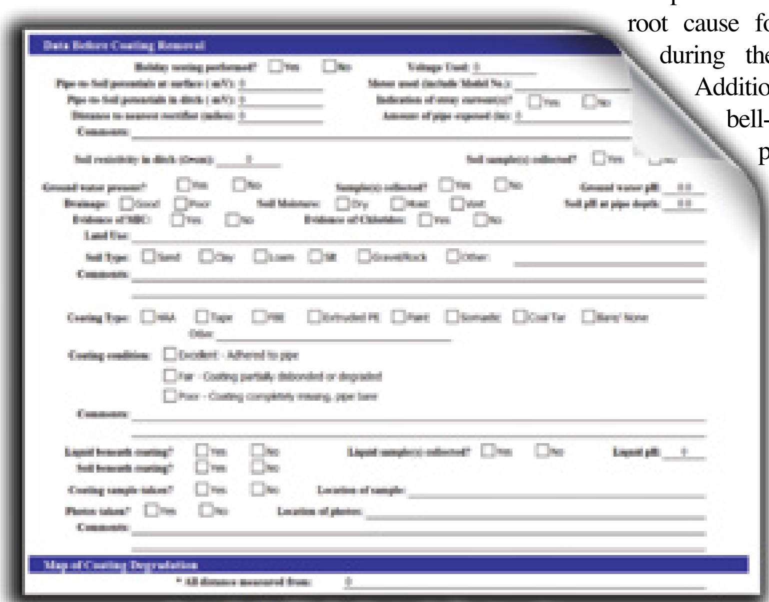
A common challenge across both the nuclear industry and gas and hazardous liquid pipeline operators is a shortage of qualified inspectors that have both the knowledge and access to the latest tools and technologies to complete a comprehensive direct examination. Furthermore, many companies lack the engineering support so that, once a direct examination is performed, a complete understanding of the data is obtained, ensuring the appropriate remediation is performed and data is fed back into the pipeline integrity program. Structural Integrity specialists have extensive expertise in evaluating the integrity of buried piping and have been certified using a wide range of NDE methodologies, broadening both the type and level of understanding of data captured during these inspections. In addition, they are supported by a team of experienced pipeline engineers to drive the appropriate actions once the inspection data is collected and analyzed.


Data Before Coating Removal
Map of Coating Degradation

Sample Bell-hole Data Collection Form

Direct examinations are typically referred to as bell-hole inspections, a term that originated in early construction days when holes shaped like a bell were required for a welder to access the pipe to complete girth welds, hot taps, and repairs in the field. The welder required a larger ditch than typically trenched to complete the tie-in welds. Hence, the widened area in the shape of a bell to allow 360° access around the piping. In order to complete a thorough direct examination, the inspector also needs the same access to the pipe, so the term bell-hole inspection has also become synonymous with direct examination.

Bell-hole inspections support pipeline integrity by identifying and quantifying degradation identified from the results of ILI, direct assessment and other indirect assessment methodologies (CIS, DCVG, APEC, GWT, etc.), as well as collect data on the potential for future degradation at a particular location. Accurate and thorough data collection can be used to prioritize mitigation and define root cause for anomalies detected during the inspection process. Additionally, well documented bell-hole inspections of pipe during routine operations and maintenance activities provide invaluable information on the condition of the pipe as well as an opportunity to confirm historical and database records that are used to feed risk assessment software and other decision-making tools.

While some tools used during Direct Examinations lack clear regulatory acceptance (NRC, NEI, PHMSA, etc.), the benefit of the additional data is clearly evident. For example, Guided Wave Technology (GWT) is often recommended to supplement direct examinations even though it in itself does not comprise a direct examination. Regulators have identified and made this gap, clear not to discourage the use of a technology that has proven to enhance the effectiveness of a buried pipe program, but to ensure comprehensive direct examination inspections are being performed.

To understand the reasons behind this recommendation, it is useful to take a look at the much larger picture. The purpose of direct examinations is to assess the condition of buried piping and quantify the extent of any degradation at locations along the pipeline deemed to be most susceptible to a particular threat, and then remediate any degradation discovered. An effective integrity management or buried pipe program then feeds those results back into a greater integrity management program to assess the risk of future degradation and further identify, prioritize, and remediate other areas that may also exhibit degradation. All the data gathered (through indirect or direct methods) can be integrated and/or overlaid to enhance reasonable assurance of capturing the worst case degradation, and upon discovery of adverse conditions establish the extent of condition and extent of cause. GWT specifically offers the opportunity to increase the reasonable assurance of detecting the worst case degradation (which may lie just beyond the excavation walls), credit the amount of coverage for indirect inspections

(i.e., knowledge of potential corrosion on line) and determine where similar conditions may exist if a scope expansion is warranted. These pieces of data and others may not be useful immediately in complying with industry regulations, but are critical to the overarching success of buried pipe programs and their continual improvement.

With pipeline regulation driving ever-increasing assessments (baseline and reassessments) involving new NDE tools and technology, the demand for quality bell-hole and NDE inspection services has risen dramatically. In the gas transmission industry, assessment programs have been evolving to include difficult-to-assess areas, where congested piping (such as compressor stations) and cased pipeline segments exists. In these scenarios, appropriate indirect inspection tools are used to prioritize direct examination locations. For example, above-ground surveys such as APEC or ACVG have been used by sites to address the effectiveness of external corrosion control. Suspected degradation has then been targeted for

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DIRECT EXAMINATIONS FOR NUCLEAR AND TRANSMISSION PIPELINE OPERATORS

CONTINUED

further evaluation using an independent complimentary technique GWT, either prior to excavation (access from risers) or inside the excavation. For difficult-to-assess cased segments, GWT has been used as a supplement to ECDA or to provide an equivalent understanding of degradation when compared to historically accepted methodologies using the Other Technology Notification (OTN) process. Direct examination plays a critical role in validating the severity classification and results of these and other indirect inspection methodologies and validating the assessment process itself.

CASE STUDY

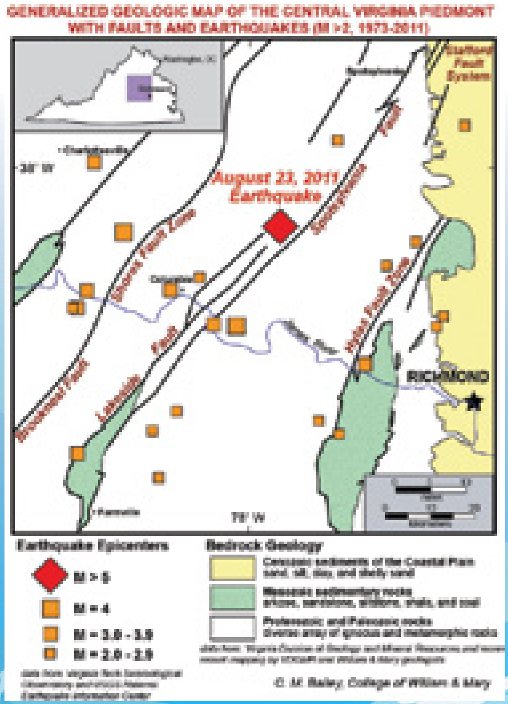
In July and August 2012, Structural Integrity was contracted to perform three direct examinations under the NEI initiative for a nuclear site. It was requested that during direct examinations, data be gathered from bell-hole inspections, soil analysis, indirect inspection using guided wave testing, and any anomalies were sized for the UT of record. One of the high-risk groups included a segment of piping containing radioactive fluid that was abandoned, but the method for draining was not well documented. Detailed UT testing for internal corrosion confirmed areas of wall loss (as predicted by the risk model) and GWT was used to calibrate off known internal corrosion inside the excavation and reasonably assure more severe degradation did not exist beyond the excavation walls. For the bell-hole inspections, pipe-to-soil readings, mapping of coating degradation, and a comprehensive soil analysis (Soil Pro™) were used to determine the effectiveness of cathodic protection, the corrosiveness of the soil and the overall likelihood of external degradation. Specialized forms developed by Structural Integrity were used to collect all the data and ensure accuracy and consistency of collection for quantifiable comparisons.

We were also contracted to perform a post- examination assessment, providing input and recommendations towards the effectiveness of the site's buried pipe program, define the next re-inspection interval and return the results back into the sites, risk algorithm BP Works™ and MapProView© databases for further trending and analysis. The value of this packaged solution is being recognized by many other sites where they have selected pieces of data that fill gaps in their program (NEI and License Renewal), and then leverags our experience to ensure the results are gathered correctly and input into their database accurately. Since Structural Integrity's inspectors are cross-trained in many indirect and direct assessment techniques, a comprehensive assessment at each site can be conducted at relatively little added expense, complication, or time.

Coating Thickness Measurements

Anomalies

Update on Fukushima Initiatives



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In March 2012, the NRC issued several orders and a 10CFR50.54(f) information request stemming from the Fukushima nuclear accident. The orders relate to portable safety equipment (e.g., back-up power supplies), BWR Mark I and II containment venting, and spent pool level monitoring.

The 10CFR50.54(f) information request relates to seismic and flooding re-evaluation. The seismic portion of the document requests each nuclear site to address Near Term Task Force (NTTF) recommendations as follows:

2.1 – HAZARD EVALUATION (PHASE 1)

- Plants are to re-evaluate external hazards using current methods and guidance. For seismic, this includes development of new seismic hazard curves and Ground Motion Response Spectra (GMRS)
- For those plants having 'exceedance', that is where GMRS exceeds the defined Safe Shutdown Earthquake (SSE), either a Seismic PRA (SPRA) or a Seismic Margins Analysis (SMA) must be developed and submitted.
- At the time of this writing, a guidance document is being finalized by the industry for the conduct of the seismic risk evaluation that is responsive to NRC comments being provided through numerous public meetings.
- Results of Phase 1 will determine whether additional regulatory actions are necessary as part of Phase 2 (e.g., updated or revised design basis, rulemaking, etc.).
- 2.3 – Walkdowns
- Plants are to generate a Seismic Walkdown Equipment List (SWEL) using prior IPEEE information as a starting point, and update this work (circa early 1990s) based on the current plant configuration.
- Complete walkdowns, including area 'walk-bys' (for areas containing SWEL equipment), and a peer-reviewed Seismic Walkdown Report using qualified and trained personnel.
- Guidance for SWEL generation and conduct of walkdowns/walk-bys is contained in an industry-generated and NRC-approved seismic walk-down document agreed upon after the date of the 10CFR50.54(f) information request. As examples, this document includes guidance for selection of SWEL equipment to address equipment not routinely inspected, equipment diversity in functions related to shutdown and containment, and equipment that could lead to draindown of the spent fuel pool.

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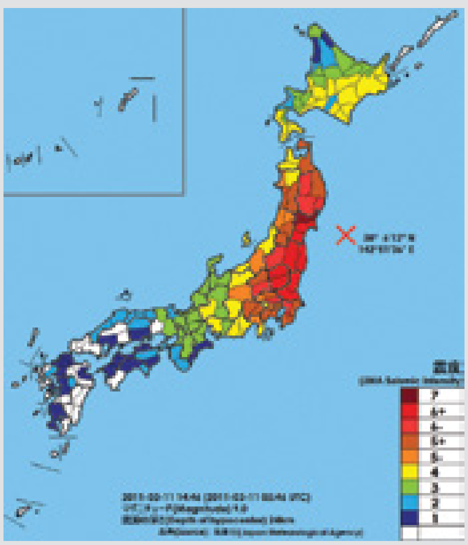
FULL SERVICE SEISMIC RISK ASSESSMENTS

CONTINUED

IMPORTANT DEADLINES RELATED TO THIS INFORMATION REQUEST ARE:

- Initial responses within 60 dates (date already passed) to address intentions to comply with industry-generated and NRC-approved guidance documents, or to propose alternative approaches, including acceptance criteria.
- Submittal of the 2.3 Seismic Walkdown Report by November 30, 2012.
- Within 1.5 years (3 years for Western US) of letter date, or September 2013, submit a Seismic Hazard Evaluation that provides a revised site-specific GMRS and compares it to the SSE. As necessary, the selected risk evaluation approach (SPRA or SME) is to be provided. In general, the SPRA is a more involved effort, but is anticipated to be warranted when exceedances are great (i.e., factor of exceedance greater than 1.3).
- By October 2016 (2017 for Western US), submit the seismic risk evaluation (i.e., either SPRA or SMA). This will complete Phase 1.



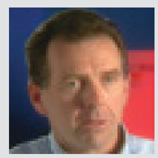
To ensure utilities respond to the NRC 10CFR50.54(f) request in a consistent manner, NEI, EPRI and the utilities formed a task group to develop the walk-down document under 2.3 as well as address other aspects related to the hazard evaluations under 2.1. EPRI is currently generating updated seismic hazard and GMRS data for each site. Output is generally expected not to be available until 2013. In the meantime, utilities are encouraged to retrieve original plant data to support future review, update and/or regeneration, as required (e.g., design basis seismic calculations, soil data, SPRA/SMA data).

Structural Integrity Associates, along with its partners SC Solutions and Anatech, has significant collective experience in soil-structure interaction analysis, in-structure response spectra generation, and analysis of nuclear power plant structures and mechanical components stemming from seismic events – each constituting critical elements of risk evaluation, whether SPRA or SMA. This experience includes evaluation of capacities of various structures, which leads to the development of seismic margins of structural systems and their components. In addition, our engineers are currently participating in 2.3 walkdowns in order to help utilities meet near-term regulatory commitments.

The most recent of the soil structure interaction (SSI) projects include seismic evaluations of AREVA's EPR (standard and site specific designs) nuclear island and several other structures, a spent-fuel storage expansion SSI analysis, and a review and confirmatory SSI analysis for a Texas site. Safety-related structural analyses, including fragility to over-pressurization of primary containment systems and seismic capacity of subsystems, have also been performed for NSSS vendors for new plant designs. Lastly, recent experience in evaluation of components for seismic loads includes qualification of control room consoles for a West Coast plant and a new plant in China, and evaluation of postulated seismic failure of piping at a central U.S. plant.

NEWS

Structural Integrity's employees take pride in being leaders and contributors in the industry. Please join us in congratulating Jeff and Rick on their leadership.



JEFF HENRY

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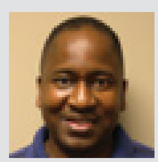
Congratulations to Jeff Henry who, is the 2012 recipient of the J. Hall Taylor Medal from ASME. This award is given for distinguished service or eminent achievement in the field of codes and standards pertaining to the broad fields of piping and pressure vessels which are sponsored or undertaken by ASME.



RICK DIXON

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Rick Dixon has been appointed the Chairman of the High Pressure Technology Committee for the ASME PVP Division. This committee focuses on the research, development, design and operation of pressure vessels, piping components and systems for high pressure service.

STRUCTURAL INTEGRITY CONTRIBUTED TO ASME PVP PAPERS

Structural Integrity recently contributed several technical papers and presentations at the ASME PVP Conference in July 2012. They are also available on our website at www.structint.com/technical-papers.

- Advanced NDE Techniques and their Deployment on High Pressure Equipment - Jeffrey Milligan, Daniel Peters, Jason Van Velsor
- Alternative Acceptance Criteria for Flaws in Ferritic Steel Components Operating in the Upper Shelf Temperature Range - Hal Gustin
- Alternative Approach for Qualification of Temperbead Welding in the Nuclear Industry - Richard Smith
- Asset Management, Life Extension and Fitness for Service in the High Pressure Industry - Daniel Peters, Kevin Haley
- COG Risk-Informed In-Service Inspection (RI-ISI) Project - Scott Chesworth
- Effectiveness of Excavate and Weld Repairs on a Large Diameter Piping Dissimilar Metal Weld by Finite Element Analysis - Francis Ku, Pete Riccardella, Aparna Alleshwaram
- Flow Loads on the Shroud in a Boiling Water Reactor due to a Recirculation Outlet Line Break: A Comparative Study Between Potential Flow and Computational Fluid Dynamics Methodologies - Raju Ananth, Sandra Sowah, Jay Gillis
- Grain Boundary Graphitization in P1 (C-1/2Mo) Alloy Pipe - Clark McDonald, Jeff Henry
- Guided Wave Testing: Maximizing Buried Pipe Corrosion Knowledge From Each Excavation - Andy Crompton, Roger Royer, Steve Biagiotti
- Improving the Value of Excavations Through Indirect Inspection and Engineering Assessments - Steve Biagiotti, Eric Houston, Dilip Dedhia, George Licina
- Investigative Study of 2-D vs. 3-D Weld Residual Stress Analyses of the NRC Phase II Mockup - Francis Ku, Stan Tang
- Probabilistic Models of Reliability of Cast Austenitic Stainless Steel Piping - Haiyang Qian, David Harris, Tim Griesbach
- Supplemental Stress and Fracture Mechanics Analyses of Pressurized Water Reactor Pressure Vessel Nozzles - Matthew Walter, Daniel Sommerville
- Technical Basis for Code Case N-806, Evaluation of Metal Loss in Class 2 and 3 Metallic Piping Buried in a Back-Filled Trench - Bob McGill

TRAINING

Structural Integrity often receives requests from clients and industry organizations to provide training courses or workshops. Most recently, these educational workshops have helped peers and clients learn more about key industry topics. The workshops can vary in topic, depth and length, and we frequently work with business partners and clients to share a full perspective. Recent examples include the following:

- HRSG/Boiler/High Energy Piping Workshop-June 12-13, Nashville, TN - This annual workshop was hosted in conjunction with TVA and featured presentations about Grade 91, HRSG, Boiler Inspection Techniques, and nondestructive examination technologies.
- Corrosion and MIC Control Training-June 18-19, Charlotte, NC - George Licina conducted this training course which focused on fundamentals of corrosion, environmental influences, mitigation, and environmental influences. If you are interested in attending this two-day course, it will be offered again June 17-18, 2013, at the EPRI Charlotte office. Contact us at info@structint.com for more information on the training.
- Nuclear Cable Workshop-August 6-7, Richmond, VA- Structural Integrity co-presented this workshop with Kinectrics at Dominion Technical Innsbrook Center. The objective was to highlight the technologies and methods used to develop practical comprehensive cable aging management programs for nuclear and featured presentations from both companies.
- Nuclear Plant Integrity Workshop-August 22-23, Charlotte, NC - This event concentrated on key industry topics, including case studies from recent work. Participants were given overviews on topics including ASME Code, Fatigue, Fabrication and Welding, and Buried Piping.

Structural Integrity customizes our training to your needs. If you are interested in a workshop or training course in your area or for your company, please let us know.
www.structint.com/resources/training

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EVENTS:
Canadian HRSG Forum
Oakville, ON, Canada, *October 22-23, 2012*
Register Now!
http://www.structint.com/events/canadian-hrsg-2012/register

TRADESHOWS:
EPRI Advances in Condition and Remaining Life Assessment for Fossil Power Plants
Hilton Head, SC *October 17-18, 2012*

EPRI Turbine Generator Users Group and Vendor Expo
Savannah, GA *January 21-23, 2013*

Energy Gen
Bismarck, ND *January 29-February 1, 2013*

NACE Corrosion
Orlando, FL *March 17-21, 2013*
Visit us at Booth #1407
Presenting: Barry Gordon

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