Structural Integrity Associates, Inc.™

NUCLEAR

MULTIDISCIPLINARY SERVICES

1-877-4SI-POWER structint.com

ABOUT STRUCTURAL INTEGRITY

Structural Integrity Associates, Inc. (SI) is a leading engineering and consulting firm dedicated to the analysis, control, and prevention of structural and mechanical failures. The company was founded in 1983 in San Jose, CA, and has since opened offices throughout the United States and Canada, as well as established overseas affiliates.

Over the past 5 years, we've expanded our mechanical-based expertise to include nuclear fuel and advanced structures analysis capabilities. We also added chemical engineering to our cadre of nuclear plant offerings. Our ability to integrate a full scope of services, from inspection and condition assessment, to monitoring and remaining life analysis, repair or remediation, and ultimately, total risk management of critical equipment and structures continues to grow.

Our history is one of innovation marked by a creative multi-disciplined approach to component evaluation and repairs, as well as development of increasingly sophisticated tools reflecting a unique blend of technical expertise with the latest computer and expert system technologies.

Over the years, Structural Integrity has established itself as an innovative and responsive resource for answering virtually any challenge in the analysis, control, and prevention of failures in critical equipment and structures. Our experience ranges from R&D to engineering, metallurgy, fabrication, and NDE; from petrochemical to nuclear and fossil-fueled power plant support.

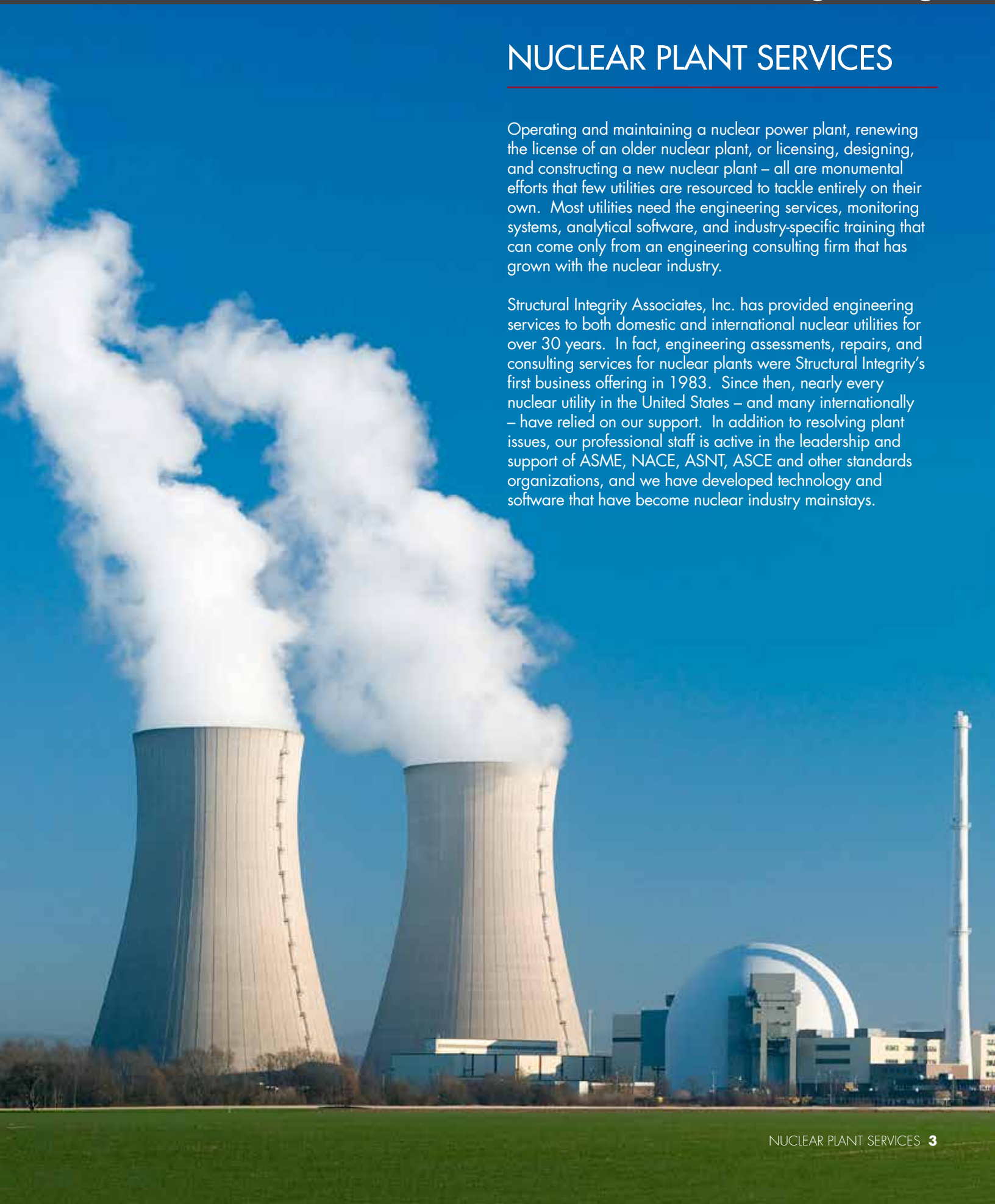
We welcome new challenges and urge you to contact us whenever the need arises **24/7/365**.

1-877-4SI-POWER
1-877-474-7693

NUCLEAR PLANT SERVICES

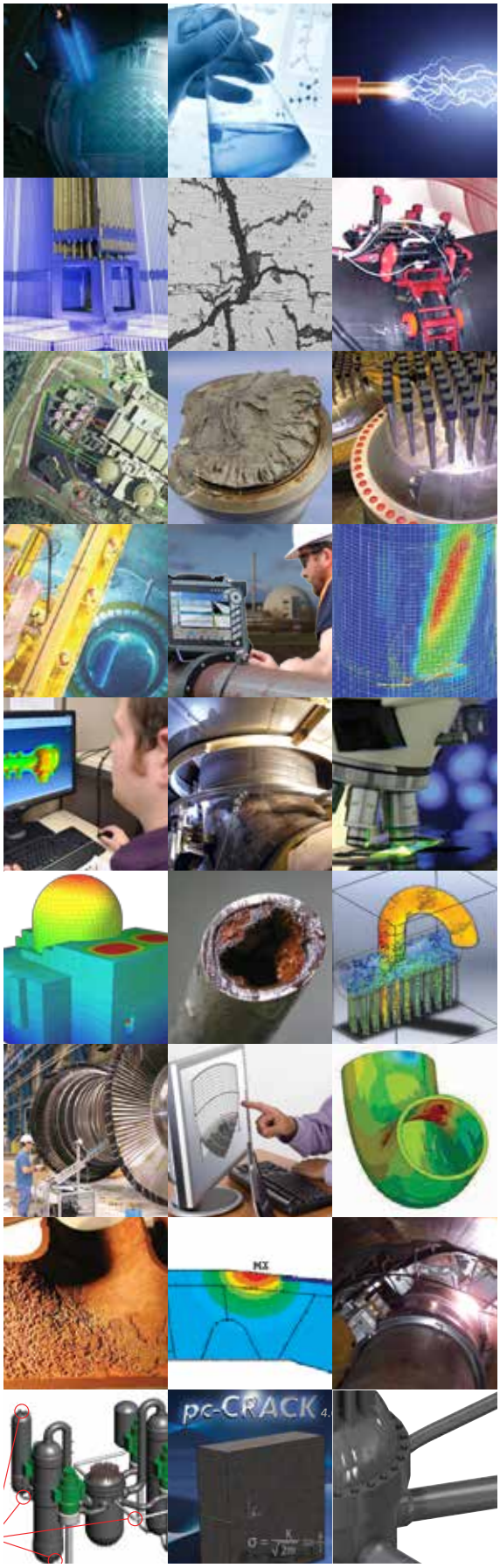
Operating and maintaining a nuclear power plant, renewing the license of an older nuclear plant, or licensing, designing, and constructing a new nuclear plant – all are monumental efforts that few utilities are resourced to tackle entirely on their own. Most utilities need the engineering services, monitoring systems, analytical software, and industry-specific training that can come only from an engineering consulting firm that has grown with the nuclear industry.

Structural Integrity Associates, Inc. has provided engineering services to both domestic and international nuclear utilities for over 30 years. In fact, engineering assessments, repairs, and consulting services for nuclear plants were Structural Integrity's first business offering in 1983. Since then, nearly every nuclear utility in the United States – and many internationally – have relied on our support. In addition to resolving plant issues, our professional staff is active in the leadership and support of ASME, NACE, ASNT, ASCE and other standards organizations, and we have developed technology and software that have become nuclear industry mainstays.



PRODUCTS & SERVICES

Engineering Services



ENGINEERING SERVICES

BWR REACTOR INTERNALS MANAGEMENT

BWR reactor pressure vessel internals cracking occurred at many units early in plant life. The industry responded in 1994 by establishing an industry-wide BWR Vessel and Internals Project (BWRVIP), which addressed all BWR internals and helped avoid mandated NRC shutdowns by instituting and executing plans to resolve issues. Structural Integrity has specialized expertise in managing BWR vessel internals, and can support utilities in implementing various aspects of the BWRVIP's Inspection and Evaluation Guidelines, including proactive analysis, outage preparation, and repair/replacement reviews. As structural margins decrease with aging, more sophisticated analysis methods may become necessary to reduce conservatism and to gain margins. Therefore, we utilize advanced linear-elastic and elastic-plastic fracture mechanics methods to evaluate internals degradation.

CANDU REACTOR SUPPORT

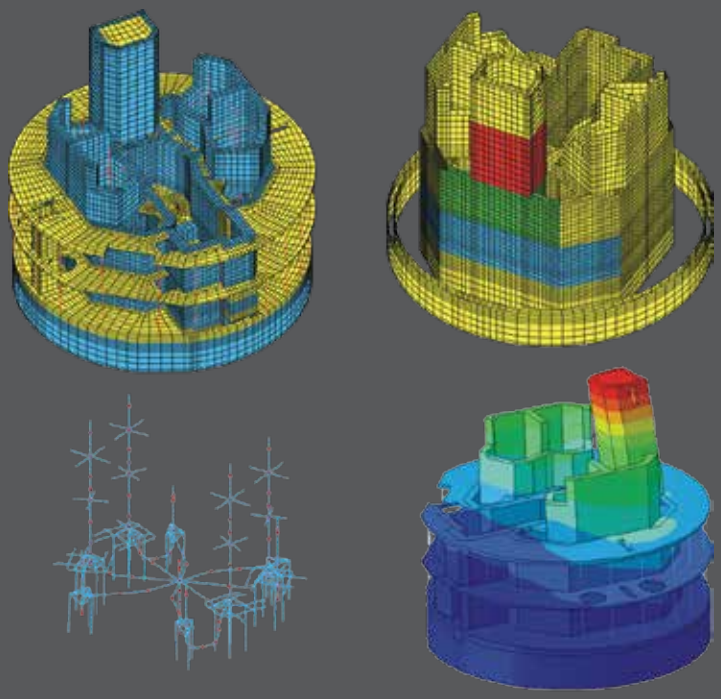
We've been involved in a number of projects with the CANDU fleet (Pressurized Heavy Water Reactors). Notable is our experience in assisting with the analysis, testing, process development, licensing, and conceptual tooling to support weld overlay repairs of FAC-thinned feeder pipes. Other CANDU projects completed to date address topics including fatigue management, dynamic pressure monitoring, risk-informed ISI and advanced fracture mechanics software and training. Our core capabilities, combined with our knowledge of CANDU plant design and operation gained through recent projects, make us a substantial engineering services resource to CANDU operators in Canada and around the world.

CHEMISTRY/CHEMICAL ENGINEERING

Power industry clients have relied on us for design, development, operational improvements, assessments and evaluations of water chemistry and power plant and industrial water processes since 1983. Our expertise in water chemistry to control environmental cracking and corrosion, ensure fuel reliability and minimize radiation fields has provided performance improvements for our clients. Our experience includes the design, fabrication and support for installation and startup of water purification system hardware and instrumentation & control upgrades at U.S. and international nuclear power plants.

CONCRETE ADVANCED STRUCTURE ANALYSIS

Concrete structures perform important functions at nuclear power plants, providing shielding, support and containment for safe operation. These structures are generally durable and trouble-free, but certain environmental conditions or changes in loading can necessitate re-evaluation. Structural Integrity has specialized expertise and finite element analysis computing power to evaluate the non-linear behavior of concrete using ANSYS, LS-DYNA, ABAQUS and ANACAP. ANACAP, Structural Integrity's in-house concrete analysis package, has been laboratory benchmarked for accuracy and can evaluate long-term irradiation effects, ASR, post-tensioning losses, concrete crushing, crack propagation, creep, shrinkage, and other non-linear concrete material behaviors. We're also involved in research and offer programs related to aging of concrete in support of the long-term operation of nuclear power plants.



ELECTRICAL CONSULTING SERVICES

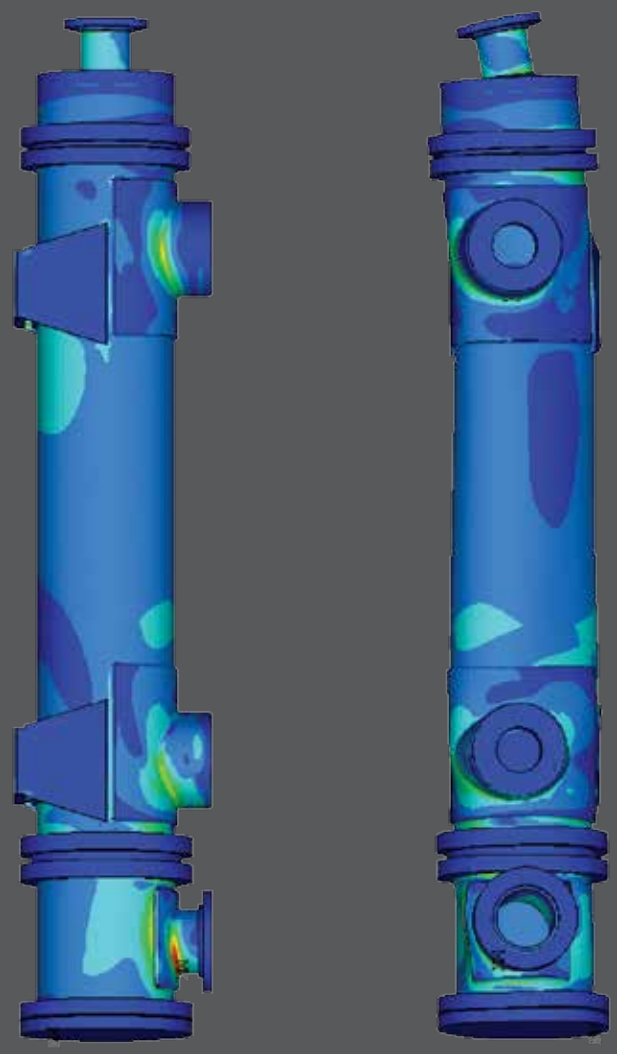
Structural Integrity offers a one-stop-shop for assessing, qualifying and extending the life of electrical components and systems. Our specialties include electrical system analysis; equipment qualification (EQ) support (seismic and environmental); and electrical component life cycle management. Our world-class electrical consulting team is well-versed in all applicable standards and uniquely qualified to resolve issues related to large electric motors, cables and containment penetrations.

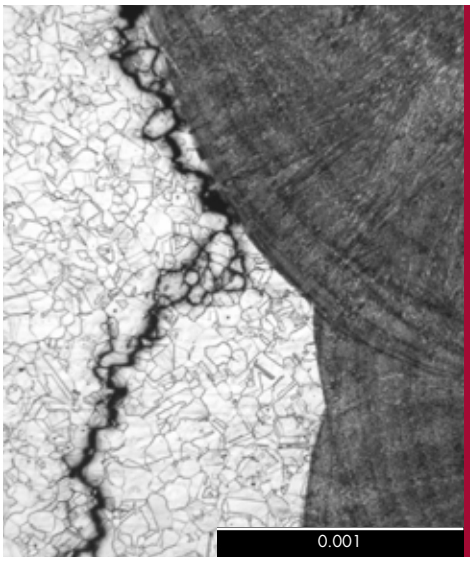
FABRICATION ENGINEERING SUPPORT

With a steady demand for replacement components, Structural Integrity has been active in providing design engineering services to fabricators. The design/analysis requirements to qualify a component to ASME Code criteria can vary from the relatively straight-forward to the more sophisticated. We have extensive experience in qualifying all classes of components, from the most safety-significant (e.g., Section III Class 1 reactor vessels) to non-safety related components evaluated to Section VIII requirements. Appropriate primary and secondary stress criteria, as well as peak stress and fatigue evaluations, are considered. Analyses vary from closed-form solutions for primary stresses to detailed finite element analyses for more complex configurations. Support can be provided that ranges from engineering support for ASME certification to developing complete design/analysis packages.

FABRICATION OVERSIGHT

Design, fabrication, and construction have begun on new nuclear power plants and will continue over the coming decades. In addition, operating plants' need for large replacement components continue. Ideally, lessons from past component fabrication, plant construction and operation will be factored into the design, fabrication, inspection, and installation of these new or replacement components. We have the necessary industry experience to address solutions to known degradation issues associated with former design and fabrication practices. We can help avoid known problems by performing detailed reviews of component and system designs, fabrication and inspection plans, and installation methods. Third-party review by Structural Integrity can prove especially valuable to new plants and components on the drawing board or under construction include stress analysis, materials selection/specification, fatigue evaluation, corrosion, welding, and inspection.



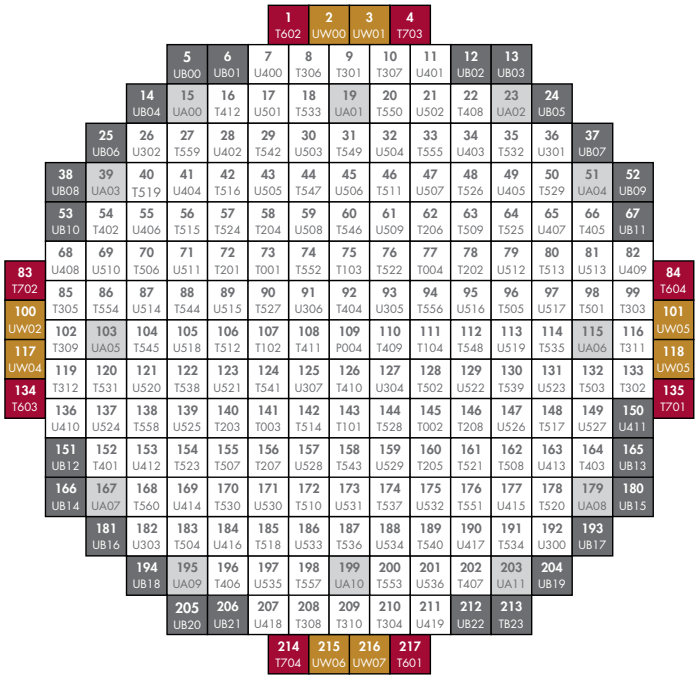


FRACTURE MECHANICS ANALYSIS AND RISK ASSESSMENT

When a flaw is found in a reactor pressure vessel, piping, or other nuclear plant component, fracture mechanics calculations are used to analyze and predict flaw behavior, including crack growth rates and critical crack sizes. Structural Integrity uses deterministic and probabilistic fracture mechanics techniques, including finite element analysis, to disposition flaws in a variety of materials, geometries, and applied stress fields. Specialized fracture mechanics software developed and used by Structural Integrity includes pc-CRACK, employed for ASME Code Section XI flaw evaluations and weld overlay design; ANSC, used for net section collapse analysis for arbitrarily flawed sections in ductile materials; and EPRI's Viper/Viper-Noz, used to determine probability of failure for reactor pressure vessel welds and nozzles.

FUEL & REACTOR TECHNOLOGY

We bring a broad perspective and first-hand knowledge of the industry's best practices in fuel design, analysis, operation, and performance and spent fuel storage and transportation. Our fuel engineers have industry expertise level knowledge in fuel behavior modeling during normal and accident conditions and specialized and unique knowledge In core neutronics, core thermal-hydraulics, design basis accident safety and radiological dose analyses. Our team specializes in fuel licensing and vendor transition projects including performance of calculations and preparation of submittals to the US NRC. Our familiarity with fuel design, manufacturing and licensing Issues enables us to design and develop very comprehensive and effective projects that will focus on client specific requirements and concerns. This breadth and depth of expertise, unparalleled in the nuclear industry, uniquely qualifies us to assist our clients in all aspects of the nuclear fuel cycle from fabrication and operation through spent fuel transportation and storage.

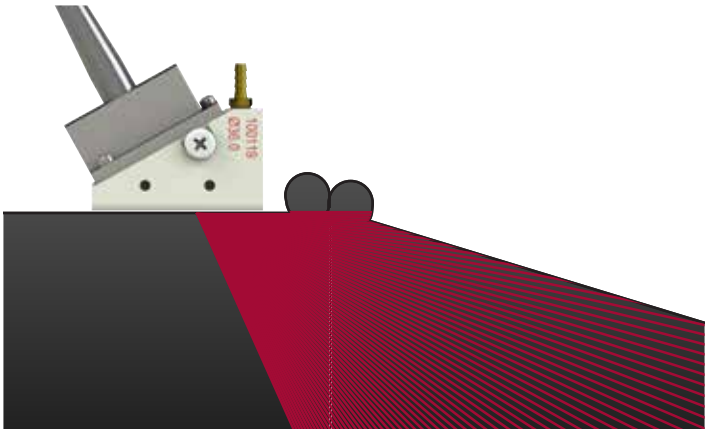


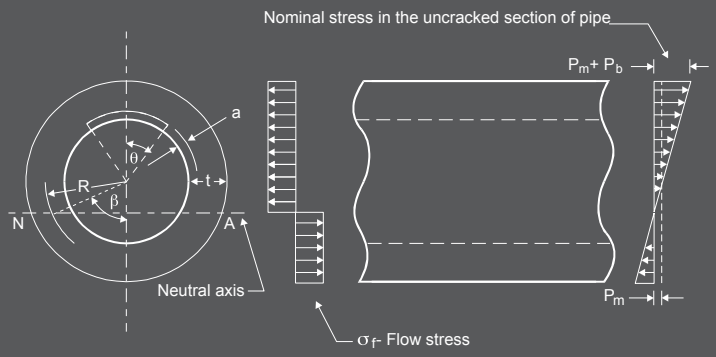
HEAT EXCHANGERS AND CONDENSERS

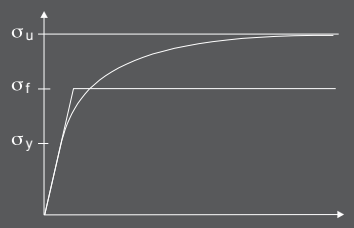
Nuclear plants contain numerous heat exchangers, ranging from very large condensers to small coolers; high energy steam generators; safety and non-safety related essential service water coolers; and regenerative MSRs. Heat exchangers are degraded by fouling resulting in a loss of heat transfer, cracking resulting in a loss of structural integrity, localized thinning and pinhole leaks, and wear resulting in the need to plug those tubes. Structural Integrity's expertise in the disposition, mitigation, and control of all known degradation mechanisms, as well as in NDE, provides the high-level assistance that the heat exchanger owner needs to maintain the system and plant reliability and safety.

HIGH-DENSITY POLYETHYLENE PIPING

A growing number of nuclear power plants are installing High-Density Polyethylene (HDPE) piping in non-safety related and safety related systems. The reason for growing interest in HDPE is its extended service life, corrosion resistance, ease of installation, and cost savings as compared to metallic pipe alternatives. Compared to its carbon steel and cast iron counterparts, HDPE does not rust, rot, or support biological growth. This assures maximum water flow throughout the system with increased reliability. In support of the energy industry's growing HDPE needs, Structural Integrity is at the forefront by offering integrated, comprehensive engineering solutions including Non-Destructive Examination (NDE), fracture mechanics, materials analysis, piping design, fabrication and installation oversight, and licensing support for replacement of existing piping systems or new plant installations.



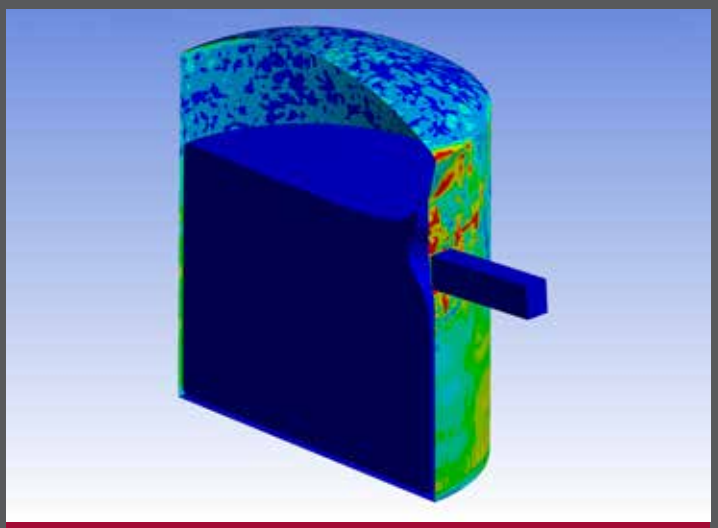




Limit Load (net section plastic collapse)
Circumferential Flaws

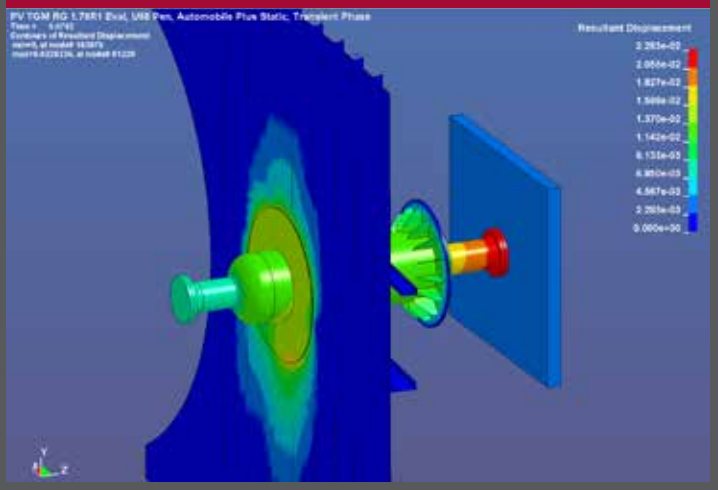
LEAK-BEFORE-BREAK EVALUATIONS

Leak-before-break (LBB) evaluations may be used to eliminate consideration of the dynamic effects of pipe rupture in nuclear systems, justifying no requirements for pipe-whip restraints and jet impingement barriers. The NRC's LBB evaluation criteria include demonstrating a low probability of pipe degradation; determining maximum critical flaw size via fracture mechanics analysis; performing thermal-hydraulic analysis to determine leakage for one half the critical size for normal plant operation; and finally demonstrating that there is adequate margin between predicted leakage and plant leakage detection capability. Structural Integrity has performed NRC-accepted LBB evaluations for numerous nuclear plants, including evaluations of piping as small as 6" diameter. We have also evaluated the effects of power uprate and weld overlays on LBB performance.



LOAD DROPS, MISSILE IMPACT, AND SHOCK

Non-linear transient dynamic analysis events such as load drops, missile impacts, shock propagation, and fluid-structure-interaction require highly non-linear analysis. Structural Integrity has experienced staff capable of providing solutions to these complex problems using explicit 3D finite element codes such as LS-DYNA, ABAQUS, ANSYS and TERRAGRANDE. Nuclear applications of explicit finite element analysis include airplane impact in design of reactor buildings, load drop evaluations of spent fuel storage casks and other heavy lifts, hydro-dynamic seismic forces on a fuel assembly in a spent fuel pool, as well as wind-borne projectiles and the associated structure's missile perforation performance. These evaluations can include pseudo-static analyses of eroding materials, rate-sensitive response, seismic loading, coupled thermal-mechanical response, and material yielding behavior.

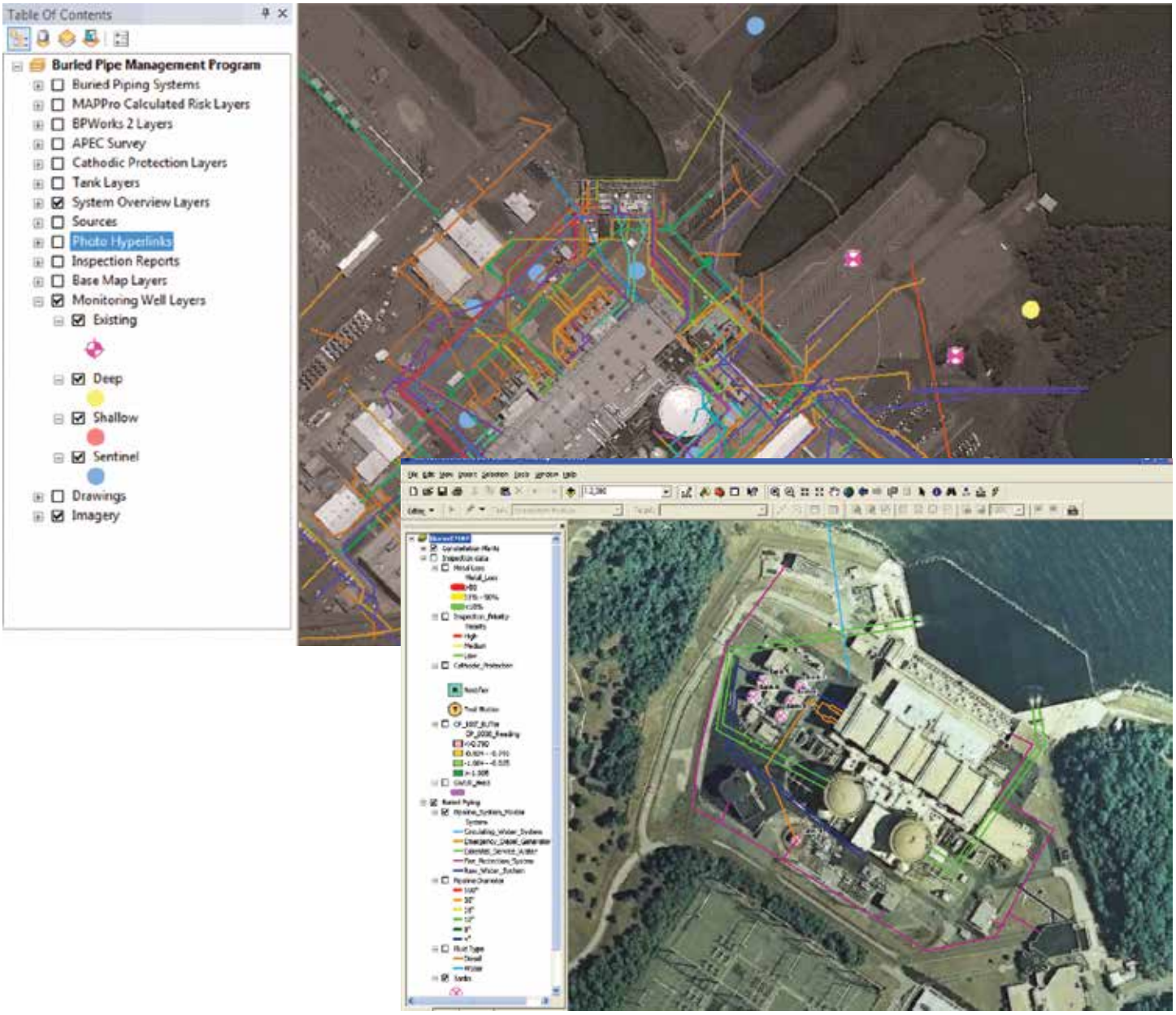


LICENSE RENEWAL / SUBSEQUENT LICENSE RENEWAL

In the United States and some international countries, after a nuclear reactor has been in operation for 40 years, operating licenses may be renewed for another 20 years provided it can be demonstrated that the unit will maintain adequate safety levels over the extended period of operation. Most U.S. plant owners have sought or will seek extended operating licenses, and most find the need for technical support to see them through the NRC license renewal process. In addition, plants are now actively considering a subsequent or second renewal for an additional 20 years to operate these valuable non-carbon emitting assets for 80 years. Structural Integrity provides comprehensive license renewal support, and has provided consultation and support to the majority of the utilities that have sought license extensions to date. Support services include preparation and review of License Renewal Applications (LRAs) including Time Limited Aging Analyses (TLAAs), Aging Management Reviews (AMRs), Aging Management Programs (AMPs), responses to NRC questions on LRA submittals, and support for implementation of LRA commitments. We have significant technical experience with a wide range of age-related degradation mechanisms, including fatigue, neutron embrittlement, CASS thermal aging, concrete degradation and metal corrosion, amongst others. Our experience can benefit plants seeking license renewal and subsequent license renewal by helping to identify the most cost-beneficial approaches to aging management.

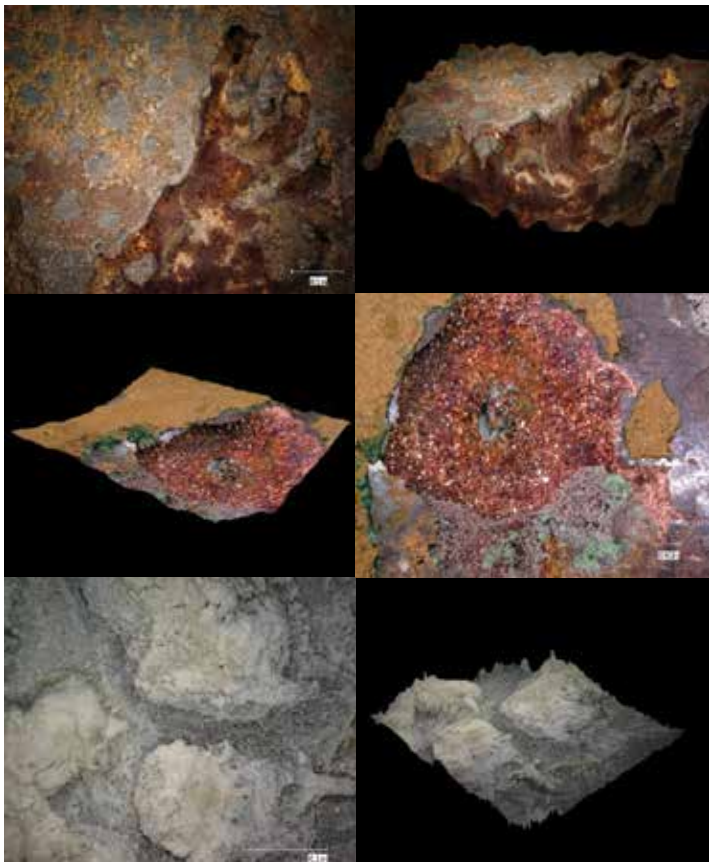
MANAGEMENT OF AGING BURIED PIPING

Many nuclear units have operated for more than 30 years, with buried piping systems that may be experiencing degradation. Using guidance from the Nuclear Energy Institute (NEI) and the Electric Power Research Institute (EPRI) for buried piping programs, Structural Integrity has developed a systematic buried piping management program (MAPPro) that includes a baseline assessment plan; data collection; risk assessment; indirect and direct examinations utilizing our long-range and short-range guided-wave ultrasonic G-Scan technology and in-line inspection using electro-magnetic acoustic transducers (EMAT); and SI developed pulsed eddy current (PEC) technology. Results from this management program include remediation or mitigation as needed, including improved cathodic-protection anode beds and rectifiers; monitoring; and prioritized maintenance.



MATERIALS/METALLURGICAL/ CORROSION EVALUATIONS

Accurate materials, metallurgical, and corrosion evaluations are essential to the appropriate disposition of degraded plant components. Such evaluations also help identify improved materials and fabrication processes to prevent future degradation. Structural Integrity offers a complete range of materials engineering services, supported by our full-service metallurgical laboratory in Austin, Texas. Our materials engineering specialties include welding engineering; corrosion and stress corrosion cracking evaluations; materials selection; and corrosion-fatigue. Low-temperature and high-temperature corrosion phenomena, including microbiologically influenced corrosion, are a particular area of our expertise.



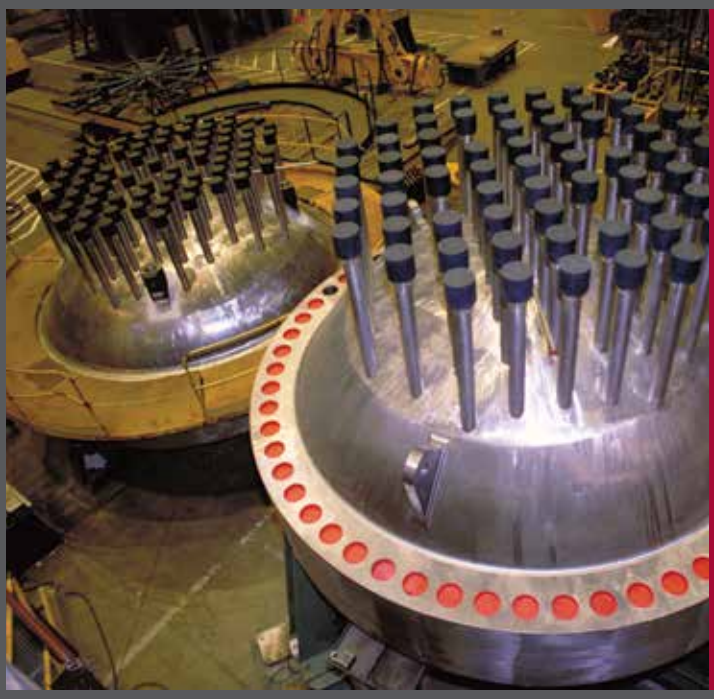
METAL FATIGUE EVALUATIONS

Metal fatigue from nuclear plant cyclic stresses and strains is a major contributor to degradation of aging components – and a specialty at Structural Integrity. In fact, EPRI relied on our metal fatigue expertise to develop the EPRI Fatigue Management Handbook as well as FatiguePro, a widely used, real-time thermal fatigue monitoring system that automatically tracks fatigue transients and usage for critical nuclear components. Our metal fatigue services and products include FatiguePro evaluations; fatigue management handbooks that help identify potential damage locations; fatigue repair support; design of modifications to extend component fatigue life; analysis of reactor vessels and piping to determine effects of reactor water environment on fatigue life; determination of fatigue impact of cyclic thermal stratification in reactor piping; and vibration fatigue.

NEI 03-08 AND MATERIALS DEGRADATION MANAGEMENT PROGRAMS

The nuclear industry's Materials Initiative, NEI 03-08, developed in response to events involving materials degradation in nuclear plants, requires a Materials Degradation Management Program at all U.S. PWR and BWR units. Audits of these programs are often conducted by INPO and the NRC. At a minimum, the programs must address BWR vessels/internals, Alloy 600 issues, reactor vessel integrity, PWR vessels/internals, boric acid corrosion control, steam generator management, primary and secondary system water chemistry, and fuel reliability. Any deviations from mandatory/needed program requirements require supporting documentation. Structural Integrity can support nuclear plants in Materials Degradation Management Program development, implementation, deviation requests, third-party reviews, utility training, preparation for INPO/NRC audits, and other related services.

Scope of NEI 03-08 Initiative
Covers RCS Materials Aging Management



NEW PLANT CONSULTING

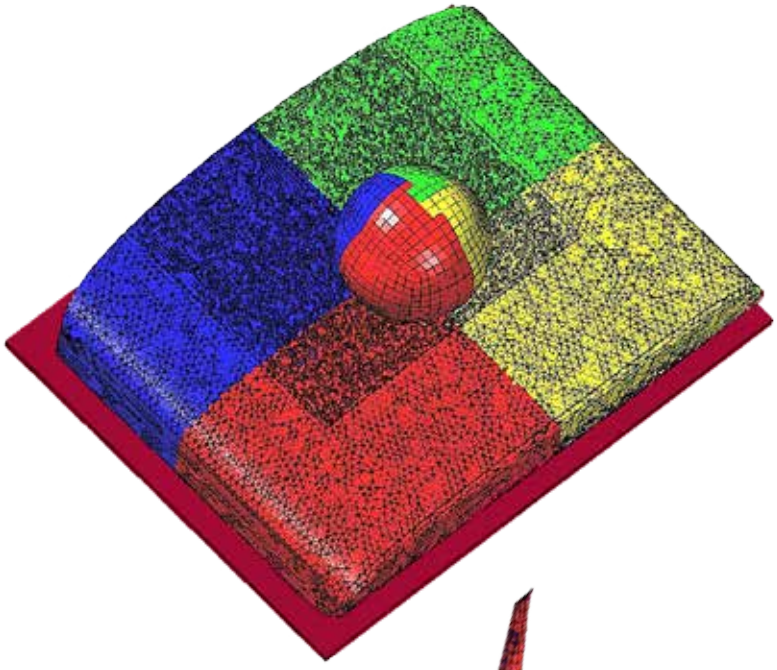
In spite of Fukushima, over 60 plants worldwide are currently under construction and or in the licensing process. Engineering and licensing a new nuclear unit can be daunting, but Structural Integrity's extensive experience with the multiple generations of nuclear units places us in a unique position to provide new plant support. Available services for new plants include design analysis/third-party design review, design specification preparation and review, stress and fatigue analyses, welding/material engineering, fabrication review, fracture toughness/pressure-temperature curves, probabilistic risk assessment reviews, and licensing support. We can also provide ASME Code consultation, startup vibration testing, buried piping program support, fatigue and condition monitoring programs, inspection programs, training programs, and many other related services.

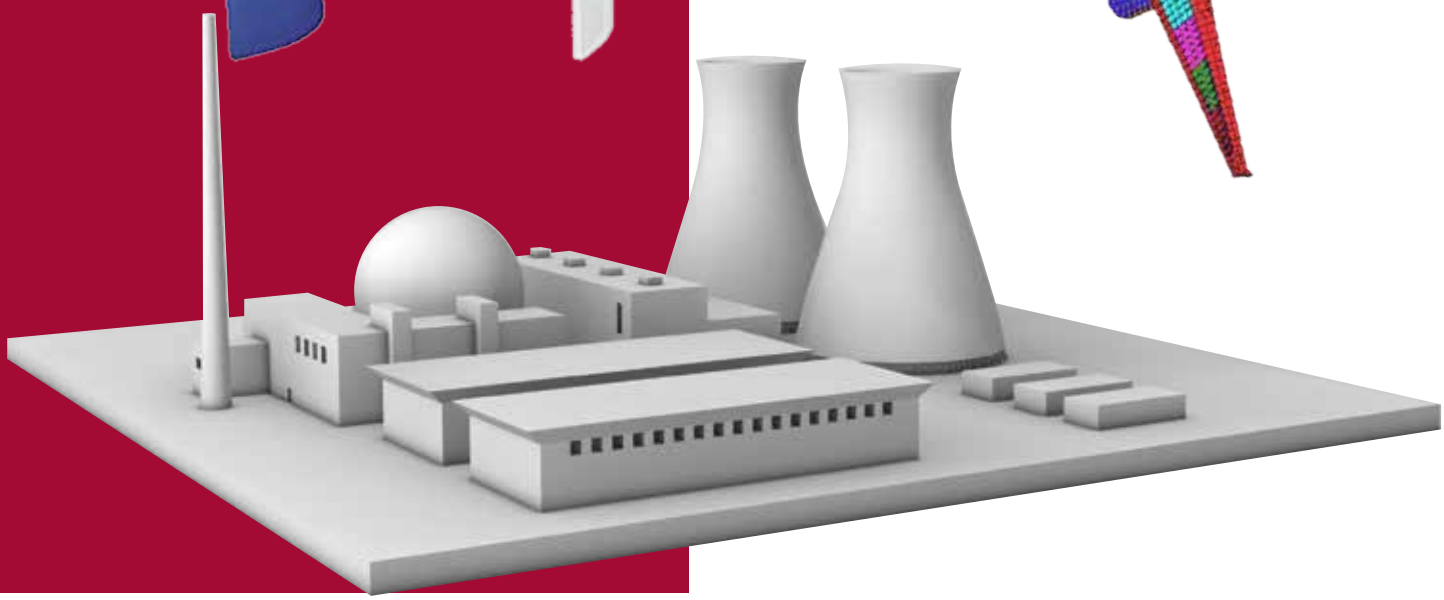
NONDESTRUCTIVE EXAMINATION

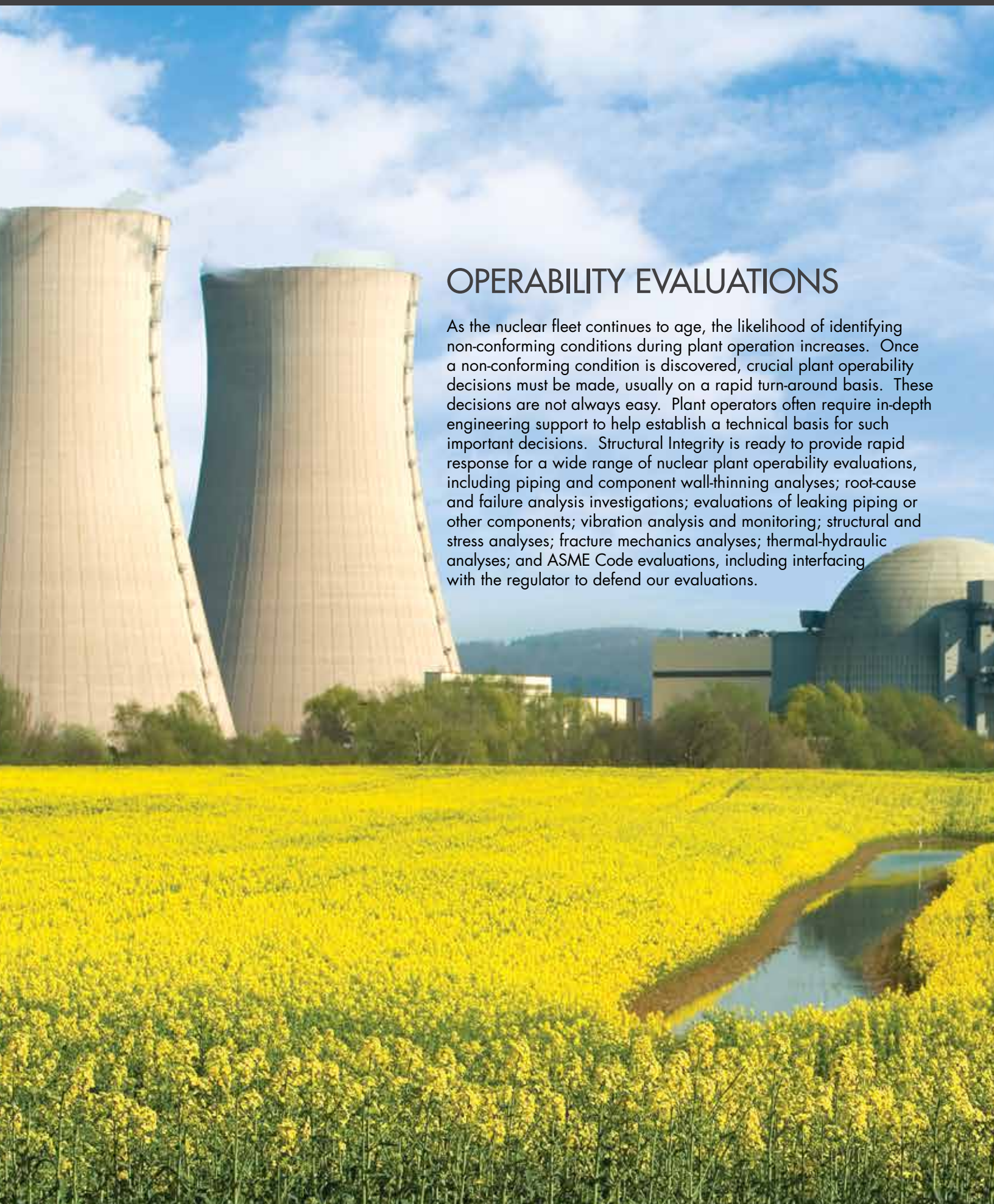
Nondestructive examination (NDE) has become one of Structural Integrity's most well-known specialties. New inspection techniques are continually developed by our NDE applications group, and our top-notch technical staff is dispatched to conduct examinations with these and other state-of-the-art NDE technologies worldwide. NDE services available specifically for nuclear plants include austenitic/ferritic piping inspections (Appendix VIII, Supplements 2, 3), vessel shell inspections (Supplements 4, 6), manual and encoded dissimilar metal weld inspections (Supplement 10), weld overlay repair inspections (Supplement 11), and ultrasound inspections in lieu of radiography. Structural Integrity also offers comprehensive turbine-generator inspections, including examinations of turbine rotor bores, blade attachments, disc rims, blade tenons, casings, peripherals, generator retaining rings, rotor dovetails, and coupling keyways. We offer guided wave ultrasonic G-Scan inspections for screening evaluations of plant piping (including buried piping). We're also available for third-party inspection oversight.

NONLINEAR TRANSIENT DYNAMIC ANALYSIS

In cases of drop, impact, shock, and events requiring highly nonlinear analysis, explicit finite element analyses are indicated. Structural Integrity has experienced staff capable to provide solutions to these complex problems using 3-D nonlinear dynamic analysis finite element codes such as LS-DYNA, ABAQUS, ANSYS and TERRAGRANDE. Nuclear applications of explicit finite element analysis include airplane impact in design of reactor buildings, drop evaluations of spent fuel storage casks and other heavy lifts, as well as projectiles. We offer drop and impact evaluations as well as dynamic and psuedo-static analyses of eroding materials, rate-sensitive response, seismic loading, and coupled thermal-mechanical response for post-yield beyond design basis loading events.

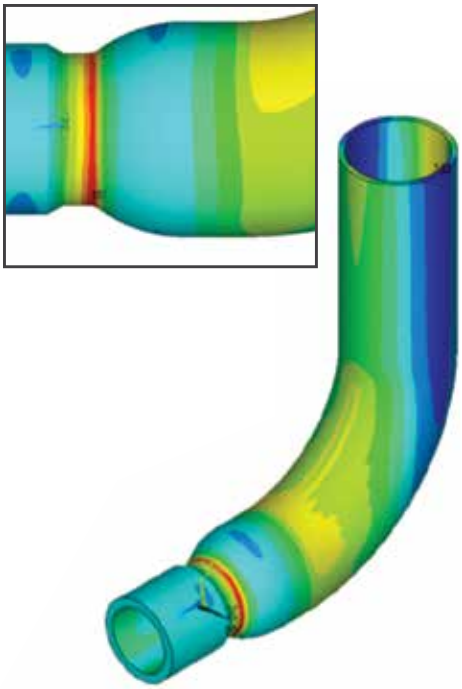






OPERABILITY EVALUATIONS

As the nuclear fleet continues to age, the likelihood of identifying non-conforming conditions during plant operation increases. Once a non-conforming condition is discovered, crucial plant operability decisions must be made, usually on a rapid turn-around basis. These decisions are not always easy. Plant operators often require in-depth engineering support to help establish a technical basis for such important decisions. Structural Integrity is ready to provide rapid response for a wide range of nuclear plant operability evaluations, including piping and component wall-thinning analyses; root-cause and failure analysis investigations; evaluations of leaking piping or other components; vibration analysis and monitoring; structural and stress analyses; fracture mechanics analyses; thermal-hydraulic analyses; and ASME Code evaluations, including interfacing with the regulator to defend our evaluations.



PIPING ANALYSIS

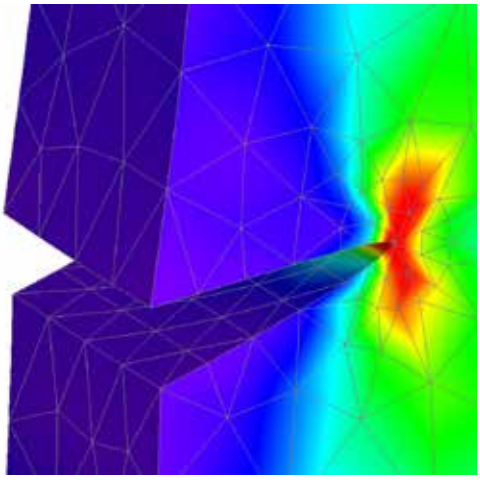
Sophisticated piping analysis – and the customized software for conducting it – are Structural Integrity specialties. Examples of our complex piping analyses used to resolve nuclear plant design and operational issues include ASME Class 1 design transient evaluations for extended license operation; thermal stratification analyses in pressurizer surge, feedwater, and spray piping; piping vibration evaluations involving socket weld cracking; analyses of flow-induced vibration in piping systems; evaluations of flow-accelerated corrosion-induced wall thinning; analyses of power uprate changes; and seismic analyses. Our proprietary software is used for analyzing thermal stratification, vessel fatigue, wall thinning, thermal shock at transitions, vibration loading, and other specific conditions. Structural Integrity also uses PIPESTRESS for ASME Class 1, 2, 3, B31.1, and B31.3 piping analyses, and ANSYS for ASME Code, Section III, NB-3200 finite element analyses.

PRESSURE-TEMPERATURE CURVES AND RPV MATERIAL SURVEILLANCE

Reactor pressure vessel (RPV) material surveillance programs are required for all U.S. PWRs and BWRs. The results of these surveillance programs are used to develop pressure-temperature (P-T) limit curves that incorporate appropriate safety margins to protect against brittle fracture of RPVs, particularly in the irradiated beltline region. These P-T limit curves must be re-evaluated using new surveillance data in situations such as license renewal, power uprates, or when revised fluence calculations affect adjusted reference temperature values. Structural Integrity, well-experienced in P-T curves and vessel integrity for both PWRs and BWRs, can provide utilities with technical support including materials reviews, P-T curve development, P-T limits reports (PTLRs), reactor vessel integrity/ P-T limit curve

PRIMARY WATER STRESS CORROSION CRACKING

Primary water stress corrosion cracking (PWSCC) can occur in PWR primary systems where Alloy 600 components and associated Alloy 82 (GTAW) and Alloy 182 (SMAW) welds were used. Such components and welds were widely applied in PWRs. Prompted by industry experience with PWSCC in PWR Alloy 82/182 butt welds and small-bore penetrations, as well as by related examination and mitigation requirements many PWRs are conducting ongoing PWSCC examinations and related repairs for unmitigated locations. Structural Integrity and its field repair partner, AZZ Nuclear, are leaders in these weld overlay butt weld repairs, as well as in nozzle repairs for small-bore primary system penetrations. Our team, has completed weld overlay projects encompassing more than 150 weld overlays since 2006 – and not a single welded repair was required for any of these overlays.



PROBABILISTIC FRACTURE MECHANICS ANALYSIS AND RISK ASSESSMENT

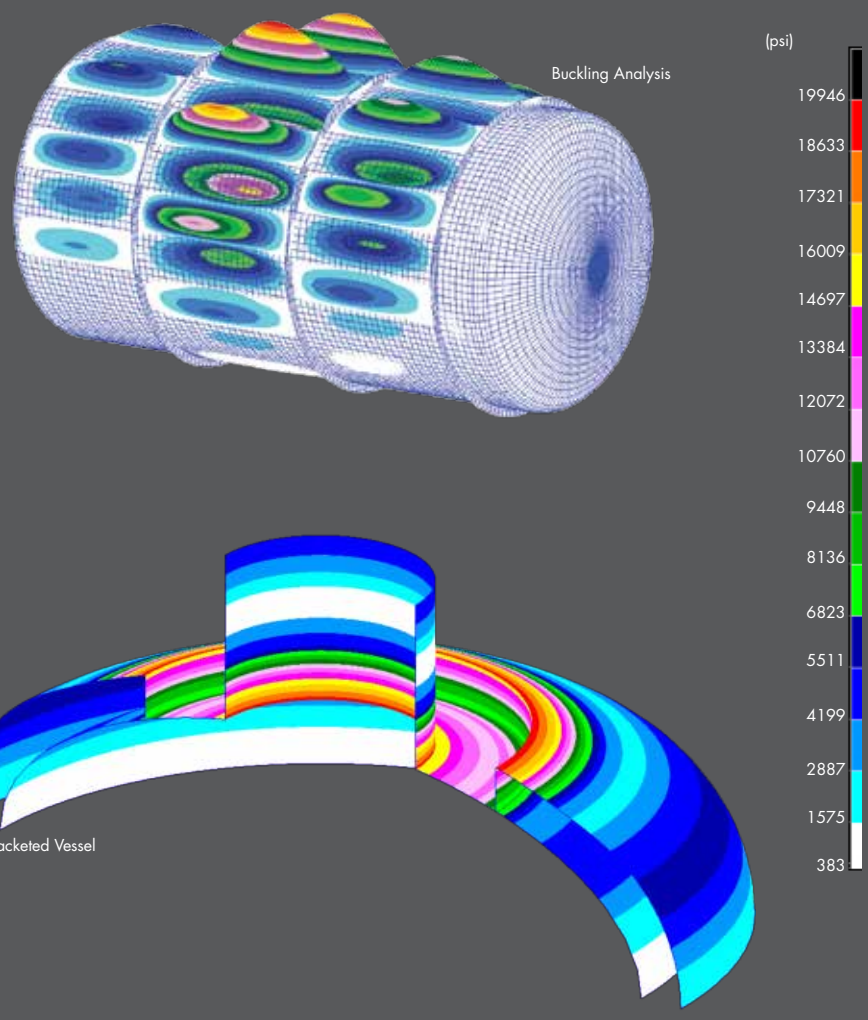
Probabilistic fracture mechanics (PFM) analysis takes conventional deterministic fracture mechanics analysis a step further, using selected random variable inputs for situations that involve a significant degree of uncertainty – such as in crack size, or scatter in test results – and PFM analyses usually yield a failure probability, rather than a specific calculation of crack size or lifetime. Structural Integrity has applied PFM analysis to piping, reactor-head penetration nozzles, and other nuclear plant components. Many of our PFM analyses employ PRAISE, originally developed by Structural Integrity under NRC sponsorship. Our latest version of the software, beyond-PRAISE, can analyze crack initiation and growth due to fatigue, PWSCC, and flow-accelerated corrosion. beyond-PRAISE is available for purchase from us in an easy-to-use Windows format.

PWR REACTOR INTERNALS MANAGEMENT

Concerns about aging degradation of PWR reactor pressure vessel internals have become a high priority as nuclear units approach and enter license renewal periods. Renewal applications must consider the effects of aging in order to meet conditions defined in the NRC's Generic Aging Lessons Learned Report. In response, the MRP's Reactor Internals Focus Group (RI-FG) has prepared inspection and evaluation guidelines for managing the effects of aging degradation in PWR internals. The guidelines, issued under the NEI 03-08 Materials Initiative, include developing an Aging Management Program (AMP) and inspection plan for PWR internals. Structural Integrity, working closely with the MRP RI-FG, has beta-tested the draft guidelines for several PWRs and has assisted with formal implementation of several inspections. We provide technical support for plants considering aging management reviews for license renewal, and for plants developing AMPs to manage the effects of aging in PWR internals.

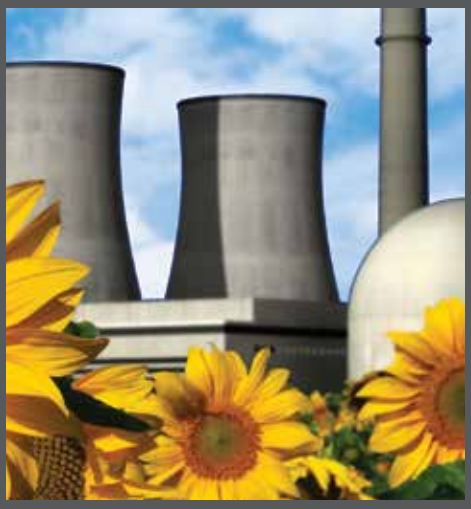
REACTOR PRESSURE VESSEL INTEGRITY

Radiation embrittlement is a known degradation mechanism in ferritic steels, and the beltline of reactor pressure vessels is particularly susceptible to radiation damage due to the high local fluence. The effects of radiation on vessel materials have impacted heatup/cooldown limits for PWRs, and increased hydrostatic test temperatures for BWRs, thereby significantly limiting plant operation. Structural Integrity, with strong expertise in managing reactor vessel embrittlement and vessel integrity, can provide nuclear plants with technical support in a number of areas, including pressure-temperature curve development; materials evaluations; third-party reviews of RPV materials surveillance program results and implementation; setpoint evaluations; pressurized thermal shock evaluations; vessel fluence evaluations; evaluations of projected vessel properties; and pressure-temperature limits for license renewal applications. We've also worked with ASME for more than 20 years to improve PWR and BWR heatup and cooldown limits.



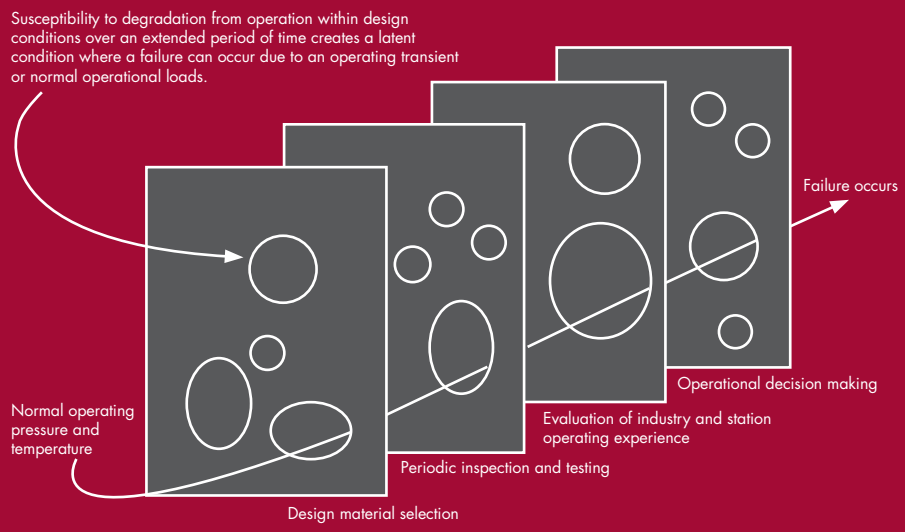
RISK-BASED PROGRAMS

Risk-Informed In-service Inspection (RI-ISI) is a cost-effective alternative to current ASME Code, Section XI inspection requirements. RI-ISI uses risk assessment, in addition to information on component-specific degradation mechanisms, as the basis for a nuclear plant piping inspection program. Structural Integrity played a key role in the development of EPRI's NRC-approved RI-ISI and RIS_B (Risk-Informed Safety-Based) methodologies, the latter a streamlined RI-ISI methodology that takes advantage of the lessons-learned through over 15 years of industry RI-ISI experience. To date, we have supported ASME Code Case N-560, N-578 and N-716 evaluations using the EPRI RI-ISI methodology at 61 nuclear units (46 PWRs and 15 BWRs). In all cases, the methodology has proven to significantly reduce the number of piping inspections compared to Section XI, with negligible impact on plant risk. Additionally, we have experience in application of risk-informed technologies to Break Exclusion Region program piping, as well as in performing RI-ISI Living Program Updates, either as part of Interval ISI Program Updates or as stand-alone evaluations.

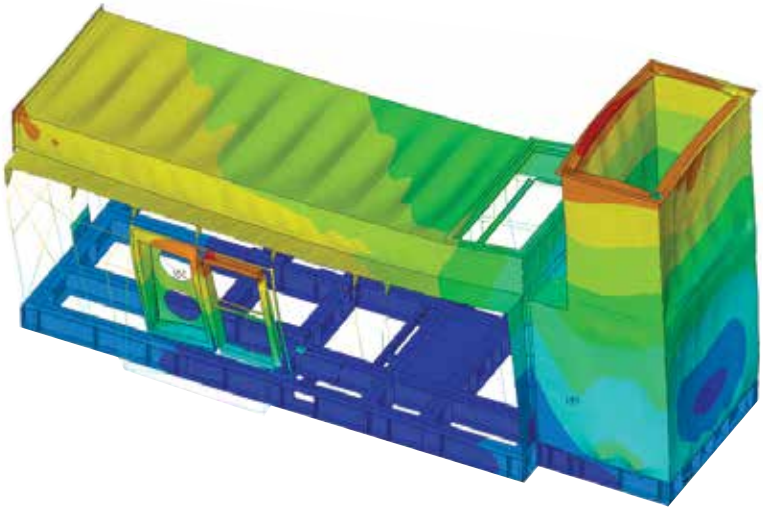


ROOT-CAUSE EVALUATION

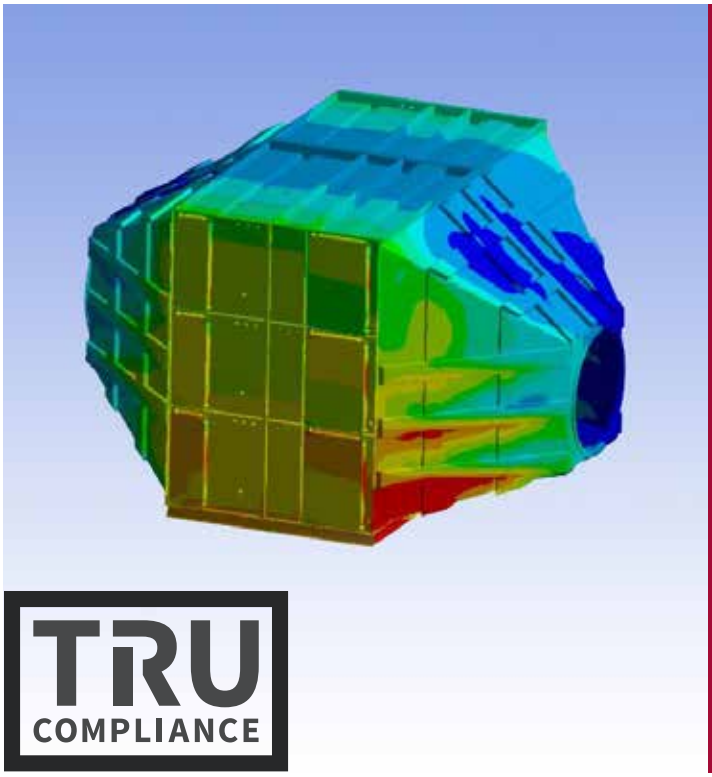
At the bottom of every plant component failure is a root-cause, and root-cause failure analyses are a proven way to avoid repeat or related failures. Structural Integrity offers a complete range of root-cause failure analyses, varying in complexity from one or two specialists focused on material fractography to a multi-discipline team performing a full-scope investigation. To support its investigations, we maintain both a metallurgical laboratory and an advanced nondestructive testing capability. Additionally, we perform human-error analyses and organizational/programmatic evaluations to uncover possible contributing factors. Structural Integrity is also available to perform third-party reviews of root-cause failure analyses, and evaluations of related corrective actions.



SEISMIC ANALYSIS AND EVALUATION



With the 2011 Fukushima accident, and the response of the US NRC and the industry, much work is being done to support seismic reevaluation of structures, systems, and components. Structural Integrity's subject matter experts (SMEs) in Soil-Structure-Interaction (SSI) analysis use Verified and Validated (V&V) software, SASSI. Our team performs site-response analysis to develop Foundation Input Response Spectra (FIRS) and can include detailed structural models to develop In-Structure-Response-Spectra (ISRS). Our team has also performed soil fragility analysis for nuclear plants as part of Seismic Probabilistic Risk Assessments (SPRA). The risks associated with the failure of nuclear facilities require significantly more rigorous design and evaluation, including a larger range of loading cases, than that which is required for traditional structural design.
Our unique experience provides clients with advanced methods for reducing overall risk. Our integrated 'living' models are created to remove significant conservatism from localized response expected with use of existing or even advanced stick models, models which are also inappropriate for treatment of high frequency exceedance. Our team also supports evaluations of non-seismic permanent plant equipment to be credited for beyond design basis event mitigation (i.e., FLEX equipment including CSTs and other possible non-seismic water sources).



TRU COMPLIANCE

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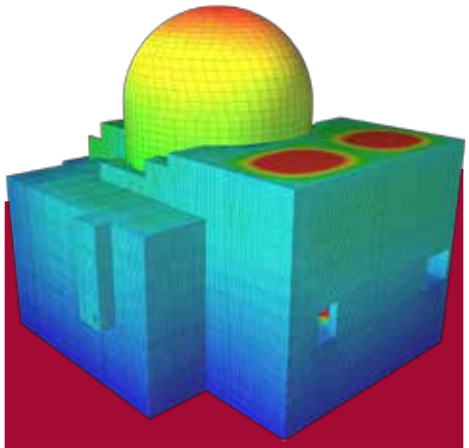
SEISMIC EQUIPMENT QUALIFICATION (TRU-Compliance)

Our team efficiently qualifies equipment through a combination of technology-driven seismic walkdowns, seismic testing, analysis, and experience data.
We leverage EPRI NP-6041-SL screening methods supplemented by GERS, SQUIRTS and additional in-house proprietary experience database that contains over 60,000 seismically qualified components. Our team of seasoned experts has widespread experience in analyzing equipment and recommending structural enhancements. Structural Integrity has proven fragility experience and employs industry recognized fragility experts who are knowledgeable in Seismic Probabilistic Risk Assessments (SPRAs), and who understand the unique features of nuclear plant designs.

SERVICE WATER

Nuclear plant service water systems are affected by a multitude of situations and operate under a wide variety of operating conditions. The differences in design, materials, water chemistry, and operation necessitate plant-specific approaches for the examination of piping, management of degradation issues, corrosion mitigation, and repairs and replacements. Many times, management approaches may be reactive (e.g., leaks present themselves, thinning is detected by inspections, run vs. repair decisions made on critical path) or preventive (proactive examinations on selected locations, heat transfer testing, water treatment, cleaning, monitoring, planned/staged repairs, and replacements). Structural Integrity's expertise in corrosion and corrosion control, materials engineering, vibration, fracture mechanics, stress analysis, statistical methods, root-cause and failure analysis, and NDE provide the multidisciplinary approach required for proactive, cost-beneficial management of service water system degradation.

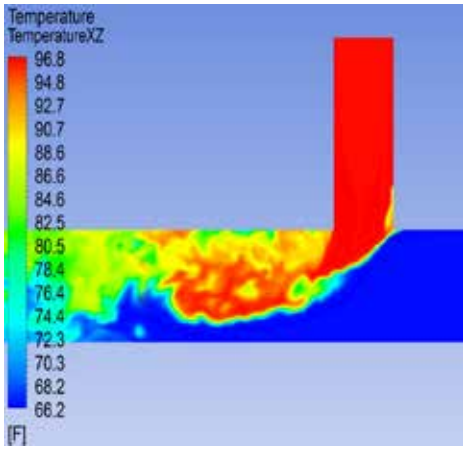


STRUCTURAL AND STRESS ANALYSIS

The performance of complex structures under thermal, static, and dynamic loadings is a crucial question at nuclear plants. Armed with an array of state-of-the-art computer codes and analytical techniques, Structural Integrity can provide limit load, linear-elastic and non-linear elastic-plastic structural analyses for nuclear plant structures, systems, and components. Our stress analysis experience includes a broad spectrum of equipment including pressure vessels, tanks, piping systems, pumps, tubing, headers, heat exchangers, valves, reactor internals, and turbines. Examples of stress analysis codes employed by Structural Integrity range from ABAQUS and ANSYS finite element software, to AUTOPIPE and PIPESTRESS for piping system analysis, to Structural Integrity's own specialized programs, including TOPBOT, used to determine stress distributions in stratified piping systems, and PIPE-TS2, used to calculate through-wall thermal gradient stresses for piping thermal transients.

THERMAL-HYDRAULIC ANALYSIS

Thermal-hydraulic analyses of nuclear plant components and structures are used to determine loadings on related components. Structural Integrity conducts a full array of steady-state and transient thermal-hydraulic analyses, using either standard textbook methods, Computational Fluid Dynamics (CFD) or specialized software, including SI-proprietary software. A few examples of complex problems that we have solved via thermal-hydraulic analyses are as follows: the evaluation of severe wall thinning in piping beyond a feedwater heater drain tank found that insufficient back-pressure and two-phase flow conditions were the culprits; the analysis of reactor containment pressure-temperature response justified conducting BWR reactor pressure tests at elevated temperatures with open containment; PWR thermocouple test data was evaluated to determine the internal piping flow and stratification conditions that exist during various operational modes with analyses determining stratified flow levels and heat transfer coefficients in piping systems subject to such stratified flow.

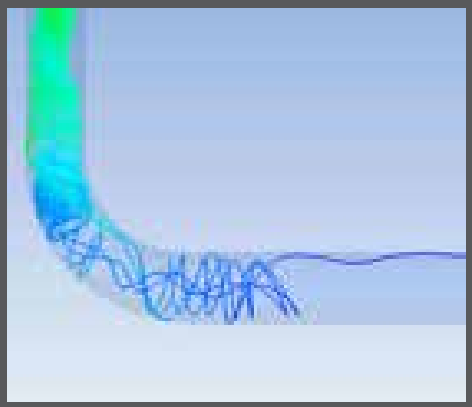


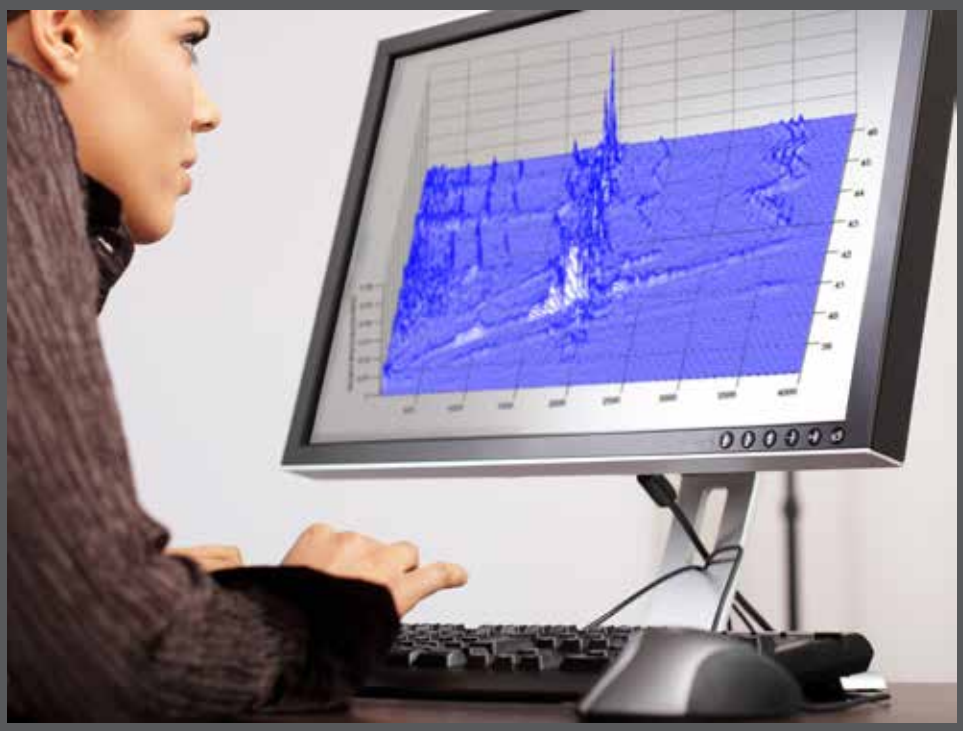
TURBINE-GENERATOR ASSESSMENTS

Turbine-generators – the business end of every nuclear plant – have to be in top operating condition. Reliable turbine-generator inspections and assessments are critical to avoiding unanticipated repairs and untimely failures, while at the same time steering clear of unnecessary repairs and replacements. Structural Integrity provides complete turbine-generator inspection and life-assessment services, including boresonic rotor inspections and linear phased-array ultrasonic inspections of rotor blades, as well as EPRI-licensed SAFER rotor integrity and life analysis, EPRI RimLife rotor assessments, EPRI RRingLife evaluations of retaining rings, and other evaluations and non-destructive examinations (see page 30). Torsional vibration assessments for turbine-generator sets are available using TTVMS (page 16). We also offer bore honing and machining in addition to our other turbine-generator services.

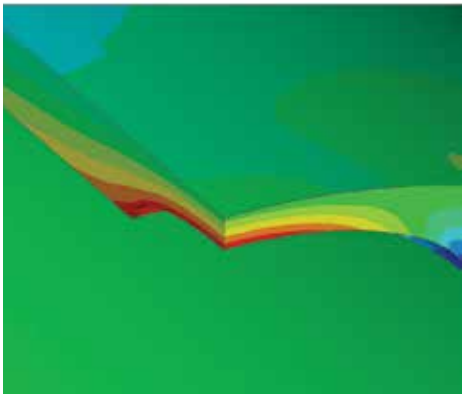
VIBRATION ANALYSIS AND MONITORING

Vibration-related nuclear plant piping problems – whether in small-bore piping, socket welds, large bore piping, or anywhere in between – can be difficult to resolve. Structural Integrity, with years of experience in structural dynamics, stress analysis, vibration testing and analysis, and applied mechanics and materials, can step in to solve nuclear plant vibration issues. Examples of recent vibration-related projects include evaluation of the effects of power uprate on small-bore piping, and design and implementation of a vibration monitoring system for main steam piping. Using our vibration expertise, we developed customized data acquisition systems that collect and analyze vibration monitoring data, including the portable SI-MiniDAS and the high-speed, automated SI-VersaDAS. These systems are used for Structural Integrity projects and are available for purchase or lease by utilities.

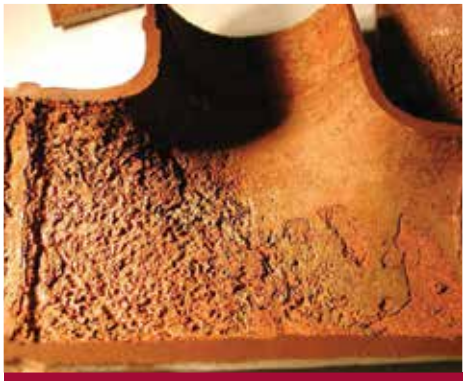




WALL THINNING EVALUATIONS



Even when local wall thinning in nuclear pressure vessels, piping, valves, or other components is well below the general minimum wall thickness required by ASME Code, continued operation may be justified by ASME-approved evaluations methodologies. Structural Integrity is a leader in wall-thinning evaluations for nuclear plants, including evaluation of mechanisms and rate of thinning, as well as familiarity with applicable ASME Code criteria. In fact, the evaluation methods in ASME Section XI Code Cases N-480, N-513, and N-597 were based on a Structural Integrity report generated for EPRI or developed by the Code committees with our significant contributions. We use either the simplified analytical methods found in the ASME Code Cases, or more-complex finite element models that determine local stress distributions in thinned components. In situations where there is local through-wall leakage, we conduct fracture mechanics analyses to demonstrate sufficient margin against fracture. With our unique industry expertise, and our catalog of evaluated flawed configurations, we can complete wall thinning evaluations quickly, enabling rapid run/repair/replace decisions.

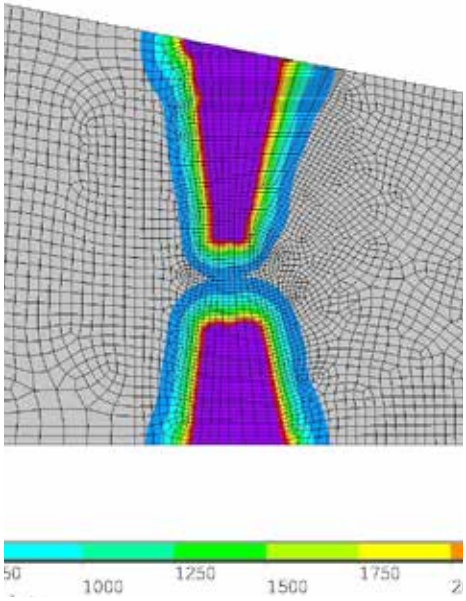


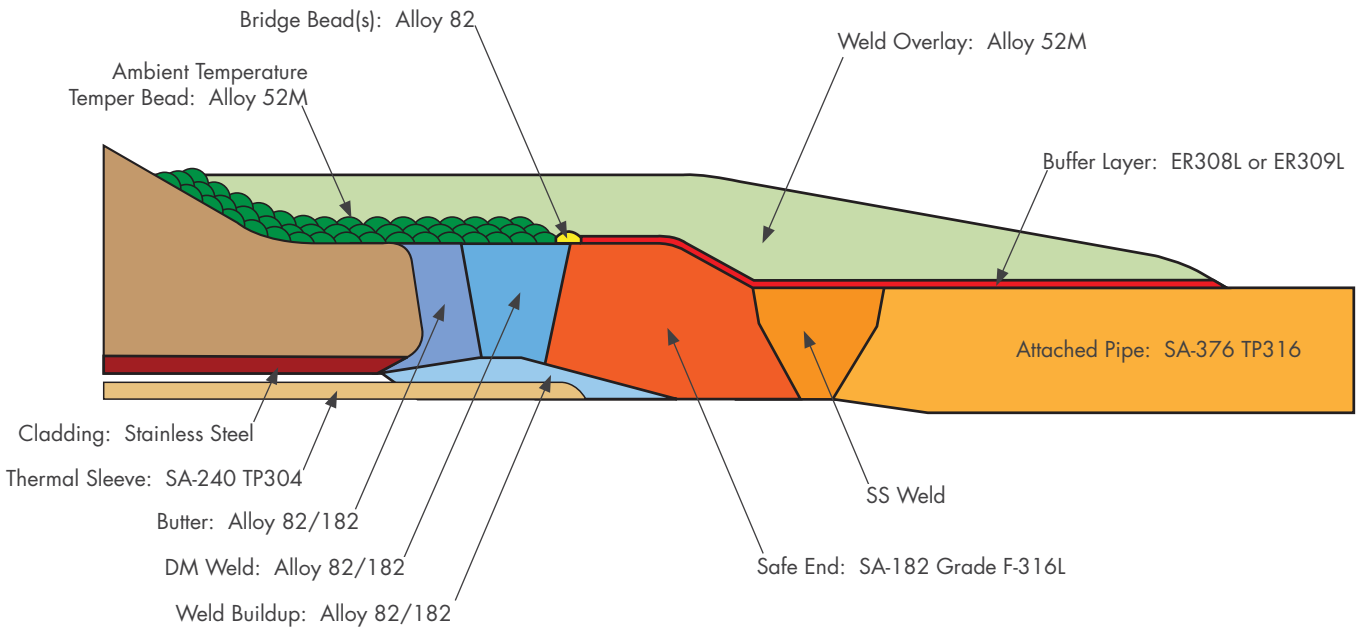
WATER CHEMISTRY AND CORROSION MITIGATION

Intergranular stress corrosion cracking (IGSCC) in BWRs and primary water stress corrosion cracking (PWSCC) in PWRs, as well as microbiologically influenced corrosion (MIC), are perennial industry concerns. These corrosion mechanisms, as well as many others, are influenced by water chemistry and especially water chemistry transients. Structural Integrity's long-time water chemistry experience can help utilities mitigate these problems in vessels and piping. We provide corrosion mitigation and remediation consulting, optimizing programs such as hydrogen water chemistry (HWC) zinc injection, and noble metal injection for BWRs, and elevated hydrogen and zinc injection for PWRs. We also offer corrosion-related weld overlays and repairs, crack growth rate modeling, alloy selection, failure analysis, MIC mitigation, and support for license renewal and NRC inspection issues involving corrosion.

WELD RESIDUAL STRESS ANALYSIS

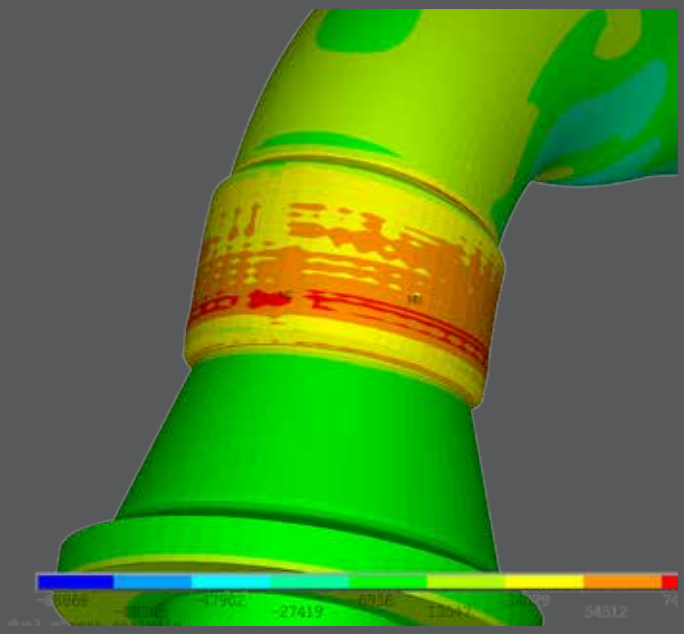
Certain welding processes – pipe-to-pipe butt welds, small-bore penetration J-groove welds, and weld overlay repairs, for example – leave residual stresses that can affect the stresses within welded nuclear plant components. Structural Integrity offers a full range of temperature-controlled, non-linear, path-dependent weld residual stress analyses, using ANSYS finite element analysis software to simulate various welding processes. These analyses simulate a thermal pass, complete with appropriate weld heat input, heat efficiency, and appropriate cooling time, to determine temperature distributions due to the welding process. A simulated stress pass in turn calculates residual stresses due to non-linear, elastic-plastic load/unload stress-reversal cycles from the heating and cooling of the weld elements throughout the thermal transients. For especially complicated weld geometries, we can perform three-dimensional moving heat source residual stress analyses.





WELDING ENGINEERING

Appropriate weld design, procedures, and qualification are vitally important at nuclear plants. Structural Integrity offers comprehensive welding engineering services, including development and review of welding programs; selection and development of welding processes for critical applications; review and evaluation of procedure qualification records and weld procedure specifications; review of welder qualification; review and evaluation of weld failures; development of corrective actions; and welding code review and reconciliation. We're also available to develop innovative welded repair techniques for specific situations. In fact, we pioneered development and application of weld overlay and temperbead welding for nuclear plant repairs with our field repair partner, AZZ Nuclear.



PRODUCTS AND SOFTWARE

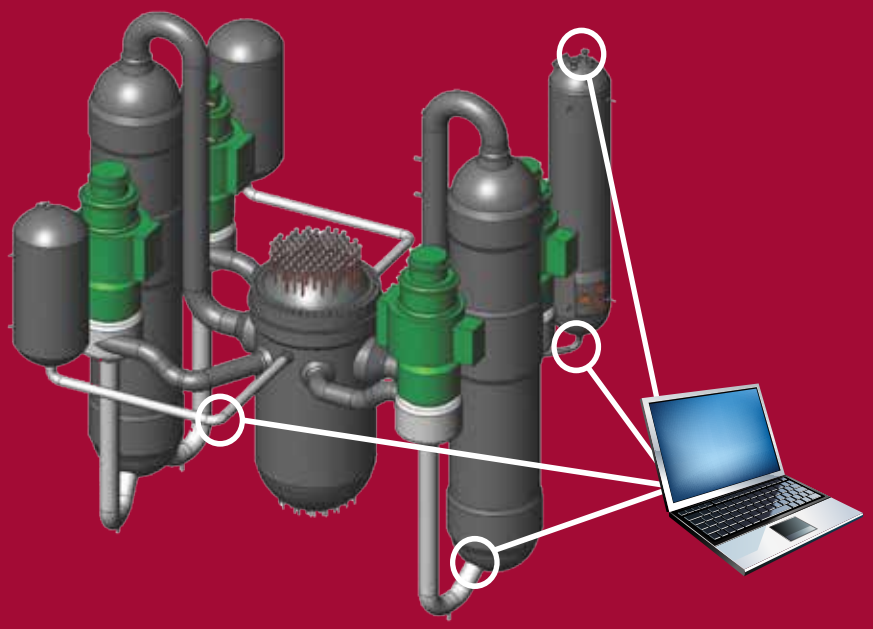
Structural Integrity also offers the following products and software:

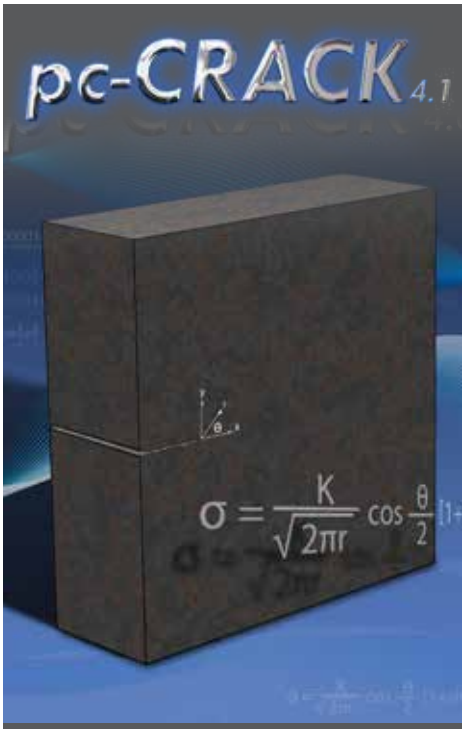
BG4 BIoGEORGE™

Microbiologically influenced corrosion is an ever-present threat to nuclear plant service water systems, particularly standby and redundant systems – including safety-related –in wet layup for extended periods of time. Fortunately, the on-line, real-time **BIoGEORGE** monitoring system can provide early warning of biofilms before these rapidly forming films can negatively impact system performance or reliability. **BIoGEORGE** also provides a reliable indication of the effectiveness of biocide treatments, plus feedback on biocide treatment selection, timing, and concentrations. This information on biocide treatment effectiveness enables stations to optimize their treatment selection and approach to lower costs and optimize performance.

SI: FATIGUEPRO™ 4.0

Metal fatigue from cyclic stresses can shorten the life of critical nuclear plant components. But the original FatiguePro, a real-time fatigue monitoring software system developed by Structural Integrity under contract to EPRI, and licensed by EPRI, automatically tracks fatigue transients and usage in these key components using existing plant instrumentation. FatiguePro facilitates plant life extension/licensing activities by providing an immediate, up-to-date and continual assessment of fatigue usage in all critical vessels and piping. As a result, this Windows-based software is used in more nuclear plants worldwide than any comparable system.





PC-CRACK™

Sophisticated fracture mechanics analyses are performed quickly and easily with Structural Integrity-developed pc-CRACK 4.1. The Windows-based software analyzes and predicts flaw behavior, including calculation of crack growth rates and critical crack sizes for pressure vessels, piping, steam turbines, and structures, with immediate display of analysis results. pc-CRACK applications include ASME Code Section XI flaw evaluations as well as repair design.

SI-VERSADAS™, SI-MINIDAS™, AND TTVMS™

Reliable vibration data is needed before any vibration issue can be resolved. Structural Integrity offers a line of data acquisition systems that collect and analyze vibration data, including portable SI-MiniDAS; high-speed, automated SI-VersaDAS; and real-time TTVMS (Transient Torsional Vibration Monitoring System), with both manual and automated acquisition capabilities. Structural Integrity's proprietary customized systems, either desktop or laptop-based, are suitable for problems involving small-bore piping, socket welds, large bore piping, turbine-generator rotors, and other vibration-prone components.

BEYOND-PRAISE™

Probabilistic fracture mechanics analyses of nuclear reactor vessels and piping can be expedited with beyond-PRAISE, originally developed for the U.S. NRC. The latest version of the software can analyze crack initiation and growth caused by fatigue, primary water stress corrosion, and flow-accelerated corrosion. Windows-based beyond-PRAISE can analyze multiple failure modes, including leaks, large leaks, and LOCAs, in a single computer run.

TRAINING

Structural Integrity's training courses focus on Linking Theory and Practice. With this focus, you'll get more in-depth education on specific topics in the industry. We know people learn in different ways and may have differing needs, so we're *Linking Theory and Practice* to provide the following advantages to our clients:

- **Build Knowledge** – We build our training courses with one goal – to equip you with the knowledge to solve more of your complex problems. All of our courses are designed to improve your understanding of a highly technical topic and are taught in a way that lets you start turning theory into practice.
- **Reduce Risk** – Challenging problems occur regularly at any facility. With the right expertise, you can solve them faster, before small issues become significant threats. You'll also be able to take the uncertainty out of your ability to analyze and review externally-generated, specialized reports, thereby ensuring you can provide the proper oversight required by regulators and other stakeholders.
- **Save Money** – Our courses help you identify issues and resolve them faster. We provide a framework you can put into practice to reduce outage critical path time and limit any reduction in capacity factors. The end result? More time generating and transmitting energy, and less lost revenue.

www.structint.com/training

WEBINARS

Structural Integrity provides webinars on numerous industry topics to our clients.

Visit our website at www.structint.com/webinars for a current schedule of upcoming webinars, related registration information, and archived versions of previously conducted webinars that are available for viewing.

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