Structural Integrity Associates, Inc.®

Combined Cycle Plant Services

Engineered Solutions for Ensuring the Safe and Reliable Performance of Combined Cycle Plant Systems, Equipment, and Materials.

CORPORATE SNAPSHOT

- **Employee-owned company founded in 1983 in San Jose, CA**
- **Branch offices througout the United States and Canada, as well as overseas affiliates**
- **280+ employees providing consistent innovation and service**

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 branch offices throughout the United States and Canada, as well as established overseas affiliates.

We are able 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.

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 plant equipment.

COMBINED CYCLE OVERALL PLANT HEALTH ASSESSMENT

Increasingly, the US and world energy policy, environmental considerations, and economic factors are influencing the mix of current and future power generation technologies. Specifically gas plants, predominately combined cycle HRSG's, are being relied upon for peak power demands and for critical base-loaded generation. Therefore, combined cycle plant safe operation, availability and reliability are more critical than ever. Structural Integrity has developed service offerings to assist with the reliability, availability, and maintenance of critical plant assets.

Structural Integrity Associates, Inc. has a team of world-class experts with the knowledge and experience to addresss the most critical issues that will affect the safe and reliable operation of your plant. If you own, operate, or maintain a combined cycle plant, we can help you manage key issues that will affect the overall health of your plant:

CORPORATE MILESTONES

- **1983 – Company Founded in San Jose, CA**
- **1985 – Established Infometrics; NDE Products Business in Washington, DC Area**
- **1989 – Established Fossil Plant Services in Uniontown, OH**
- **1991 – Acquired IST, Inc. and Focused Array UT Inspection Technology in Ft. Lauderdale, FL**
- **1995 – Opened Charlotte, NC Office**
- **2000 – Opened Denver, CO Office**
- **2002 – Established Materials Science Center in Austin, TX Office**
- **2002 – Opened Stonington, CT Office**
- **2004 – Acquired GWT Technology; Established Pipeline Services Group**
- **2005 – Established Structural Integrity Canada in Toronto, Ontario**
- **2007 – Established Structural Integrity Expert Solutions in Salt Lake City, UT**
- **2008 – Opened Chattanooga, TN Office**
- **2011 – Acquired the Inspection Services Group from FBS, Inc. of State College, Pennsylvania**
- **2013 – Structural Integrity's 30 Year Anniversary**

Many combined cycle units have high energy piping fabricated from Grade 91 material, a Creep-Strength Enhanced Ferritic (CSEF) steel. Several problems have been identified during the fabrication and operation with this steel. Deficiencies in the processing of Grade 91 and other CSEF steels have been implicated in several well-publicized failures, forced outages, construction extensions, and premature component replacements in combined cycle plants in the US and worldwide. Recent inspections at many U.S. electric generating facilities detected a large number of improperly processed welds and components, and called into question the future reliability of similar critical components throughout the industry.

To help manage the issues associated with Grade 91/CSEF steels, Structural Integrity has developed a three-phased programmatic approach as described below.

PHASE ONE

VINDEX ***- Risk-Based Prioritization: Know where to look.***

The component and welds in the piping systems are prioritized using Structural Integrity's Vindex methodology developed specifically for Grade 91 materials (V91). Our V91 process is founded in our industry knowledge and leadership with EPRI-sponsored international research surrounding Creep-Strength Enhanced Ferritic (CSEF) steels. These processes are risk-based; the prioritization is based on the likelihood of damage and the consequence of a failure.

- We apply industry experience on high likelihood damage areas based on design and/or operational events/factors (nozzles, tube to header connections, flat end caps, header nozzle designs, and attemperator proximity).
- Consequence values are determined based on local configuration, man-pass frequency and proximity to plant areas such as maintenance shops, control rooms, and locker rooms.

DELIVERABLES

- Prioritized list of inspection locations
- Inspection protocols
- Recommendations for risk mitigation strategies
- Stress analysis
- HP/HR system solid models

PHASE TWO

SITE EVALUATION

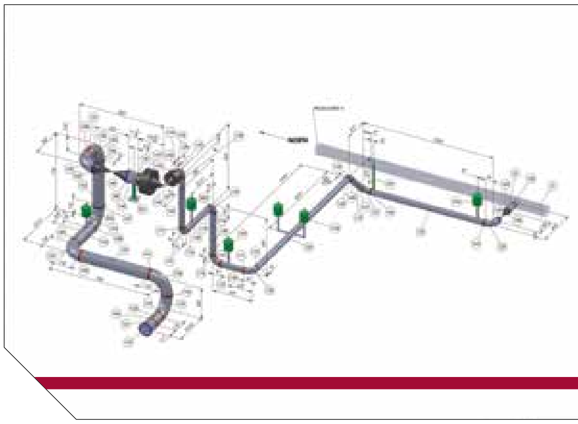
The second phase is the execution of the inspections and evaluations prescribed in Phase One. These can include material evaluations, replication, sampling, hardness, weld inspections, and others. It also includes an analysis of the data to refine the life estimates developed in Phase One. In addition, it is critical to have an appropriate data management system in place to store and make available this data for future use.

Specific inspection tasks are consistent with updated CSEF steel protocol, which Structural Integrity co-developed with EPRI. Where previous protocol used in industry Grade 91 inspections was primarily designed for the detection of maltreated material, the new proprietary SI updated protocols recommended for the current Grade 91 assessments, as part of Phase Two, includes weld evaluation using NDE for service related damage. Such NDE is useful for detecting design, operating and fabrication anomalies responsible for premature failure. We use the most advanced state-of-the-art technologies. These include linear phased array, annular phased array, and various metallurgical technologies.

PHASE THREE

LIFE ASSESSMENT

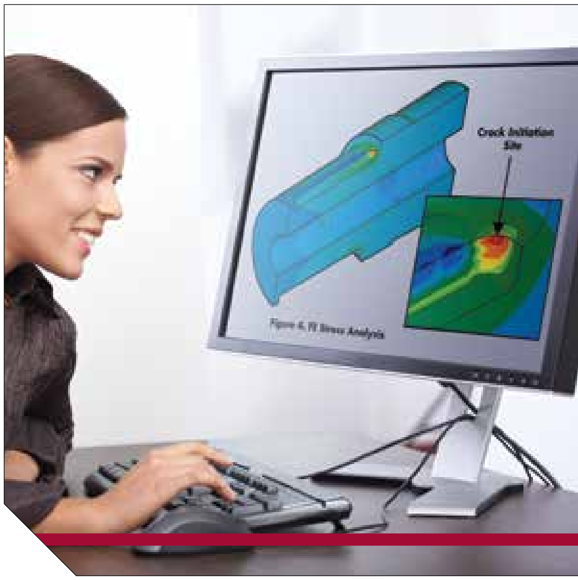
Phase Three is the cornerstone of Structural Integrity's CSEF/91 Program. The maltreated material, significant fabrication defects, or service related damage identified during Phase Two will require engineering evaluation. Any material which has been identified as suspect will be subjected to further life predictions which will include end of life calculation estimates. Plant management and SI would then develop a recommended course of action for the pipe section in question (Run, Replace, Repair).

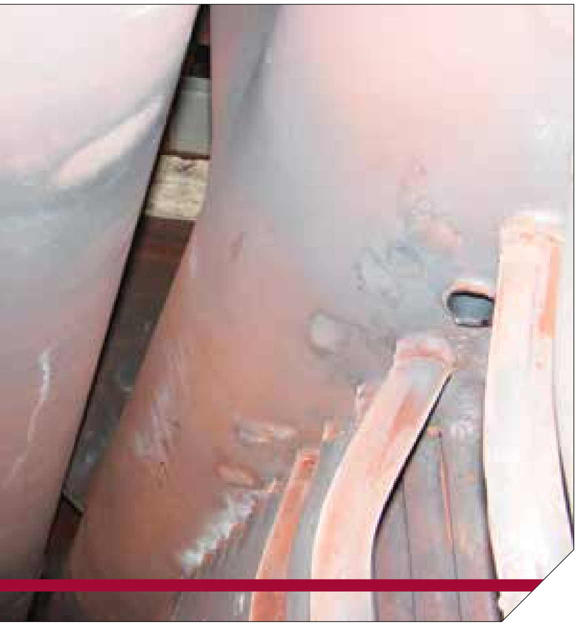


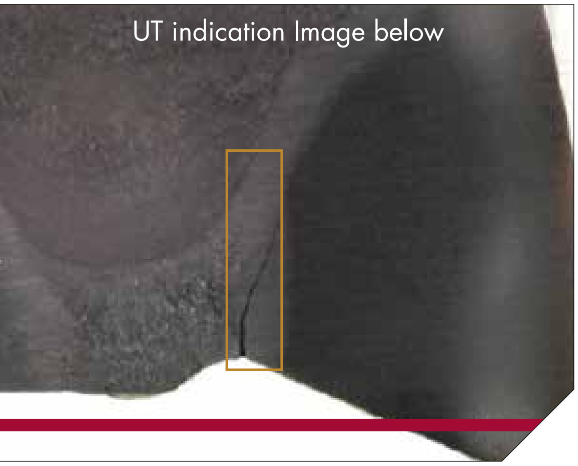
DELIVERABLES

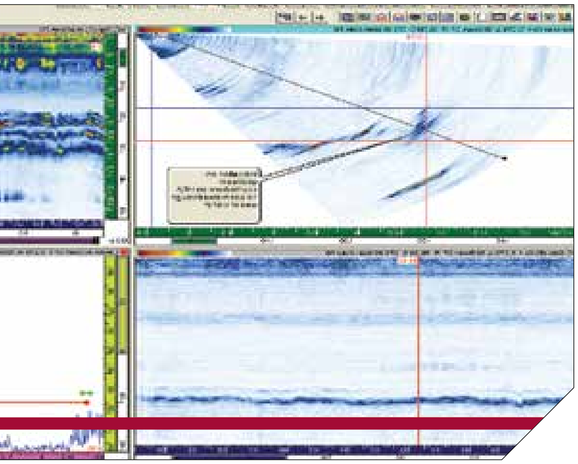
- Life calculation estimates
- Run/Repair/Replace decisions

GRADE 91 REPAIR









ATTEMPERATOR PIPE CRACKING

Improper design, operation, maintenance and control logic for interstage attemperators in the High Pressure Superheat (HPSH) and Hot Reheat (HRH) piping of Combined Cycle plants have resulted in several through-wall leaks and multiple cracking throughout the industry worldwide. As this piping is external to the HRSG, these leaks represent a serious personnel safety risk and can have a significant adverse affect on the overall plant reliability. Not only do these attemperator issues affect the downstream piping, they can also have a major negative impact on the associated headers and tubing.

Structural Integrity has developed the technology and has the technical expertise and experience to identify these problems before they occur and to help manage this condition once it occurs. More importantly we can help minimize the chance that it happens again.

Why does this cracking occur?
The root cause of the cracking is thermal fatigue, which is often associated with inadequate attemperator performance which produces repeated thermal quenching of the ID surfaces resulting in high tensile stresses. These thermal stresses can often be extremely high and have resulted in cracking in less than 5 years of operation. Given the severity of these stresses, it is a certainty that cracking will initiate again without modification to the attemperator and control practices.

Structural Integrity's detailed assessments have revealed:

- 82% of the plants assessed have attemperator piping arrangements that allow unvaporized, or leaking, spraywater to flow directly into harps during low or zero steam flow conditions.

INTERSTAGE ATTEMPERATOR PROGRAM

Phase 1: Perform an overall HRSG Level One assessment of the plant for cycle chemistry, FAC and thermal transients. SI has characterized the various aspects of location, operation and control which lead to attemperation problems. Most often we have been able to identify a problem before it occurs. If there already is a problem (cracking/damage to piping, headers or tubing) then the same approach can be used to identified the root cause drivers.

Phase 2: Perform site evaluations using advanced NDE techniques to determine the extent of any existing damage. This includes Linear Phased Array (LPA) ultrasonic techniques.

Phase 3: Perform Fitness-for-Service analysis in order to develop run/repair/replace decisions if any damage is identified through Phases 1 and 2.

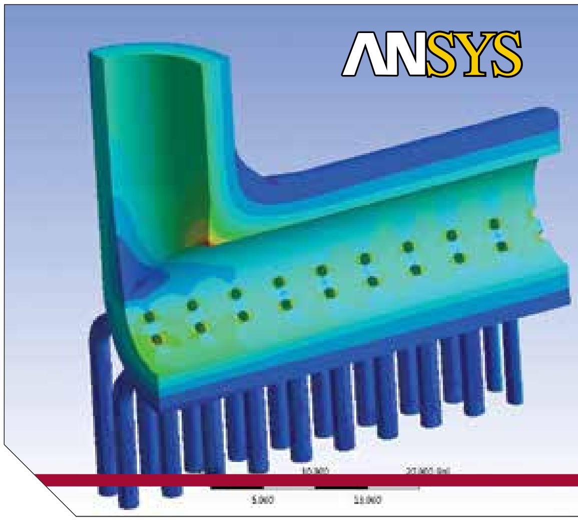
Phase 4: Perform a Root Cause Investigation to identify the source(s) of the thermal stresses and develop recommendations for corrective action. Most often the preferred approach is to identify the root cause drivers as early in life as possible. This is accomplished through the Level One Assessment methodology in Phase 1.

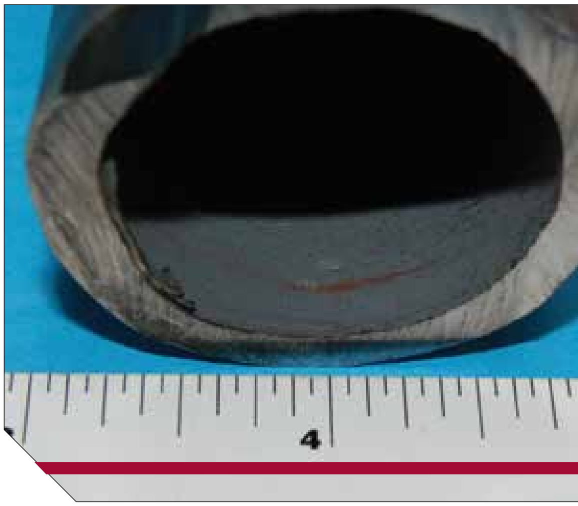
Phase 5: Implement the corrective action and perform follow-up monitoring to ensure they have resulted in the desired effect. The same tools used in Phases 1 and 4 can be used to determine the efficiency of any solution suggested and applied.

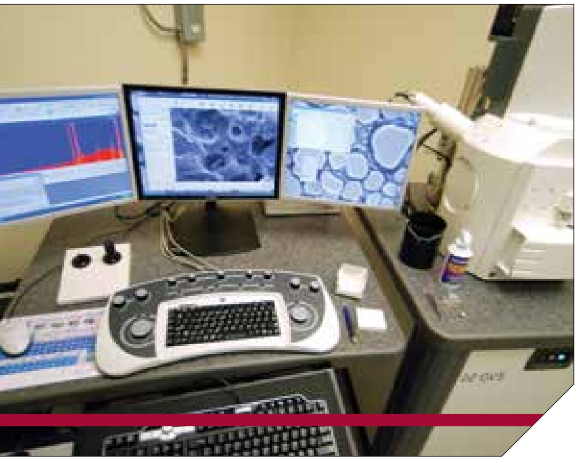
TUBE FAILURE PREVENTION AND ANALYSIS

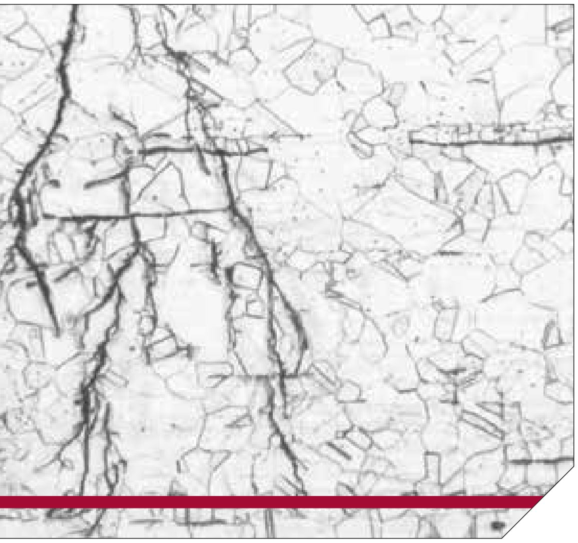
PROGRAM SUMMARY

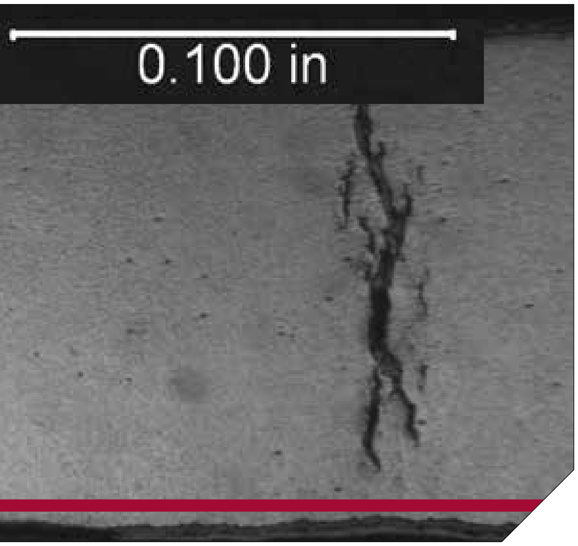
1. Mechanism identification through destructive metallurgical analysis
2. Full Root Cause Analysis for HRSG Tube Failures (HTF), including identification of appropriate corrective actions to eliminate repeat failures
3. Inspection services including:
    - Internal tube, header and drum inspection (visual and fiber optics)
    - Surface inspection (VT,PT, MT, ECT)
    - Volumetric inspection (various UT techniques)
    - Metallographic replication
    - Hardness testing
    - In situ chemical analysis
4. Stress Analysis/Finite Element Modeling for the tube/header connections involving T91/P91, T91/P22, and T22/P22 which are susceptible to thermal fatigue, creep and creep fatigue
5. Remaining life assessments
6. Cycle chemistry review, recommendations for system upgrade and optimization, support for chemical cleaning, etc.











STRUCTURAL INTEGRITY'S MATERIALS SCIENCE CENTER IN AUSTIN, TX

By utilizing the broad capabilities at Structural Integrity's Materials Science Center in Austin, Texas, our metallurgical experts are consistently well-equipped to tackle the toughest industry problems affecting material performance. Understanding material behavior and the reasons why materials fail is crucial for maintaining safe and reliable operation. Having such information readily available focuses your limited resources on mitigating the true root cause of equipment failure, thus avoiding the downtime and costs associated with recurring problems. Our laboratory capabilities include: Quantitative Microstructural Analyses, Fractography, Scale and Deposit Analyses, Metal Chemical Analysis and Alloy Verification, Cyro-Cracking, Heat Treating, In-place Metallography and Replication, Hardness Testing, Miniature Sampling, Specialized Corrosion Testing.

A vital part of an HRSG tube prevention program is the metallurgical analysis of the failed tube. Repairing an HTF in place and/or not removing the failure location for analysis means that there will be no identified mechanism. Without this, it is often impossible to address the root cause and solve the problem.

HRSG Tube Failure Analysis:

1. The tube section will be visually examined and photographed in the as-received condition.

2. The damaged area will be removed from the bulk tube section for more thorough examination, which may include examination and documentation using a stereomicroscope and/or sectioning the tube so the internal surface can also be examined.

3. If necessary, the damaged area will be examined in a scanning electron microscope (SEM) for higher magnification evaluation. This task is particularly likely for a fracture so that the fracture origin area can be evaluated and documented.

4. If corrosion is found to have contributed to the failure, corrosion products will be analyzed using energy dispersive X-ray spectroscopy (EDS) as part of the SEM examination. This task may include elemental mapping of the corroded area to show how any corrosive species are layered or dispersed within the corrosion products. This step may also pertain to internal oxides for high temperature failures.

5. If necessary, cross-sectional samples will be removed from the damaged area and prepared for metallographic examination of the fracture morphology, the tube surface conditions, and the tube microstructure. Hardness measurements will be made on the metallographic samples.

6. The tube material will be analyzed to determine its chemical composition. The tube chemical composition may be checked against its specification through PMI (positive metal identification).

7. We provide preliminary results within two weeks of receiving the samples and authorization to proceed with the analysis. A final report containing a description of the laboratory procedures and results, discussion and documentation of the results, conclusions and, as appropriate, recommendations, will be issued within three weeks of completing the laboratory analysis.

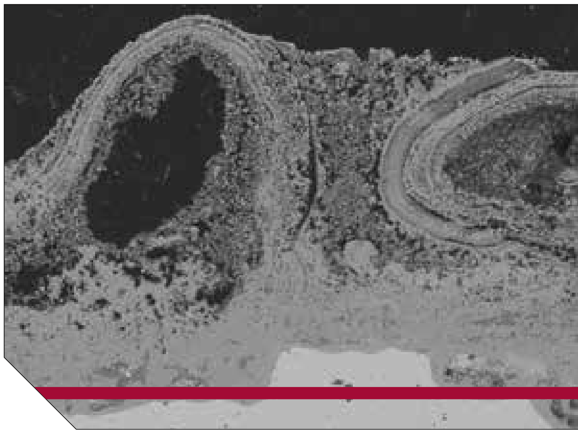
The major HTF mechanism of under-deposit corrosion includes hydrogen damage, acid phosphate corrosion, and caustic gouging. These mechanisms only occur in areas where there are excessive deposits. Structural Integrity has developed a three-pronged approach to conducting these analyses and published a Deposit Map which helps organizations recognize when HP evaporators need to be cleaned. Our process also assists the development of the optimum cycle chemistry, because deposition in the HP evaporator is a direct function of the chemistry used in the lower pressure circuits which controls FAC. Our results clearly show that deposition increases with the use of reducing agents and amines in the low pressure circuits, and with the use of phosphates in the HP drum other than only tri-sodium phosphate. The following represents the protocol that we use.

STANDARD HP EVAPORATOR TUBE EXAMINATION PROTOCOL:
The tube will be visually examined and photographed in the as-received condition.

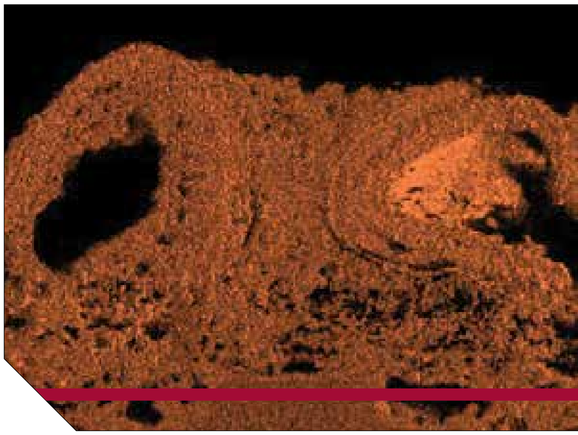
1. The internal deposit loading will be measured in accordance with ASTM D 3483 using the glass bead blasting deposit removal technique. The deposit loading coupons will be documented before and after cleaning so the condition of the deposits and condition of the tube ID surface can be noted.

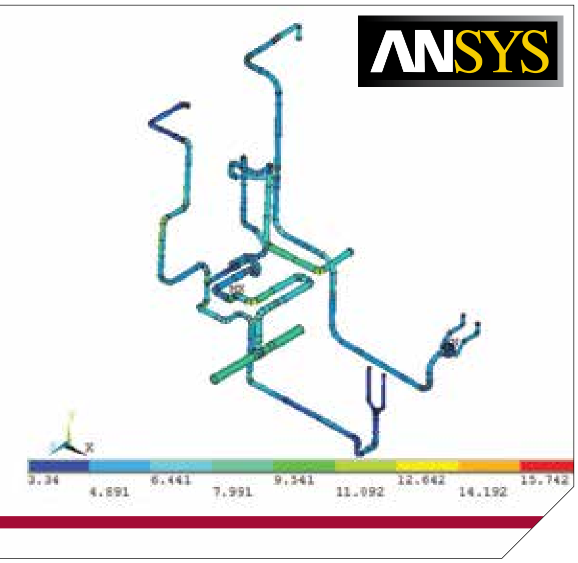
2. Bulk internal deposits will be collected from the hot side of the tube [heaviest deposit weight density (DWD)] and analyzed in a scanning electron microscope using energy dispersive X-ray spectroscopy (EDS) to identify the elements present.

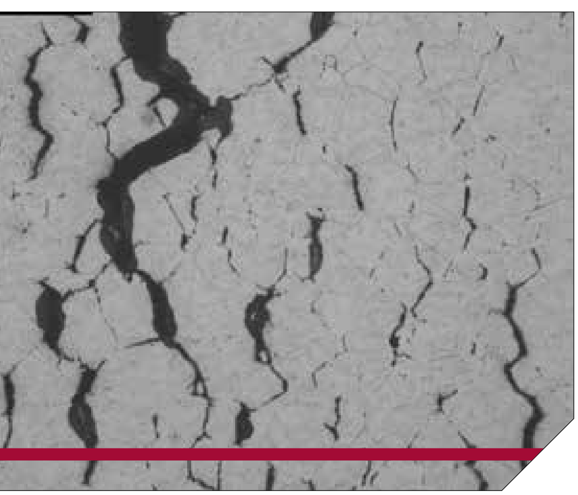
3. A cross-section from the gas turbine (GT)-facing side of the tube will be removed and prepared for internal deposit evaluation, which will include optical metallography, SEM imaging and elemental mapping. This task includes measurements of the ID oxide/deposit thickness and mapping of any impurities throughout the deposit layer.



We provide preliminary results within two weeks of receiving the samples. A final report containing a description of the laboratory procedures and results, discussion and documentation of the results, conclusions and, as appropriate, recommendations will be issued within four weeks of receiving the sample and authorization to proceed with the analysis.







LEVEL ONE PLANT ASSESSMENT

The overall objective of our Level One Assessment is to assist your plant in identifying any aspects of operation of the combined cycle unit which will affect the safe operation, future availability and/or damage accumulation. It is also clearly recognized that thermal transients in HRSGs must be identified as early in life as possible to prevent thermal fatigue and creep-fatigue failures. A typical project is designed to help our clients develop the optimum cycle chemistry and to determine if unanticipated thermal transients are likely to lead to pressure part failures well in advance of the anticipated service life of the Combined Cycle Unit. With respect to the influence of thermal transients on plant reliability, the deliverable will be an assessment of whether thermal transients are possible and could be damaging.

- Cycle Chemistry
- Flow Accelerated Corrosion
- Thermal Transients

MANAGEMENT OF CONDENSATE IN SYSTEMS AND ATTEMPERATORS

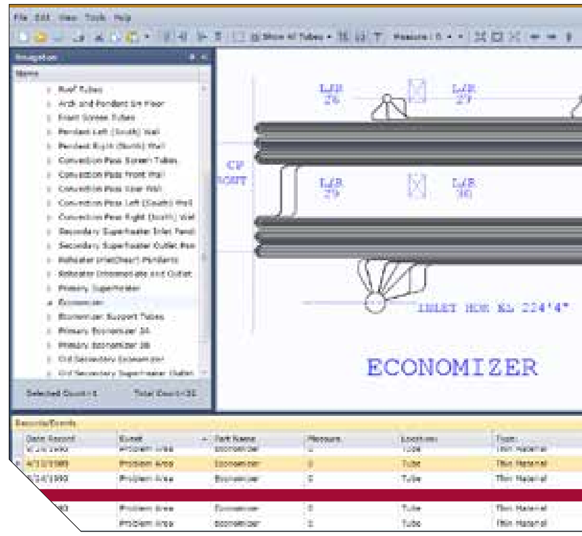
The main reasons for severe thermal transients are related to inadequate management of condensate which forms during the purge, inadequate drain systems and attemperators. Installed diagnostic/troubleshooting monitoring is used to characterize the severity and timing of the potentially damaging thermal transients and verify that the corrective actions taken were successful.

LEVEL TWO AND THREE ASSESSMENT ACTIVITIES

Our HRSG team can frequently recognize and address critical construction, design and operational features without the installation of thermocouples and detailed thermal analyses. Level Two and Three activities in the cycle chemistry area involve assisting the organization to optimize the unit cycle chemistry (feedwater, drum treatments), developing adequate total iron monitoring processes, and ensuring that a fundamental level of instrumentation is in place that is alarmed in the control room. We use the cycle chemistry guidance documents from IAPWS (www.IAPWS.org) which are regarded as the world standards for instrumentation and volatile treatments. Level Two and Three activities in the FAC area involve identification of the areas in the low pressure circuits where FAC may be active. Rectification of FAC involves optimizing the cycle chemistry throughout the plant and ensuring that the total iron levels match the Structural Integrity "Rule of 2 and 5" (< 2ppb in the feedwater, <5ppb in each drum).

THE WEB-ENABLED COMPONENT ASSET MANAGEMENT SYSTEM

Common throughout the power industry is a need for user-friendly information management systems to store and manage critical data including component design, inspection records, engineering records, and analysis documentation. Recognizing that such systems must have secure network access, be scalable, and easy to use, Structural Integrity Associates developed an internet-enabled application called PlantTrack. This builds on the legacy TubeTrack software providing a validated solution to your data management needs.



PLANTTRACK SIMPLIFIES THE RECORDING AND TRACKING OF EQUIPMENT CONDITIONS BY PRESENTING INFORMATION IN COMMON EVERYDAY WEB PAGE FORMATS.

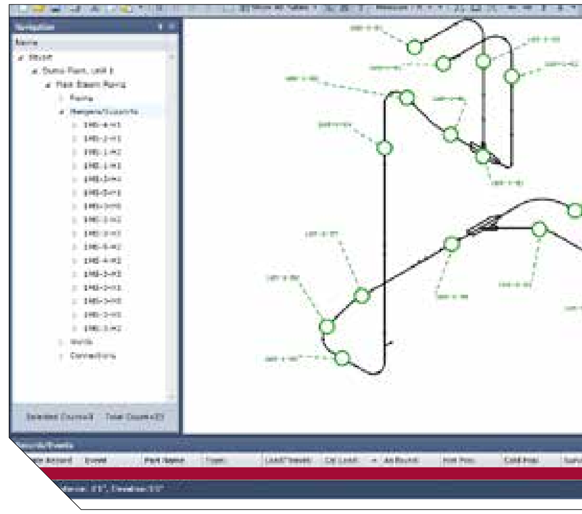
- Using a web browser, the user can surf the pages to view real-time component details including engineering specifications, analysis and inspection history details.
- Navigate your data graphically through interactive drawings and other graphic representations that facilitate use and bring greater meaning, particularly when used for tracking and trending conditions assessment data.
- One-stop shop for component information by allowing the linking of unlimited numbers and types of data files (pictures, documents, drawings, spreadsheets, etc.) to each of the component, analysis and inspection records.
- Develop reports detailing the part inventory, tests scheduled, tests performed and test engineer credentials

VERSATILITY

- PlantTrack is adaptable to all power plant equipment through user-created data fields and drop-down lists. No need to reprogram or pay for 3rd party modifications.
- PlantTrack can be used to house the information for a single unit, a single facility, or the entire fleet…there's no limit to the number and types of components defined.

PLANTTRACK ADDITIONAL FEATURES

- Data queries can be tailored to meet user-defined criteria and data fields
- PlantTrack permits interfacing with other database tools, such as MS Access and Excel
- PlantTrack can be provided as a service via the worldwide web (www)
- PlantTrack can also be installed locally on a corporate intranet



Structural Integrity
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Experts in the prevention and control of structural and mechanical failures

For more information on our products and services please contact a member of Structural Integrity's Combined Cycle Team.

www.structint.com
877-474-7693
(**877-4SI-POWER**)

Akron, OH	Austin, TX	Charlotte, NC	Chattanooga, TN	Chicago, IL	
330-899-9753	512-533-9191	704-597-5554	423-553-1180	877-474-7693	
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