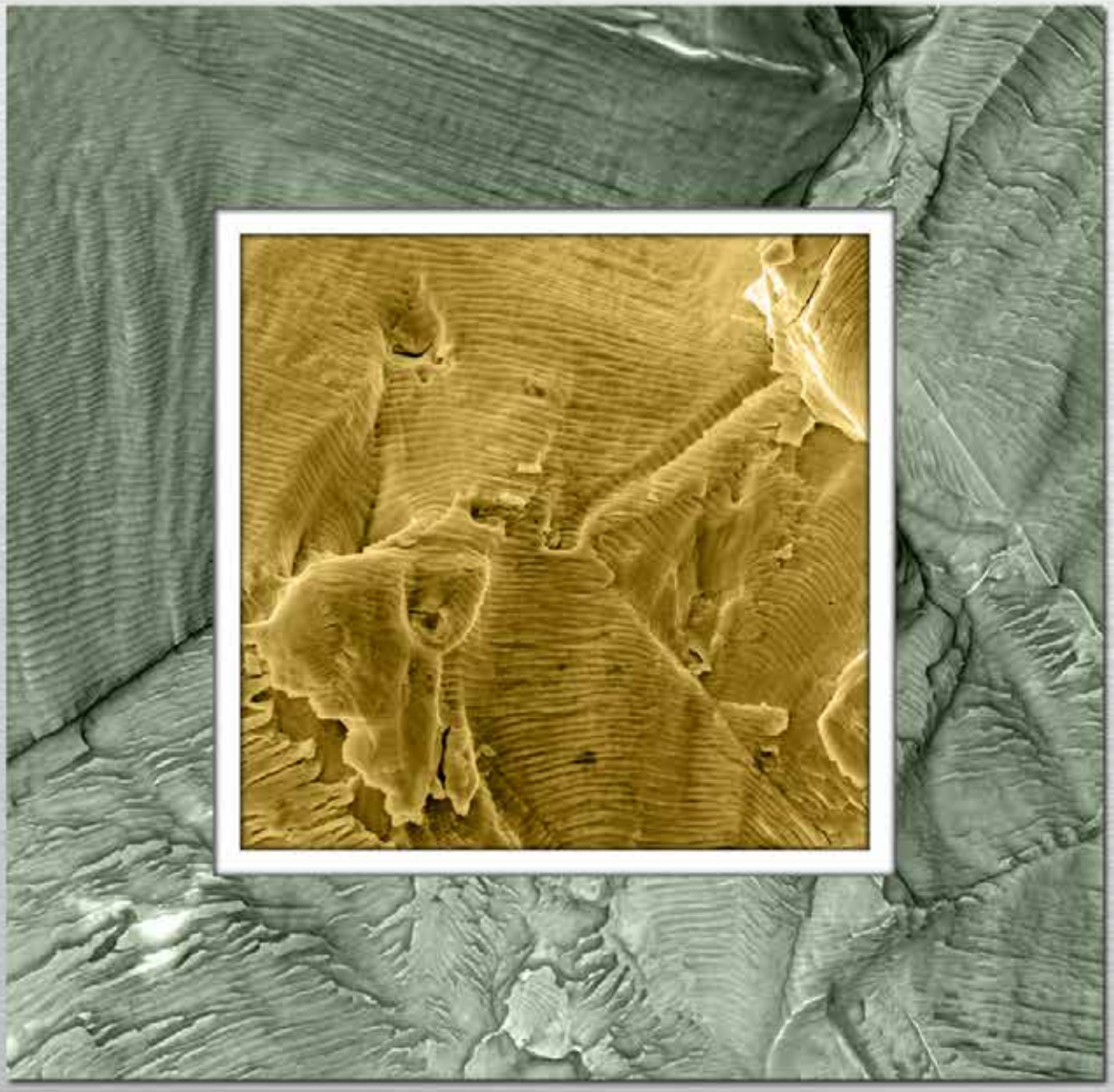
Materials Engineering



design • analysis • testing

STRESS ENGINEERING SERVICES INC.®

an employee-owned company

Failure Analysis

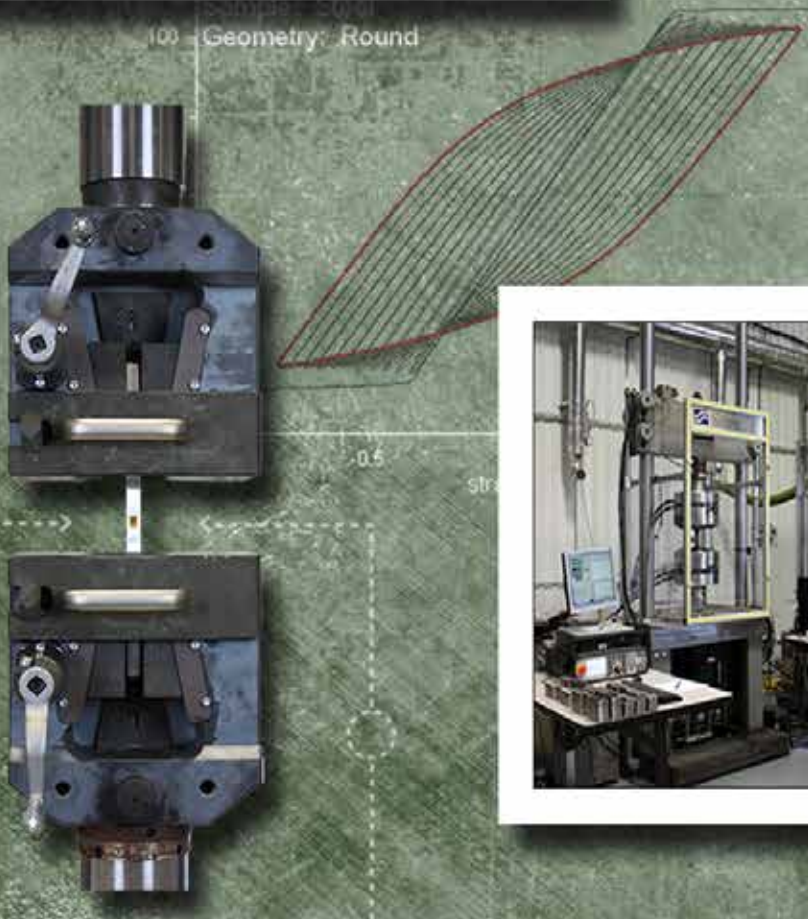
There may be several reasons why a component fails in service. However, to properly establish the cause of the failure, the right combination of advanced analytical equipment and experience is essential. At Stress Engineering Services, our focus extends beyond “why did it fail?” We extensively examine the operating parameters, component designs, materials, and environment, as well as consider the equipment’s condition and maintenance history, to identify the mechanisms that led to the failure.

Our comprehensive ability to identify potential failure mechanisms is based on decades of experience evaluating material and component failures in a broad range of components, structures, and products. Our experience encompasses piping, pressure vessels, consumer products, cranes, wind turbines, electronic components, plastic products, and medical devices.

We have an extensive background in a variety of engineering disciplines and fields including materials engineering, mechanical engineering, electrical engineering, biomedical engineering, polymers, and packaging. Furthermore, we have significant experience with all types of materials including metals, plastics, glass, elastomers, and composites, as well as product design and nearly every type of manufacturing process.

The collective skills and knowledge of our staff, along with our broad testing capabilities and state-of-the-art laboratories, enable our engineers and metallurgists to provide complete, reliable, and timely results that can help prevent future failures.

- History of Component
- Visual Examination
- Photographic Documentation
- Sample Selection
- Collect Deposits
- Sectioning
- Fractography
- Viscosity and Melt Flow
- Metallography
- SEM/EDS/XRD
- Chemical Analysis
- Mechanical Testing
- Corrosion Testing
- Non-Destructive Examination
- FTIR/GCMS/TGA of Plastics
- Field Metallurgical Replication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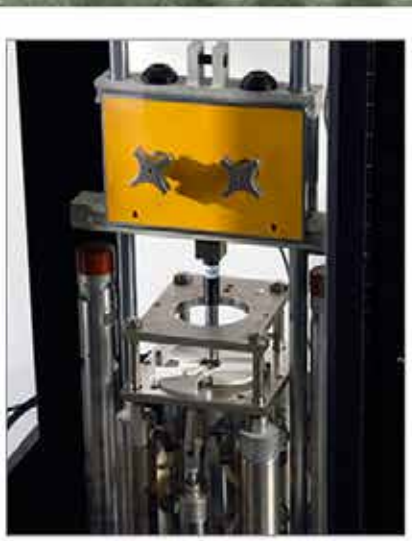


Materials Testing

The foundation of our materials engineering and metallurgy services is our comprehensive, laboratory-based material testing and characterization capabilities. Our independent materials testing laboratories are equipped with state-of-the-art equipment for a wide range of material-testing methods including static tensile, compression, fatigue, chemistry, impact, environmental-related loading, creep, and relaxation. In addition, we offer a wide range of custom testing procedures designed to accurately define failure modes and assist in dependable material selection.

- Material testing for mechanical properties and material degradation, such as aging and environmental stress cracking
- Product performance testing under various conditions
- Life assessment testing of components and devices
- Instrumentation of components for use in actual devices in order to quantify in-use loads, temperature, pressure, strain, etc.

HARSH ENVIRONMENT TESTING - Our materials testing facilities host a full-service fatigue and fracture laboratory for materials testing in sour (H_2S), high-pressure/high-temperature, low temperature, CO_2, nitrogen, methane, and other extreme environments. In addition, we provide materials characterization and selection assistance for equipment used in harsh environments, as well as full-scale equipment assessments. The laboratories feature digitally controlled, servo-hydraulic material test frames with capabilities ranging from 22 to 150 kip (98 to 667 kN) for both standard and non-standard tests.

- Sour Service Testing
- Fracture Toughness Testing
- Small-Scale Component / Assembly Characterization
- Component Testing
- Cyclic Fatigue and Fracture Testing
- Tensile and Compression Testing

HIGH TEMPERATURE CREEP TESTING - Sustained loads and elevated temperatures can accelerate creep-related failure mechanisms. The Stress Engineering Services creep testing facilities provide a valuable resource to support areas such as risk and remaining life assessment, fitness-for-service evaluations, material selection, pressure vessel re-rates, and experimental verification and validation of design procedures. These also serve as a center for exploring and developing innovative methods for creep evaluation of service-exposed components. Our expansive creep laboratories provide high temperature creep testing across a full range of engineering applications – from sub-ambient to 2000°F (1093°C) on materials of virtually any description.

- 50 Conventional Tensile Creep Machines
- Electro-Hydraulic Test Rigs for Subcomponent and Cyclic Testing
- Two 100,000 lb (445 kN) Creep Machines for Testing of Weldments

Polymers / Non-Metallics

Our materials engineering capabilities cover a wide range of polymeric materials, elastomers, composites, and manufacturing processes. Equipped with state-of-the-art testing laboratories and specialized tools, our engineers and technicians can skillfully identify the characteristics and properties of many non-metallic materials.

We use advanced techniques to test the mechanical responses of materials under various conditions such as temperature, climate, impact, multi-axial tensile, fatigue, and chemical exposure to determine their effects on material behaviors including creep, physical and chemical aging, stress cracking, stress relaxation, strain, and others. Our engineers apply this essential material data to establish the most applicable materials and to verify that the material will perform as specified.

- High Strain Rate Tensile Testing (HSRT)
- Biaxial Tensile Testing
- High Frequency Tension/Compression Testing
- Drop Impact Testing
- Static Load and Friction Testing
- Pressure, Fatigue, and Temperature Testing
- Creep Testing
- Accelerated Aging of Plastics

Accelerated Life Testing

Accelerated life testing is the process of inducing degradation and/or failure of a component or assembly in a relatively short period of time compared to that expected while in service. This vital data can be used to predict product performance and identify material problems during the early stages of product development.

Utilizing our technical expertise in predictive analysis and accelerated aging testing methodologies, we have developed an approach that enables predicting long-term product life from relatively short-term test data. We use an assortment of methods to induce life-limiting failure modes such as creep cracking, environmental stress cracking, and cracking under relaxation conditions—all on a dramatically accelerated time scale.

Our testing laboratories feature advanced equipment to control temperature, humidity, stress/strain levels, and product contact conditions on hundreds of test specimens or product assemblies at the same time. This ability to condition and fixture specimens over such a broad range of variables in a short period of time, allows us to provide clients with highly reliable failure-rate data and reliability statistics.

Corrosion Engineering

Our engineers are renowned experts in the areas of corrosion modeling and corrosion control, including design and evaluation of corrosion inhibition programs and inhibitor qualification. We utilize our extensive corrosion expertise along with highly advanced tools to examine the critical issues and atmospheric/environmental service conditions to effectively identify the source of the failure. Our objective is to ensure that the most effective corrosion control methods are used and appropriate replacement materials are selected.

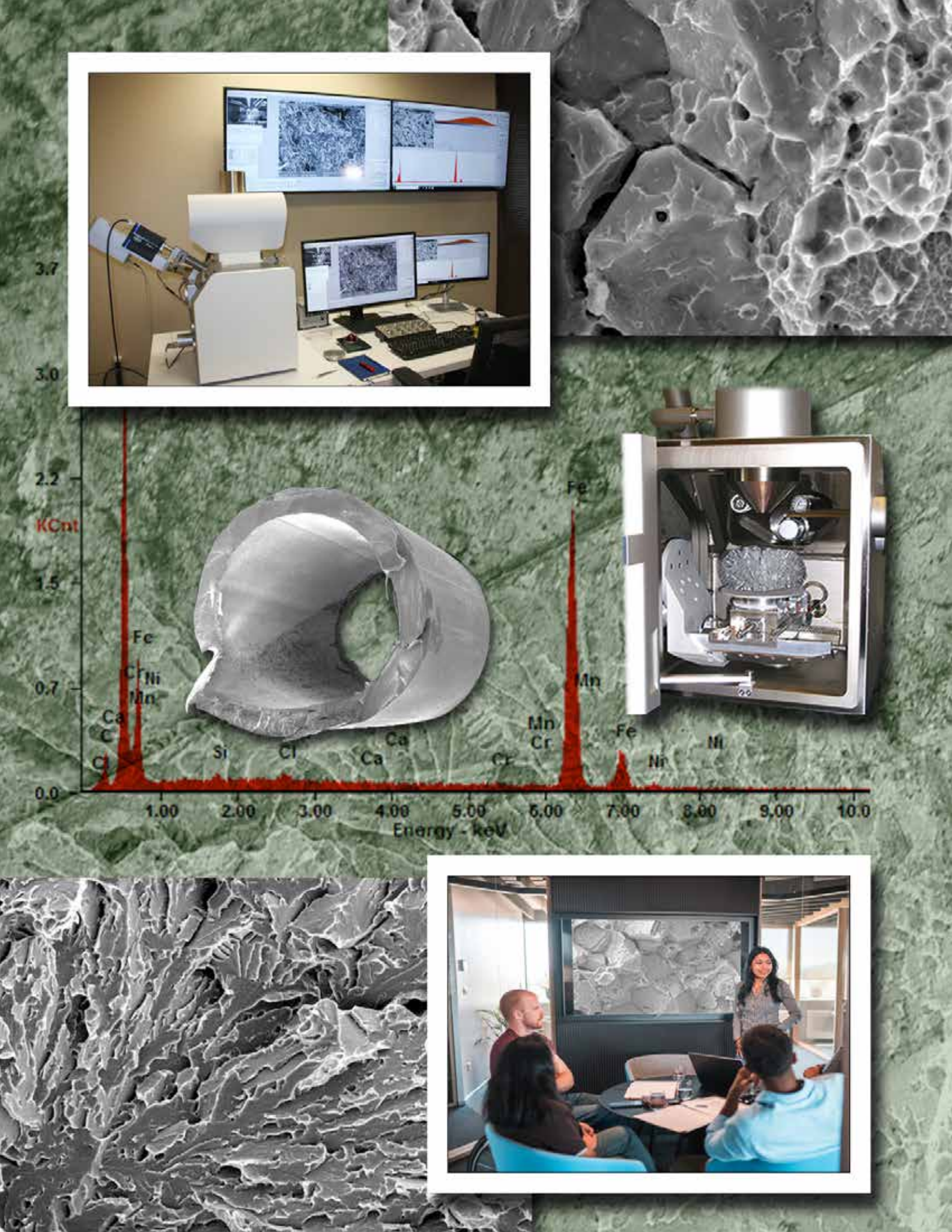
- Investigations and Assessments
- Materials Characterization and Selection
- Evaluation for Aggressive Conditions *(Sour Service and HPHT)*
- Corrosion Modeling and Corrosion Control
- Design / Management of Test Programs
- Regulatory Compliance

Welding Engineering

Welding and joining processes are used in virtually all materials systems. From glued joints in plastic to automated sub-arc welding of steel riser pipe, joints are a common location of failures. The materials, metallurgical, and welding engineers at Stress Engineering Services have examined thousands of welds involving a wide range of materials, processes, and industries.

Our welding experts have assisted clients in a variety of weld and joint related matters including failure analysis, materials selection, post weld treatment assessments, non-destructive evaluation, mechanical testing, and the review of welding procedures and specifications. Our engineers also maintain an extensive knowledge of many ASME, API, CSA, and AWS welding codes, recommended practices, and industry standards.

- Technical review of welding procedures for:
  - Customer specifications and applicable industry standards and code compliance
  - Welding variables to metallurgical structure and mechanical properties comparisons
- Preparation of welding procedures for client/contractor qualifications
- Monitor/witness welding fabrication to ensure specification conformity
- CTOD Testing used in welding procedure qualification
- Welding procedures for sour service and high-pressure vessels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Materials Selection & Evaluation

When selecting potential materials for an engineering application, it is important to have a comprehensive understanding of the materials, especially their properties and behavior. A vast number of materials are now available, and it can be very difficult to select the best candidates. Getting it right is critical because selecting, testing, and qualifying materials are among the most important product development decisions made.

At Stress Engineering Services, we focus on assisting clients with material selection processes to ensure that the most suitable materials for a particular application have been identified. Our engineers utilize their in-depth experience and an assortment of situation-specific testing methods to efficiently acquire the crucial data needed for practical material selection and qualification.

Scanning Electron Microscopy

Scanning electron microscopy (SEM) is one of the most powerful methods for evaluating engineering materials and understanding how they perform in real-world applications. We combine state-of-the-art SEM and microanalysis with comprehensive materials engineering expertise to help clients understand how materials behave. Our engineers apply our extensive SEM capabilities and resources to:

- Identify failure modes such as fatigue, stress cracking, and hydrogen embrittlement
- Evaluate and photograph surfaces, particles, defects, and structures of engineering materials at magnifications up to 100,000X
- Measure chemical composition of any sample
- Identify and evaluate the crystalline structure of materials and how it is influenced by manufacturing processes and services

At Stress Engineering Services, highly skilled materials engineers and technologists with decades of industrial and failure analysis experience operate our SEM. Our materials engineers understand engineering materials and effectively interpret SEM results for our clients. When engineering support is not required, our technologists operate the SEM and microanalysis system at lower cost for clients who prefer this level of service.

- Large sample chamber accommodating objects 6” (15.24 cm) diameter by 3.5” (8.89 cm) tall and weighing up to 18 lbs (8.2 kg)
- Live high-resolution projection of SEM images and microanalysis data
- Remote viewing from multiple locations via the Internet

Reliability vs. Time

Reliability

Reliability is characterized as the ability of a system, device or process to perform its intended functions for a specified period of time under specified operating conditions. A large extent of reliability is achieved by designing products that are tolerant to variations in manufacturing, able to withstand extreme use, and made of materials that are suitable for the long-term loads, sterilization, and the environment to which the product will be exposed.

Predicting product performance can be very complex and generally requires a host of multidisciplinary testing and analysis to accurately identify material behaviors. We offer an array of material testing, characterization, and analysis services designed to skillfully evaluate and resolve performance, reliability and safety issues.

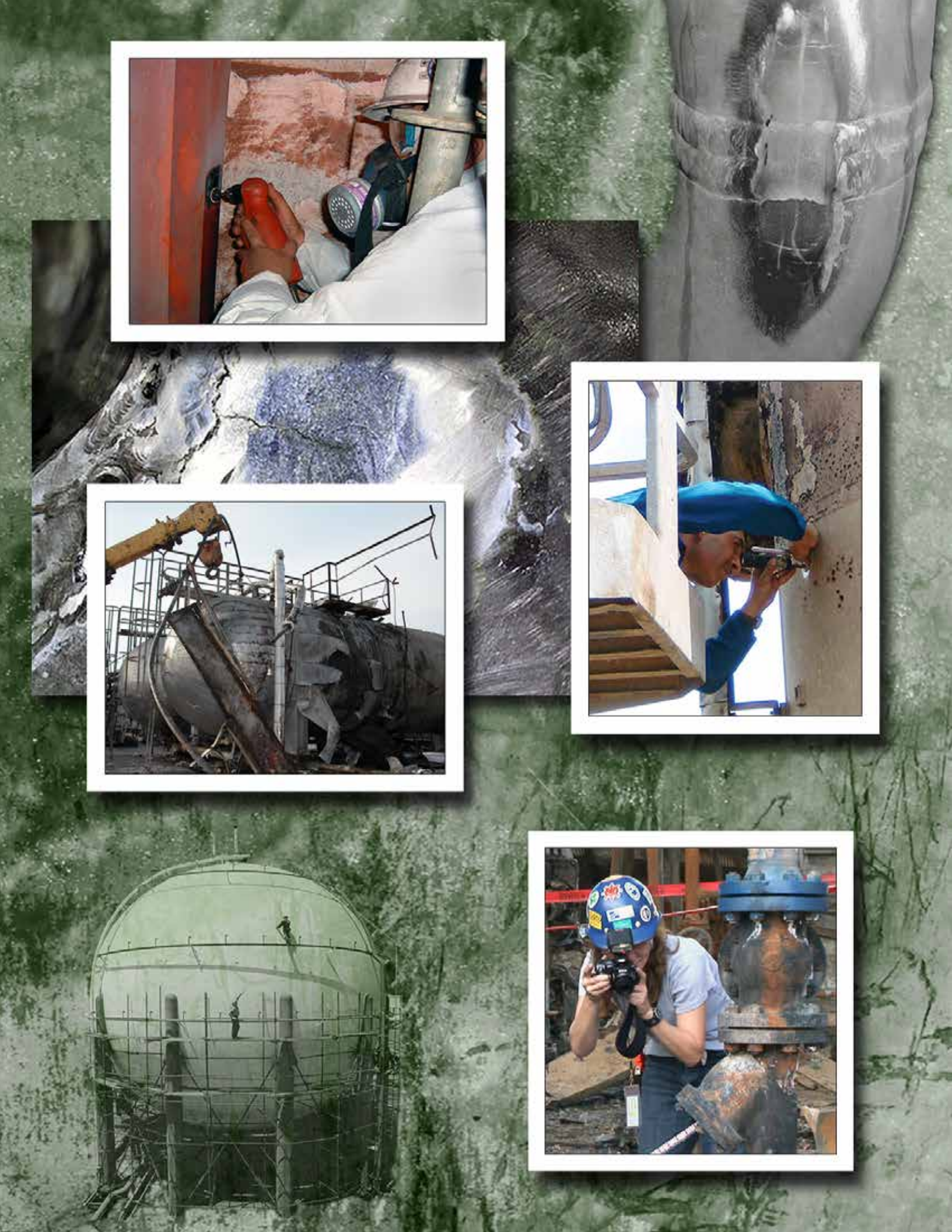
- Accelerated Life Testing of Components and Assemblies
- Material Characterization including:
  - Sterilization Effects
  - Long-term Storage
  - Environmental Degradation
  - Impact and Other Complex Behaviors
- Failure Modes and Effects Analysis (FMEA or FMECA) for Design, Process, and Application
- Fault Tree Analysis (FTA) Critical Component Identification
- Validation Testing Quantitative Life Calculations

Life Prediction

Most engineered structures experience some type of material failure or depletion during their service life. When this occurs, operations can be seriously disrupted with unplanned downtime, and severe damage or dangerous conditions can be created.

Many instances of material degradation and failure occur due to improper design and material selection, manufacturing defects, maintenance practices, or operating parameters. These can also be the result of exposure to one or more damage mechanisms such as stress, corrosion, temperature, creep, and fatigue.

Stress Engineering Services routinely provides reliable life predictions and fitness-for-service evaluations for determining the serviceability of damaged structures and components. Our experts use advanced analytical tools and methodologies to assess degradation, flaws, damage, and material aging, and then establish the integrity, safety, and reliability of the structure.



Field Inspection and Testing

Stress Engineering Services is a leader in inspection and non-destructive testing of engineered components and structures. Our multidisciplinary team of skilled engineers and technicians regularly perform in-situ assessments and non-destructive testing to identify the root causes of failures and assess the degradation mechanisms that impact the service life of components and structures.

Our work frequently begins by examining a component on-site, understanding its environment and service history, and selecting critical samples. We use our vast experience along with a wide variety of macroscopic and microscopic analysis and testing techniques to document the component, determine material properties, and identify the failure mode or suitability for continued service.

At Stress Engineering Services, we specialize in non-destructive testing methods and techniques that can accurately locate, characterize, and size flaws in a variety of components and structures from coke drums and consumer products to pipelines and medical devices.

- Acoustic Emission Testing
- Field Metallurgical Replication
- Magnetic-Particle Testing
- Dye-Penetrant Examination
- Radiographic Testing
- Ultrasonic Evaluation

Forensic Support

The forensic engineers at Stress Engineering Services are widely regarded for their expertise in forensic investigation, evidence collection, failure analysis, specialized testing, and engineering consultation. Our qualified staff, extensive materials-engineering knowledge, and wide-ranging testing capabilities provide a valuable resource for assisting with all types of forensic investigation issues.

Our forensic engineering practice comprises engineering experts with an average of 25 years of applied industry experience and advanced degrees in engineering disciplines including mechanical, civil, electrical, marine, chemical, metallurgical, materials, and structural. All of our forensic engineers are respected authorities in their areas of specialization and accomplished in addressing a host of complex forensic engineering assignments around the world.

- Accident, Fire, and Injury Investigations
- Equipment and Accident Site Inspections
- Evidence Collection and Documentation

ABOUT STRESS ENGINEERING SERVICES

Stress Engineering Services is a leader in providing proven engineering services and solutions for a broad range of industries worldwide. Always at technology's leading edge, we set the standard in technical excellence by delivering the right answers - on time.

Since 1972, we have been servicing the needs of clients who require special, in-depth technical knowledge in the areas of materials engineering, metallurgy, testing, fitness-for-service, risk and feasibility assessments, floating production systems, riser design and analysis, pipeline engineering, mechanical design, fluid and fracture mechanics, process technology, product design and development, data acquisition, instrumentation, and more.

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