The Equity Engineering Group, Inc.

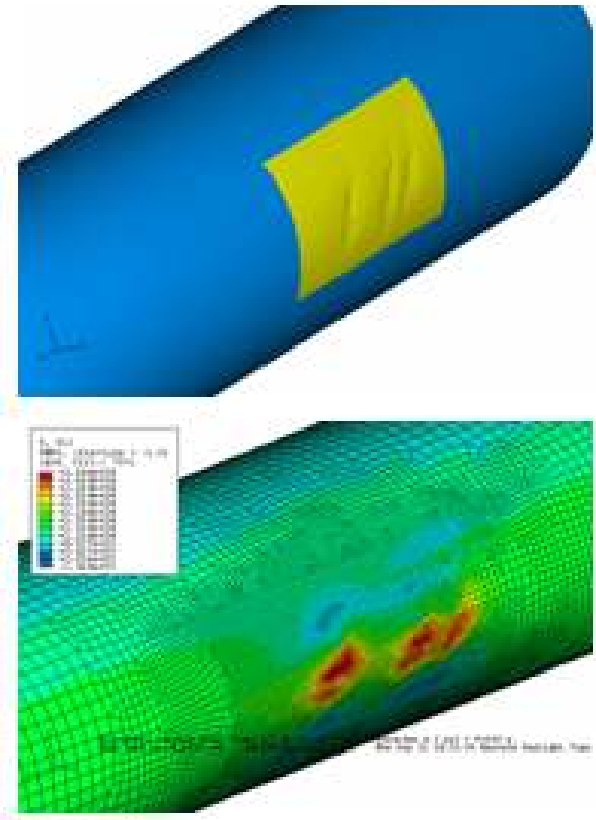
Advanced Fitness-For-Service Methodologies for the Oil Refining and Petrochemical Industries

E^2G Leadership in FFS Assessments:

- Proprietary cutting-edge technology
- Practical, cost-sensitive solutions
- Targeted analysis to solve the problem
- Major savings in unnecessary repairs
- Performance improvement evaluations
- Emergency turnaround on tight

E²G Offers a Full Range of FFS Experience

E²G has an unparalleled range of expertise in the use of FFS technology. We have evaluated all types of damage experienced in the refining and petrochemical industries on a wide variety of pressure vessels, process piping, transmission pipelines, storage tanks, heat exchangers, heaters (casing, tubes, and stacks), and mechanical components of specialized equipment. We have evaluated:



Level 3 Assessment of a transmission pipeline dented by a back hoe. Accurate measurements were taken of the dents and applied to the Finite Element model. E²G's assessment showed that an emergency Gas Plant shutdown could be avoided.

- General and Locally Corroded Areas, including Pitting
- Crack-like Flaws, including Stress Corrosion and Fatigue Crack Growth
- Laminations and Blisters, HIC and SOHIC
- Bulges and Out-of-Roundness in Vessels and Tanks
- Dents and Gouges in Vessels and Pipelines
- Fire Damage to Process Equipment and Structures
- High Temperature Creep and Local Hot Spots
- High Temperature Hydrogen Attack
- Heater Tube Remaining Life
- Thermal and Mechanical Fatigue
- Ring Joint Flange Cracking
- Tank Shell and Edge Settlement
- Brittle Fracture Assessments and Tank Hydrotest Exemption
- Local PWHT of Weld Repairs
- Modeling of Weld Residual Stresses
- Wind Induced Vibration of Towers, Stacks and Pipelines
- Mechanical Vibration
- Blast Loading and Other Dynamic Effects
- Hot Tap Thermal Analysis
- E²G's new Buckeye Sampler™ cuts samples in varying sizes for metallurgical and mechanical testing

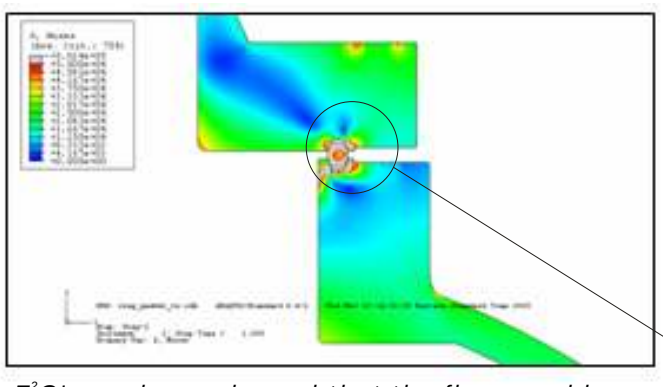
We had a safety audit raise some concern regarding our use of explosive charges to remove catalyst. E²G performed a fitness for service assessment and showed that the loads from these repeated detonations didn't affect the vessel's remaining life.

Inspector
Midwest Refinery

E²G FFS Assessments Improve Your Bottom Line

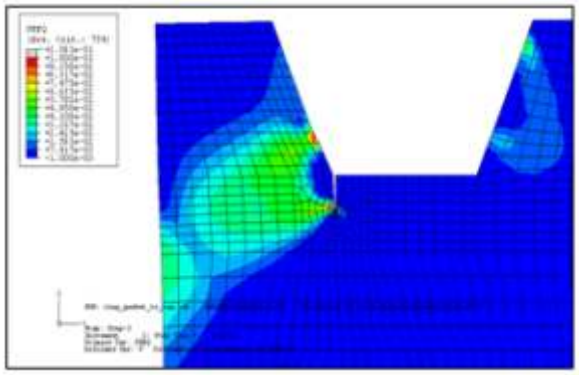
In the past three years, E²G's use of FFS technology has allowed our clients to save over $25MM in unnecessary repairs or replacement, avoidance of lost operating revenue and improved process conditions. These benefits go straight to your bottom line. For example, we've saved our clients by:

- Performing advanced nonlinear fracture mechanics analyses of Ring Joint Flanges to determine fitness for service with crack-like flaws in the ring joints. We have shown most of these flanges to require only a change in gasket arrangement and future monitoring.

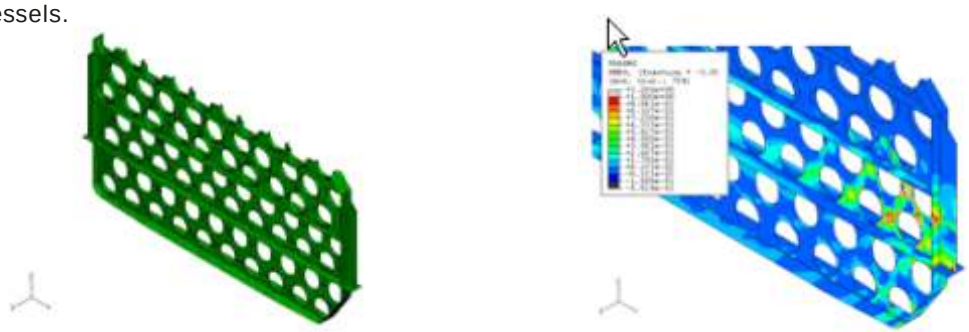


E²G's analyses showed that the flaw would not advance under continued operation. Costly repairs were avoided.

Finite Element Stress Analysis of RTJ Cracking. E²G used Non-linear Fracture Mechanics to evaluate a crack in the ring

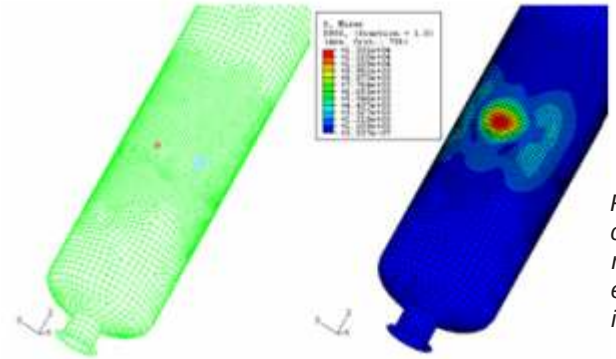


- Performing state-of-the-art creep damage calculations to determine the fitness for service of a variety of high temperature components including FCC vessels and piping, furnace tube sheets and tube hangers, and other process vessels.



Finite Element Stress Analysis Model of HK-40 Tube Sheet and Creep Damage Plot. Creep analyses performed by E²G used an MPC Omega model to determine stresses and creep damage (regions in gray exceed 100% Creep Damage for one set of future conditions). The plant was provided an operating temperaturetime envelope that allowed them to set operating conditions (feed rates) that would result in the desired length of run. The results also indicated areas to focus inspection and repairs at the next planned outage.

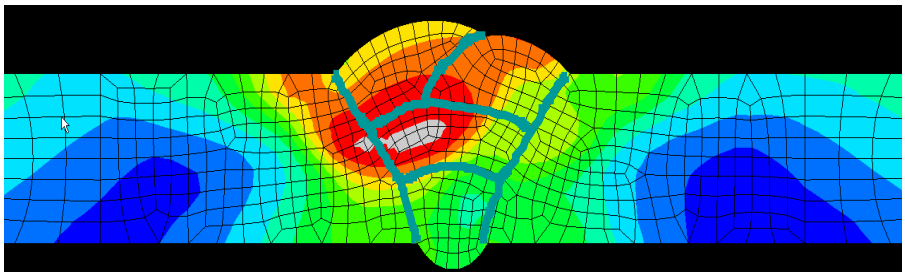
- Performing fitness for service analyses considering dynamic loads such as blast loads and determining vessel fitness or remaining life.



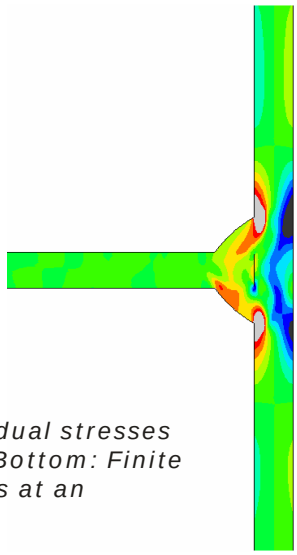
FFS Analysis of internal detonations used to remove catalyst from a vessel (detonation sources are shown in red and light blue on the mesh on the left). A fatigue evaluation satisfied safety personnel that the vessel's integrity was not compromised by repeated use of this

E²G's Residual Stress Modeling Improves Your Assessment

E²G utilizes state-of-the-art residual stress modeling using advanced finite element techniques. Our residual stress models can accurately model residual stresses from welding, as well as stresses resulting from local Post Weld Heat Treatment. The modeling can address:

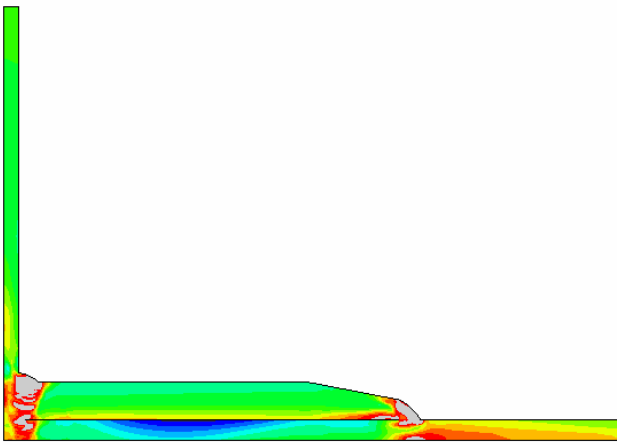


- Butt welds, fillet welds, nozzle attachment welds, repair welds and stiffener and plate attachment welds
- All types of materials
- A full range of welding parameters
- 2D and 3D welded geometry including weld intersections



Top: Finite element model of residual stresses in a butt weld with four passes. Bottom: Finite Element Model of residual stresses at an internal ring attachment.

The results of our residual stress modeling can provide more realistic residual stress values to improve assessments of crack-like flaws and can be used to optimize heat treatment procedures when performing a local Post Weld Heat Treatment.



Stress results from analysis of Local Post Weld Heat Treatment. Residual stress modeling was performed to optimize size, and location of heating bands and heat treatment procedure.

Why Owners Choose E^{2}G for FFS

Recognized Leader

The Equity Engineering Group, Inc. (E^{2}G) is internationally recognized in the refining and petrochemical industries as the leader on aging infrastructure services and support. Our company has pioneered the development of advanced Fitness-For-Service (FFS) technologies, and our engineers lead the way on the technical expertise required to implement them. E^{2}G's unique combination of world class mechanical engineering and metallurgical engineering FFS experts, supported by state-of-the-art tools, work together seamlessly to provide insight and solutions that no-one else can.

Technical Excellence

Our engineers were the principal developers of the landmark *Recommended Practice for Fitness-for-Service, API 579* and *Damage Mechanisms Affecting Fixed Equipment in the Refining Industry, API 571*. These documents form the basis for most FFS assessments performed in the U.S. as well as many other countries.

Sophisticated Servicing

E^{2}G's involvement in developing industry technology and standards enables us to give better service to our clients. Because we helped write the standards for FFS, we know the maximum extent each can be used to provide a safe answer. And we continue to put significant effort into future development.

Practical Experience

E^{2}G's engineers have all worked for owner-users, so we understand the changing dynamics of a plant's operating environment and the pressures you face. We know your concern is for safety, reliability and optimizing your plant's operating conditions for profitability and not needlessly inspecting, replacing or shutting it down. We also know that you need practical recommendations in a short time frame.

Focus on Your Profitability

Our unique blend of state-of-the-art analytical skills and significant owner-user experience allows us to give practical, cost-effective solutions to complex problems. Our goal is to help optimize your plant's equipment availability by making run-repair-replace decisions that ensure plant safety, improve performance and avoid unnecessary repairs or replacements.

R-Stamp

E^{2}G maintains a National Board R-Stamp to facilitate implementation of Repairs and Alterations that may result from a FFS Assessment.

We had modest thinning around nozzle-to-shell junctions on our hydrocracker vessels because of compromised nozzle liners over the years. E^{2}G performed an API 579 Level 3 analysis that showed the vessels were fit-for-service and costly repairs were not necessary. Their prompt analysis saved us about $1,000,000 off of our shutdown budget.

Maintenance Supervisor
North American Refinery

E^{2}G's FFS Assessments Maximize Your Equipment's Availability

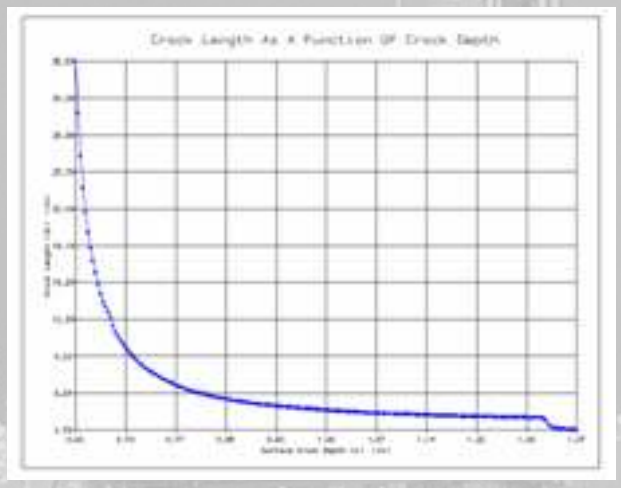
E^{2}G's assessments of fixed equipment can improve your plant's reliability, saving you time and money by:

- Providing practical and cost-sensitive solutions to challenging FFS problems
- Utilizing advanced FFS techniques to extend equipment life
- Evaluating changes in service that enhance equipment performance
- Designing effective temporary or permanent repairs
- Reducing shutdown time for repairs
- Providing quick turnaround in emergency situations

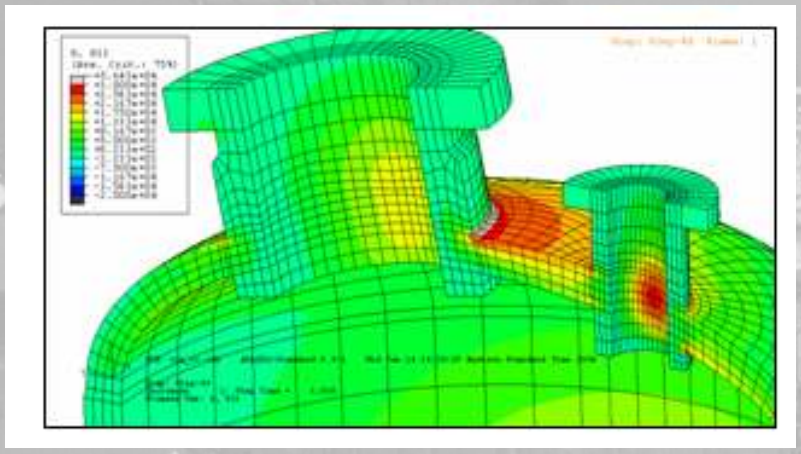
Equity Engineering is the recognized leader on aging infrastructure service and support for the oil refining and petrochemical industries. E²Gs experts help improve your plant's profitability by supplying state-of-the-art products and services that ensure equipment operational availability, control inspection costs, and avoid costly shutdowns.

E²G Tailors FFS Assessments to Your Problem

E²G specializes in providing the appropriate level of analysis required in solving problems, including the Level 3 assessments that no one else can tackle. We routinely use non-linear finite element analysis to conduct advanced mechanical integrity assessments (i.e., *API 579* Level 3 assessment) to accurately model equipment and process behavior. Our proprietary software *VCESage*™ performs *API 579* Level 1 and Level 2 assessments quickly and precisely.



Results of a Level 2 Critical Flaw Size Assessment of HDS Reactor Welds. The analysis was done using E²G's VCESage™ program.



Finite Element Model for a Level 3 FFS Assessment of a Mole Sieve. Critical Flaw Sizes were determined for areas around top and bottom nozzles. The client used E²G's results to established criteria for future inspection.

E²G can deliver FFS assessments on a normal schedule, on an emergency basis, or as part of an on-site Turnaround Problem Solving Team. We can provide FFS services on a conventional contract basis or though our *Virtual Central Engineering (VCE)*™ service. For companies without a large staff, *VCE* functions as a dedicated internal central engineering resource that draws on the vast experience of E²G's professional engineers and specialists.

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