Corrosion & Erosion

Inspection solutions for detection sizing & mapping

Find Corrosion Before Corrosion Finds You

Man-made structures, such as bridges, cars, ships, refineries, and aircraft, are all subject to environmental stresses. Light, temperature changes, water, and gases in the air all play a role in the breakdown of materials. The one major difference is just how quickly that breakdown occurs. A general term for the degradation of man-made structures is corrosion. Scientists try to understand the mechanisms by which corrosion occurs, design barriers to corrosion, find ways to monitor the progress of corrosion, and build processes for asset maintenance and systems to reduce the overall costs of corrosion to society.

Impact of Corrosion

The negative effects of corrosion and erosion cost the oil & gas, power generation and aerospace industries billions of dollars every year in unscheduled plant or pipeline shutdowns, inefficient or lost production, high maintenance repair costs or imposed fines. According to the WCO – The World Corrosion Organization - the estimated cost of corrosion to all the world's economies is $2.2 trillion USD annually. Experts believe that 20% to 25% of corrosion-related costs could be avoided. Corrosion and erosion detection, sizing and monitoring technologies are important elements toward realizing those savings.

Given the enormous costs associated with corrosion, it is not surprising that there are large industries centered on corrosion prevention (such as additives in water systems, coating materials like paint for automobiles, etc.), corrosion repair, as well as maintenance and corrosion monitoring, detection, and measurement.

This e-book focuses on corrosion monitoring, detection, and measurement as it pertains to rotating machinery, pipes, tubes, tanks and vessels fabricated from metals, with and without protective coatings.

Corrosion Inspection

Think of the industrial infrastructure of a turbine, plant, mill, refinery or manufacturing facility as a human body; the metal pipes and vessels are the circulatory system and organs, the turbine is the heart.

While turbines and rotating machinery create energy and force to move products, the pipes transport water, processed chemicals, and raw materials such as gas, crude oil and waste products. Vessels, like organs, accept the materials brought to them, and manage temperature and pressure to circulate materials (product and wastes) back into the system for distribution.

Engineers choose pipe, tube, tank and vessel materials that can withstand the elements that cause corrosion at the intended temperature, pressure, and product environment. While these pipes and vessels are still subject to corrosion, the degrees and types can vary.

Corrosion Inspection Technologies

Accurate and adequate inspections plays a crucial role in asset integrity. Due to constant innovation there are several nondestructive techniques available to detect corrosion indications.

Remote Visual Inspection is a cost-effective inspection technique used to capture real-time views and images from inside of tubes, pipes, rotating machinery, engines, heat exchangers, tray towers, refractory-lined vessels and enclosed structures.
RVI can be a perfect complementary technique to other NDT disciplines and is frequently used as the primary or initial inspection screening method to find localized corrosion and erosion. On-demand surface scanning and analysis with a 3D Point Cloud of pits, cracks and corrosion is possible.

Eddy current is a fast, accurate and cost-effective electro-magnetic method for detection of surface or near-surface flaws such as metal loss due to corrosion or erosion. It is commonly used for the inspection of heat exchanger tubing and piping, shell-side components such as support plates and rotating equipment such as turbine blades.

Digital radiography (DR) is a tool to detect corrosion under insulation and flow accelerated corrosion. It is fast (reduces inspection times by more than 95%) and does not require the insulation to be removed and replaced. Digital radiography also makes it easier to manage large volumes of inspection data using DICONDE-compliant digital reporting tools.

Corrosion Monitoring and Pit Detection Using Phased Array Ultrasound

Regularly scheduled inspections can validate corrosion rates and allow to better plan for maintenance situations. Ultrasound thickness (UT) readings may not provide enough precision by the collection of manual thickness readings to adequately determine wall thickness losses from corrosion. Pitting cannot be reliably detected by conventional UT methods simply because the size of the defect is small compared to the area inspected. **Phased array ultrasound** (PAUT) techniques can be used to approach the needed precision and get great coverage quickly.

Conclusion

The costs of corrosion can be staggering. With improved inspection technologies and maintenance schedules, equipment manufacturers and providers are helping organizations control costs and get a better handle on the health of their assets.

Types of corrosion

typically fall into three main categories:

Predictable

If a given material is passing through a given pipe, tube, tank, vessel or rotating machinery at a given set of temperatures and pressures, general corrosion is expected and predictable. Materials in this category are most often under a comprehensive maintenance and inspection program.

Unpredictable, but expected

Certain conditions may give rise to localized corrosion environments, such as:

Corrosion under insulation (CUI). In the process of transforming raw materials to products, temperature is often a major control requirement meaning that pipes or vessels are insulated. In many cases insulation can be damaged or degraded. It is not always easy to recognize the areas of concern, and it is costly to remove insulation, inspect for damage, and then reapply insulation.

Flow accelerated corrosion (FAC) has known locations of likelihood (a pipe elbow after a valve), but there is a low probability of knowing which elbows have had FAC. Again a quick reliable tool for elbows is needed.

Unpredictable

An example of unpredictable corrosion would be in the production of crude oil. If a well picks up significant sand or other abrasive material, it can cause very fast-acting corrosion.

Corrosion Inspection Applications

Technology Selection Guide

These are some typical examples of corrosion trouble spots in industrial process piping and vessels in the oil and gas, petrochemical, power generation and process industries. This guide helps you find the best technology to inspect for corrosion in these applications.

Air Fin-Fan Tube ID Condition

→ Remote Visual Inspection (RVI) / Eddy Current Testing (ET)

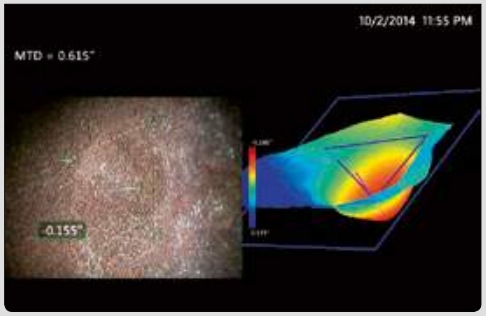
Air fin heat exchanger tube damage can cause significant operational problems

- Carbon steel tubes can be inspected by eddy current techniques
- RVI can be used to rapidly assess specific tube conditions for assistance in run-replace decisions
- Tubes can be accessed with minimum preparation for fast evaluation of tube condition

Boiler Tube Hydrogen Damage

→ Remote Visual Inspection (RVI) / Ultrasonic Testing (UT)

Localized corrosion damage in carbon steel can be confirmed using visual methods



- Hydrogen damage can be caused by condenser leakage; failures can lead to unit outages
- External UT/EMAT scanning can be used to identify suspected areas of wall loss
- RVI can rapidly find internal indications or confirm external inspections for exact location and severity of boiler tubes for ID damage

Bottom Mounted Instrumentation (BMI)

→ Remote Visual Inspection / Ultrasonic Testing (RVI/UT)

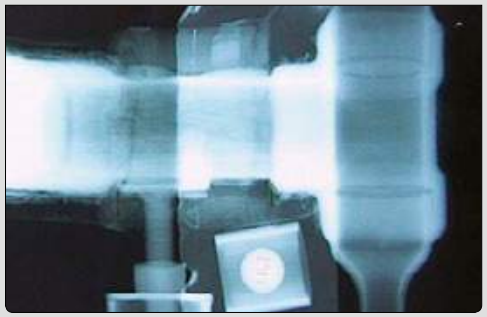
Bottom mounted instruments present a challenge for mechanical Integrity assessment

- Instrument penetrations have caused significant reliability concerns at nuclear plants
- Difficult access and need for detailed inspection data requires multi-modal approach for proper integrity assessment
- Combination of RVI, UT and eddy current techniques help assess BMI guide tubes to prioritize need for repair

Corrosion Under Insulation/ Fireproofing

→ *Radiographic Testing (RT)*

Industrial environments will promote significant corrosion of carbon steel piping components



- Insulation and fireproofing can accumulate moisture and cause accelerated corrosion
- Breaches of weather jacketing increases with age and mechanical damage
- Extensive stripping and abatement needed for visual testing and ultrasonic testing
- Digital X-ray can give general condition a specific thickness in recordable format for prioritization of additional inspection/ remediation can be scheduled

Creep of High-Pressure Steam Pipe

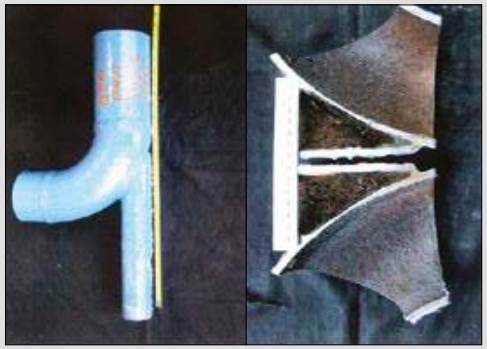
→ *Ultrasonic Phased Array (UT-PA)*

Elevated temperature damage can occur with increasing age and operation severity

- High-pressure steam pipe may be exposed to stresses above design and suffer high-temperature creep damage resulting in incidents with multiple fatalities and major consequences
- Field metallographic replication (FMR), and magnetic particle testing can only detect creep damage on the outer surface, not a volumetric assessment
- Phase Array can easily be field deployed to investigate volumetric creep damage in areas of concern in steam pipes

Dead-End Dead-Leg Corrosion

→ *Computed and Digital Radiography (CR & DR)*



Dead Ends/Dead Legs may suffer significantly higher corrosion rates than adjacent piping components

- Intentional and unintentional stagnant piping legs and connections may have signigicantly higher corrosion conditions than existing pipe components
- Piping TML's and spot UT may be misleading as to connection condition
- DR and CR images provide measurable, recordable, remotely accessible, high-quality documentation of condition
- Images can be archived in typical plant Data Management systems

Flow-Assisted Corrosion Utility Steam Pipe

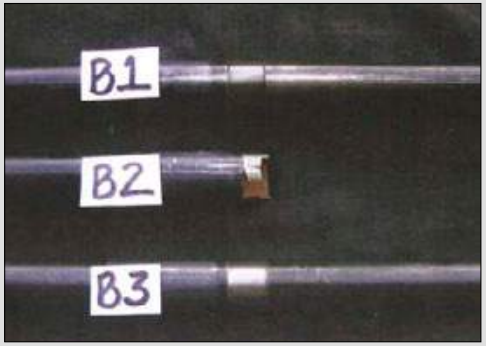
→ *Radiographic Testing (RT) / Remote Visual Inspection (RVI)*

Carbon steel piping has failed catastrophically from FAC

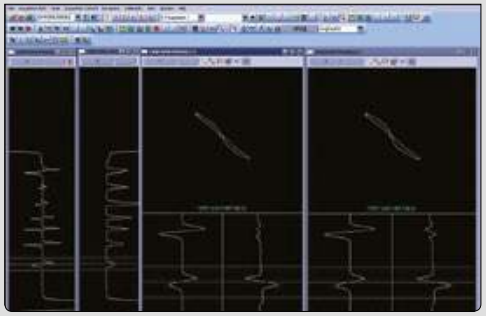
- Flow-assisted corrosion can occur in all piping that contains water and water/steam mixtures
- Single liquid phase or dual phase (wet steam) as shown below can cause severe local metal wastage
- Water treatment, design and metallurgy can help prevent for damage
- Digital radiography can be used for volumetric examination of specific suspect locations
- RVI gives visual of internal health before FAC causes failures

Heat Exchanger Damage

→ *Eddy Current Testing (ET) / Remote Visual Inspection (RVI)*



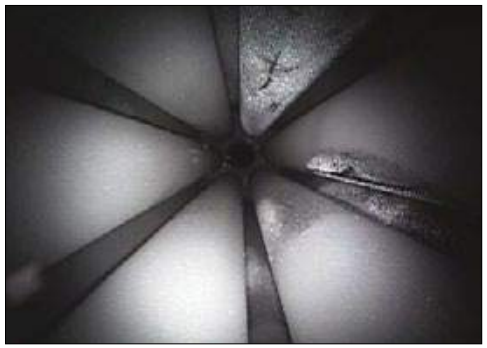
Heat exchanger tubing can suffer damage that can be precisely qualified by ET



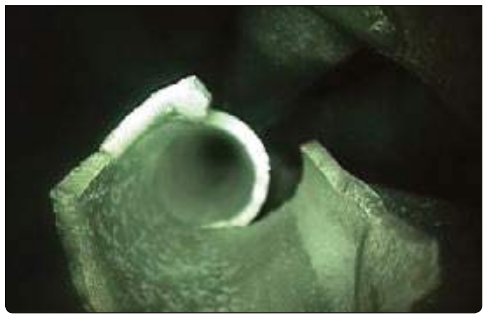
- Heat exchanger tube problems can cause unit outages and significant environmental impact
- Damage can occur suddenly (i.e. titanium tube support plate wear after 2 weeks of abnormal flow conditions) or longer term
- RVI can provide internal condition. Leak testing does not provide volumetric assessement and validated ET indications
- ET is preferred method of tube inspection for non-ferrous alloy tubing

Heat Exchanger Tubing Failures

→ *Remote Visual Inspection (RVI)*



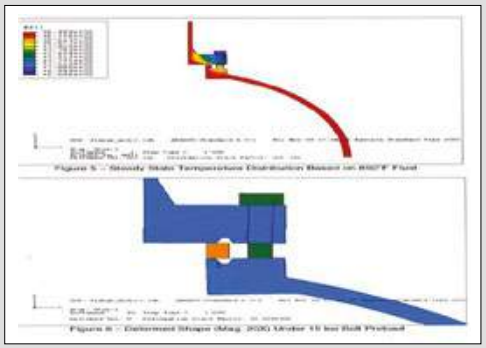
RVI with experienced personnel can provide rapid damage mode identification



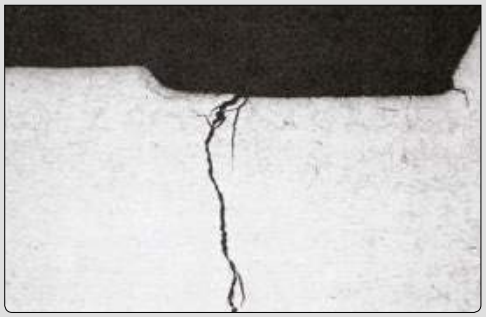
- Rapidly assess damage mechanism for expedited corrective actions
- Instant RVI diagnosis with our experienced technicians can produce data for immediate repair/plug/bring in additional NDT technique decisions
- Use of RVI with experienced plant personnel can greatly reduce outage duration
- Inspection provides recordable, indexed, high quality documentation for review

High-Pressure Piping Ring-Joint Cracking

→ *Remote Visual Inspection / Ultrasonic Testing (RVI/UT)*



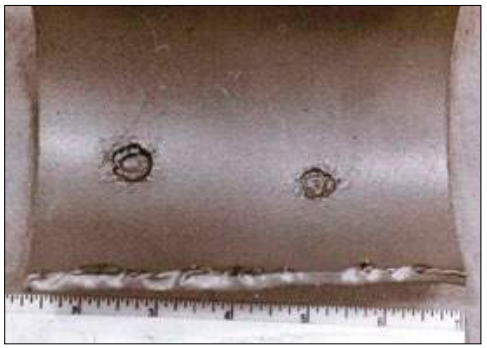
Ring Joint Cracking can be significant enough to necessitate replacement. PA –UT can be used to detect and size damage



- Ring Joint flanges can have significant cracking from mechanical and Stress Corrosion Cracking
- Typically discovered by PT or manual UT after flanges have been opened during turnaround. May extend unit downtime
- PA-UT significantly enhances detection and sizing of cracking damage while vessel is in service or just off line to allow for repair/replace planning

Service Water Piping Corrosion

→ *Remote Visual Inspection / Ultrasonic Testing (RVI/UT)*



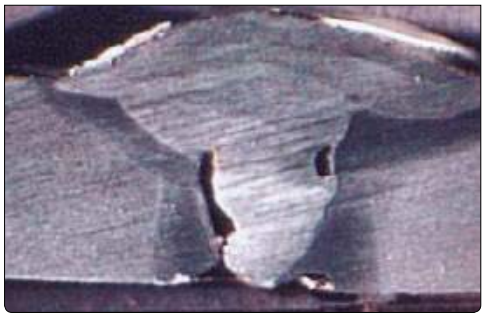
Microbiologically Influenced Corrosion (MIC) can be highly localized and cause significant penetration in a short period of time

- Extended downtimes and idle service water systems have promoted microbiological corrosion
- MIC can be highly localized and cause complete penetration in short time periods
- Use RVI, RT or both in complementary mode

Weld Heat-Affected-Zone Inspection

→ *Radiographic Testing (CR & DR)*

Weld defects can cause significant equipment inspection challenges

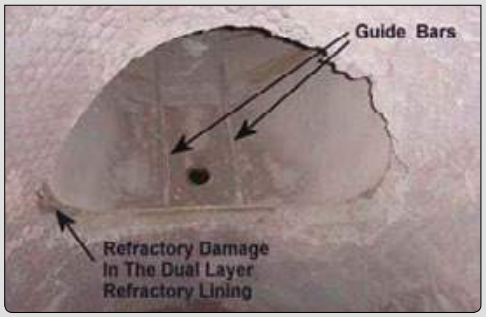


- Greatly enhance weld inspection and flaw sizing with digital radiography
- Digital radiography is both qualitative and quantitative
- Digital radiography produces fast scanning and can go through insulation

Refractory Vessel Damage

→ *Remote Visual Inspection (RVI)*

Refractory damage can be unexpected and lead to significant turnaround repair



- Many refractory lining conditions can not be evaluated by UT or RT
- Manual inspection requires staging, scaffolding and proper confined space entry precautions
- RVI can be used to obtain refractory condition assessment to prioritize internal inspection and repair execution to expedite turnaround resources

Tank Bottom Pitting

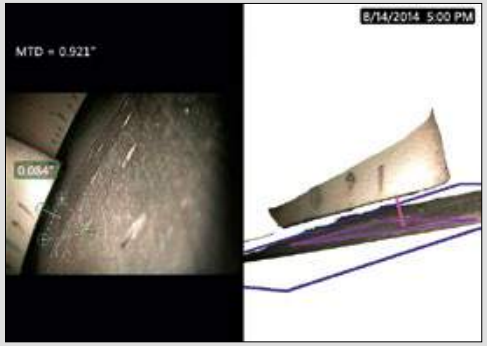
→ *Ultrasonic Testing (UT)*

Mentor UT can be used to accurately quantify the extent and severity of general wall loss detected in tank bottoms

- API 653 mandates periodic internal tank floor inspection with volumetric assessment
- Magnetic Flux scanners provide rapid general floor condition assessment
- Mentor UT can rapidly “prove-up” scanning results with greater detail than conventional UT

Compressor Blade Damage

→ *Remote Visual Inspection (RVI)*

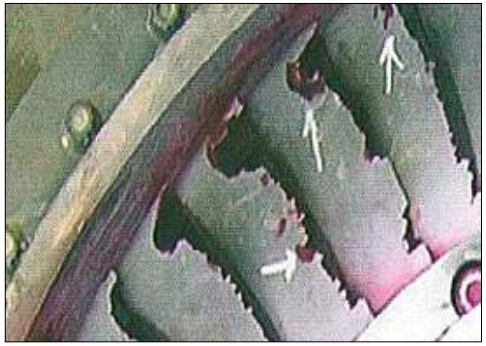


Tip damage (rubbing) can be identified by vibration analysis and monitored off line with RVI

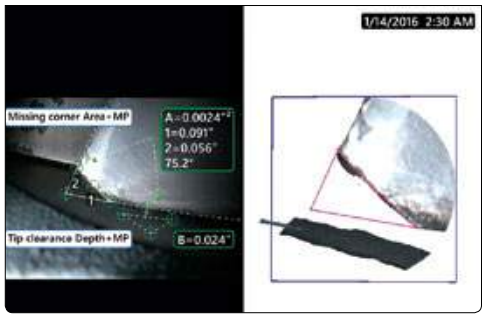
- Compressor blade rubbing and damage can lead to loss of efficiency and potential catastrophic failures
- Tip damage may be significant before serious vibration damage is noted
- RVI can allow rapid, recordable assessment of compressor blade condition for evaluation by experts in remote locations

Turbine Blade Erosion

→ *Remote Visual Inspection (RVI)*



Catalyst and solids can cause severe damage to rotating and stationary blades

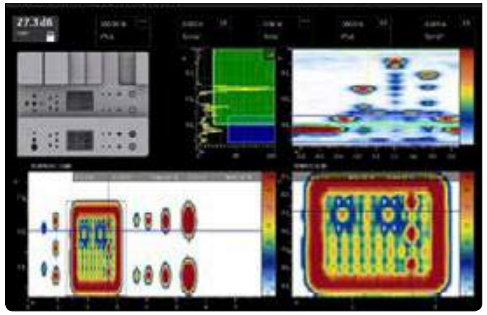


- Turbine blade erosion can lead to decreased performance and blade failure
- Pitting may occur on industrial turbines before vibration analysis can detect a problem
- RVI can rapidly assess internal health and equipment can be monitored for serviceability or scheduled for detailed preventative maintenance
- Area of blade loss can be quantified with 3D visual measurement
- On-demand 3D scanning & measurement analysis of indications allows quicker decisions

Corrosion Damage Sizing & Mapping

→ *Ultrasonic Testing (UT)*

Mentor UT has Dual Element Phased Array capability for accurate, rapid damage sizing

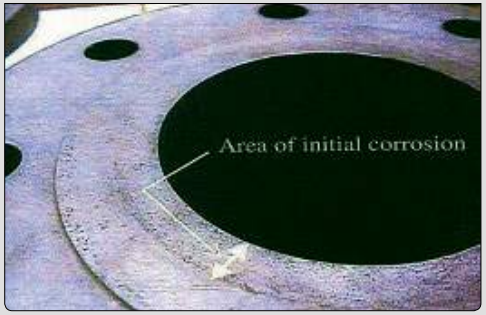


- Phased Array capability in readily portable equipment
- Assess damage extent and improve sizing from field personnel
- Improved inspection productivity in a sharable format
- Obtain better information for Risk Based Inspection (RBI) and Fitness For Service (FFS) Evaluations

HF Unit Flange Face Corrosion

→ *Ultrasonic Phased Array (UT-PA)*

Hydrofluoric (HF) scale and corrosion can significantly compromise flange integrity



- HF unit flange integrity must be assessed per API 751 (American Petroleum Institute)
- Manual flange disassembly, opening and inspection is nearly as costly as outright replacement
- UT-PA imaging can significantly enhance detection and sizing of flange face corrosion damage for replacement prioritization during turnaround
- Proven to be accurate and cost effective over conventional inspection methodologies

Nuclear Containment Building: IWE/IWL

→ *Remote Visual Inspection (RVI)*

Remote Visual Inspection provides recordable, indexed, high quality documentation

- 10CFR 50.55a requires inspection of the entire surface area of the containment building
- Containment liner and external extended surface must be inspected in accordance with ASME Section XI Subsections IWE and IWL
- Auto pan-tilt-zoom functions based on plant geometry & input grid for recordable, indexed, high quality documentation with 100% repeatability
- Capable of VT qualification with reduced personnel exposure and increased data integrity

Overview

GE's Inspection Technologies business, part of GE Oil & Gas, is a leading innovator for inspection solutions that deliver accuracy, productivity and safety to customers in a wide range of industries, including oil & gas, power generation, aerospace, transportation and government infrastructure.

Our advanced nondestructive testing and imaging technologies utilize electromagnetic, radiographic, ultrasonic or remote visual inspection to test and inspect a wide range of components. We have enormous depth and breadth of know-how which can be applied to your needs.

We offer a comprehensive selection of testing and inspection capabilities and other products for industrial applications. Our strength lies in the use of field experience and customer feedback to build the most productive inspection solutions in the industry. With the industry's broadest complement of nondestructive test methods, our customers can be confident they are getting the optimal solution to meet their needs.

INSPECTION DATA ➤ INFORMATION ➤ KNOWLEDGE ➤ DECISION

Our NDT technologies help you collect important data and convert it into useful information. Coupled with historical plant data, intelligent software, image enhancement, databasing, applicable codes and application knowledge, asset owners can make better-informed decisions regarding treatment, mitigation, remaining life, component replacement and plant operating parameters.

GE’s Corrosion Inspection Solutions

Remote Visual Inspection (RVI)

RVI is a cost-effective inspection technique used to capture real-time views and images from inside voids such as tubes, pipes, rotating machinery, engines, heat exchangers, tray towers, refractory-lined vessels and enclosed structures.

RVI can be a perfect complementary technique to other NDT disciplines and is frequently used as the primary or initial inspection screening method to find localized corrosion and erosion.

Video Borescopes

We offer an array of technologically advanced borescopes, from basic utility systems to the most capable video borescopes, all designed for portability and ease-of-use while delivering video images of unsurpassed quality. When remote Subject Matter Expertise is needed, real-time video inspection feeds are possible.

Mentor Visual iQ VideoProbe is our most advanced, portable, connected video borescope with 3D Point Cloud Measurement. With InspectionWorks Connect, inspectors can collaborate in real time, providing expertise anywhere in the world.

It is commonly used to diagnose operational problems with turbines, heat exchangers, small vessels and pressure pots, rotating equipment and Balance Of Plant assets.

Pan-Tilt-Zoom (PTZ) Cameras & FAST RVI Crawlers

GE has a full range of rugged industrial PTZ cameras for remote viewing in large areas. Three interchangeable zoom camera head diameters with high-intensity lighting, pan-and-tilt mechanisms and industrial waterproof packaging for protection from extreme environments.

PTZ cameras are submersible and are used to inspect the integrity of vessels, large piping, down-comers and refractory condition. Time, scaffolding and EHS confined space concerns are reduced or eliminated.

Ca-Zoom PTZ cameras may also be deployed on GE's robotic visual inspection crawler, the ideal solution to inspect tanks, vessels and pipes. FAST RVI allows the operator to access areas that could not be accessed by human, get more coverage, inspect behind baffles & obstacles.

On-site Remote Visual Inspection Service

Our staff of experienced remote imaging specialists, equipped with the latest remote visual inspection equipment, is available around the clock. We can assist during planned and unplanned outages, preventive maintenance, emergency services or with state or federal compliance issues. FOSAR, loose part and FOD retrievals, as well as piping an turbines clean-out are key specialties.

Ultrasonic Testing (UT)

Ultrasound is a fast and accurate inspection method to evaluate internal product integrity. Ultrasound penetrates deeply into materials searching for metal loss and material degradation associated with corrosion and erosion.

Ultrasonic Flaw Detectors

Conventional ultrasonic flaw detectors like **USM Go+** and **Krautkramer USM 36** are portable instruments with wide-spread acceptance. Corrosion measurement in the power generation and petrochemical industries can be carried out using dual element probes, where the screen displays both the thickness measurement and the A-scan, ensuring maximum reliability. A minimum capture mode provides the thinnest measured reading at the end of a continuous scan. An auto-freeze function, which minimizes the probe's surface contact time, is used for measuring structures and components with hot surfaces.

Phased array ultrasound (PAUT) technics can be used for applications where precision and great area coverage is needed.

Mentor Corrosion Toolkit

Mentor UT is a powerful, connected ultrasonic flaw detector optimized for corrosion and erosion mapping of process vessels and piping. Mentor UT combines outstanding UT performance with today's advances in software to create a new kind of inspection experience. Mentor UT brings the power of phased array inspection to everyday use with an intuitive, touch-screen interface and customizable inspection applications. Increase inspection productivity through guided, on-device setup and calibration. Use GE-provided on-device apps for corrosion inspection, or create your own using GE's desktop software, Mentor Create.

In connection to the Mentor UT instrument, the **DM Corrosion Probe** accurately detects corrosion and pitting. An X-Y Scanner provides encoded positional data.

The Guided Corrosion Inspection App allows multiple views of UT array inspection data for easy identification of wall loss.

Corrosion Thickness Gages

These useful and productive tools are designed to help improve safety and ensure reliability of equipment and materials subject to corrosion or erosion. Data can be imported and exported from these devices for mapping and trending. The **DMS Go+ Series** A-Scan corrosion thickness gauge is a simple, easy-to-use instrument for measuring remaining wall thickness of corroded tubes, pipes, tanks and vessels and stores/exports data for analysis.

Transducers

GE manufacturers a wide range of standard and custom ultrasonic testing transducers including conventional phased array for corrosion and erosion applications. Phased-array and dual-element transducers are optimized for performance at elevated temperatures and detection of isolated pitting.

Radiographic Testing (RT)

Radiography is one of the oldest, most reliable and proven nondestructive testing methods and offers unique benefits, such as revealing changes in thickness, internal and surface defects, large-area coverage and more. We offer conventional film radiography, digital technologies, including computed radiography and direct radiography, portable or stationary X-ray sources, 3D computed tomography and analytical X-ray.

Conventional and Computed Radiography

In the industrial environment of refineries and chemical plants, inspections have to be performed on a variety of difficult to reach locations, on pipes that might be isolated and where people are working around the clock. On-stream radiographic imaging is the most used technique to detect general internal erosion or corrosion of non-insulated piping and detection of internal and external corrosion under thermal insulation (CUI). This is where Computed Radiography (CR) comes in. Although the execution of CR is similar to conventional radiography, it has several important advantages: weaker Isotopes can be used for the exposure of the imaging plates and the digital readout of the wall thickness highly improves accuracy and reproducibility.

The **CRxFlex scanner**, in combination with GE's phosphor imaging plates, is a globally accepted, field-proved computed radiography scanning platform that delivers outstanding performance and image quality. CRxFlex offers DICONDE compliant image analysis, data management and image storage software with GE's powerful Rhythm software.

Direct Radiography

GE's **DXR250C-W / DXR250U-W** are portable, wireless and robust digital X-ray detectors for flexible, efficient field installation inspections. Ideal for places which offer difficult access and where utmost portability is needed. These detectors use the wireless and battery-operating technology that simplify handling and operation leading to overall productivity gain for its users.

Portable X-ray Generators

ERESCO MF4 industrial X-ray generators are designed for reliability in some of the world's toughest conditions. The user interface features graphic visualization and menu driven operation. The robust construction of the control and the tube heads make them suitable for operation in rugged environments. Low power consumption reduces energy cost and makes operation with portable power supplies easier.

Rhythm® Software

Rhythm can acquire image data from CR and DR sources or from film digitizers. This data can be displayed on the monitor of a standard PC. Rhythm offers standardized reporting capability in easy-to understand formats, with DICONDE-tagged images. This allows fast historical and meaningful comparison of reports from different inspectors.

Eddy Current Testing (ET)

Eddy current is a fast, accurate and cost-effective electro-magnetic NDT method for detection of surface or near-surface flaws such as metal loss due to corrosion or erosion. It is commonly used for the inspection of heat exchanger tubing and piping, shell-side components such as support plates and rotating equipment such as turbine blades.

Flaw Detectors

GE's **Mentor EM** is an eddy current NDT portable with easy access to on-device workflow applications that efficiently guide the inspector while capturing electromagnetic (eddy current) inspection data. Real-time collaboration with remote experts allows fast and accurate indication confirmation. The instrument offers superior signal-to-noise ratio for an incredibly clean and sharp signal, easy-to-read high-resolution display for visibility in tough conditions and downloadable on-device workflow applications for fast and consistent inspections.

Probes

Eddy current testing is different from other non-destructive testing method in one important respect: the equipment used, in particular the probes, is specific to the inspection task. Eddy current testing is therefore inherently flexible. In order to get the best results, it is vitally important to choose the optimum equipment for each task.

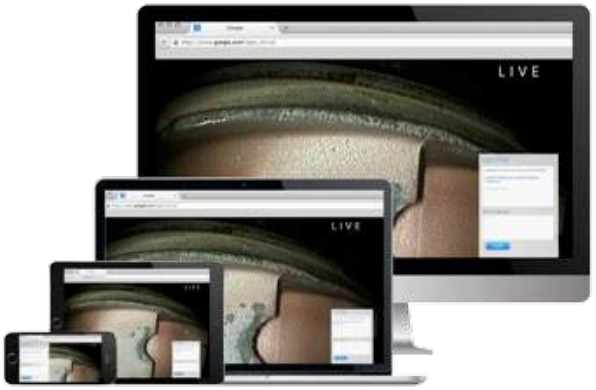
GE designs and manufacturers a complete line of eddy current tubing probes for many heat exchanger tube diameters and materials including ferrous and non-ferrous. Custom probes are also available. Detachable probe heads allow for quick change and re-use of the probe's push-pull cable. This unique design and construction increases field crew productivity, while lowering operating cost for heat exchanger inspection.

Area Coverage

Special eddy current array probe technology allows for wide-area scanning on metal surfaces of unusual or complex geometry. This technology increases coverage while improving probability of detection of complex geometries, such as turbine rotor dovetails.

Software Solutions

GE offers advanced and user-friendly software that improves productivity by making smarter and quicker decisions in the field and in the office. Our software covers all Nondestructive Testing (NDT) applications and methods, including software for data input, analysis, image review, reporting, data management, remote collaboration and storage.



InspectionWorks Connect

GE's **InspectionWorks Connect** platform provides real-time remote access to inspections from anywhere, to anywhere in the world. Experts can view a live inspection anywhere in the world through real-time video and advanced collaboration tools, enabling smarter decisions, faster. Expertise delivered where it's needed, when it's needed to keep assets running and maximize efficiency. The software is currently available for the XLG3 and Mentor Visual iQ remote visual inspection devices and the ultrasonic Mentor UT instrument.

Rhythm® - Remote Expert

Rhythm makes it easy for experts to share images and information simply and quickly via removable media, LAN connections, or on the web.

Rhythm® - Data Management

Manage all your NDT inspection data in one platform. Rhythm makes querying and retrieving previous inspection data as simple as a few clicks. All data is stored in DICONDE, an industry standard, reducing any risk of data or information loss over time. Rhythm can tie directly to your ERP system.

Mentor Create

The **Mentor Create App Development kit**, available for free, allows experts to create custom corrosion inspection apps for Mentor connected inspection products. Embed media and inspection procedures, lock settings and preset inspection parameters to speed inspections and improve consistency.

Imagination at work

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