NDT SCOOP

INSPECTION MAGAZINE

by NDT CORNER

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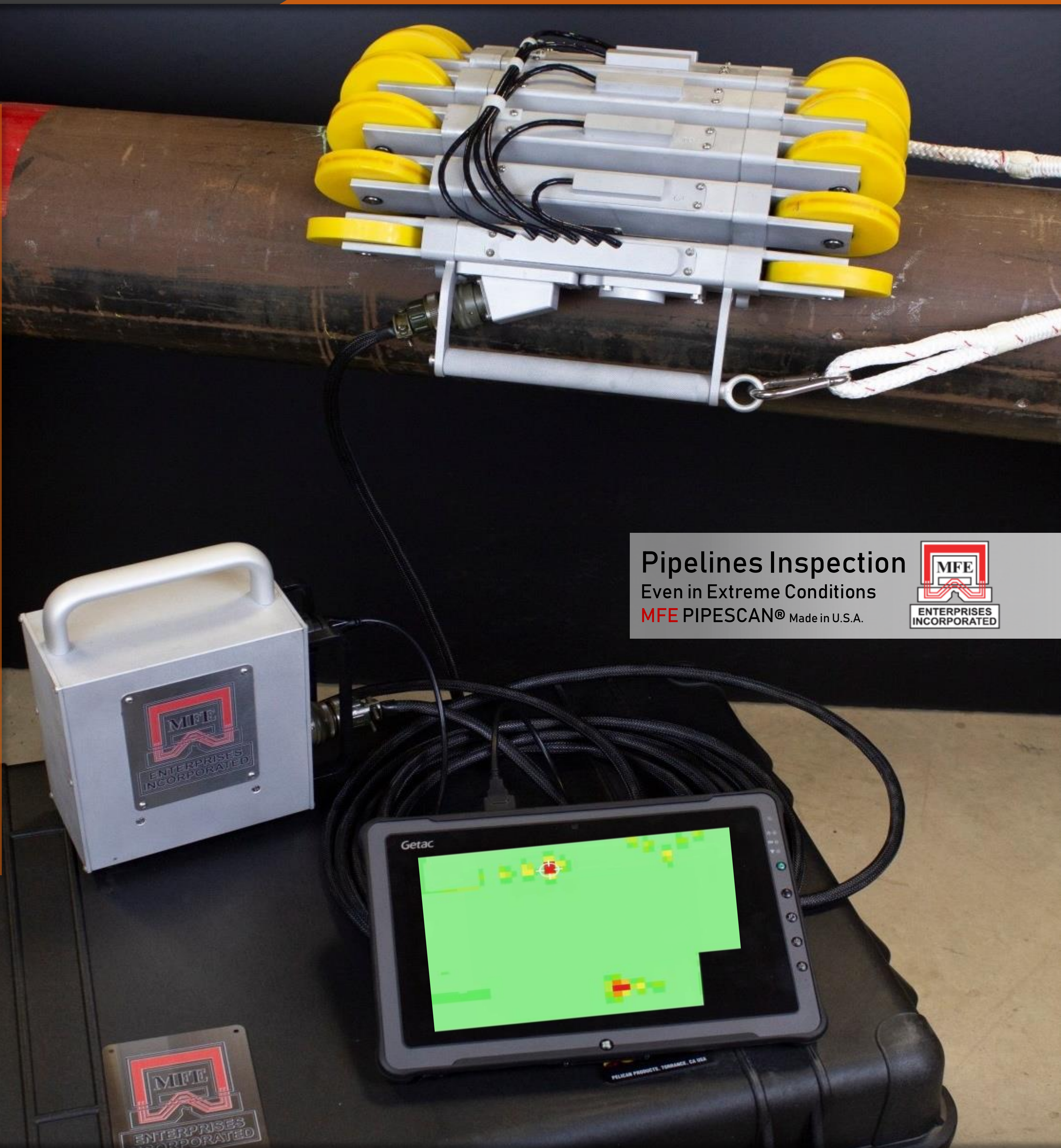

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ON THE COVER

MFE Enterprises manufactures Non-Destructive Testing (NDT) and Magnetic Flux Leakage (MFL) inspection equipment for both storage tank and pipeline applications. Our mission has never changed: We provide educational information to the NDT community about MFL technology and the advantages of deploying our MFL Scanners for FAST and ACCURATE inspection of your plant assets. mfeenterprises.com

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Eddy Current Testing (ECT)

What is Eddy Current Testing?

Eddy current testing is a non-destructive testing (NDT) inspection method used for a variety of purposes, including for flaw detection, material and coating thickness measurements, material identification and establishing the heat treatment condition of certain materials.

Eddy current testing is one of several non-destructive testing methods that uses the electromagnetism principle for flaw detection in conductive materials. A specially designed coil energized with an alternating-current is placed in proximity to the test surface, generating a changing magnetic field that interacts with the test-part and produces eddy currents in the vicinity.

Variations in the changing phases and magnitude of these eddy currents are then monitored using a receiver-coil or by measuring changes to the alternate current flowing in the primary excitation-coil.

The electrical conductivity variations, the magnetic permeability of the test-part, or the presence of any discontinuities, will cause a change in the eddy current and a corresponding change in phases and amplitude of the measured current. The changes are shown on a screen and are interpreted to identify defects.

Standards and Calibration

All the systems must be calibrated using appropriate reference standards – as for any NDT method and is an essential part of any eddy current testing procedure. The calibration blocks must be of the same material, heat treatment condition, shape and size of the item to be tested.

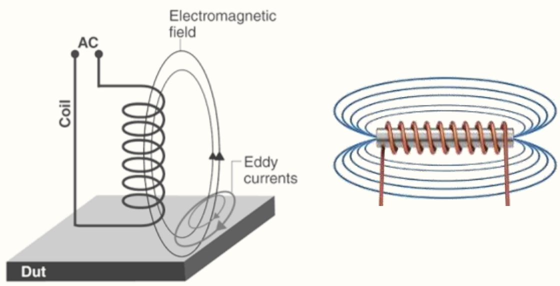
For defect detection, the calibration block contains artificial defects that simulate defects, whereas, for corrosion detection, the calibration block has different thicknesses. The eddy current method requires a highly skilled operator - training is essential.

Common eddy current reference standards include:

- ► Conductivity standards.
- ► Flat plate discontinuity standards.
- ► Flat plate metal thinning standards. (Step or tapered wedges)
- ► Tube discontinuity standards.
- ► Tube metal thinning standards.
- ► Hole (with and without fastener) discontinuity standards.

How Does Eddy Current Testing Work?

The process relies upon a material characteristic known as electromagnetic induction. When an alternating current is passed through a conductor – a copper coil for example – an alternating magnetic field is developed around the coil and the field expands and contracts as the alternating current rises and falls. If the coil is then brought close to another electrical conductor, the fluctuating magnetic field surrounding the coil permeates the material and, by Lenz's Law, induces an eddy current to flow in the conductor. This eddy current, in turn, develops its own magnetic field. This 'secondary' magnetic field opposes the 'primary' magnetic field and thus affects the current and voltage flowing in the coil.



Any changes in the conductivity of the material being examined, such as near-surface defects or differences in thickness, will affect the magnitude of the eddy current. This change is detected using either the primary coil or the secondary detector coil, forming the basis of the eddy current testing inspection technique.

Permeability is the ease in which a material can be magnetized. The greater the permeability the smaller the depth of penetration. Non-magnetic metals such as austenitic stainless steels, aluminum and copper have very low permeability, whereas ferritic steels have a magnetic permeability several hundred times greater.

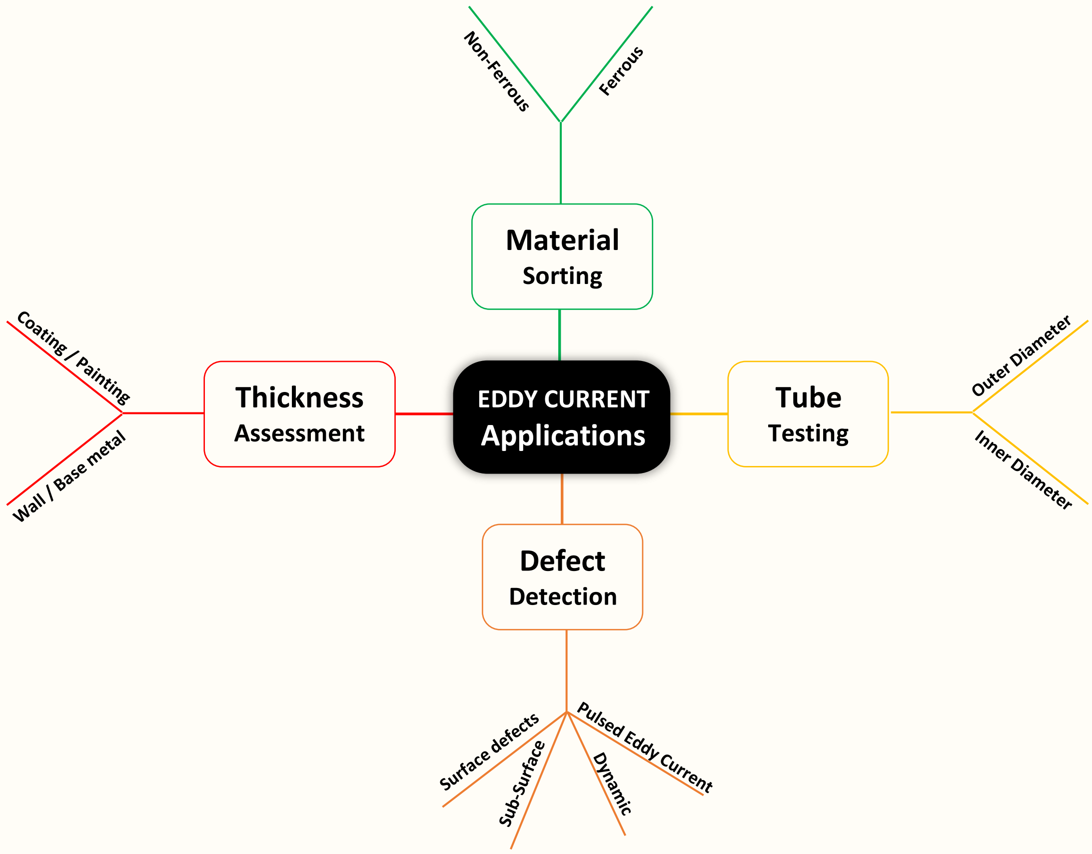
Eddy current density is higher, and defect sensitivity is greatest, at the surface and this decreases with depth. The rate of the decrease depends on the "conductivity" and "permeability" of the metal. The conductivity of the material affects the depth of penetration. There is a greater flow of eddy current at the surface in high conductivity metals and a decrease in penetration in metals such as copper and aluminum.

The depth of penetration may be varied by changing the frequency of the alternation current – the lower the frequency, the greater depth of penetration. Therefore, high frequencies can be used to detect near-surface defects and low-frequencies to detect deeper defects. Unfortunately, as the frequency is decreased to give greater penetration, the defect detection sensitivity is also reduced. There is therefore, for each test, an optimum frequency to give the required depth of penetration and sensitivity.

Continue Eddy Current Testing

ECT Applications

Inspection of parts or components including: Welded joints - Bores of in-service tubes - Bores of bolt holes - Metal tubes - Friction stir welds - Gas turbine blades - Nozzle welds in nuclear reactors – Cast Iron Bridge – Lack of fusion - Identification of both ferrous and non-ferrous metals and with certain alloys in particular the aluminum alloys - Establishing the heat treatment condition - Determining whether a coating is non-conductive - Heat treat verification of metals - Generalized corrosion (particularly in the aircraft industry for the examination of aircraft skin and more.



Eddy Current Advantages

► Able to detect surface and near-surface cracks as small as 0.5mm

► Able to detect defects through several layers, including non-conductive surface coatings, without interference from planar defects

► Non-contact method making it possible to inspect high-temperature surfaces and underwater surfaces

► Effective on test objects with physically complex geometries

► Provides immediate feedback

► Portable and light equipment

► Quick preparation time – surfaces require little pre-cleaning and couplant is not required

► Able to the measure electrical conductivity of test objects

► Can be automated for inspecting uniform parts such as wheels, boiler tubes, or aero-engine disks.

Eddy Current Limitations

► Can only be used on conductive materials.

► The depth of penetration is variable.

► Very susceptible to magnetic permeability changes – making testing of welds in ferromagnetic materials difficult – but with modern digital flaw detectors and probe design, not impossible.

► Unable to detect defects that are parallel to the test object's surface.

► Careful signal interpretation is required to differentiate between relevant and non-relevant indication.

Continue Eddy Current Testing

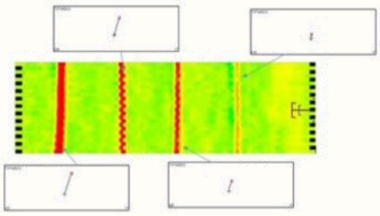
What is Eddy Current ARRAY?

Eddy current array and conventional eddy current technology share the same basic principle. Alternating current injected into a coil creates a magnetic field (in blue). When the coil is placed over a conductive part, opposed alternating currents (eddy currents, in red) are generated. Defects in the part disturb the path of the eddy currents (in yellow). This disturbance can be measured by the coil.

Eddy current array (ECA) is an assembly of single eddy current sensors or coils that are multiplexed in a certain order to obtain the required sensitivity. There are many different designs of eddy current probes, including flexible probes, padded probes or spring-loaded fingers.

Eddy current array (ECA) technology provides the ability to electronically drive multiple eddy current coils placed side by side in the same probe assembly. Data acquisition is performed by multiplexing the eddy current coils in a special pattern to avoid mutual inductance between the individual coils.

Most conventional eddy current flaw detection techniques can be reproduced with an ECA inspection. With the benefits of single-pass coverage, and enhanced imaging capabilities, ECA technology provides a remarkably powerful tool and significant time savings during inspections.



Advantages of Eddy Current Array

► Reduction in inspection time, as: The coils in the probe have been specifically arranged to cover a particular area the scanning speed can be adjusted A wider range of samples of can be inspected due to a wider range of probe types that are available

► Multi-frequency approach – possible to inspect a test object with several central frequencies simultaneously – allowing the user to assess the most optimized central frequency for the inspection

► Post analysis of results – the equipment's built-in software enables the use of filters and other process to highlight or hide certain features

Limitations of Eddy Current Array

► Eddy current array inspections use advanced equipment that requires additional operator training.

► Longer set-up time than a conventional eddy current inspection.

Industries That Benefit from Eddy Current

Aviation and Aerospace

Eddy current technology is commonly used for crack and corrosion detection, and conductivity testing in the aviation and aerospace industries. Eddy current equipment is highly sensitive when detecting surface and subsurface cracks and corrosion, which is important in these industries where the smallest defects could cause costly or even catastrophic failures. Conductivity testing can be used to identify and sort ferrous and nonferrous alloys, and to verify heat treatment. Eddy current devices are used to inspect wheels, struts, propellers, airframes, hubs, engine components, and other key parts.

Oil and Gas

Eddy current equipment is used for crack detection in welds throughout the oil and gas industry. Nondestructive testing is critical for both the integrity of equipment and the safety of petroleum refining and extraction operations. Detecting cracks in welds in metal pipelines is critical in the oil and gas industry.

Shipbuilding

Eddy current equipment is used for crack detection in welds in the shipbuilding industry. Weld inspection is important in shipbuilding because, if the welds fail, often the structure will fail, and this leads to costly repairs and potential health and safety risks. The most critical flaws are cracks, lack of fusion or penetration, and undercut; it is these flaws that most quality codes and standards in shipbuilding are designed to avoid. Eddy current technology is highly sensitive to surface and subsurface cracks in welds, which helps manufacturers ensure high-quality welds and respond to any damage quickly.

Automotive

Eddy current equipment is used for inspecting components for defects and carrying out hardness and heat-treatment testing in the automotive industry. Eddy current inspection systems can be automated and added to the manufacturing process. A machine picks up a part or component, moves it into the test position, brings the test coil down on the part or lifts the part onto the coil, and sends the signal to the instrument. Automated eddy current inspections are fast, clean, and keep the line moving. Identifying defects in the automotive industry is essential for ensuring quality control and meeting health and safety guidelines.

Power Generation and Chemical Refinery

Eddy current equipment is used for tube testing and weld inspection in the power generation and chemical refinery industries. These industries require precise and reliable technology to inspect critical assets and ensure safe, cost-effective operations. Eddy current equipment enables remote inspection of areas unsafe for humans to operate because of hostile and dangerous conditions. Uses for eddy current equipment in the power generation and chemical refinery industries include the inspection of turbines, primary and secondary pipes, welds and vessel components, heat exchangers, reactor vessels, nuclear fuel pools, and more. Eddy current technology provides reliable and accurate condition inspection. Unidentified defects can be catastrophic in an industry that operates with dangerous chemicals and machinery.

Continue Eddy Current Testing

ECT Testing of Chiller Tubes

Eddy current testing is a nondestructive testing method commonly used to inspect tubing in heat exchangers, condensers, air coolers, and other appliances. Eddy current testing is a high-speed method that can be performed to inspect through painting and coatings and is used to assess the condition and lifespan of tubes. Tubes can become damaged over time through corrosion, pitting, cracks, erosion, and other changes. Detecting these flaws is a vital process to help keep appliances working reliably and to meet certain quality and health and safety standards. Different tubes are subject to different stresses, meaning their inspection often requires different equipment and processes. In this article, we will discuss what eddy current equipment you need for inspecting chiller and heat exchanger tubes to save repair costs and ensure quality standards are met.

Eddy Current Testing of Chiller Tubes

Chiller tubes undergo daily stress, which can lead to rust and corrosion. This rust can also infiltrate the evaporator tubes of the chillers, potentially leading to further damage to the compressor and preventing the water from chilling effectively. Common defects to look out for include:

- Pitting.
- Freeze ruptures.
- External corrosion.
- Internal pitting.

Left untreated, these flaws can lead to costly repairs. This is why regular nondestructive testing is used to help detect these malformations early.

Chiller Tube Inspection Equipment

Using eddy current testing equipment on chiller tubes is a proven and effective flaw detection method. Any irregularities will disrupt the eddy current flow generated by the probe, signaling to the user that there may be a flaw in the test material. The ideal equipment for chiller tube inspection includes a testing instrument that enables simultaneous injections and multiplexed frequencies. These two features result in:

- Improved efficiency
- Increased inspection speed
- Remote field testing (RFT)

The multitiered frequency is used to detect a range of flaws, from surface cracks to irregularities deep below the surface. You should look for chiller tube inspection equipment that can be used to inspect most tubing materials, including carbon steel or magnetic alloys. Using cutting-edge technology can help inspectors detect these flaws when they're beginning to develop, eliminating costly overhead costs further down the line. This makes investing in effective instrumentation important when inspecting chiller tubes.

Eddy current testing is an efficient choice for the inspection of chiller tubes.

ECT Testing of Heat Exchanger Tubes

Eddy current testing equipment is also a reliable and highly effective method for measuring wall thickness and cracks in heat exchanger tubes. Like chiller tubes, inspection of heat exchanger tubes requires quality instrumentation to accurately identify defects at an early stage. High-fluid pressure causes expansions and contractions in heat exchanger tubes, making them more susceptible to surface and subsurface defects.

Heat Exchanger Tube Inspection Equipment

Users have two primary choices when it comes to eddy current equipment for heat exchanger tube inspection. A testing instrument combining multiplex and simultaneous injection will lead to faster inspection times and more accurate data, these are used solely for heat exchanger testing. Another option would be a tubing/surface instrument, which can be used for heat exchange inspection along with other applications.

Multiplex eddy current equipment enables you to test all the different tube types, which is ideal for users who want to use their instrument for a diverse range of applications. These devices can be used for detecting abnormalities, such as cracking, putting, and cuts. They can also be used for remote field testing (RFT), enabling users to obtain accurate data in any testing radius. Using a device with multiplex technology, users can take advantage of:

- Enhanced detection probability for surface and subsurface flaws
- SI technology that increases inspection time, enables RFT, and supports multiple coil frequencies.

A final option for users looking to use eddy current technology to inspect heat exchanger tubes is remote acquisition units with tubing and surface array configurations. This enables the detection of surface and subsurface indications using surface array.

The best eddy current testing equipment for heat exchanger tubes should possess the following features:

- Superior detection quality
- Lightweight portability
- Automated analysis software
- Fast inspection speed

The software is one of the most important aspects when it comes to choosing to eddy current testing equipment for tubes. Your software should be able to provide fast analysis results and reporting as data is acquired, as well as being capable of distinguishing between circumferential and axial indicators. Quality should be a serious consideration when investing in eddy current technology for heat exchanger tube testing. Inferior equipment can lead to missed flaws, operational failures, and inflated repair costs.

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- Holiday Testing Coating inspection covering all aspects of surface finishing.
- Corrosion under Insulation Detection using PEC.
- Expert Pipeline Inspection: welding inspections of pipeline construction using X-Ray and Automated Ultrasonic Testing (AUT).
- Rope Access for working-at-height solutions for NDT inspection, asset integrity services and basic maintenance. A safer, faster and more efficient alternative to scaffolding or cranes.

Traditional and Advanced NDT Methods

- **UAIS- uses a large range of both traditional and advanced NDT tech-**

- Advanced NDT Techniques:
   - Phased Array Ultrasonic Time of Flight Diffraction (TOFD)
   - Automated and Remote Ultrasonic Testing
   - Magnetic Flux Leakage
   - IRIS (Internal Rotational Inspection System)Testing
   - Computerized Radiography
   - Alternative Current Field Measurement (ACFM)
   - Guided Wave Ultrasonic
   - Acoustic Pulse Reflectometry
   - Rapid Gear Scan

- Traditional NDT Techniques:
   - Radiography
   - Ultrasonic
   - Visual Inspection
   - Magnetic Particle
   - Penetrant Testing
   - Eddy Current Testing
   - Painting and coating Inspection

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Guidelines on Codes & Standards

Offshore Asset Management

A Comprehensive Guide to Standards on Asset Management and Sensors for Monitoring Offshore Facilities.

It is important that asset management is conducted in accordance with the industry standards and specifications. There are multiple standards that include harmonized international standards that are appropriate for these applications. Also, each operation requires software application based on industry standards, hence the operator must select a particular set of recognized standards. **Table 1** gives a list of some standards bodies while **Table 2** lists some standards that are related to asset management, integrity, and reliability and monitoring.

Table 1. **List of some standards bodies and certification agencies**

Different National/International Standards Bodies and Certification Agencies	
International Organization of Standardization (ISO)	Det Norske Veritas & Germaine Lloyds (DNV GL)
International Electro technical Commission (IEC)	International Civil Aviation Organization (ICAO)
Institute of Electrical and Electronics Engineers (IEEE)	American Society for Testing and Materials (ASTM)
Standards Organization of Nigeria (SON)	Bureau of Indian Standards (BIS)
International Maritime Organization (IMO)	American Petroleum Institute (API)
Bureau Veritas (BV)	British Standards Institution (BSI)
European Standard (EN)	National Fire Protection Association, (NFPA)
American Society of Mechanical Engineers (ASME)	American National Standards Institute (ANSI)
International Association of Marine Aids to Navigation and Lighthouse Authorities (IALA)	Industry standards for the Norwegian continental shelf (NORSOK)
Standards Council of Canada (SCC)	Danish Standards Association (DSA)
Lloyds Registers	Standards Norway (NORSOK)
American Bureau of Shipping (ABS)	Bureau of Safety and Environmental Enforcement (BSEE)

Continue Guide to Standards on Asset Management and Sensors for Monitoring Offshore Facilities.

Table 2. Standards related to asset management, integrity, reliability and monitoring

Standard's Reference	Title of Standard
BS ISO 55001:2014; ISO 55001:2014	Asset management—Management systems—Requirements
BS ISO 55002:2018; ISO 55002:2018	Asset management—Management systems—Guidelines for the application of ISO 55001
ASTM E2675-22	Standard Practice for Asset Management System Outcomes
ASTM E2812-17	Standard practice for uniform data management in asset management records systems
ASTM E3257-21	Standard practice for asset taxonomy.
ASTM E3035-15(2020)	Standard classification for facility asset component tracking system (FACTS).
PD IEC/TR 62978:2017	HVDC installations. Guidelines on asset management.
BS ISO 15686-6:2004	Buildings and constructed assets. Service life planning. Procedures for considering environmental impacts
BS 8536-2:2016	Briefing for design and construction. Code of practice for asset management (Linear and geographical infrastructure)
ASTM E2983-14(2019)	Standard guide for application of acoustic emission for structural health monitoring.
BS IEC/IEEE 80005-2:2016	Utility connections in port. High and low voltage shore connection systems. Data communication for monitoring and control
ASTM F3079-14(2020)	Standard practice for use of distributed optical fiber sensing systems for monitoring the impact of ground movements during tunnel and utility construction on existing underground utilities.
BS EN 13160-6:2016	Leak detection systems. Sensors in monitoring wells
BS EN ISO 17643:2015	Non-destructive testing of welds—Eddy current testing of welds by complex plane analysis.
ISO 15548-1	Non-destructive testing—Equipment for eddy current examination—Instrument characteristics and verification
ISO 15548-2	Non-destructive testing –Equipment for eddy current examination –Part 2: Probe characteristics and verification
BS EN 1711:2000	Non-destructive examination of welds. Eddy current examination of welds by complex plane analysis
ISO 15549:2008	Non-destructive testing—Eddy current testing—General principles
ISO 15548-3:2008	Non-destructive testing—Equipment for eddy current examination—Part 3: System characteristics and verification
ISO 19902	Petroleum and natural gas industries—Fixed steel offshore structures
ISO 16587:2004	Mechanical vibration and shock. Performance parameters for condition monitoring of structures.
BS EN ISO 18797-2:2021	Petroleum, petrochemical, and natural gas industries. External corrosion protection of risers by coatings and linings. Maintenance and field repair coatings for riser pipes
API RP 2SIM:2014	Structural integrity management of fixed offshore structures—recommended practice.
API RP 17N	Subsea production system reliability and technical risk management and integrity management
API RP 14J	Recommended Practice for Design and Hazards Analysis for Offshore Production Facilities

Continue Guide to Standards on Asset Management and Sensors for Monitoring Offshore Facilities.

API RP 75	Recommended Practice for Development of a Safety and Environmental Management Program for Outer Continental Shelf (OCS) Operations and Facilities
API RP 581: 2016	Risk-Based Inspection Methodology
API RP 580: 2016	Risk-Based Inspection
API RP 574: 2016	Inspection Practices for Piping System Components
API RP 575: 2020	Inspection Practices for Atmospheric and Low Pressure Storage Tanks
API RP 754: 2021	Process Safety Performance Indicators for the Refining and Petrochemical Industries
API 570: 2016	Piping Inspection Code: In-service Inspection, Rating, Repair, and Alteration of Piping Systems
API 510	Pressure Vessel Inspection Code: Maintenance Inspection, Rating, Repair, and Alteration
API Standard 598	Valve Inspection and Testing
API RP 578	Material Verification Program for New and Existing Piping Systems
API RP 577	Welding Inspection and Metallurgy
API RP 576	Inspection of Pressure-relieving Devices
API RP 574	Inspection Practices for Piping System Components
API RP 583	Corrosion Under Insulation
API RP 584	Integrity Operating Windows
ASME CA-1:2020	Conformity assessment requirements
ASME PCC-1	Guidelines for Pressure Boundary Bolted Flange Joint Assembly
ASME PCC-2	Repair of Pressure Equipment and Piping
ISO 20815	Production assurance and reliability management
ISO 6385:2004	Ergonomic principles in the design of work systems
ISO Guide 73: 2009. ISO 31073:2022	Risk Management—Vocabulary.
ISO 31000:2018	Risk management—Guidelines
ISO 31000:2009	Risk Management—Principles and guidelines
IEC 31010; ISO 31010:2019	Risk Management—Risk Assessment Techniques
ISO-22316:2017	Security and resilience—Organizational resilience—Principles and attributes
ISO 2394:2015	General Principles on Reliability for Structures
ISO 17776:2016	Petroleum and natural gas industries—Offshore production installations—Major accident hazard management during the design of new installations
ISO 19900	Petroleum and natural gas industries—General requirements for offshore structures
ISO/TR 31004:2013	Risk management—Guidance for the implementation of ISO 31000
NORSOK N-006:2015	Assessment of structural integrity for existing offshore load-bearing structures
NORSOK Z-013: 2010	Risk and emergency preparedness assessment
NORSOK N-005:2017	Condition monitoring of load bearing structures
NORSOK S-001	Technical safety
NORSOK S-002	Working environment
NORSOK N-004:2004	Design of steel structures
NORSOK Y-002:2010	Life Extension for Transportation Systems
ISO 19011	Guidelines for auditing management systems
ISO 9000	Quality management systems—Fundamentals and vocabulary
ISO 9001	Quality management systems—Requirements
ISO 14001	Environmental management systems
ISO 55000:2014	Asset management—What to do and why?

Continue Guide to Standards on Asset Management and Sensors for Monitoring Offshore Facilities.

ISO 55000:2016	Asset management—Overview, principles, and terminology
ISO 14224:2016	Petroleum, petrochemical and natural gas industries—Collection and exchange of reliability and maintenance data for equipment
ISO/TS 12747:2011	Recommended Practice for Pipeline Life Extension
NACE RP 0472	Methods and Controls to Prevent In-Service Environmental Cracking of Carbon Steel Weldments in Corrosive Petroleum Refining Environments
NACE MR 0103	Materials Resistant to Sulfide Stress Cracking in Corrosive Petroleum Refining Environments
NACE SP 0102	In-Line Inspection of Pipelines
NACE RP 0502	Pipeline External Corrosion Direct Assessment. Methodology
IEC 61508-0	Functional safety for electrical, electronic and programmable electronic safety related systems
IEC 61508-1	General requirements
IEC 61508-2	Requirements for E/E/PE safety-related systems
IEC 61508-3	Software requirements
IEC 61508-4	Definitions and abbreviations
IEC 61508-5	Examples and methods for the determination of safety integrity levels
IEC 61508-6	Guidelines on the application of IEC 61508-2 and IEC 61508-3
IEC 61508-7	Overview of techniques and measures
IEC 61511	Process industries
IEC 61400-1 2010	Wind turbine. part 1: Design requirements
IEC 61400-4 2012	Wind turbines. part 4: Design requirements for wind turbine gearboxes
IEC 61400-3 2009	Wind turbines. part 3: Design requirements for offshore wind turbines
DNV RP-A203	Qualification procedures for new technology
DNV-RP-H101	Risk Management in Marine—and Subsea Operations
DNVGL-RP-C208 2016	Determination of Structural Capacity by Non-linear FE analysis Methods
DNV-CG-0121	Offshore Classification Based on Performance Criteria Determined from Risk Assessment Methodology
DNVGL-RP-G101	Risk-based inspection of offshore topsides static mechanical equipment
NFPA 704	Standard System for the Identification of the Hazards of Materials for Emergency Response

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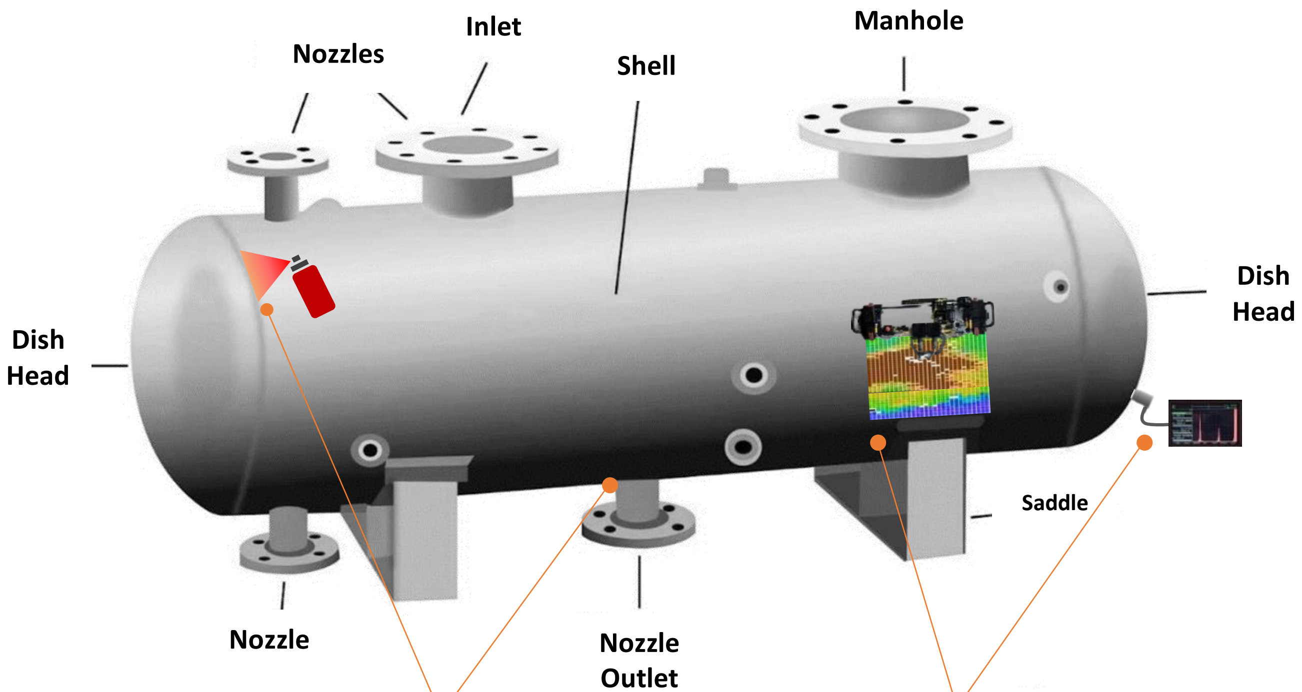
AN ASSET TO INSPECT

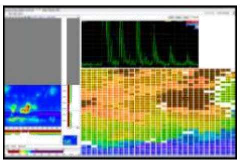
HOW TO INSPECT PRESSURE VESSEL?

Pressure Vessel Integrity

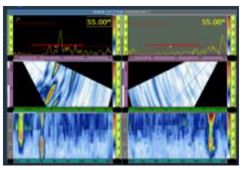


WELDS
- MT/ PT
- UT FD / Shear Wave
- Phased Array (PAUT)
- EC for surface cracks

SHELL PLATES
- Automatic UT Corrosion Mapping
- UT with A-SCAN / UT Grid Scan
- Visual Test / PAUT for corrosion
- Pulsed EC for insulated Vessels



AUT scan



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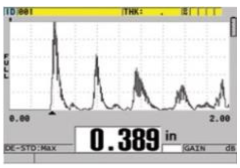
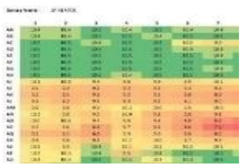


UT scan



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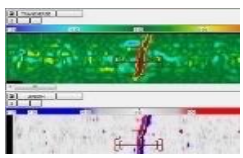

ECT scan

What Is Pressure Vessel?

Pressure vessels are containers that hold liquids or gases at a pressure that differs substantially from the outside pressure. Pressure vessels can be found in homes and industrial facilities all over the world. Some applications of pressure vessels include in steam boilers, engine cylinders and storing chemicals or petroleum products. These examples only begin to scratch the surface, as pressure vessels have nearly endless applications.

While pressure vessels are extremely useful and likely will continue to be used indefinitely into the future, they can be problematic. The difference between the pressure inside a pressure vessel and the pressure outside makes for a potentially hazardous situation. Pressure vessels have long been known to be dangerous and have caused fatal accidents in the past. Because of this, the way pressure vessels are made and used is specified by engineering authorities, and these authorities are supported by governmental legislation.

These standards also specify the need for testing and include guidelines for pressure vessel inspection procedures. The inspection of pressure vessels is both required and smart practice for anyone who wants to avoid an accident that could result in unplanned downtime, damaged equipment and potentially fatal injury to workers.

In this article, we will learn more about different types of pressure vessels, what pressure vessel inspections consist of and when they are required as well as different methods of testing.

Types of Pressure Vessels

Pressure vessels are designed differently based on their end application, though they all tend to look similar and include the same basic parts. Pressure vessels are typically cylindrical with rounded edges or are spherical. That is because these shapes avoid stress raisers.

Common appendages include a pressure gauge, fusible plug and a differential pressure switch, which causes the compressor to come on when pressure drops and to turn off when pressure is at a max. Most pressure vessels are also equipped with a manhole, hand hole or sight hole, which is for general cleaning and inspection. You may also find a condensate drain on the bottom of some pressure vessels. This feature either automatically drains or allows for manual draining of moisture. This is a helpful feature since, depending on the material; moisture in a tank can cause corrosion or pitting.

Beyond their appearance, pressure vessels carry out different functions. One basic way of classifying pressure vessels is to divide them into two categories — fired and unfired, or non-fired. A typical example of a fired pressure vessel would be a boiler. Unfired pressure vessels are not connected with any steam generation or anything with a flame.

We can further divide pressure vessels into a few different types. Though there are some outliers**, the most common pressure vessels fall into three types — storage tanks, heat exchangers and process vessels:**

1. Storage Tanks

Storage tanks are the most common type of pressure vessel. They come in various shapes and sizes, but they are all designed to store liquids and gases under pressure. They might hold fuel oil, liquefied hydrogen or compressed natural gas or other materials that are valuable in industrial applications. These tanks are often made from carbon steel, though they may be coated in a different material on the inside.

2. Heat Exchangers

Heat exchangers are the second most common type of pressure vessel. Heat exchangers transfer heat between mediums, often liquids. This way, heat exchangers are useful for both cooling and heating processes. Heat exchangers can be found in furnaces in homes all over, but they are also essential to processing and manufacturing plants. A common type of heat exchanger used in chemical processes is the shell and tube. With this type, within a pressurized shell, one liquid runs through tubes while the other liquid flows over the tubes, causing heat to transfer from one liquid to the other.

3. Process Vessels

Process vessels, as the name suggests, are used to facilitate a process in a controlled environment. This process is typically one-step in a more extensive process. This sub-process could involve combining materials, separating materials, agitating a mixture, breaking down products or removing an element from a product. Process vessels are designed and constructed with the specific process they are intended for in mind. Sub-types of process vessels include Drums, Reactors, Columns & Gravity separators.

What Is Pressure Vessel Inspection & When Is It Required?

Pressure vessel inspection, or pressure vessel testing, involves non-destructive tests that ensure the integrity of a new pressure vessel or on previously installed pressure equipment that has been altered or repaired.

In the early days of pressure vessels, many pressure vessels were over-pressurized, and they would explode. This problem was part of why the American Society of Mechanical Engineers (ASME) formed. This body came up with specifications to govern the way pressure vessels are manufactured and maintained. Today, the ASME is still responsible for establishing standards for pressure vessels in the U.S. Other countries have their own standards for pressure vessels.

There are two standards that every manufacturer and user of pressure vessels should be aware of:

- **ASME Section VIII**: ASME Section VIII covers the requirements for both fired and unfired pressure vessels, including how they're designed, the way they're fabricated, how they should be inspected and tested and what's required for their certification.
- **API 510**: Another relevant standard to be aware of is API 510, which is an inspection code from the American Petroleum Institute. This standard specifies how inspections, repairs, alterations and other activities should be carried out on pressure vessels and pressure-relieving devices.

Certain industries and government agencies may have their own stringent standards that govern the requirements for pressure vessels. For example, NASA uses pressure vessels and systems to store gases and liquids that are used in launches and on-orbit operations. Once these vessels are in space, they usually can't be serviced, so it's crucial that they are rigorously examined before they leave Earth. Therefore, NASA has its own standards it abides by.

Manufacturers should keep all the relevant standards in mind when designing and building pressure vessels. However, just attempting to follow the standards isn't enough. There needs to be a way of confirming that every pressure vessel that enters the market is safe. This is where pressure vessel inspection comes in. There are various tests a professional can employ to make sure a pressure vessel meets the necessary pressure vessel testing requirements and is ready to be used. For example, the inspector must check that the vessel's shell is thick enough to keep the pressure in.

After a pressure vessel moves from its initial manufacturing and testing to its end application, it may undergo alterations or repairs. Whenever something like this happens, the pressure vessel needs to be inspected again to see whether it still meets all requirements.

While the two scenarios above are times when pressure vessel inspections are required, a vessel could experience issues over time that could cause it to break down and no longer be safe, especially if it is not properly maintained. Here, again, pressure vessel inspection plays an important role.

If there are any issues that could lead to more serious problems, an inspector can point these out, so the necessary maintenance is carried out. This can prevent a pressure vessel from failing and causing severe injury to workers and damage to a manufacturing plant or other type of facility.

Methods of Pressure Vessel Testing

Pressure vessels need to be structurally sound to maintain their internal pressure and not to allow whatever material is contained inside to leak out. Testing is intended to ensure that pressure vessels do not contain any flaws like punctures, cracks or loose connections that could compromise their efficacy.

Two primary types of tests that are performed on pressure vessels include **hydrostatic** and **pneumatic** tests. The key difference between these two types is that hydrostatic testing uses water as the test medium, and pneumatic testing uses a non-flammable, non-toxic gas like air or nitrogen.

A concern with pneumatic testing is that, if a fracture occurs during testing for some reason, it could lead to an explosion. This makes hydrostatic testing a safer option since the volume of water does not rapidly increase when it is suddenly depressurized. However, there are situations where pneumatic testing is a viable option.

Hydrostatic testing involves filling a vessel entirely with water, pressurizing it up to one and a half times its design pressure limit and then watching for any leakage. Adding a tracer or a fluorescent dye to the water inside can make it even easier to see where there may be leaks. Hydrostatic testing could cause damage to a pressure vessel if the water is pressurized too much or if the pressure causes a small fracture to spread rapidly.

Beyond these basic types of testing, OSHA identifies **five non-destructive testing (NDT),** also called non-destructive examination (NDE), methods that are widely used on vessels: VT, PT, MT, RT, UT

Pressure Vessel Testing Benefits

Pressure vessel testing, as we've seen, is required at certain stages, but it's also something all manufacturers and end users should want to prioritize since it's so critical to maintaining their operations and people's safety. If a pressure vessel holds a poisonous gas, a rupture could allow for a dangerous gas leak. Even if the material inside is not poisonous; a ruptured vessel could lead to an explosion or a serious fire.

An event like this could quickly bring your operations to a halt. Consider what operations in your business are, in some way, dependent on a pressure vessel. Now imagine those operations ceasing until the pressure vessel is replaced. Unplanned downtime can result in a great financial loss.

An accident from a pressure vessel could also severely damage equipment within the vicinity of the pressure vessel. It could cost hundreds, thousands or even millions of dollars to replace the damaged equipment. And, of course, any equipment out of commission will add to the issue of unplanned downtime.

An even graver consequence than financial loss is if any workers are poisoned or caught up in an explosion or fire. Employers are responsible for maintaining a safe working environment for their workers, and an injury or death due to a faulty pressure vessel can seriously compromise this environment.

None of this will seem important if you assume your pressure vessels are in good shape. While this is hopefully the case, you cannot know for sure unless your vessels are tested. The results of a pressure vessel inspect may surprise you. According to OSHA, recent pressure vessel inspections have revealed the fact that many pressure vessels in workplaces are cracked or damaged.

Regular inspections can make all the difference in preventing a dangerous failure. Pressure vessel inspection frequency depends on a variety of factors, but a general rule of thumb is that **you should have your pressure vessel inspected every five years**. **These inspections should be thorough and involve a visual inspection, a hydrostatic pressure test, a thickness evaluation, a stress analysis and an inspection of any pressure release valves.**

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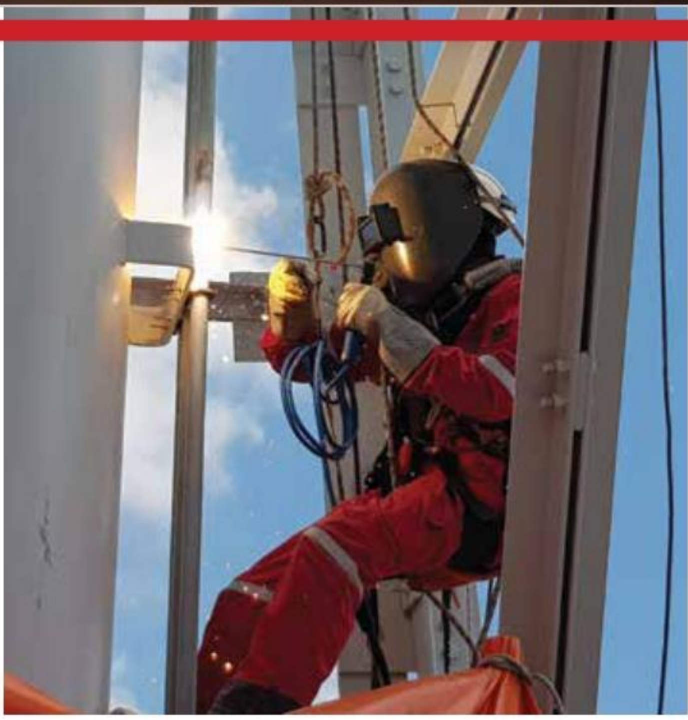

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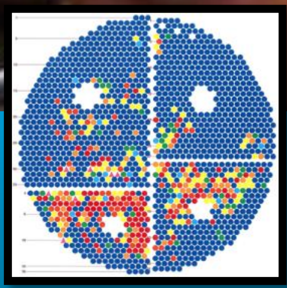

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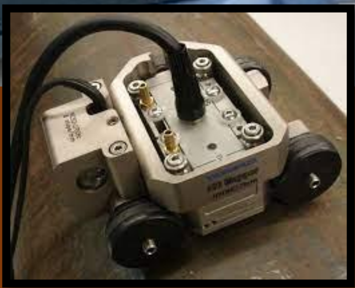

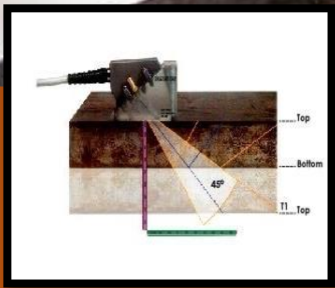

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TOP

Oil & Gas contracts in 2023

The momentum for projects activities in the Middle East is picking up again!

1 Drilling

ADNOC Drilling

ADNOC on March 2 signed an agreement to purchase ten new build hybrid power land drilling rigs for a total of $252 million. The use of hybrid power solutions is an essential element of ADNOC Drilling's "rigorous de-carbonization strategy," the company noted.

The rigs use a high-capacity battery and engine automation in parallel with the rigs' traditional diesel generators. The hybrid power technology system stores energy in its batteries to use when there is a need for continuous power or to provide instant extra power when there is an increase in demand, reducing a rig's greenhouse gas emissions intensity by 10% to 15%.

Each of the rigs will have the provision to be connected to the electrical grid with minimum adjustment, depending on rig location and the availability of grid power, further reducing emissions.

2 Design & Engineering

Forum Energy Tech.

Houston-based technology provider Forum Energy Technologies (FET) secured a $25 million contract from Aramco for providing the design, engineering services and supply of four electrostatic de-salter systems for an onshore project at the Safaniyah oil field in Saudi Arabia. According to the contract, the de-salter systems will utilize FET's Edge desalting technology, ForuMix high efficiency multiphase mixer technology.

3 Logistics services

ADNOC L&S

ADNOC Logistics & Services signed a $2.6 billion contract with ADNOC Offshore to provide integrated logistics services for its new Integrated Logistics Services Platform, one of the largest turnkey offshore logistics offerings in the world that is expected to coordinate end-to-end management of logistics and maritime operations.

4 Offshore EPC

L&T

Indian contractor L&T secured multiple offshore EPCI contracts from Saudi Aramco under a long-term agreement (LTA) framework to which a select group of international contractors have access.

The company specified that as per its classification, the major project be in the range of over $600 million.

5 Construction

Heavy Engineering Industries and Shipbuilding.

Kuwait's Heavy Engineering Industries and Shipbuilding Co (HEISCO) announced in a statement that it has secured a five-year contract from Kuwait Oil Co (KOC) for the construction of flow lines and associated works in West Kuwait Area.

The value of the contract is KWD 68.5 million ($223.7 million).

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DE-CARBONIZATION: Urgency to Achieving Operational Efficiency!

Setting emission-reduction targets in the oil and gas sector is still in its beginning stages. In fact, it is expected that oil and gas corporations' reported plans to reduce Greenhouse Gas (GHG) emissions by approximately 30%, significantly below the standards set forth in the Paris Agreement. Potentially, improved operating efficiency, digitalization, and the utilization of renewable energy sources might enable oil and gas activities to completely decarbonize. The majority of de-carbonization capability must be realized through capital spending, although some strategies, such as the use of renewable energy, electrification, and operational efficiency, are now economically viable for several oil and gas projects. Besides other things, the de-carbonization capacity of oil and gas sites differs depending on the product, oil and gas activity, power source, and network emissions.

Effective operation equates to responsible operation. Most of all, it is a cost-effective first move in lowering pollutants, the third largest cause of pollutants, as well as intermittent flaring and venting. A recent study demonstrates that firms in the top percentile of operational efficiency have the least pollutants in the industry based on the resilience of their operations across a worldwide range after fundamental considerations are taken into account. The finest resources emit approximately three times as much as those in the third quartile, which can accomplish just under 7 kg per barrel of oil equivalent.

Furthermore, the country's demand for fossil fuels is rising in spite of efforts to transition to a carbon-neutral society. The oil and petrol sector has a problem in supplying the rising demand for energy while also lowering total emissions. In order to promote the transition to a low-carbon future, such situations require persuasive methods.

As suggested by a data analyst in the oil and gas industry, "While [de-carbonization] is underrated, it is one of the most practical ways to allow oil and gas companies to be able to become effective in their operations, but also it will allow [companies] to achieve targets in sustainability and take off some of the pressure that oil and gas companies are facing because of the amount of emissions." One method to uphold environmental requirements is to integrate carbon-neutral forms of technologies like wind and solar within carbon-intensive projects in the industry. Oil and gas firms may anticipate cutting emissions and use of energy along the whole production chain by using dependable and integrated solutions.

Some studies have suggested cost up to $5.8 USD trillion would be needed annually until 2050 to enable the energy transition. The oil and gas industry is highly suited to finance new energy ventures due to its extensive expertise in obtaining cash, even in the most intense of sectors, in addition to its capacity for sustaining strong balance books and reliable returns.

Markets for renewable energy are expanding quickly. Decision making on the optimum source of energy for each effort will get more difficult as technology evolves and as clean energy, sources expand. Hence, the oil and gas industry has long used competitive intelligence to provide the appropriate energy to the appropriate location at the appropriate time at the appropriate price.

Businesses are beginning to understand how de-carbonization may help them keep their market share and provide fresh potential growth. Organizations need a transition process to take use of evolving environmental goals without losing efficiency in order to make the most of these new prospects.

Iraq Signs Oil, Gas Deals with UAE's Crescent Petroleum, Chinese Firms

Iraq's oil minister said the new energy deals are expected to produce more than 800 MMscf/d of gas.

BAGHDAD, Feb 21 (Reuters) - Iraq signed deals with UAE firm Crescent Petroleum and two Chinese companies for the development of six oil and gas fields as it seeks to produce much needed natural gas for power stations and cut imports burdening the country's budget.

United Arab Emirates-based Crescent Petroleum signed three 20-year contracts to develop oil and natural gas fields in Iraq's Basra and Diyala provinces in northeastern Baghdad.

The Crescent Petroleum contracts include the Gilabat-Qumar and Khashim fields in Diyala, which are expected to begin producing 250 million standard cubic feet per day of natural gas within 18 months, the company said.

Crescent Petroleum also plans to explore and develop Khider al-Mai, a third block in Basra province for oil and gas.

China's Geo-Jade also signed two contracts for exploration and development rights to Iraq's Huwaiza oilfield in the south and Naft Khana northeast of Baghdad, both near the Iranian border.

Chinese oil and gas company United Energy Group Ltd signed a contract to develop the Sindbad oilfield near Basra.

Iraq expects the new deals to help produce more than 800 million standard cubic feet per day of natural gas (mcf/d), Iraq's oil minister Hayan Abdel-Ghani said during the signing ceremony, which Prime Minister Mohammed al-Sudani attended.

The OPEC producer heavily relies on Iranian gas imports to feed its power grid.

Ghani said Iraq was planning to launch a new bidding round to try to maximize gas production.

The new round will include exploration blocks in the country's north, central and western regions, he said.

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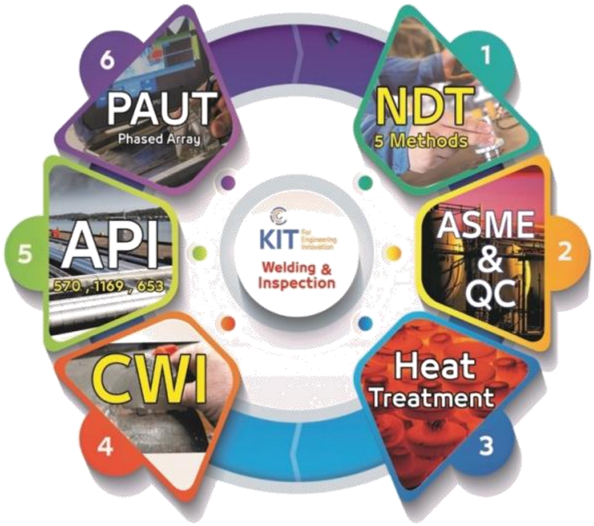

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Piping Vibration Risks & Integrity Assessment

Vibration analysis per EI 2008 Guidelines for the avoidance of vibration induced fatigue failure (AVIFF).

Piping vibration problems are a reality at onshore or offshore production facilities, pipeline stations, refineries, and petrochemical plants. Facility owners are extremely sensitive to these integrity risks because of the significant consequences associated with product releases from ruptured piping.

Recent examples in the press highlight situations where piping failures caused explosions, loss of life, and environmental damage due to onshore and offshore spills, lawsuits, and facility shutdowns.

Vibration can cause reliability problems on equipment, fatigue failure on process piping, and small branch connections including relief lines, instrumentation ports, nozzles, drains, and valves. Vibration on compressor and pump packages is also a reliability issue but is addressed in separate scopes of work.

What Is Piping Vibration?

Piping vibration is simply the movement of pipe away from its static, at-rest position. Some vibration can be seen by the naked eye, some vibration can be felt or heard, and some vibration occurs only occasionally under certain operating conditions, and may not be recognized until a piping failure has occurred.

What Piping Is Most At Risk?

Around 80% of vibration-induced failures are associated with small-bore connections (SBCs).

This is due to several reasons:

- Stress concentrations at the weld to the main pipe or vessel.
- Large unsupported valves.
- Lack of evaluation of vibration and fatigue risk, beyond a reactive approach after a failure.
- Disconnects between the SBC design intent and site fabrication, particularly regarding local support/bracing.

The remaining 20% are generally associated with parent pipe girth weld failure.

Why Should I Care About Piping Vibration?

21% of hydrocarbon releases are due to vibration-induced fatigue failures (UK Health & Safety Executive). These releases can have a significant impact on public and employee safety, the environment, production and financial performance.

The piping system is by far the leading source of failures in facilities (Marsh & McLennan). This is in part due to the sheer quantity of piping in facilities, but also due to inadequacies in integrity programs to consider vibration and fatigue. The situation is compounded by the fact that commonly used design codes do not consider vibration in detail.

Overall, only a small portion of piping is of high risk of failure, but identifying those high-risk locations is the challenge. Piping vibration risks can be identified at any stage of the asset lifecycle, but few companies have a systematic approach to evaluating these risks.

Vibration Sources

- Pulsations - Reciprocating Compressor or Pump
- Pulsations - Centrifugal Compressor or Pump at Vane Passing Frequency
- Pulsations - Screw Compressor or Pump at Pocket Passing Frequency
- Flow Induced Turbulence (FIT)
- Flow Induced Excitation or Vibration (FIE or FIV)
- Acoustic Induced Excitation or Vibration (AIE or AIV)
- Water Hammer - Valve Opening and Closing
- Momentum Change - Valve Opening
- Cavitation/Flashing
- Machinery Unbalanced Forces and Moments
- Crosshead Guide Forces
- Temperature and Pressure Differential
- Lifting
- Bolt-up Strain
- Environmental Loads
- Machinery Mean & Alternating Torque

Piping Vibration Risks in Onshore & Offshore Facilities

Gas Plants, Refineries, Pipelines, Pumping and Compressor Stations

Common piping risks to be evaluated in a piping assessment:

- Small-bore connections (SBCs) and branch attachments connect to the main process piping. These small attachments, typically less than 8 cm (3 inches) in diameter, are the most common cause of integrity problems. Even if the main process piping has acceptable vibration, the vibration can be amplified on SBC causing failures. For large facilities, there can be thousands of SBCs that pose this integrity risk.

- Process piping vibration can cause excessive vibratory stress on nozzles and tees leading to cracks.

- Failure of bypass lines, PSV or relief lines.

- Transient related events such as starting, stopping, emergency shutdown or closing and opening valves can cause momentum changes in the gas or liquid (fluid hammer), resulting is excessive stress.

- Fretting and damage to pipe supports.

- Pipe stress analysis can be in conflict with vibration design requirements. Unless the design resolves the conflict between Mechanical Vibration Design (adding stiffness to control vibration) and the Piping Stress Analysis (increasing flexibility for thermal analysis), there are risks that the piping system will experience stress failures.

- Space on an offshore production facility is limited, and the piping layout is often very compact, the tight layout creates unique challenges in controlling piping vibration.

- The piping system is often elevated, connecting rotating machinery to overhead coolers, vessels, or headers. Elevated piping is typically much more flexible than rigidly connected or buried piping because of the difficulties in designing sufficiently stiff piping supports (that prevent vibration).

- Safety requirements often require “double block and bleed” valves on many small-bore connections. The geometry of these valve configurations and the heavy overhung weight creates much higher chances of excessive stress and failure.

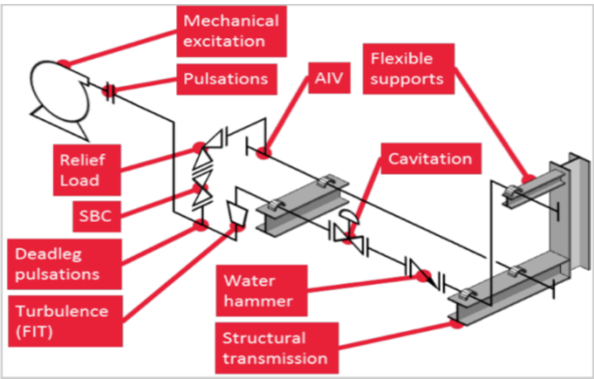
How Can I Address Piping Vibration?

Risk-based assessments are the most cost-effective and reliable method to identify, quantify, inspect, measure and mitigate vibration and fatigue risks. These assessments look at the vibration integrity problems a facility faces, from start-up to shut down.

The risk-based approach allows for a proactive management of vibration, only where there are risks present. Risk-based assessments integrate with and complement conventional integrity management programs that typically focus on corrosion/erosion – saving time and money for operators.

Design and in-service inspection standards typically highlight the risk posed by vibration but fail to provide appropriate management strategies, often leaving the identification of vibration issues to operators.

Typical vibration risks in a piping system



Effects of Piping Vibration & Associated Risks

These pipe vibrations have the potential to destroy the piping systems and cause issues with the equipment. These undesirable pipe vibrations put further strain on the piping system, which eventually leads to failure. If the stress stays and causes a crack in the pipe, the whole pipe system could fail.

The vibrations of the pipes cause cyclic relative motion cyclic relative motion, which can cause fretting in addition to the stress content. This wears away the surface of the pipes.

Small-bore connections are to blame for the majority of pipe system failures (SBCs). Several of the causes include.

- If the enormous pipes are not supported.
- When regular pipe vibration checks and maintenance are neglected.
- When the flow of liquid is under stress from repeated bends, etc.

The Accepted Defect Size in Ultrasonic Testing

Indications which are identified using any NDT method is accepted or rejected in reference to the standards.

The standards which client accepts or the standard which we follow for production is called acceptance criteria. Following are a few of the important acceptance criteria…

Acceptance Criteria

ASME Section VIII Division 1 – Pressure Vessel Construction – Ultrasonic Testing (UT) Inspection Services

These Standards shall apply unless other standards are specified for specific applications within this Division.

Imperfections which produce a response greater than 20% of the reference level shall be investigated to the extent that the operator can determine the shape, identity, and location of all such imperfections and evaluate them in terms of the acceptance standards given in (a) and (b) below.

Indications characterized as cracks, lack of fusion, or incomplete penetration is unacceptable regardless of other imperfections are unacceptable. If the indications exceed the reference, level amplitude and have lengths that exceed:

- 1/4 in. (6 mm) for t up to 3/4 in. (19 mm)
- 1/3t for t from 3/4 in. to 21/4 in. (19 mm to 57 mm)
- 3/4 in. (19 mm) for t over 21/4 in. (57mm).

Where t is the thickness of the weld excluding any allowable reinforcement. For a butt weld joining two members having different thicknesses at the weld, t is the thinner of these two thicknesses. If a full penetration weld includes a fillet weld, the thickness of the throat of the fillet shall be included in t.

ASME B 31.1 – Power Piping – Ultrasonic Testing.

Welds that are shown by ultrasonic examination to have discontinuities that produce an indication greater than 20% of the reference level shall be investigated to the extent that ultrasonic examination personnel can determine their shape, identity, and location so that they may evaluate each discontinuity for acceptance in accordance with (B.1) and (B.2) below.

- (B.1) Discontinuities evaluated as being cracks, lack of fusion, alternatively, incomplete penetration is unacceptable regardless of length.

- (B.2) Other discontinuities are unacceptable if the indication exceeds the reference level, and their length exceeds the following:
  - (B.2.1) ¼” (6.0 mm) for t up to ¾” (19.0 mm).
  - (B.2.2) 1/3 t for t from ¾” (19.0 mm) to 2 ¼ “(57.0 mm).
  - (B.2.3) ¾”. (19.0 mm) for t over 2¼” (57.0 mm)

Where t is the thickness of the weld being examined. If the weld joins two members having different thicknesses at the weld, t is the thinner of these two thicknesses.

ASME B 16.34 – Valves – Ultrasonic Testing Acceptance Standards.

Straight Beam Examination
Indications, which are equal to or exceed that obtained from a 6.4 mm (0.25 in.) diameter flat-bottomed hole in a calibration test piece of thickness equal to the defect depth, are unacceptable.

Angle Beam Examination
Indications, which are equal to or exceed those obtained from a 60 deg V-notch, 25 mm (1.0 in.) long and having a depth not greater than 5% of the nominal wall thickness in a test piece are unacceptable.

ASME B31.3 Process Piping – Ultrasonic Testing Inspection of Weld Joints carried as per ASME Section V, Article 4 Pipe and Tubing

Pipe and tubing required or selected in accordance with Table K305.1.2 to undergo ultrasonic examination, shall pass a 100% examination for longitudinal defects in accordance with ASTM E213 Ultrasonic Testing of Metal Pipe and Tubing. Longitudinal (axial) reference notches shall be introduced on the outer and inner surfaces of the calibration (reference) standard of ASTM E213 to a depth not greater than the larger of 0.1 mm (0.004 in.) or 4% of specimen thickness and a length not more than 10 times the notch depth.

Any indication greater than that produced by the calibration notch representation Welds over 6mm thick can be ultrasonically tested in reference to procedure given in ASME Sec V article 4.

Indications shall be sized using the applicable technique(s) provided in the written procedure for the examination method. Indications shall be evaluated for acceptance as follows:

All indications characterized as cracks, lack of fusion, or incomplete penetration are unacceptable regardless of Indications exceeding 1/8 in. (3 mm) in length are considered relevant and are unacceptable when their lengths exceed.

- 1/8 in. (3 mm) for t up to 3/8 in. (10 mm).
- 1/3t for t from 3/8 in. to 21/4 in. (10 mm to 57 mm).
- 3/4 in. (19 mm) for t over 21/4 in. (57 mm),

Where “t” is the thickness of the weld excluding any allowable reinforcement. For a butt weld joining two members having different thicknesses at the weld, t is the thinner of these two thicknesses. If a full penetration weld includes a fillet weld, the thickness of the throat of the fillet shall be included

API 1104 Welding of Pipelines & Related Facilities – Ultrasonic Testing – Acceptance level Acceptance Standards 9.6.2.1 Indications determined to be cracks (C) shall be considered:

- **Linear Surface (LS)** indications (other than cracks) interpreted to be open to the D. or O.D. surface shall be considered defects should any of the following conditions exist:
  1. The aggregate length of LS indications in any continuous 12” (300-mm) length of weld exceeds 1”. (25 mm).
  2. The aggregate length of LS Indications exceeds 8% of the weld.

- **Linear Buried (LB)** indications (other than cracks) interpreted to be subsurface within the weld and not I.D. or O.D. surface-connected shall be considered defects should any of the following conditions exist:
  1. The aggregate length of LB indications in any continuous 12” (300-mm) length of weld exceeds 2” (50 mm).
  2. The aggregate length of LB indications exceeds 8% of the weld.

- **Transverse (T) indications** (other than cracks) shall be considered volumetric and evaluated using the criteria for volumetric indications. The letter T shall be used to designate all reported transverse indications.
- **Volumetric Cluster (VC)** indications shall be considered defects when the maximum dimension of VC indications exceeds ½’’ (13 mm).
- **Volumetric Individual (VI)** indications shall be considered defects when the maximum dimension of VI indications exceeds ¼’’ (6 mm) in both width and

- **Volumetric Root (VR)** indications interpreted to be open to the D. surface shall be considered defects should any of the following conditions exist:
  1. The maximum dimension of VR indications exceeds ¼’’ (6mm).
  2. The total length of VR indications exceeds 1/2 “ (13 mm) in any continuous 12” (300 mm)

- **Relevant Indications (AR)** shall be considered a defect when any of the following conditions exist.
  1. The aggregate length of indications above evaluation level exceeds 2 “(50 mm) in any 12” (300mm) length.
  2. The aggregate length of indications above evaluation level exceeds 8% of the weld.

How NDT Supports Gas & Steam Turbine Maintenance & Inspection

Blades have to be Checked In-Situ

Removing a blade to test it is not ideal. The testing has to take into account how the blade fits into the rest of the turbine. That means shutting down the machine.

TURBINE engines can harbor many undetected flaws that could hamper machine functionality. **Years ago**, **liquid penetrant testing (LPT)** was one of the most common testing methods, but more modern nondestructive testing (NDT) techniques have emerged as being more effective. Gas turbine engine maintenance and inspection plans call for precise NDT campaigns that can perform actions such as measuring the size of gas turbine cracking.

Turbines Have Complicated Geometries

Testing is never cut-and-dried, of course, but it is easier on surfaces that are entirely flat. For obvious reasons, a smooth unbroken plane would not work for turbines. In particular, the blade attachment serrations are extremely complex and intricate.

Standard NDT testing would not be able to handle every turn, nook, and attachment on the surface, to say nothing of detecting subsurface cracks.

Any Downtime Is Lost Revenue Downtime for a generator means less power, which could lead to dissatisfied customers and other issues. Downtime needs to be avoided as much as possible. Yet, that is the dilemma as inspections are needed, which can be complicated. Complications increase downtime. So how that should be avoided? The best ways are the advanced methods that can quickly and efficiently handle the complexities.

NDT SOLUTIONS for gas turbine inspections are phased array ultrasonic testing (PAUT) and eddy current array (ECA). ECA and PAUT provide the necessary reliability that can access hard-to-reach regions. This article will explain why ECA and PAUT are two preferred methods for the inspection of gas turbines and vanes.

Gas Turbine Engine Maintenance and Inspections Plans.

The array capabilities of ECT and UT offer a detailed inspection that can find many types of flaws in the form of corrosion, cracking, and pitting. PAUT and ECA provide an in-depth view of spotted defects, with the addition of customizations and tailored mechanisms that can conform to unconventional contours of gas turbine engines.

The array options provide greater flexibility and tailored choices that allow inspectors to finish the testing sessions faster.

Gas turbine engine maintenance and inspection plans have relied on LPT (Liquid Penetrant Test) in the past, but since LPT provides substandard data and cumbersome setup procedures, PAUT and ECA outperform LPT in almost every way. The array option also enhances UT and ECT in many regards, including the measurements of cracking or the detection of corrosion within multi-layered structures. Therefore, technicians can spot indications early and alert maintenance crews of necessary repair mandates.

Turbine Inspection Solutions

ECA SOLUTION

Eddy Current Array

The ECA probes can conform to complex geometric patterns of turbines. Users can also apply multi-coil for any part of the turbine inspection, ensuring a testing regimen that is devoid of misalignments or haphazard adjustment schemes. Additionally, the rows of coils allow analysts to extract more data in a single pass, hastening inspection times while receiving quality data. Moreover, array capabilities provide detachable encoders that can inspect multiple positions of a turbine, streamlining the testing process and ensuring that all areas of the testing radius are adequately covered.

To maximize inspection parameters for turbines, look for the following attributes in eddy current testing (ECT) instrumentation:

- Handheld portability and ergonomics that allow technicians to comfortably inspect more areas for increased inspection productivity.
- Advanced features that help technicians find more flaws in less time.
- Dual frequency mixing that dispels unnecessary signals
- Compatibility with a wide range of probes and scanners, including flexible probes that enable technicians to inspect challenging or hard-to-reach areas.
- Intuitive user interface, which leads to an inherently higher probability of detection and reduces the amount and frequency of training required.

The dual-frequency function is especially noteworthy due to its ability to compensate for air gaps between the layering that can cause unneeded signals to flourish, fostering a signal-to-noise ratio that can further probe multi-layer structures found within blades. Complex layering can be challenging to inspect, but a good ECT instrument can adjust to skin thickness variations or multiple layers while producing a sharpened signal quality. When paired with array features, ECT equipment can expedite the inspection process by as much as 95% compared to standard pencil probing. Analysts can also achieve the same efficient inspection benefits if they need to inspect gas turbine engines volumetrically.

PAUT SOLUTION

Phased Array Ultrasonic Testing

PAUT relies on wave beam customizations, enhanced focus depths, and multiple probing angles. The improved speed and resolution fosters a more complete picture of internal layouts. PAUT differs from conventional UT because ordinary UT provides fixed beaming positions, which often fail to detect varied forms of disruptions that can degrade machine functionality.

On the other hand, PAUT allows users to apply various angles without incessant probe changes or frequent adjustments. Therefore, users can find flaws that would have remained hidden otherwise. Further, the linear scanner usability supplants raster motion, which secures a better-rounded coverage feature.

The instrumentation behind PAUT is just as important as the probe. Look for the following qualities in your instrumentation:

- Advanced techniques such as Time-of-Flight Diffraction (TOFD)
- Fully integrated and portable
- Powerful software features and capabilities

The software dexterity is imperative because it provides easier online and offline data analysis than other NDT methods. UT software also provides high-resolution mapping, which can be further enhanced by using instruments that can support the total focusing method algorithm.

More importantly, UT equipment has enough power to pervade thick welding and/or composite sections of turbines and vanes, allowing the probes to reach further into the subsurface layers and obtain accurate data.

The biggest benefit is the portable instrumentation for PAUT. Technicians have to be able to maneuver and carry it in tight quarters. Testing equipment that is portable, fully integrated with capable software, and has 2D matrix array capabilities.

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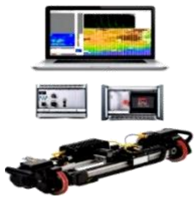

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UPCOMING EVENTS

EGYPS Exhibition 2023
13 – 15 February 2024

The EGYPS Technical Conference brings together global oil, gas and energy professionals to showcase the latest technical opportunities and challenges, breakthrough research findings, innovative technologies and industry solutions, creating an excellent learning and networking hub for the industry's technical experts. In 2023, the Technical Conference will showcase the technologies being used today and those transforming the industry of the future. Our international technical expert speakers will share their wealth of experience and knowledge. With 19 technical categories to select from, we look forward to receiving your abstract submissions.

Nigeria Oil & Gas International
09 – 13 July 2023

The **NOG International Exhibition** in Abuja, is Nigeria's most important **oil, gas, LNG and energy exhibition**, where energy professionals convene to exchange in dialogue, showcase technological advancements, identify innovative solutions and forge business partnerships. The NOG International Exhibition will take place from **9 – 13 July 2023 in Abuja** at the **International Conference Centre** with an expanded exhibition space of **5,000 sqm** attracting **5,000+ attendees** from Africa, Middle East, Europe, Asia and the USA to create and unparalleled business opportunity for exhibiting companies to tap into this vital market.

Fujairah Bunkering & Fuel Oil Forum (FUJCON)
2023

Along with our hosts, the Government of Fujairah & Port of Fujairah, we are pleased to hold the 13th International Fujairah Bunkering & Fuel Oil Forum (FUJCON 2023) from 13-15 March 2023 in Fujairah, UAE, under the Patronage of H.H. Sheikh Hamad bin Mohammed Al Sharqi, and the support of the Fujairah Oil Industry Zone.

SPRINT Robotics
2023

Submit your abstract to speak at the SPRINT Robotics Asia-Pacific Summit 2023, a key event for Inspection, Maintenance & Cleaning robotics professionals. We are welcoming abstracts about use cases or new technologies for robotics for Inspection & Maintenance in capital-intensive industries. The SPRINT Robotics Asia-Pacific Summit will take place at the end of March 2023 in Singapore. The event features a dynamic program of technical presentations, an exposition, and demonstration day and dedicated networking events. The planning for the I&M Robotics week will be announced at the beginning of November.

PETROCHEMICAL & REFINING CONGRESS: EUROPE
2023

Petrochemical and Refining Congress is an annual downstream oil and gas B2B networking platform which is gathering more than 350 industry leaders from major companies including BP, Shell, Eni, McDermott, Fluor, Wood, BASF, Borealis, SABIC, and many others. The PRC Europe 2023 edition raises such hot questions as industry de-carbonization, petrochemicals and alternative fuels production, recycling technologies and plant improvements.

World Petrochemical Conference (WPC)
2023

The World Petrochemical Conference (WPC) is the premier gathering for the petrochemical industry, bringing together more than 1,000 senior chemical industry decision-makers from more than 40 countries for networking, unparalleled insight, and critical analysis from IHS Markit, your trusted partner in decision-making.

Hydrogen Technology Conference & Expo
28 June 2023

Hydrogen Technology Conference & Expo is North America's must-attend exhibition and conference that is exclusively dedicated to discussing advanced technologies for the hydrogen and fuel cell industry. The event brings together the entire hydrogen value chain to focus on developing solutions and innovations for low-carbon hydrogen production, efficient storage, and distribution as well as applications in a variety of stationary and mobile applications.

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CONVERSATION FACTORS

LENGTH

1	Centimeter	=	0.3937	Inches	1	Inch	=	2.54	Cms
1	Meter	=	3.2808	Feet	1	Foot	=	0.3048	Meters
1	Kilometer	=	0.62137	Miles	1	Mile	=	1.60934	Kilometers
1	Kilometer	=	0.53996	Naut. Miles	1	Naut. Mile	=	1.852	Kilometers

AREA

1	Sq. meter	=	10.7639	Sq. Feet	1	Sq. Feet	=	0.092903	Sq. meters
1	Hectare	=	2.47105	Acres	1	Acre	=	0.404686	Hectares
1	Sq. Km	=	0.3861	Sq. Miles	1	Sq. Miles	=	2.58999	Sq. Kms
1	Sq. Km	=	247.105	Acres	1	Acre	=	0.004047	Sq. Kms

WEIGHT

1	Kilogram	=	2.20462	Pounds (lbs)	1	Pounds (lbs)	=	0.45359	Kilogram
1	Metric Ton	=	0.98421	Long Tons	1	Long Ton	=	1.01605	Metric Tons
1	Metric Ton	=	1.10231	Short Tons	1	Short Ton	=	0.907185	Metric Tons

VOLUME

1	Liter	=	0.2642	U.S. Gallons	1	U.S. Gallon	=	3.785	Liters
1	Liter	=	0.21997	U.K. Gallons	1	U.K. Gallon	=	4.546.9	Liters
1	Cu. Meter	=	6.2898	Barrels	1	Barrel	=	0.159	Cu. Meters
1	Barrel	=	42	U.S. Gallons	1	Barrel	=	158.97	Liters

STANDARD ENERGY EQUIVALENTS

1000 metric tons of oil equiv. (TOE)		1000 barrels of oil Equivalent (BOE)		1000 metric tons of coal equiv. (TCE)	
10	Tera calories (net)	1.43	Tera calories (net)	7	Tera calories (net)
41.9	Tera joules (net)	6	Tera joules (net)	29.3	Tera joules (net)
1.43	thousand metric tons of coal equiv.	0.204	thousand metric tons of coal equiv.	0.84	million cubic meters of natural gas
1.2	million cubic meters of natural gas	0.172	million cubic meters of natural gas	8.14	gigawatt hours of electricity
11.63	gigawatt hours of electricity	1.661	gigawatt hours of electricity	0.7	thousand barrels of oil equiv.
7	thousand barrels of oil equiv	0.143	thousand barrels of oil equiv.	27.78	billion (10^9) BTUs (net)
39.68	billion (10^9) BTUs (net)	5.674	billion (10^9) BTUs (net)		

SPECIFIC GRAVITY: VOLUME PER TON

Degrees API	Specific Gravity @ 60°F	Barrels per*	
		Met. Ton	Long ton.
25	0.904	6.98	7.09
26	0.898	7.02	7.13
27	0.893	7.06	7.18
28	0.887	7.1	7.22
29	0.882	7.15	7.27
30	0.876	7.19	7.31
31	0.871	7.24	7.36
32	0.865	7.28	7.4
33	0.86	7.33	7.45
34	0.855	7.37	7.49
35	0.85	7.42	7.54
36	0.845	7.46	7.58
37	0.84	7.51	7.63
38	0.835	7.55	7.67
39	0.83	7.6	7.72
40	0.825	7.64	7.76
41	0.82	7.69	7.81
42	0.816	7.73	7.85

SPECIFIC GRAVITY RANGES

	Specific Gravity	Barrels per metric ton
Crude Oils	0.80 - 0.97	8.0 - 6.6
Aviation Gasolines	0.70 - 0.78	9.1 - 8.2
Motor Gasolines	0.71 - 0.79	9.0 - 8.1
Kerosine's	0.78 - 0.84	8.2 - 7.6
Gas Oils	0.82 - 0.90	7.8 - 7.1
Diesel Oils	0.82 - 0.92	7.8 - 6.9
Lubricating Oils	0.85 - 0.95	7.5 - 6.7
Fuel Oils	0.92 - 0.99	6.9 - 6.5
Asphaltic Bitumen's	1.00 - 1.10	6.4 - 5.8

CALORIFIC VALUE OF FUELS

Rough Gross Values in Btu Per lb	
Crude Oils	18 300 - 19 500
Gasolines	20 500
Kerosine's	19 800
Benzole	18 100
Ethyl Alcohol	11 600
Gas Oils	19 200
Fuel Oil (Bunker)	18 300
Coal (Bituminous)	10 200 - 14 600
LNG	22 300

Multiples

micro	=	one millionth	hecto	=	one hundred
milli	=	one thousandth	kilo	=	one thousand
centi	=	one hundredth	mega	=	one million
dec	=	one tenth	giga	=	one billion (10^9)
deca	=	ten	tera	=	one trillion (10^{12})

Ref. Petroleum Magazine