NDT SCOOP

Quarterly Nondestructive Testing Magazine

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global NDT vanguard

Mohammed Abu four:

Over 42 years of experience advancing inspection excellence across the oil and energy industry.

Saudi Arabia

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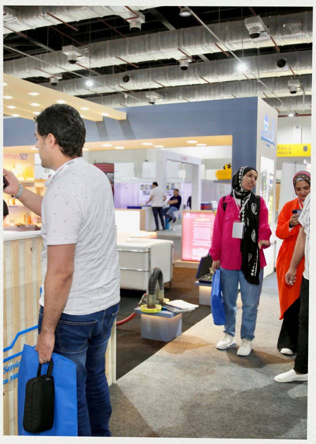

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Fast After Service
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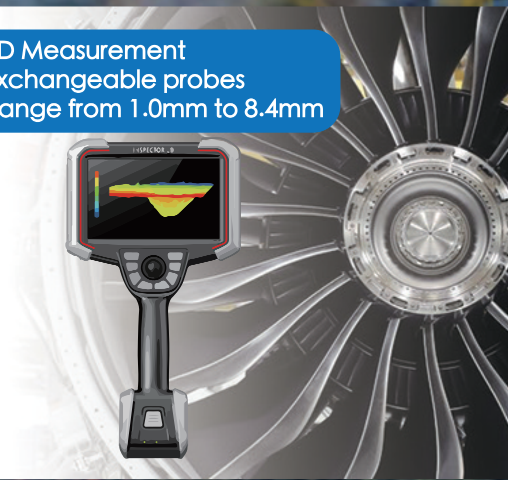

RVI Infinity Innovation

AWS SENSE PROGRAM

Schools Excelling through National Skills Standards Education

American Welding Society®

aws.org

Why spend hours planning your upcoming welding training curriculum, if someone else has already done the heavy lifting? The AWS SENSE curriculum is a turnkey framework you can use to assess, test and qualify your students' welding skills to nationally recognized industry standards.

What is SENSE?

SENSE is a comprehensive set of minimum standards and guidelines established by AWS for welding educators to follow when developing their welding training curriculum. While comprehensive, these standards are also flexible enough that almost any welding program will readily be able to implement them.

SENSE Facts

- Governed by a set of specifications written by industry experts
- Flexible standards and modularized framework
- Alignment to industry recognized national education standards
- SENSE exams are hosted on an LMS platform, SENSE Online
- Students earn verifiable AWS certificates and wallet cards Complimentary online training
- Complimentary online training

Key Benefits

Upon registration, schools receive Complimentary One-Year Educational Corporate Membership that includes:

- 3 individual memberships offering discounts on AWS publications, Certifications, and conferences.
- Additional discounts on Certified Welding Educator (CWE) credentials for instructors participating in the SENSE Program.
- Access to SENSE LMS: Tools for administering theory exams, and entering practical assessments, and student credentialing.
- Verifiable Credentials: Students earn certificates and wallet cards stored in the AWS Certificate Verification Database.
- Complimentary Standards Library: 8 selected standards for educational use.

Who Can Become a SENSE School?

- Industrial Training Institutes
- Career Technical Education
- Polytechnic Colleges
- Any Institution Offering Welding Education Programs

How Does SENSE Work?

- 2 Modular Programming Levels (Level I and Level II)
- Instructors and administrators determine the best method(s) and order in which to review curriculum content with their students
- Instructors may choose any curriculum as long as it aligns to SENSE guidelines and are not required to teach content in a specific order
- Instructors may include topics outside of the SENSE guidelines to use within their welder training program, allowing them to teach topics that students will need in their local welding community, making their graduates more employable
- Instructors administer the AWS-developed multiple choice test and (as applicable) a performance evaluation in the process(es) or topics they are covering

SENSE Modules, Standards & Specifications

SENSE LEVEL I MODULES

GTAW | FCAW | GMAW | SMAW

Level I Standards:

- QC10: Specification for Qualification and Certification of SENSE Level I – Entry Welders
- EG2.0: Guide for the Training of Welding Personnel: SENSE Level I – Entry Welders
- EG2.0 Supplement: Supplement SENSE Level I – Entry Welder Training Performance Testing Procedures

SENSE LEVEL II MODULES

SMAW PLATE | GTAW PLATE | FCAW PIPE | FCAW PLATE | GMAW PIPE | GMAW PLATE | SMAW PIPE

Level II Standards:

- QC11: Specification for Qualification and Certification of SENSE Level II – Advanced Welders
- EG3.0: Guide for Training of Welding Personnel: SENSE Level II – Advanced Welders
- EG3.0 Supplement: Supplement SENSE Level II – Advanced Welder Training Performance Testing Procedures

For more information, visit:

AWS Contact: Ramesh Shankaran, Regional Director,
International Certification & Accreditation
(Mob: +91 9845537670, Email: rshankaran@aws.org)

مركز مهارات للتدريب الانشائي

MAHARAT Construction Training Center

Dr Payel Dutta Chowdhury

Marketing and Communications Content Specialist (Asia, Africa & Oceania) for the American Welding Society

The 1st AWS SENSE Institution

in Saudi Arabia

"MAHARAT's commitment to developing a highly skilled workforce is aligned to the National Vision 2030."

Amidst significant growth in industrial sectors like aerospace, defense, and automobiles, the Middle East region faces considerable skills gap, particularly in vocational and specialized skill areas. The World Bank's latest reports highlight a significant skills gap in the Middle East and North Africa (MENA) region, particularly concerning the digital economy and the need for specialized skills to meet the demands of a rapidly evolving job market.

The skills gap can be noticed in welding and fabrication too, affecting various industries, including construction, manufacturing, and oil and gas.

This shortage is driven by several factors, including rapid economic growth, increasing demand for skilled labor, and limited access to comprehensive welding and fabrication training programs.

Saudi Arabia's Vision 2030 and Maharat Construction Training Center

Saudi Arabia's Vision 2030, a comprehensive government program launched in 2016 by Crown Prince Mohammed bin Salman, amidst other things, focuses on addressing the skills gaps existing in the country. It aims to diversify the Saudi economy beyond oil and transform the country socially and culturally. It envisions a vibrant society, a thriving economy, and an ambitious nation, focusing on areas like tourism, renewable energy, and education.

At the heart of Saudi Arabia's Vision 2030 lies a fundamental challenge and opportunity – transforming the kingdom's workforce to meet the demands of a rapidly evolving construction sector. Rising to this with purpose and precision is the Maharat Construction Training Centre (MCTC, maharat.edu.sa), a pioneering institution redefining vocational excellence. Since its inception in February 2022, MCTC has rapidly emerged as a cornerstone of Saudi Arabia's Vision 2030 workforce development agenda. Born from the merger of two strategic partnership institutes, this not-for-profit institution was established with the combined expertise of Saudi Aramco, the Technical and Vocational Training Corporation (TVTC), and the Human Resources Development Fund (HRDF). MCTC works towards cultivating a highly skilled, industry-ready construction workforce through innovative, relevant training and internationally recognized certifications. In collaboration with the American Welding Society (AWS), MCTC is striving to bridge the skills gap in the Kingdom of Saudi Arabia (KSA) and transform the landscape of vocational training in Saudi Arabia's construction sector.

AWS
American Welding Society

MCTC's Comprehensive Portfolio

MCTC's portfolio spans TVTC-accredited diplomas, short courses, professional certifications, and specialized programs in welding, pipefitting, electrical, and construction safety. From day one, the center has emphasized close alignment with leading contractors' needs – both within Saudi Aramco's expansive network and among independent firms – ensuring that each graduate is immediately employable in the Kingdom's booming construction sector.

A Mission Built on Collaboration and Quality

On March 13, 2025, Maharat Construction Training Centre was distinguished as an institution excelling through the esteemed National Skills Standards Education. MCTC achieved a historic first in Saudi Arabia by earning SENSE (Schools Excelling through National Skills Standards Education) recognition from the American Welding Society. By aligning with the rigorous provisions outlined in AWS QC10 and QC11 as well as the associated EG standards, MCTC is set to offer world-class, industry-recognized SENSE Level I and II welding certifications. This recognition significantly elevates Maharat's standing in the sector, providing opportunities to cultivate a highly skilled workforce and solidifying its position as a leader in welding education and certification.

Welding Training Area at MCTC

Having also completed third party Aramco prequalification as an approved testing center, MCTC is poised to launch its AWS-accredited automated and semi-automated welding programs in September 2025. This milestone solidifies the center's leadership in welding education and positions it as the region's premier hub for advanced welding training.

In less than three years, MCTC has transformed the landscape of vocational training in Saudi Arabia's construction sector. By staying at the forefront of technological innovation, forging strategic alliances, and aligning every program with Vision 2030's Saudization goals, MCTC continues to set the standard for industry-relevant education.

As the center prepares for its AWS SENSE launch and explores new frontiers in digital and safety training, -its unwavering commitment to quality ensures that the Kingdom's construction workforce is not only larger, but smarter, safer, and more agile than ever before.

The key personnel from MCTC coordinating with AWS on the SENSE program include Mr. Hakeem Taysser Hubail, Welding Manager, who acts as the principal liaison between the welding curriculum and Maharat's overarching strategic objectives. Under the visionary leadership of Eng. Mansour Shehri, Chairman of the Board, Maharat has launched pioneering training programs that directly advance Saudi Vision 2030. Mr. Sami Musali, Managing Director, translates these strategic directives into daily operational targets, cultivating enduring partnerships with sponsoring companies, regulators, industry stakeholders, service providers, trainees and the wider community. As Business Development Director, Mr. Muntaser Ali spearheads the execution of these initiatives, ensuring mutual benefit for every Maharat partner and reinforcing Maharat's stature as a catalyst for production, Saudization, sustainability and industry excellence. In addition, MCTC staff Nikhil Sasidharan Pillai, Semiautomatic Welding Trainer; Biju Koshy, Welding Theory Trainer/ Mechatronics Engineer; Jennis James, Automatic Welding Engineer; and Reji Ramachandran, Fitting/Clamp Operator Trainer are also responsible for coordinating with AWS on the SENSE program.

AWS SENSE Program:
An Overview

AWS SENSE, a comprehensive set of minimum standards and guidelines for welding educators to follow when developing their welding training curriculum, aligns with industry-recognized national education standards. While comprehensive, these standards are also flexible enough that almost any welding program will readily be able to implement them. The SENSE exams are hosted on an LMS platform, SENSE Online. On successful completion of the program, students earn verifiable AWS certificates and wallet cards. The AWS SENSE program also offers complimentary online training.

Becoming an AWS SENSE institution is *beneficial* for both educators and students. SENSE institutions receive a complimentary one-year Educational Institution Membership with AWS which provides them access to various resources. *They also receive eight* ***free AWS reference books***, including the Welding Handbook and Guide for Nondestructive Examination of Welds, for their classroom or library. Additionally, SENSE institutions also get access to SENSE standards and exams through AWS Learning ensuring alignment with industry-recognized certifications. SENSE institutions can leverage their AWS membership to connect with other welding educators and industry professionals, fostering collaboration and knowledge sharing.

Students graduating from SENSE programs earn AWS credentials, demonstrating their proficiency and expertise in welding. They are listed in the SENSE Training Database, making them more visible to potential employers and highlighting their SENSE-certified training. AWS credentials and SENSE training can significantly improve students' career prospects, making them more competitive in the job market. Specialized welding certifications, including AWS credentials earned through SENSE, can lead to higher salary potential and better job stability.

For more information on AWS SENSE, visit:

https://www.aws.org/educators/sense/

Cementing a Legacy of Excellence through AWS SENSE

Maharat's mission to elevate the standard of vocational training in KSA is making progress through the AWS SENSE program. The skills gap in the country is being addressed by providing a standardized, internationally recognized curriculum for welding education, leading to higher quality training and certification for welders, and helping to build a skilled and employable workforce.

The AWS-MCTC collaboration through the SENSE platform enables the establishment of a comprehensive set of guidelines for welding education, ensuring that trainees receive a thorough and consistent education in the field. Since this curriculum is designed and developed by industry experts, MCTC ensures that trainees acquire the skills necessary to be hired and productive in the welding industry. The program's focus on both theoretical knowledge and practical application results in welders who are better prepared for real-world welding challenges.

The AWS-MCTC collaboration is extremely beneficial for trainees, as successful candidates will receive SENSE certificates and wallet cards, providing evidence of their skills, making them more attractive to employers in the region. SENSE-compliant programs are recognized by the U.S. Department of Education, making them eligible for funding through grants like Perkins grants, benefiting schools and businesses in the ME region. AWS is a globally recognized organization, and AWS-MCTC collaboration through the SENSE program carries international weight, making it easier for Middle Eastern welders to find opportunities in other countries. By providing a pathway for training and cert., MCTC as an AWS SENSE institution can help address the shortage of skilled welders in the Middle East, which is crucial for the region's growth and development in sectors like oil & gas, infrastructure, and manufacturing.

MCTC

in World Skills Competition

MCTC's *vision* to be the kingdom's leading institution for innovative, industry-aligned construction training is making significant strides. Their capacity has grown almost three-folds from 353 active trainees in 2022 to 993 by February 2025, offering TVTC accredited diplomas and specialized programs in welding, safety, and multi-skilling. The AWS-MCTC collaboration through the SENSE program will result in a wide range of positive outcomes for the youth of Saudi Arabia as well as for the country's economic development and industrial competitiveness.

Looking Ahead to Excellence in Welding

Operating as a not-for-profit, MCTC remains purpose-driven and agile, focused on national development and industry needs. It integrates cutting-edge training with strong industry linkages, positioning itself not just as a skills provider but as a key architect of the kingdom's construction future.

By integrating cutting-edge training with community engagement and industry collaboration, Maharat is redefining what vocational training looks like in Saudi Arabia. In doing so, it is playing a pivotal role in shaping the kingdom's construction workforce – and helping to turn the ambitions of Vision 2030 into tangible, sustainable reality.

For more information on AWS SENSE, visit:

https://www.aws.org/educators/sense/

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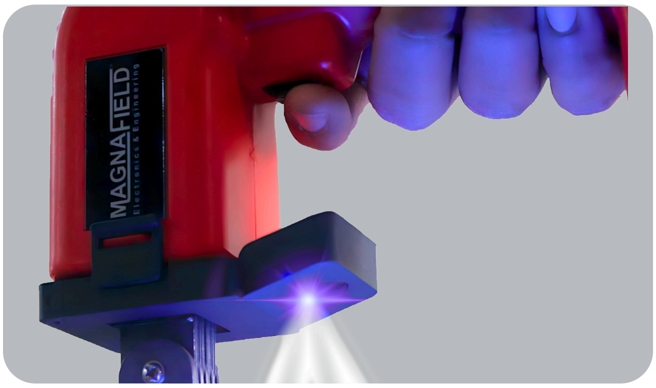

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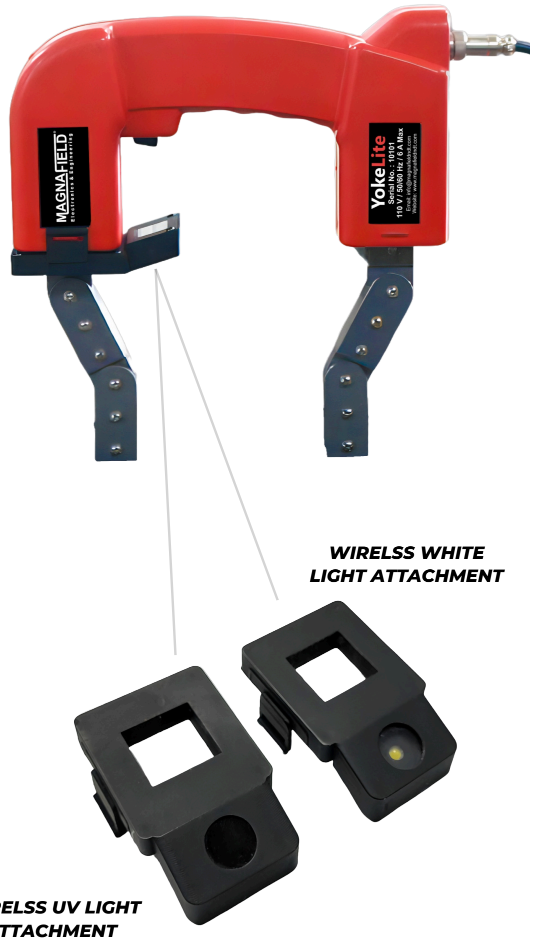

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From Hammers to High NDT Tech.

Non-Destructive Testing

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NDT Manager, Dura-Bond Industries, McKeesport, PA (USA)
Welding Expert, Welspun Pipes Inc., Little Rock, AR (USA)

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Non-Destructive Testing (NDT) is the silent sentinel of industrial safety and reliability. It enables professionals to detect flaws and defects in materials, components, and structures - without altering or damaging them. Whether it's an aircraft wing, a bridge girder, or a nuclear reactor weld, NDT ensures structural integrity and operational continuity in critical systems.

Over time, NDT has evolved from being an intuitive skill practiced by artisans to a highly sophisticated discipline driven by data, automation, and intelligent systems. Today, with the advent of NDE 4.0, the field is undergoing a digital transformation, integrating artificial intelligence, robotics, the Internet of Things (IoT), and real-time analytics to achieve predictive, precise, and proactive inspection strategies.

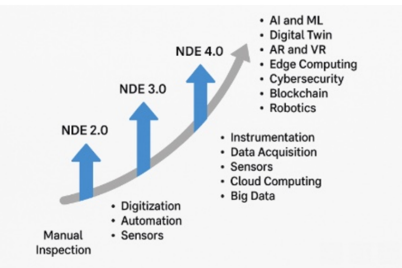


Figure 1: Evolution of Nondestructive Evaluation (NDE) Technologies

Early Practices: The Foundation of Inspection through Senses

Before the emergence of formal testing technologies, craftsmen relied on sensory inspection - sight, sound, and touch - to assess quality and detect irregularities.

- **Blacksmiths**: They would heat the metal and tap it with a hammer. By carefully listening to the sound that the metal made—a clear, crisp "ding"—they could tell if the metal was strong and free of hidden flaws. This simple test allowed them to decide if the metal was ready for use.
- **Potters**: Before putting their clay creations into the kiln, potters would closely examine each pot for any tiny cracks or weak areas. They knew that even a small crack could lead to breakage later, so they made sure each piece was perfect before firing.
- **Carpenters**: When working with wood, carpenters didn't just rely on their eyes. They would run their hands along the surface to feel for any soft spots, knots, or irregularities that might mean the wood was weak. This hands-on approach helped them ensure that the wood was solid and suitable for building.

Even the skilled Roman engineers used these sensory methods in their inspections. For example, while examining aqueducts, they would listen carefully for any hollow sounds in the stone, which could indicate problems with the foundation. Although these early methods were not as scientific as today's tests, they were extremely practical. They helped people learn to trust their senses and set the stage for the development of modern testing techniques. These methods, although rudimentary, formed the philosophical foundation of today's NDT principles: detect flaws early and non-invasively.

1900s: A New Era with X-Ray Imaging

The discovery of **X-rays by Wilhelm Roentgen in 1895** revolutionized inspection. By the early 20th century, industries began using **radiographic techniques** to identify internal flaws in welds and castings.

- Railroads and steam engines were among the first to benefit from X-ray inspections, which helped prevent catastrophic failures.
- The Titanic tragedy of 1912 underscored the need for better quality checks—if X-ray technology had been widely applied, weak rivets might have been detected in time.

1920s–1940s: War-Driven Innovation

World War II accelerated the development of diverse and more advanced NDT techniques:

- **UT:** Enabled internal flaw detection in thick metals using high-frequency sound waves—critical for naval and aerospace applications.
- **PT**: A surface inspection method using vivid dyes to reveal cracks invisible to the naked eye.
- **MT**: Allowed visualization of discontinuities on ferromagnetic surfaces through disrupted magnetic fields.

These methods allowed for fast, efficient inspections under battlefield conditions, where failure was not an option.

1950s–1970s: Standardization and Industry Integration

Post-war industrial growth led to the **formalization of NDT practices** and wider adoption across high-stakes industries:

- **Eddy Current (ET)**: Made it possible to detect subsurface flaws and measure conductivity in conductive materials, ideal for aerospace skin inspections.
- **ASNT and other global organizations** began developing standardized training, certification, and procedural guidelines, ensuring consistent inspection quality worldwide.

NDT became indispensable in nuclear energy, aviation, and petrochemicals, where operational failures could be devastating.

1980s–1990s: Digital Technologies Improve Accuracy and Efficiency

During the 1980s and 1990s, the digital revolution introduced powerful tools that made inspections faster, more precise, and easier to understand. Here's a closer look at the key changes:

- **Digital RT (DR)**: This technology replaced old-fashioned film with modern digital sensors. Instead of waiting to develop film, inspectors could see images right away on a computer. This saved time, made it easier to spot issues, and improved the quality of inspections.
- **PAUT:** This method used sound waves to check for hidden flaws in materials. Unlike older techniques, PAUT could scan from multiple angles at once and adjust the waves using a computer. This made it much better at finding and describing defects, and it reduced mistakes caused by human error.
- **Software-Assisted Analysis**: New computer programs started helping inspectors by automatically detecting flaws in the images or data. This reduced errors that could happen when people tried to interpret complex information on their own.

These digital tools greatly improved the reliability of inspections. They were especially important in industries like oil and gas pipelines, car manufacturing, and refineries, where finding and fixing problems quickly was critical to safety and quality. By making inspections more accurate and efficient, these technologies helped businesses save time and money while keeping their operations running smoothly.

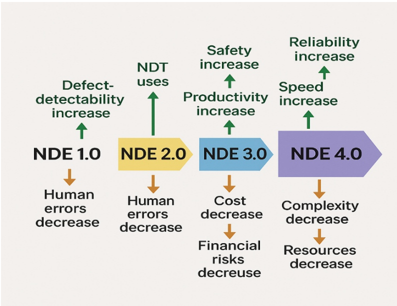
2000s–Today: The Rise of NDE 4.0

We are now witnessing the fourth industrial revolution in NDT—NDE 4.0—characterized by interconnected, smart systems. Key developments include:

Technology	Functionality	Impact
AI & Machine Learning	Processes large datasets to identify trends and predict failures	Enables predictive maintenance and decision-making
Drones & Robots	Conduct inspections in hazardous or inaccessible areas	Improves safety and efficiency
Augmented Reality (AR)	Displays inspection overlays and instructions in real time	Enhances technician accuracy and training
Digital Twins	Simulate asset behavior under real-world conditions	Allows virtual inspections and lifecycle forecasting
Blockchain	Secures and tracks inspection data records	Ensures traceability and data integrity
5G & Edge Computing	Delivers real-time data processing at the inspection site	Supports fast, localized decision-making

Real-World Example: **In wind energy, drones equipped with thermal imaging** now detect blade anomalies without requiring technicians to scale turbines, improving both safety and inspection turnaround.

Advancements in Nondestructive Evaluation (NDE) from 1.0 to 4.0



As Nondestructive Evaluation (NDE) has evolved from version 1.0 to 4.0, several key performance factors have significantly increased. NDE 1.0 brought an improvement in defect detectability, while NDE 2.0 enhanced the broader use of NDT methods across industries. With the introduction of NDE 3.0, productivity and safety saw notable growth, making inspection processes more efficient and secure. In the current era of NDE 4.0, the focus has shifted to boosting speed and reliability through the integration of smart technologies, automation, and real-time data analysis.

Alongside these enhancements, the evolution of NDE has also led to several reductions in critical areas. Both NDE 1.0 and 2.0 helped decrease human errors by standardizing techniques and promoting better training. NDE 3.0 contributed to cost reduction and minimized financial risks by streamlining inspection workflows. Finally, NDE 4.0 has significantly decreased system complexity and resource consumption, enabling more agile, accurate, and sustainable NDT operations.

Current Challenges & Industry Considerations

Despite impressive advances, the field still faces several challenges:

- **Skills Gap**: Technicians are now expected to master not only classic NDT but also digital tools, data interpretation, and automation tech.
- **High Capital Costs**: Implementing AI-driven inspection, digital twins, and robotics requires significant investment—especially burdensome for small to mid-size service providers.
- **Cybersecurity Risks**: With NDT systems increasingly connected to networks and cloud platforms, there is a rising concern over data breaches and cyberattacks on assets.
- **Data Overload**: High-resolution sensors and continuous monitoring systems generate massive datasets, making storage, processing, and interpretation a challenge.
- **Interoperability Issues**: Lack of standardization in hardware, software, and data formats can hinder the seamless integration of different tools and platforms.
- **Regulatory & Certification Gaps:** Existing NDT codes and standards often lag the technology, creating ambiguity in the compliance and certification of new systems.
- **Change Management Resistance**: Many industry stakeholders are hesitant to adopt new tech due to fear of disrupting workflows or roles.
- **AI Explainability and Trust**: The black-box nature of many AI algorithms raises concerns about the reliability of automated decisions in safety-critical inspections.
- **Limited Talent Pool:** There is a shortage of cross-disciplinary professionals who understand both engineering fundamentals and digital transformation technologies.
- **Infrastructure Limitations**: Remote or harsh environments may lack the digital infrastructure (e.g., stable internet, power supply) required for real-time NDE 4.0 operations.
- **Cost-benefit justification**: Many organizations struggle to quantify the ROI of digital transformation in NDT, which can slow down investment decisions.
- **Legacy System Integration**: Many facilities still operate with older equipment that cannot easily be upgraded or integrated into modern, data-centric systems.
- **Calibration and Validation of Smart Systems:** Ensuring accuracy and repeatability in AI-augmented or automated inspections demands new protocols for system validation.
- **Ethical and Legal Concerns**: Data ownership, consent, and liability in the event of false positives/negatives from automated systems are emerging legal challenges.
- **Global Standard Harmonization**: Different regions may adopt varying standards and protocols, leading to challenges in international projects and cross-border data usage.

A Snapshot of NDT's Evolution

Era	Methods	Innovation	Industries	Challenges	Advantages
Pre-1900s	Visual tactile auditory	Sensory inspection	Crafts masonry blacksmithing	No internal defect detection	Simple practical
Early 1900s	Radiography	First internal imaging	Rail shipping	Radiation risks slow process	Visualization of hidden flaws
1920s–1940s	UT PT MT	Acoustic & surface flaw detection	Defense aerospace	Limited surface geometry handling	Quick effective
1950s–1970s	ET UT improvements	Standardization	Nuclear aviation	Composite inspection challenges	Global reliability
1980s–1990s	DR PAUT	Digital imaging & automation	Oil & gas automotive	Equipment costs	Speed data-driven
2000s–Now	AI IoT AR	Predictive and smart systems	Energy smart cities	Cybersecurity training gaps	Real-time connected insights

The Road Ahead

Where NDT is Headed

The future promises continued evolution, with exciting possibilities on the horizon:

- Quantum Sensing: May eventually detect flaws at the atomic scale, drastically improving resolution.
- Self-Optimizing AI Systems: Will continuously learn from inspection data, reducing the need for manual interpretation.
- Sustainable Energy Integration: As green technologies grow, NDT will play a pivotal role in ensuring the safety of hydrogen pipelines, solar farms, and offshore wind platforms.

Imagine an ecosystem where **NDT sensors are embedded** within structures, continuously streaming health data—monitored and analyzed by intelligent systems capable of preemptive maintenance alerts. This is the future NDT professionals are helping to build.

Conclusion:

A Profession Built on Precision and Progress
From the clang of a blacksmith's hammer to the silent pulse of AI-driven sensors, Non-Destructive Testing has come a long way. Today's NDT professionals are not just inspectors, they are data analysts, system integrators, and strategic decision-makers.

As industries continue to evolve, NDT will remain at the core of innovation-ensuring safety, enabling sustainability, and optimizing performance. The shift to NDE 4.0 is not just a technological leapt, a professional revolution, and those equipped with the right knowledge and skills will lead the way.

Whether you're in aerospace, energy, automotive, or infrastructure, one thing remains constant: the world runs safely because of NDT.

DOPPLER®

Guangzhou Doppler Electronic Technologies INC

Guangzhou Doppler Electronic Technologies INC (stock code: 301528) was established in 2008, focusing on the field of industrial nondestructive testing and committed to providing customers with high-performance testing equipment and solutions. As a leading nondestructive testing brand in China, the company's products cover industrial ultrasonic phased array testing equipment, automatic testing systems, ultrasonic transducers, customized defect intelligent analysis software and related parts, which can fully meet the needs of customers for ultrasonic nondestructive testing.

NOVASCAN V3

(TFM) PAUT Instrument

FMC/TFM, imaging pixel 1024 * 1024
3D real imaging
DMA probe supported
Automatic defect area statistics

FLEXSCAN

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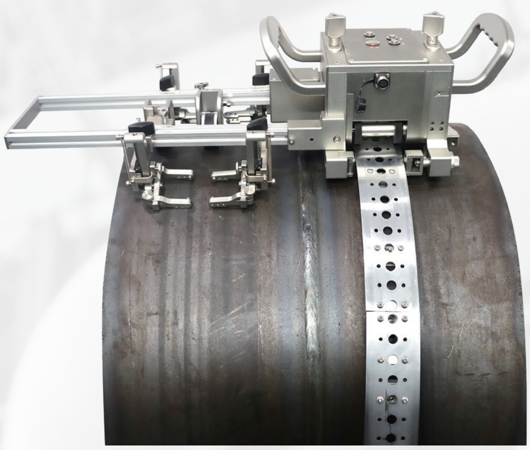
Flexscan PAUT Instrument
16/64PR 32/64PR
Premium Quality PAUT Probes
Versatile Scanners And Crawlers

SCANNER

GUIDE RAIL SCANNER FOR PIPELINE

Remote control via wire or wireless
Step of encoder: 24steps / mm
Repeated positioning accuracy: ± 1mm
Adjustable speed: 5~100 mm / sec
Protection: NEMA 4, IP65
Used for regular hard pipes, run freely on rusty, residual or frozen pipes surface



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ARORA
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Introduction

Since its inception in 2007, Arora Technologies has been a trailblazer in Non-Destructive Testing (NDT) solutions. Based in Navi Mumbai, Maharashtra, the company is committed to the "Make in India" initiative, delivering innovative and reliable NDT equipment to industries such as aerospace, oil & gas, power generation, manufacturing, and nuclear energy. With a focus on technological advancement and customer satisfaction, Arora Technologies has become a trusted partner for businesses worldwide.

Business Overview

Arora Technologies is dedicated to developing cutting-edge NDT solutions for industry-specific challenges. With a robust in-house R&D team, state-of-the-art manufacturing facilities, and strategic global collaborations, the company serves sectors like heavy engineering, aviation, petrochemicals, and power stations through three key verticals:

- **Manufacturing:** In-house design and production of NDT products and accessories.
- **Distribution:** Marketing and distribution of renowned North American and European NDT brands in India.
- **Automation:** Development of online and offline NDT systems under global technology leaders.

Comprehensive Product & Service Offerings

Arora Technologies provides a wide range of NDT solutions for quality control and defect detection:

- **Manufacturing of NDT Products:** Includes Magnetic Particle Testing (MPT) equipment, Liquid Penetrant Testing (LPT) solutions, Radiographic Testing (RT) instruments, Ultrasonic Testing (UT) devices, Eddy Current Testing (ECT) equipment, and Remote Visual Inspection (RVI) tools.
- **Distribution of NDT Solutions:** Features Ultrasonic Solutions, Electromagnetic Testing, X-ray Inspection Systems, Remote Visual Inspection (RVI) Equipment, and NDT Simulation Software & Training Aids.
- **Automated NDT Systems:** Offers Ultrasonic Testing Systems, Eddy Current Testing Systems, Magnetic Flux Leakage (MFL) Systems, and Ultrasonic Immersion Scanners.
- **Calibration & Support Services:** Provides periodic calibration, technical training workshops, and application-based support.

Manufacturing Excellence

Arora Technologies' state-of-the-art facility in Navi Mumbai adheres to global standards, with stringent quality control and an innovative R&D team ensuring precision, reliability, and compliance with ISO standards and international safety regulations.

Competitive Strengths

The company's leadership stems from:

- Technological Innovation through continuous R&D.
- Uncompromising Quality with stringent measures.
- Customer-Centric Approach with customized solutions.
- Global Collaborations bringing world-class technology to India.

Future Outlook

Arora Technologies aims for growth and sustainability by focusing on:

- Global Expansion into new markets.
- AI-Integrated & Digital NDT Solutions.
- Sustainability & Green Manufacturing practices.
- Workforce Development & Training.

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Stress Relaxation Cracking in Austenitic Materials: Mechanism, Mitigation, and ASME BPVC Code Considerations

BAHER ELSHEIKH
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Stress Relaxation Cracking (SRC) is a critical failure mode in high-temperature applications of austenitic materials, it can occur where high level of tensile residual stresses especially within the weld heat-affected zones (HAZ) or in cold formed area. It is particularly prevalent in austenitic stainless steels and nickel-based alloys used in the fabrication of critical components such as superheaters and reheaters in petrochemical and power generation industries. Unlike traditional forms of cracking like hot cracking or creep rupture, SRC develops during the relaxation of residual or applied stresses at elevated temperatures.

This article explores the fundamental mechanisms of SRC, compares Alloy 800H with stainless steel grades like SS347H in their susceptibility and response to SRC, and examines mitigation strategies under ASME Boiler and Pressure Vessel Code (BPVC) provisions as the main design code for pressure vessels and boilers in oil and gas industry and in nuclear applications as well.

Special Consideration

Addressing stress relaxation cracking (SRC) in equipment and weld joints requires special attention for three key reasons. First, SRC is challenging to detect during its early stages, yet once it initiates, it often progresses rapidly to failure in a brittle manner—typically rupture—early in the equipment's service life. Second, SRC predominantly occurs in thick-walled components operating at elevated temperatures, which are typically used in critical, high-risk applications. Third, the current design codes, such as the ASME Boiler and Pressure Vessel Code (BPVC), do not fully account for all the factors necessary to prevent SRC. A recent report by the U.S. Nuclear Regulatory Commission (NRC) [1] identified this as a significant gap in the ASME BPVC provisions.

Figure 1 [Ruptured Superheater steam coil, SS316H by SRC [2]]- shows the rupture of a superheated steam coil outlet header, made from 48 mm thick SS316H, caused by stress relaxation cracking (SRC) at the longitudinal seam weld. The rupture resulted in extensive damage within the convection section of the steam reformer at a methanol plant. Additionally, large fragments of debris were projected up to 100 meters across the site, impacting surrounding areas [2]

There are other names of stress relaxation cracking mechanism as indicted below [3]:

During fabrication	During service
Reheat cracking	Creep Embrittlement Cracking
Stress Relief cracking	Stress Induced Cracking
	Stress Assisted Grain Boundary Oxidation Cracking

Morphology and critical factors of SRC

SRC is intergranular and can be surface breaking or embedded depending on the state of stress and geometry. It is most frequently observed in coarse-grained sections of a weld HAZ; however, it can also occur in weld deposits.

In many cases, cracks initiate at some type of stress concentration. Once initiated, SRC cracks can enable further propagation by fatigue cracking.

There are three main factors contributing to SRC, 1)Residual stresses 2) Susceptible microstructure 3) elevated temperature in creep dominant regime [10]. Cracking happens without any gross plasticity, and most of the deformation is concentrated at grain boundaries. Alloys susceptible to SRC contain alloying elements that encourage the formation of fine intragranular precipitate particles, making the grains stronger than the grain boundaries.

Consequently, creep deformation resulting from stress relaxation concentrates at the grain boundaries and eventually causes intergranular cracking. [1]. That is why stabilized grades of austenitic stainless steel like SS347 and SS321 are more susceptible than SS304. [3]

Smaller grain sizes resist SRC better. Grain growth can be controlled by using lower solution annealing temperatures, achieving ASTM 4 or finer grains. Traditional heat treatment of austenitic alloys results in coarse grains (ASTM 5 and coarser), which improve creep resistance but also increase SRC risk after cold forming.[3]

The cracks are always located on the grain boundaries and in front of the crack's, small, isolated cavities are present. Mostly, a metallic filament is present on the cracked grain boundaries. This filament is enclosed by a chromium-rich oxide layer. In this oxide layer, the Ni and Fe contents are low. The chemical composition of the metallic filament is material dependent but always low in chromium and high in nickel (for 800 alloys) and iron (for SS alloys). Refer to figure-2 for typical crack morphology.

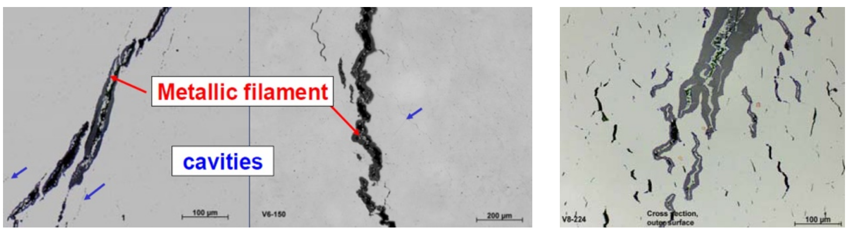

Figure-2, Typical SRC morphology showing metallic filaments enclosed by rich oxide layer [11]

Review of applicable standards and guidelines

Although SRC is well addressed and known damage mechanism, up to date there is lack of coverage of the special guidelines in the applicable codes in such a way that equipment can be designed in compliance with the design code while still prone to SRC and immature brittle failures. In this section, the most common standards and guidelines will be discussed.

ASME BPVC SEC II Part D [4]

In non-mandatory Appendix A " Issues associated with materials used in ASME code construction, paragraph A-206 addresses SRC that can occur in cold- or warm-worked austenitic materials when precipitation of temper-resistant particles occurs at defect sites introduced during mechanical working. When the material is exposed to intermediate temperatures (510°C to 760°C) during heat treatment or service, strain localizes at the grain boundaries, leading to rapid intergranular creep cracking.

The code highlights that this phenomenon has led to through-wall failures in pressure parts made from susceptible heats of materials like 347H and 310HCbN, even during heat-up for solution annealing. To reduce the risk, ASME has introduced rules in PG-19 (Section I) and UHA-44 (Section VIII, Division 1), specifically aimed at mitigating SRC risks during design and fabrication.

This inclusion confirms that SRC is recognized and partially addressed within the ASME Code framework, though additional design-specific considerations may still be necessary.

ASME BPVC SEC VIII Div.1 [5]

In Nonmandatory Appendix UHA-A, paragraph UHA-A-4 acknowledges that stress relaxation cracking (SRC) may develop in P-No. 8 materials, not only in cold-formed areas but also in weld zones where high residual tensile stresses are present. To minimize this risk, the code advises applying post-weld heat treatment (PWHT) in accordance with Table UHA-44, unless specific criteria are met—such as when the design temperature is below 1000°F (540°C) or the welding is limited to low-risk configurations (e.g., circumferential welds or fillet welds with a thickness of 13 mm or less, or specific fin welding scenarios under tightly defined limits). This reflects the code's recognition of SRC and its efforts to provide guidelines for mitigating it during design and fabrication.

It's important to highlight that Table UHA-44 recommends solution annealing as the heat treatment method for relieving stress in cold-formed parts that exceed allowable fiber elongation. For example, the minimum recommended heat treatment temperature for SS347H is 1095 °C.

Meanwhile, in the mandatory portion of the code, Table UHA-32-3 outlines PWHT requirements for P-No. 8 materials and states that PWHT is neither required nor prohibited, effectively deferring the decision to the user, guided by non-mandatory Appendix UHA-A.

This creates a grey area in the code, possibly since PWHT itself can introduce SRC under certain conditions, in addition to increasing the risk of sensitization

By contrast, the treatment of Alloy 800 series materials (UNS N08800, N08810, N08811) is more explicit. Paragraph UNF-56(d) mandates PWHT at 885 °C when the design temperature exceeds 540 °C, providing a clear preventive measure against in-service SRC. Notably, design software tools typically account for such conditional requirements, whereas manual design calculations might overlook them—posing a risk of noncompliance or design oversight.

ASME BPVC SEC I [6]

ASME Section I presents similar guidance to that of Section VIII, Division 1 regarding post-weld heat treatment (PWHT) for P-No. 8 materials. According to Table PW-39-8, PWHT is neither mandated nor prohibited. However, Note (b) in the same table suggests that PWHT may be advisable to mitigate the risk of stress relaxation cracking (SRC), particularly for thick sections operating at elevated temperatures, aligning with the recommendations in ASME Section II, Part D, Nonmandatory Appendix A. Ultimately, as in Section VIII, the decision is left to the user's discretion, based on the specific service conditions and fabrication details.

API RP 571 [7]

API RP 571 SRC as a damage mechanism discussed in Paragraph 3.54. It identifies susceptible materials including austenitic stainless steels (304H, 316H, 321, 347) and nickel-based alloys (Alloy 800H, 800HT, 617). SRC typically occurs in the 500–750°C range and is influenced by grain size, material composition, weld strength, residual stresses, section thickness, and fabrication conditions. Large grain sizes and high residual stresses, especially in thick sections, increase SRC risk. The RP also notes that stress relief or stabilization heat treatments can sometimes worsen SRC.

API TR 942A [8]

This API technical report addresses material selection, fabrication, and repair concerns for hydrogen and syngas reformer furnace outlet pigtails and manifolds. It highlights SRC as a major failure mode in these components when exposed to fabrication and operating temperatures between 500°C and 750°C. Additionally, the report includes a case history of SRC occurred in pigtail fabricated from alloy800HT see Figure-3.

Figure-3, SRC of alloy 800HT inlet pigtail [8]

API TR 942B [9]

This report examines Stress Relaxation Cracking (SRC) in austenitic alloys used in high-temperature refinery services, detailing its causes, susceptibility, and prevention.

- Report ranked the alloy Susceptibility as : 800HT > 347 SS > 800H > 321 SS > 304 SS > 316 SS (higher susceptibility in alloys with fine intergranular precipitates).
- Grain Size & Cold Deformation: Finer grains (ASTM 3.5+) resist SRC; ≥2% cold deformation increases risk, mitigated by 980°C stabilization heat treatment.
- Mitigation Strategies:
- Welding: Minimize restraint, avoid stress concentrations, and use low heat input techniques.
- Heat Treatment: PWHT (843°C to 899°C) or multistep treatment (stress relief → solution annealing → stabilizing at 593°C).
- Material Considerations: Limit Bismuth (Bi≤0.002%) in Type 308 FCAW weld metal for temperatures >538°C.

API TR 942B recommends the application of PWHT for some austenitic SS grades and at temperature quite different than the advisable by ASME BPVC. For example, the recommended PWHT temperature for SS 347 is 900 C (1hr / 25 mm, 3 hrs. minimum), followed by still air cool.

Case Histories:

The following are **two case histories** for two of the most vulnerable materials to SRC: alloy 800H and stainless steel grade347H

CASE-1:

Cracking of Alloy 800H Reformer Riser [12]

A failure occurred in a steam reformer riser where a cast HP Micro Alloy riser tube was welded to an alloy 800H transition piece. While the first incident in 2010 was caused by thermal shock from a water leak, further inspections revealed multiple cracks in the heat-affected zones (HAZ) of the 800H welds—not linked to water damage. This prompted a detailed investigation.

The cracking showed classic signs of Stress Relaxation Cracking (SRC), including:

- Intergranular cracks in the HAZ
- Voids and grain boundary oxidation
- Nickel-rich metallic filaments with chromium-depleted zones
- Cracking in areas with hardness near 200 HV
- Occurrence within 1–2 years of service at around 600°C

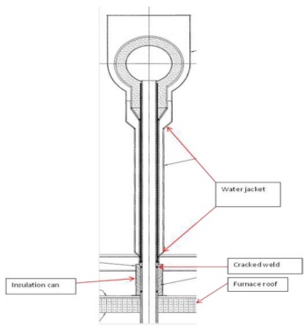

Figure 4-a Top section of the modified riser design illustrating the location of subsequent failures [12]

The design had been modified in 2006, moving the weld joint location closer to a cooler area near a water jacket. This location likely created the ideal conditions for SRC: high residual stress, coarse grains, and operating temperatures within the critical 500–750°C range.

The solution was to perform post-weld heat treatment (PWHT) at 885°C, which relieved stress and reduced hardness. After this treatment, no further cracking was observed, confirming that SRC was the root cause. Which is the recommended heat treatment condition in ASME BPVC sec VIII div.1 para UNF-56 as explained earlier in the article, and this is an example for how such requirements can be missed.

This clearly illustrates how SRC can silently damage high-temp. components and the critical role of heat treatment in preventing it—even in austenitic alloys like 800H, which were once thought to be immune

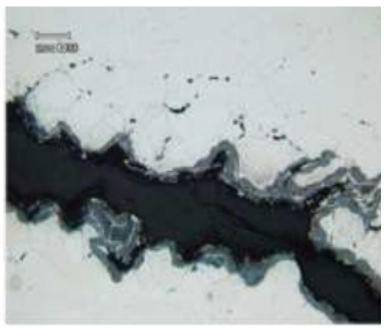

Figure 4-b Cracking of the alloy 800H transition cone with typical morphology of SRC [12]

CASE-2:

Cracking of SS 347H pipe at inlet of Steam Reformer [13]

Inlet piping of steam reformer fabricated from SS 347H failed at welded support pad. Cracking occurred in less than 16 months. The failures were observed in welded reinforcing pads and branch connections of inlet pipes. Notably, no Post-Weld Heat Treatment (PWHT) had been applied.

Key features of SRC observed included:

- Intergranular cracks originating at grain boundaries.
- Nickel-rich metallic filaments surrounded by chromium-rich oxide layers.
- Cavities and signs of localized embrittlement.
- Hardness >200 HV at crack locations with no visible plastic deformation.

Corrective actions included:

- Replacing welded supports with clamp-type supports to reduce restraint.
- Applying PWHT at 875–930°C to relieve residual stress and reduce hardness.
- Improving insulation to prevent sensitization and external corrosion.

This case history reinforces the importance of considering SRC in 347H, even when codes do not mandate PWHT, especially for thick sections, critical welds, or high-stress configurations in high-temperature environments.

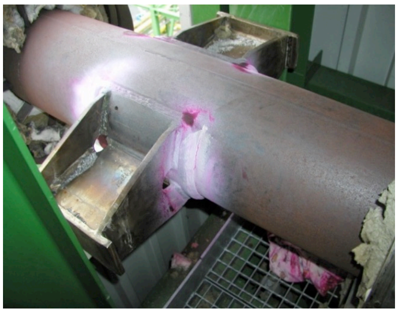

Figure 5-a Cracked pads of horizontal guides [13]

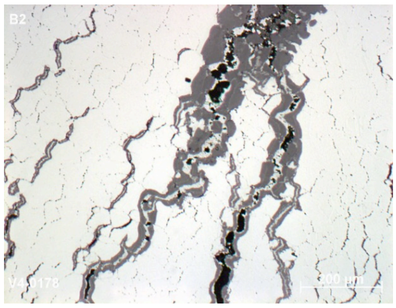

Figure 4-b Cracking of SS 347H pad with typical morphology of SRC [13]

Conclusion:

Stress Relaxation Cracking (SRC) is a critical yet often overlooked failure mechanism in austenitic stainless steels and nickel-based alloys used in high-temperature environments. While industry codes such as ASME BPVC and API standards address SRC, it remains a complex challenge influenced by residual stress, material microstructure, and operating conditions. The case studies discussed—particularly those involving SS347H and Alloy 800H—highlight that SRC can still occur even when materials are used within code limits, revealing the gap between compliance and true reliability.

To mitigate the risk of SRC, engineers must focus on minimizing cold work and residual stresses, applying appropriate post-weld heat treatment (PWHT), carefully managing grain size, and identifying high-risk configurations like thick sections and welded supports. While ASME codes acknowledge SRC, their guidance—especially on PWHT—is often non-mandatory or loosely defined, leaving engineers and designers responsible for making informed decisions. Ultimately, preventing SRC requires a combination of deeper technical understanding, proactive design strategies, and greater industry awareness. By prioritizing these factors, we can enhance the long-term integrity and reliability of high-temperature pressure equipment, reducing the likelihood of premature failures.

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Global Vanguard in Non-destructive Testing

Mohammed Abu four is a globally acclaimed leader in the field of Nondestructive Testing (NDT), with over 42 years of experience advancing inspection excellence across the oil and energy industry. A graduate of the University of Northampton (UK) with a degree in NDT, Mohammed also holds numerous professional certifications that have enabled him to play a transformative role in shaping the future of inspection technologies, quality assurance, and asset integrity.

He has mastered more than fifteen advanced NDT technologies, and this extensive expertise has empowered him to develop multiple advanced inspection techniques that have successfully resolved complex challenges across a wide range of critical applications.

As a Lifetime Member of the American Society for Nondestructive Testing (ASNT), Mohammed holds ASNT Level III certifications in UT, MT, and VT. His technical leadership has driven the enhancement of inspection procedures and the qualification and certification of both local and international NDT technicians. His unwavering commitment to excellence continues to inspire engineers and professionals to uphold the highest standards of safety, reliability, and quality.

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A strong advocate of NDT 4.0, Mohammed is dedicated to merging traditional NDT expertise with digital transformation. He champions the integration of smart technologies, real-time data, and strategic development initiatives to build intelligent, adaptive inspection ecosystems that support predictive maintenance and long-term asset reliability.

Mohammed previously served as a member of the ASNT Board of Directors and contributed to ASNT's Certification Management Committee (CMC) for over a decade. He continues to influence the global NDT landscape as an ASNT Ambassador, Industry Qualification Committee Member, and Chairman of the ASNT Saudi Arabian Section. Through these leadership roles, he fosters international collaboration and drives the professional development of the global NDT community.

Mohammed's excellence has been widely recognized—he is the recipient of six prestigious global honors in Europe and the USA, reflecting his enduring impact on inspection innovation, safety, and industry advancement.

With unmatched expertise, visionary leadership, and a passion for progress, *Mohammed Abu four remains a defining force in the evolution of NDT technologies and* the global empowerment of NDT 4.0.

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AI-Powered End-to-End Inspection Software: How deeplify's Transforms NDT Workflows

Christoph Siemer
deeplify GmbH Co-Founder & COO

Introduction: Industry Challenges

Non-destructive testing (NDT) has evolved significantly over the past two decades, with modern inspection methods generating large volumes of complex data. Despite advances in equipment and robotics, inspection data is still analyzed and reported manually slowing processes, introducing inconsistencies, and limiting scalability. At the same time, the skilled labor shortage in NDT has reached critical levels across the sector.

Industry reports indicate a significant skills gap, with estimates suggesting that thousands of new NDT technicians will be needed in the coming years. This situation is not isolated—refineries, aerospace facilities, power plants, and construction sites are all experiencing similar challenges as experienced inspectors retire without adequate replacements.

Meanwhile, inspections are becoming more complex. New materials and components require more sophisticated testing, generating larger datasets that are harder to manage and interpret. Yet NDT data often remains fragmented across devices, formats, and locations—ultrasonic data in one system, radiographs in another, and reports scattered across spreadsheets and paper archives. This fragmentation reduces efficiency and introduces risks when critical information is not easily accessible.

These challenges demand more than incremental improvements—they require a fundamental shift in how inspections are conducted and managed. That's what we focus on at **deeplify**: an end-to-end AI-powered inspection software that fully digitalizes the inspection workflow, centralizes all NDT data, and uses AI to support analysis and reporting across inspection methods—improving safety, consistency, and operational efficiency.

End-to-End AI Integration

Inspection Task Management
To this day, inspection task management often remains a fragmented process—inspection orders are still received via paper, email, PDFs, or spreadsheets, making coordination and tracking inefficient. However, the information provided by the inspection task is crucial for subsequent reporting. **deeplify** streamlines this process by enabling users to create inspection tasks directly or flexibly import them from asset management systems, regardless of format. Once a task is in the system, all critical information—such as test objects, measuring points, inspection methods, applicable standards, and instructions—is clearly organized and made accessible on the **deeplify** platform. With full visibility into job status and responsibilities, teams benefit from improved coordination and complete transparency throughout the inspection process.

The Importance of Digital Infrastructure

Data fragmentation remains a major hurdle for many NDT departments. Most inspection workflows rely on equipment from multiple vendors, each using proprietary data formats and software—making it difficult to consolidate and leverage inspection data effectively. Yet a robust digital infrastructure is essential for enabling AI-assisted analysis and digital inspection workflows.

deeplify addresses this challenge with a strong focus on data standardization and accessibility. Our platform supports all common industry formats, including DICONDE (the ASTM standard for NDT imaging), ensuring consistent, vendor-neutral data handling. We also support advanced formats like HDF5, offering flexibility for diverse data types and inspection methods. At the core of our infrastructure is a dedicated PACS (Picture Archiving and Communication System) designed specifically for NDT. With a secure, cloud-first architecture, **deeplify** provides a scalable, interoperable foundation for storing, archiving, and managing inspection data—across assets, inspection methods, and inspection teams.

Intelligent Analysis Using AI

At **deeplify**, we believe the future of NDT lies in combining human expertise with the capabilities of artificial intelligence. Currently optimized for radiographic testing and ultrasonic testing, our system is built to scale across all major NDT methods. It systematically supports and enhances human decision-making throughout each step of the inspection workflow.

1. Pre-Check: Intelligent Quality Control

Before defect analysis begins, **deeplify's** AI ensures that only high-quality records proceed. It automatically detects low-quality data, identifies artifacts or anomalies in X-ray images, and verifies the presence of essential markers like IQIs and reference objects. Automated quality control enables early identification of data quality issues, significantly reducing the need for retesting later in the process.

2. Critical Defect Screening

deeplify's AI analyzes all inspection data first to automatically flag potential critical defects. This built-in early warning system ensures that high-risk indications are prioritized for immediate human review, preventing dangerous backlogs and enabling faster response times—especially when dealing with large volumes of data.

3. Detailed Defect Analysis

Following prioritization, the software assists human inspectors with in-depth analysis:

- **AI-Based Defect Recognition**: Automatically detects, classifies, and highlights defects in the inspection data.
- **Quantitative Defect Analysis:** Precisely measures defect characteristics—such as size, shape, and location—and evaluates them against industry standards and predefined acceptance criteria.
- **Human-in-the-Loop Validation:** All AI-generated findings are presented for inspector review. Experts can validate results, make manual adjustments, or refine assessments as needed.

Compliant Inspection Reporting

deeplify automatically generates inspection reports that comply with major industry standards, tailored to the specific method and use case.

- **Structured, Method-Specific Reports**: Reports follow industry conventions, with appropriate formatting and detail for each inspection type.
- **Automated Data Extraction**: Key information—such as acquisition parameters, inspection settings, and defect measurements—is pre-filled to ensure accuracy and completeness while reducing manual effort.
- **Digital Signatures & Traceability**: Electronic approval workflows ensure full auditability and compliance with quality and data integrity standards.
- **ERP Integration**: Connection to asset management systems allows inspection results to directly inform asset integrity activities.

Measurable Impact of AI-Assisted NDT

- **Improved Safety & Consistency**: AI assistance minimizes human error and reduces interpretation variability, delivering more consistent and reliable results than traditional manual workflows. Our approach leads to more consistent defect detection and significantly improved efficiency by reducing false positives.
- **Up to 70% Higher Inspection Efficiency**: AI automation of pre-checks, defect screening, defect analysis, and reporting enables inspectors to process more data in the same amount of time.
- **100% Digital Traceability**: Every inspection is digitally recorded, fully traceable, and accessible at any time—ensuring maximum transparency and compliance.

What is Essential When Introducing AI into NDT?

Successfully digitizing NDT and leveraging AI involves far more than simply integrating pre-built models into inspections. It requires a clear understanding of the foundational elements that make AI effective, reliable, and scalable in industrial environments.

The **following pillars are essential** for any organization aiming to implement AI in NDT:

1. Holistic AI Infrastructure

Effective AI systems do not operate in isolation—they require a structured infrastructure that supports the entire AI lifecycle. This includes data preparation, model development, validation, deployment, monitoring, and continuous improvement. A successful digital NDT strategy should tightly integrate AI into every stage of the inspection—not as an add-on, but as a core component of the workflow.

2. Monitoring, Reproducibility & Continuous Learning

AI models must be actively monitored in production to ensure ongoing reliability. This includes:

- **Reproducibility**: The ability to repeat analyses and obtain consistent results under identical conditions.
- **Performance Monitoring**: Tracking accuracy over time to detect drift or degradation.
- **Retraining Pipelines**: Mechanisms to update and improve models as new data becomes available.

3. Certification and Compliance Readiness

In safety-critical environments like NDT, AI systems must meet strict regulatory and certification requirements, such as those outlined in the EU AI Act and industry-specific standards. Ensuring that AI is traceable, auditable, and explainable is essential for building trust, achieving approvals, and enabling long-term scalability.
deeplify is built around these principles from the ground up. Moreover, we actively participate in industry working groups for AI in NDT, contributing to the development of emerging standards and best practices. In parallel, we collaborate with certification partners to help our customers streamline the certification process once the system is deployed.

deeplify's AI-First Approach

These are not just best practices - they are essential building blocks for a future-ready NDT strategy.

deeplify is AI-first by design, with an integrated infrastructure that enables continuous learning, real-time monitoring, and scalable deployment.

This foundation allows organizations to confidently digitize inspections, implement AI at scale, and stay aligned with both regulatory and operational requirements - ensuring safety, consistency, and long-term reliability.

CONCLUSION & OUTLOOK

Artificial intelligence is rapidly changing the landscape of NDT. Already delivering measurable improvements in inspection quality, efficiency, and traceability—particularly in common inspection methods like radiographic and ultrasonic testing—AI is proving its value in real-world workflows. But this is only the beginning. Looking ahead, AI will continue to expand into additional NDT methods, increasing automation potential across a broader range of inspection use cases.

As AI adoption grows, so too will the standards and regulatory frameworks that guide its use. Initiatives like the EU AI Act and industry-specific certifications will play an increasingly important role in ensuring the safety, transparency, and reliability of AI systems. Continued participation in industry working groups is critical to shaping these evolving standards and ensuring practical, certifiable solutions.

Equally important is understanding the impact of AI on human performance. As AI takes over more complex analytical tasks, the role of the inspector will shift from manual evaluation to AI-assisted decision-making. This transition calls for a thoughtful human-machine collaboration model and new skill sets—from data interpretation to algorithm oversight. deeplify is actively researching how to best support this shift through system design, training, and applied studies.

In summary, the future of AI in NDT is both exciting and transformative. With the right infrastructure, a focus on responsible AI integration, and a strong commitment to collaboration and evolving standards, the industry is well positioned to unlock safer, more consistent, and more efficient inspection practices.

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Managing Surge Pressures in Liquefied Gas Terminals

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Article Synopsis

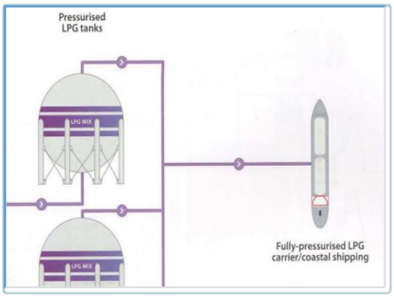
This article will explore the critical importance of managing surge pressures in liquefied gas terminals, offering insights into the physical phenomena, associated risks, and best practice mitigation strategies. Starting with an overview of how hydraulic surge analysis is integrated into the pipeline system design phase, the piece will outline the operational consequences of pressure surges during cargo transfer. It will examine how operators and engineers can recognise, prevent, and control surge pressures by understanding key contributing factors such as valve closure scenarios and emergency shutdowns.

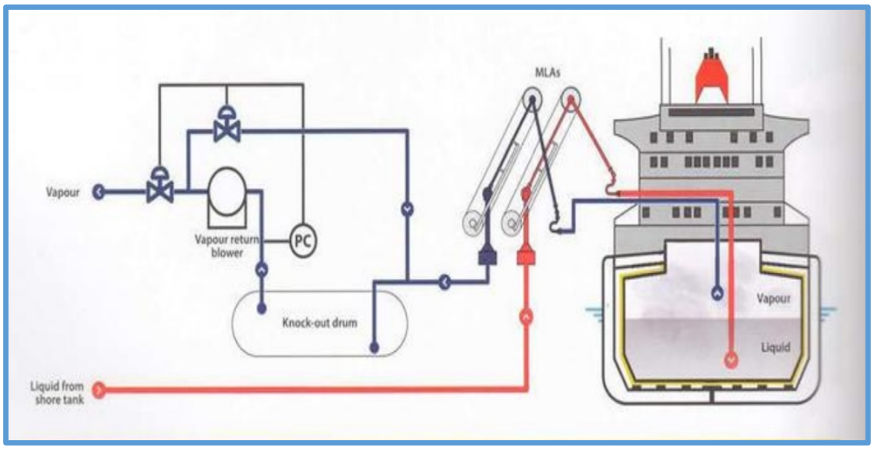
1. Liquefied Gas Terminals

Liquid gas terminals are specialized facilities designed for the storage, handling, and transfer of liquefied gases. These terminals play a critical role in the global supply chain for energy and chemical products, as they enable the efficient transportation of gases in their liquefied state, which significantly reduces their volume. Liquefied gases are typically stored in large, insulated tanks at low temperatures or high pressures to maintain their liquid form. These terminals are equipped with advanced infrastructure, including pipelines, pumps, compressors, and loading/unloading systems, to ensure the safe and efficient handling of these volatile substances. They are often located near ports, industrial zones, or distribution hubs to facilitate the import, and export of liquefied gases.
The products handled at liquid gas terminals include a wide range of liquefied gases used in various industries. The most common products are liquefied natural gas (LNG) and liquefied petroleum gas (LPG).

2. Liquefied Gas Terminals Handling Operations

The handling operations at these terminals are highly technical and involve a series of carefully controlled processes to ensure safety, efficiency, and environmental compliance. These operations include receiving liquefied gases from ships, pipelines, or railcars, storing them in insulated or pressurized tanks, and transferring them to their next destination, such as ships, trucks, or pipelines, for further distribution.



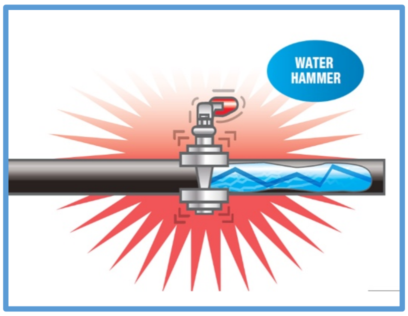


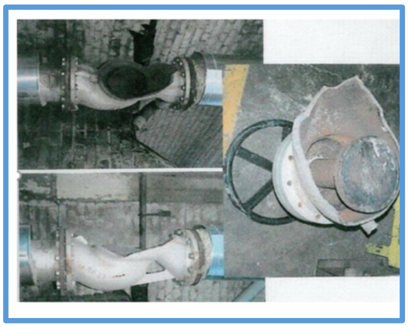
The first step in handling operations is the unloading or loading of liquefied gases from transport vessels, such as LNG carriers or LPG tankers. This process involves connecting the vessel to the terminal's loading arms or hoses, which are designed to handle cryogenic or pressurized conditions. During unloading, the liquefied gas is transferred from the ship to the terminal's storage tanks, while loading operations involve transferring the gas from the storage tanks to the vessel. These operations require precise control of flow rates, temperatures, and pressures to prevent leaks, spills, or equipment damage. Additionally, vapor return systems are often used to manage the displacement of gas vapors during loading or unloading, ensuring that pressure levels remain stable, and emissions are minimized.

Once the liquefied gas is stored in the terminal's tanks, it may undergo further handling operations, such as regasification, blending, or transfer to other modes of transport. For example, LNG terminals often include regasification facilities that convert the liquefied gas back into its gaseous state for injection into natural gas pipelines. Similarly, LPG terminals may blend propane and butane in specific ratios to meet market requirements. Throughout these operations, safety is a top priority, with terminals employing advanced monitoring systems, emergency shutdown mechanisms, and strict operational protocols to mitigate risks.
It is very important to manage many risks in such hazardous cargo operations, and in this respect, the surge pressure risk of handling liquid cargo is very important.

3. Hydraulic Surges in Liquid Gas Terminal Operations

Hydraulic surges, also known as water hammer, occur in liquid gas terminals due to the sudden changes in the velocity of a liquid or liquefied gas within a pipeline. These surges are governed by key physical principles, including the conservation of momentum, compressibility of the fluid, and elasticity of the pipeline material. When the flow of a liquid is abruptly stopped or altered such as during rapid valve closures, pump shutdowns, or sudden changes in flow direction a pressure wave is generated. This pressure wave travels through the pipeline at high speed, causing a rapid rise and fall in pressure, which can lead to mechanical stress, equipment damage, or even catastrophic failure if not properly managed.





The first principle behind hydraulic surges is the conservation of momentum, which explains how the inertia of the moving liquid resists sudden changes in velocity. When a valve is closed quickly, the liquid's momentum creates a force that compresses the fluid and the pipeline walls, generating a pressure wave. This wave propagates back and forth through the pipeline until the energy dissipates. The magnitude of the surge pressure depends on factors such as the velocity of the liquid, the speed of valve closure, and the density of the fluid. In liquid gas terminals, where liquefied gases like LNG or LPG are handled, the high density and low temperatures of these fluids can amplify the effects of hydraulic surges.

Another critical principle is the compressibility of the fluid and the elasticity of the pipeline material. While liquids are generally considered incompressible, they do exhibit slight compressibility under high pressure, which contributes to the propagation of pressure waves.

Similarly, the elasticity of the pipeline material allows it to deform slightly under pressure, which affects the speed and intensity of the surge wave. In cryogenic or pressurized systems, such as those in liquid gas terminals, the combination of fluid compressibility and pipeline elasticity plays a significant role in determining the behavior of hydraulic surges. To mitigate these effects, terminals use surge protection devices, such as surge relief valves, accumulators, and pressure dampeners, as well as operational strategies like gradual valve closures and controlled pump operations.

However, most importantly, by performing hydraulic surge analysis and calculating the maximum pressure to which the equipment will be exposed, it can know whether the designs and choices are correct, so that the operation manuals and safety barriers can work.

4. Surge Analysis

Surge analysis is conducted to predict and calculate these pressure fluctuations, evaluate their impact on the infrastructure, and design appropriate mitigation measures to ensure safe and efficient operations.

The process of surge analysis involves the use of advanced computational tools and hydraulic modeling software to simulate the behavior of liquid cargo within the terminal's pipeline network. Key parameters such as flow rates, pipeline dimensions, fluid properties (e.g., density, viscosity, and compressibility),

And operational scenarios (e.g., valve closure times or pump failures) are input into the model. The analysis calculates the magnitude and propagation of pressure waves, identifying critical points in the system where surge pressures may exceed safe limits. For liquid cargo operations involving liquefied gases like LNG, LPG, or ammonia, the analysis must also account for the unique properties of these fluids, such as their cryogenic temperatures, high pressures, and potential phase changes, which can amplify surge effects. The results of surge analysis are used to design and implement effective surge mitigation strategies.

By conducting thorough surge analysis, liquid cargo terminals can ensure the safety and reliability of their operations, protect critical infrastructure, and comply with industry standards and regulations.

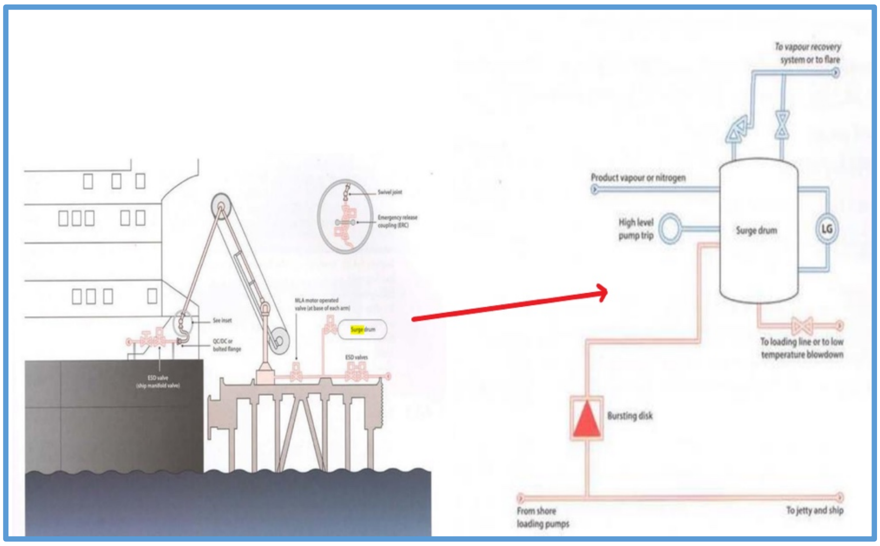
5. Surge mitigation and manage strategies.

Effective management of surge pressures involves a combination of engineering controls, operational strategies, and regular maintenance to mitigate risks and protect both personnel and infrastructure.

One of the primary methods for managing surge pressures is the use of surge protection devices. Surge Drum systems are commonly installed in pipelines to release excess pressure when a surge occurs, preventing damage to the system. Proper pipeline design, including the use of expansion loops, flexible joints, and gradual bends, also helps to minimize the impact of surge pressures by allowing the system to absorb and distribute the forces more effectively.

Operational strategies play a crucial role in managing surge pressures as well. Gradual valve closures and controlled pump start-ups and shutdowns are essential to prevent sudden changes in flow velocity, which are the primary cause of surges. In particular, the closing time of emergency shut-off valves should be determined according to the data from surge analyses and the closing time should be at a safe level.

A vital consideration, particularly during loading, is the possibility of surge pressure generation when the ship's ESD system is actuated. The situation varies from terminal to terminal and is a function of the loading rate, the length of the terminal pipeline, the rate of valve closure and the valve characteristic itself.



The phenomenon of surge pressure generation is dangerous and its effects, such as the rupture of hoses or hard arm joints, can be extreme.

Precautions are, therefore, necessary to avoid damage and sometimes-loading jetties are fitted with surge pressure drums.

Terminals should, for example, confirm the ship's ESD valve closure times and adjust loading rates accordingly, or place on board a means to allow the ship to actuate the terminal ESD system to halt the flow of cargo before the ship's ESD valves start to close. Consultation between the ship and shore should always take place to establish the parameters relevant to surge pressure generation and to agree a safe loading rate.

5.1 Reduction of Pressure Surge Hazard

1) Operational parameters for maximum allowable flow rates and minimum valve closure times should be established based on an engineering surge analysis.

2) Where motorized valves are installed, several steps can be taken to reduce the risk of pressure surge problems: Reduce the flow rate, i.e. the rate of transfer of cargo, to a value that makes the likely surge pressure tolerable. Increase the effective valve closure time. This will depend on the valve design but, in general terms, total closure times should be 30 seconds or more.

3) Use a pressure relief system, surge tanks or similar devices to absorb the effects of the surge sufficiently quickly.

4) Provide a linked ship/shore ESD system including appropriate optional activators in the system to enable cargo pumps to be stopped immediately once a surge event is initiated

5) Program valves fail in last position to prevent unexpected and immediate closure due to power failure.

Note

Where manually operated valves are used, good operating procedures should avoid pressure surge conditions. It is important that a valve at the end of a long pipeline should not close suddenly against the flow and so all changes in valve settings should be made slowly.

Conclusion

By combining engineering solutions, operational best practices, and thorough surge analysis, liquefied gas terminals can effectively manage surge pressures. This ensures the safety and efficiency of operations, protects critical infrastructure, and minimizes the risk of accidents or equipment damage.

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