Inspection and Quality Assurance of Welded Steel Storage Tanks: An API 650-Based Framework for Safe Construction and Long-Term Reliability

Prashant Gunjan

Independent Reseacher, Storage Tank, VCS quality services Pvt LYD

Abstract

Welded steel storage tanks are extensively used in the petroleum, petrochemical, chemical, power, and water industries for the storage of atmospheric liquids. Due to the large volume of hazardous and valuable products stored, maintaining the structural integrity of these tanks during construction is of paramount importance. The American Petroleum Institute (API) Standard 650 provides internationally accepted requirements for the design, material selection, fabrication, erection, welding, inspection, testing, and acceptance of above-ground welded steel storage tanks.

This paper presents a comprehensive inspection and quality assurance framework based on the engineering principles of API 650 and practical industrial inspection experience. The study examines critical inspection activities including material verification, hydraulic jacking, fit-up inspection, welding quality control, non-destructive examination (NDE), dimensional inspection, nozzle orientation, coating inspection, hydrostatic testing, and documentation. In addition, the paper discusses occupational safety requirements during tank erection and the emerging role of Industry 5.0 technologies, including artificial intelligence (AI), machine vision, drones, and digital inspection systems in improving inspection accuracy and reducing construction defects.

The proposed framework demonstrates that systematic inspection throughout the construction process significantly improves weld quality, dimensional accuracy, corrosion resistance, and structural reliability while reducing rework, leakage, and operational failures. The findings provide practical guidance for quality engineers, welding inspectors, project managers, and construction organizations involved in the fabrication and erection of API 650 storage tanks.

Keywords: API 650, Storage Tank, Quality Assurance, Welding Inspection, NDT, Industry 5.0, Artificial Intelligence, Risk Assessment, Hydrostatic Testing, Digital Inspection

1. Introduction

Atmospheric welded steel storage tanks are essential infrastructure in petroleum refineries, oil terminals, chemical plants, fertilizer industries, power plants, ethanol facilities, and water treatment systems. These tanks are designed to safely store large quantities of liquids while maintaining structural integrity throughout their service life. Any defect introduced during fabrication or erection can compromise safety, increase maintenance costs, and potentially lead to environmental contamination or catastrophic failure.

The quality of a storage tank depends not only on engineering design but also on strict adherence to construction standards and inspection procedures. API 650 has become the globally recognized standard for the construction of welded steel storage tanks because it establishes requirements for materials, fabrication, welding, inspection, testing, and acceptance. Compliance with these requirements minimizes construction defects and ensures that tanks are fit for long-term service.

Quality assurance begins with the inspection of raw materials and continues through every stage of fabrication and erection. Material certificates, welding procedure qualifications, dimensional verification, non-destructive examination, coating inspection, and hydrostatic testing collectively contribute to the production of a safe and reliable storage tank.

Practical field experience indicates that many construction defects originate from improper fit-up, inadequate welding practices, dimensional deviations, insufficient inspection, or poor documentation. Common defects include porosity, slag inclusions, lack of fusion, shell misalignment, incorrect nozzle orientation, coating failures, and leakage during hydrostatic testing. These deficiencies often result in costly repairs and project delays.

Recent advancements in digital technologies have transformed inspection practices. Industry 5.0 integrates artificial intelligence, machine vision, cloud computing, drones, and real-time monitoring systems into quality assurance activities. These technologies enable automatic defect detection, digital documentation, predictive maintenance, and improved decision-making during construction.

This paper combines the engineering principles of API 650 with practical inspection methodologies used in industrial projects to propose a comprehensive quality assurance framework for welded steel storage tanks.

2. Research Objectives

The objectives of this research are:

1. To study the inspection requirements during the construction of API 650 welded steel storage tanks.
2. To evaluate the importance of material inspection, fit-up, welding, coating, and dimensional verification.
3. To analyze the contribution of non-destructive examination in ensuring weld quality.
4. To investigate the role of hydrostatic testing in verifying structural integrity and leak tightness.
5. To identify critical construction defects and recommend preventive inspection measures.
6. To emphasize the importance of quality documentation and traceability.
7. To explore the application of Industry 5.0 technologies and artificial intelligence in modern storage tank inspection.

3. Literature Review

The construction of welded steel storage tanks has evolved considerably with advancements in welding technology, inspection methods, and international engineering standards. API 650 provides comprehensive technical requirements for the design and construction of atmospheric storage tanks and is widely adopted throughout the petroleum and process industries.

Previous studies have shown that welding defects remain one of the primary causes of structural failures in storage tanks. Researchers have emphasized that proper joint preparation, qualified welding procedures, certified welders, and systematic inspection significantly reduce weld discontinuities and improve structural performance.

Non-destructive examination methods, including Visual Testing (VT), Radiographic Testing (RT), Ultrasonic Testing (UT), Magnetic Particle Testing (MT), and Liquid Penetrant Testing (PT), have become indispensable quality assurance tools. These techniques allow inspectors to detect surface and subsurface discontinuities without causing damage to the structure, thereby improving construction quality while minimizing repair costs.

Material quality has also been identified as a critical factor influencing tank reliability. Verification of Material Test Certificates (MTCs), chemical composition, mechanical properties, and heat number traceability ensures that only compliant materials are incorporated into construction.

Dimensional inspection plays an equally important role. Measurements of shell plumbness, roundness, circumference, verticality, and nozzle orientation ensure that the completed tank satisfies design tolerances and facilitates proper installation of piping and accessories.

Hydrostatic testing represents the final verification stage before commissioning. A successful hydrotest confirms that the completed structure can safely withstand operational loading conditions without leakage or unacceptable deformation.

Recent literature has increasingly focused on the integration of artificial intelligence, machine vision, robotics, drones, laser scanning, and digital quality management systems into industrial inspection. These technologies enhance inspection efficiency by enabling real-time defect detection, digital record management, and predictive quality control.

Although numerous publications discuss individual aspects of storage tank inspection, limited research integrates practical construction experience with the complete quality assurance process prescribed by API 650. This study addresses that gap by presenting a comprehensive inspection framework applicable throughout the entire fabrication and erection process.

4. Research Methodology

This study adopts a qualitative and practice-oriented research methodology based on internationally recognized engineering standards, industrial inspection procedures, and practical experience in the construction of welded steel storage tanks. The research integrates the requirements of API 650 with field inspection practices used during tank fabrication and erection.

The study examines each stage of storage tank construction, beginning with material receipt and concluding with commissioning. Information was synthesized from engineering standards, quality assurance documentation, inspection procedures, and practical observations to develop a systematic inspection framework.

The research methodology consists of the following stages:

1. Review of API 650 requirements for fabrication, welding, inspection, and testing.
2. Analysis of quality control activities during tank construction.
3. Evaluation of inspection techniques and non-destructive examination methods.
4. Assessment of occupational safety practices during tank erection.
5. Investigation of digital inspection technologies associated with Industry 5.0.
6. Development of recommendations to improve construction quality and reliability.

This methodology enables the identification of critical inspection points that significantly influence the structural integrity and service life of welded steel storage tanks.

4.1 Research Gap

Existing studies on API 650 primarily focus on the design requirements, welding procedures, non-destru ctive examination (NDE), or isolated aspects of storage tank construction. While these studies provide valuable technical guidance, limited research presents a comprehensive inspection framework that integrates all stages of quality assurance—from material receipt and fit-up to welding, coating, dimensional inspection, hydrostatic testing, documentation, and final commissioning—based on practical field implementation.

Furthermore, most published studies emphasize conventional inspection techniques and provide limited discussion on the application of emerging Industry 5.0 technologies, such as artificial intelligence (AI), machine vision, drones, and digital inspection systems, for real-time quality monitoring during storage tank construction.

This study addresses these gaps by proposing an integrated API 650-based quality assurance framework that combines established inspection practices with practical industrial experience. In addition, the study highlights how modern digital technologies can support inspectors by improving defect detection, documentation, traceability, and overall construction quality.

5. Inspection Framework During Storage Tank Construction

Quality assurance should begin before fabrication starts and continue until commissioning. Every construction stage requires systematic inspection to ensure compliance with engineering drawings, project specifications, and API 650 requirements.

5.1 Material Inspection

Material inspection is the first quality control activity during storage tank construction. Only approved materials should be used for fabrication.

Each steel plate should be accompanied by a Material Test Certificate (MTC), which includes:

- Material grade
- Heat number
- Plate thickness
- Chemical composition
- Mechanical properties
- Manufacturer's identification

Inspectors should verify that the heat number stamped on each plate matches the corresponding Material Test Certificate to maintain complete material traceability.

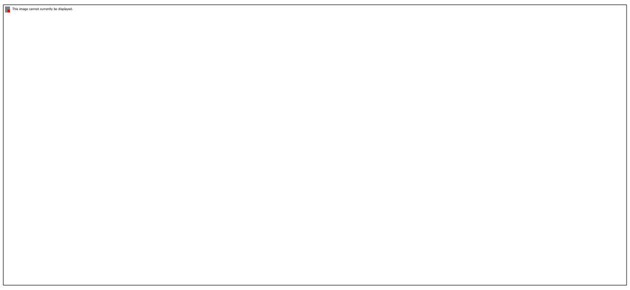
Chemical properties should satisfy the specified limits for carbon, manganese, phosphorus, sulfur, and alloying elements. Mechanical properties, including yield strength, tensile strength, elongation, and impact toughness (where applicable), should also comply with the specified material standard.

Plates should additionally be inspected for surface defects such as cracks, laminations, corrosion, dents, edge damage, and excessive warping before fabrication begins.

The use of certified materials significantly improves the long-term durability and reliability of storage tanks.

5.2 Hydraulic Jack Inspection During Shell Erection

Hydraulic jacking systems are widely used during shell erection. As additional shell courses are fabricated, the lifting load continuously increases.



Before lifting operations begin, the hydraulic jacks should be inspected for:

- Load carrying capacity
- Calibration
- Hydraulic pressure
- Leakage
- Stability of supporting columns
- Synchronization of lifting

The total lifting capacity should safely exceed the combined weight of shell courses and temporary construction loads.

Uneven lifting may result in:

- Poor shell alignment
- Improper fit-up
- Excessive root gap
- Plate mismatch
- Increased welding distortion

Routine monitoring throughout lifting operations is therefore essential for maintaining dimensional accuracy.

5.3 Fit-up Inspection

Proper fit-up is essential for producing sound welds.

Inspectors should verify:

- Root gap
- Plate alignment
- Edge preparation
- Groove angle
- High-low (misalignment)
- Tack weld quality

For thicker plates, joint preparation should conform to the approved Welding Procedure Specification (WPS). Where specified by the design and qualified welding procedure, a double-V groove joint may be adopted for thicker plates to achieve full penetration while reducing welding distortion.

Improper fit-up often results in welding defects, increased repair rates, and dimensional deviations.

5.4 Welding Quality Control

Welding is one of the most critical operations during storage tank construction.

All welding should be performed according to approved:

- Welding Procedure Specification (WPS)
- Procedure Qualification Record (PQR)
- Welder Performance Qualification (WPQ/WQT)

Inspectors should verify:

- Welding process
- Electrode or filler material
- Welding current
- Voltage
- Travel speed
- Heat input
- Preheating (where required)
- Interpass temperature
- Welding sequence

Compliance with qualified welding procedures ensures consistent weld quality and minimizes construction defects.

5.5 Common Welding Defects

Several welding discontinuities may occur during fabrication.

Weld defect	Percentage
Porosity	35%
Slag inclusion	25%
Lack of fusion	20%
Undercut	12%
Others	8%

Porosity

Porosity develops when gas becomes trapped in the molten weld pool before solidification.

Common causes include:

* Moisture contamination
* Dirty base metal
* Improper shielding
* Incorrect welding parameters

Proper cleaning of the joint, correct storage of welding consumables, and adherence to the WPS reduce the occurrence of porosity.

Slag Inclusion

Incomplete removal of slag between weld passes may result in slag inclusions.

Each weld pass should therefore be cleaned thoroughly before depositing the next weld layer.

Weld Reinforcement

Weld reinforcement should comply with the acceptance criteria specified in the project requirements. Excessive reinforcement may create stress concentrations, while insufficient reinforcement may indicate inadequate weld deposition.

Visual inspection should verify weld profile, reinforcement, continuity, and surface finish before non-destructive examination is performed.

6. Non-Destructive Examination (NDE)

Non-Destructive Examination (NDE) is an integral part of the quality assurance process during the fabrication and erection of API 650 welded steel storage tanks. NDE techniques are employed to detect surface and internal discontinuities without impairing the serviceability of the structure. The extent and acceptance criteria for examination shall comply with API 650 and the approved Inspection and Test Plan (ITP).

6.1 Visual Testing (VT)

Visual Testing is the primary inspection method and should be performed on all welds (100% VT). Inspection is carried out before welding, during welding, and after completion of welding to identify visible defects.

Typical observations include:

- Cracks
- Undercut
- Overlap
- Excessive or insufficient weld reinforcement
- Arc strikes
- Incomplete fusion visible at the surface
- Surface porosity
- Weld profile and finish

Since visual inspection is the first level of quality control, early detection of defects reduces repair costs and prevents the propagation of discontinuities into subsequent welding stages.

6.2 Dye Penetrant Testing (PT)

Dye Penetrant Testing is used to detect surface-breaking defects in welds. In many projects, the root pass is subjected to 100% PT before subsequent weld passes are deposited, ensuring that cracks or pinholes are identified and repaired at an early stage.

6.3 Radiographic Testing (RT)

Radiographic Testing is employed to examine the internal quality of butt welds.In API 650 Section 8.1, 100% Radiography is optional (Design Joint Efficiency E = 1.0). Spot Radiography (E = 0.85) or No Radiography (E = 0.70, for thin shells/specific design cases) are standard options dependent on shell thickness and design stress. Clarify that RT frequency depends directly on the designated Joint Efficiency (E) selected in design.

6.4 Vacuum Box Testing:

Essential for 100% of bottom plate and roof plate lap welds and shell-to-bottom inside fillet welds (if chalk-kerosene is not used).

7. Dimensional Inspection

Dimensional accuracy is essential for the structural integrity and proper functioning of storage tanks.

7.1 Plumbness Verification

After completion of each shell course, plumbness should be checked at several locations around the tank. Proper vertical alignment ensures correct fit-up of subsequent shell courses and minimizes welding distortion.Plumbness (Verticality): Max out-of-plumbness from top to bottom shall not exceed 1/200 of total height [API 650 7.5.2].

Poor plumbness may result in:

- Plate misalignment
- Excessive root gap
- High-low mismatch
- Increased residual stresses
- Difficulty during roof installation

Peaking and Banding:

Peaking at vertical weld joints: Max 13mm (1/2in.) measured using a 36-inch (900mm) curved sweep board [API 650 7.5.4].

Banding at horizontal weld joints: Max 13mm (1/2in.) measured using a 36-inch (900mm) straight edge [API 650 7.5.5].

7.2 Roundness Measurement

Radius tolerance measured at 1ft above the shell-to-bottom weld (e.g.+-13mm to +-25mm depending on diameter) [API 650 7.5.3].

7.3 Nozzle

The orientation of nozzles is another critical dimensional parameter. Each nozzle should be installed at the correct angular position, elevation, and projection according to the approved construction drawings.

Incorrect nozzle orientation may lead to piping misalignment, additional field modifications, excessive stresses, and delays during commissioning.

8. Coating Inspection

Protective coatings are applied to minimize corrosion and extend the service life of storage tanks.

Before coating application, inspectors should verify:

- Surface cleanliness
- Surface profile
- Ambient temperature
- Relative humidity
- Dew point

During coating application, wet film thickness should be monitored, and after curing, Dry Film Thickness (DFT) should be measured using calibrated instruments.

Proper coating inspection significantly reduces corrosion-related failures and maintenance costs throughout the service life of the storage tank.

9. Leak Testing and Final Acceptance

9.1 Hydrostatic Testing

Hydrostatic testing is the final acceptance test performed after completion of fabrication. The storage tank is gradually filled with water according to the approved testing procedure.Water quality requirement: If testing stainless steel tanks, water chloride content must be kept below 50ppm(or 250ppm for carbon steel depending on standing time) to prevent pitting/SCC.

Specify foundation settlement readings: Measurements should be taken before filling, at filling stages (25%, 50%, 75%, 100%), during the holding period (min 24 hours), and after emptying.

A successful hydrostatic test confirms the structural integrity and leak-tightness of the storage tank and demonstrates its suitability for commissioning.

9.2 Pneumatic Leak Testing

Pneumatic testing is commonly performed on reinforcing pads (repads), manholes, and sump connections. Air pressure is introduced into the test cavity, and any leakage is detected using an approved leak-detection method. standard pneumatic pressure for repads is 100kPa (15psig) using soapy water solution for bubble test [API 650 7.3.5].

9.3 Chalk–Kerosene / Vacuum Box Test

The chalk–kerosene test is commonly used for the shell-to-bottom corner joint. Kerosene is applied to one side of the weld while chalk is applied to the opposite side. If kerosene penetrates through the weld and appears on the chalk surface, leakage is indicated and the weld must be repaired before acceptance. Vacuum Box Testing (at 21kPa to 35kPa /3–5psi vacuum) is the primary method for bottom plate seams under current field practices.

10. Safety During Storage Tank Construction

Safety is a fundamental requirement during storage tank fabrication and erection.
Most construction activities involve working at height, lifting heavy shell courses, hot work, and confined spaces. Therefore, appropriate safety measures should include:

- Properly designed and inspected scaffolding.
- Certified lifting equipment and hydraulic jacks.
- Full-body safety harnesses and lifelines for personnel working at height.
- Hot work permits for welding and cutting operations.
- Personal Protective Equipment (PPE), including helmets, gloves, safety shoes, eye protection, and fire-resistant clothing.
- Fire prevention measures and emergency response planning.
- Daily toolbox talks and risk assessments before commencing work.

Strict implementation of safety procedures minimizes accidents and enhances productivity.

11. Quality Documentation

Comprehensive documentation provides traceability and demonstrates compliance with project specifications.
The final quality dossier should include:

- Material Inspection and Receiving Report (MIR/IMIR)
- Material Test Certificates (MTC)
- Purchase invoices
- Fit-up inspection reports
- Welding inspection reports
- NDE reports
- Coating inspection reports
- Dimensional inspection reports
- Hydrostatic and pneumatic test reports
- Calibration certificates
- Commissioning and final acceptance reports

Proper documentation facilitates audits, maintenance planning, and future inspections throughout the operational life of the storage tank.

12. Industry 5.0 and Artificial Intelligence in Tank Inspection

Industry 5.0 introduces advanced digital technologies that enhance the efficiency and accuracy of inspection activities.

Artificial Intelligence (AI), machine vision, drones, laser scanning, and digital monitoring systems can be integrated into storage tank construction to perform real-time inspection of fit-up, welding, and coating quality.

Inspection item	Conventional	AI-based
Fit up	Manual	Camera + AI
Welding	Inspector	Real-time AI
Coating	DFT gauge	Digital monitoring
Documentation	Paper	Cloud based

AI-assisted camera systems are capable of detecting defects such as undercut, porosity, incomplete fusion, and improper weld profiles during welding operations. Real-time feedback enables immediate corrective actions, reducing repair work and improving construction quality.

Digital inspection platforms also improve traceability by automatically recording inspection data, photographs, and quality reports. The integration of Industry 5.0 technologies is expected to improve inspection reliability, reduce human error, enhance safety, and support predictive quality management in future storage tank construction projects.

Potential Failure	Possible Cause	Inspection Method	Preventive Action
Leakage from Weld Joint	Porosity, Lack of Fusion, Cracks	Radiographic Testing (RT), Ultrasonic Testing (UT), Visual Inspection (VT) Weld repair, re-inspection, procedure	Weld repair, re-inspection, procedure improvement
Roof Misalignment	Poor Plumbness, Incorrect Assembly	Survey Measurement, Dimensional Inspection	Realignment, correction of erection sequence
Shell Deformation	Improper Welding Sequence, Residual Stress	Visual Inspection, Dimensional Survey	Controlled welding sequence, stress management
Corrosion Failure	Poor Surface Preparation, Coating Defects	Dry Film Thickness (DFT), Holiday Testing	Surface preparation improvement, recoating
Foundation Settlement	Improper Foundation Work	Level Survey, Settlement Monitoring	Foundation correction, periodic monitoring
Nozzle Misalignment	Incorrect Fabrication or Installation	Dimensional Inspection, Alignment Check	Repositioning and welding correction
Weld Defects	Improper Welding Parameters	VT, PT, MT, RT	Welder qualification, repair welding

13. Discussion

The construction of welded steel storage tanks requires a systematic quality assurance program that integrates inspection activities throughout every stage of fabrication and erection. This study demonstrates that compliance with API 650 requirements, combined with practical inspection procedures, significantly improves the structural integrity, safety, and operational reliability of storage tanks.

Material inspection forms the foundation of quality assurance. Verification of Material Test Certificates (MTCs), heat number traceability, and mechanical and chemical properties ensures that only compliant materials are incorporated into the tank. The use of certified materials minimizes the risk of brittle fracture, premature corrosion, and structural failure during service.

Proper fit-up and welding are equally important. Qualified welding procedures (WPS), Procedure Qualification Records (PQRs), and qualified welders (WPQ/WQT) provide consistency in weld quality. Inspection during fit-up reduces misalignment, improper root gaps, and distortion, while effective welding supervision minimizes discontinuities such as porosity, slag inclusions, incomplete fusion, and excessive reinforcement.

Non-destructive examination (NDE) plays a vital role in verifying weld quality. Visual Testing (VT), Dye Penetrant Testing (PT), Radiographic Testing (RT), and other examination methods enable inspectors to identify defects before the tank is placed into service. Dimensional inspections, including shell plumbness, circumference verification, and nozzle orientation, ensure compliance with design tolerances and facilitate proper assembly.

Coating inspection and hydrostatic testing provide additional assurance of long-term performance. A correctly applied protective coating reduces corrosion, while successful hydrostatic testing demonstrates structural integrity and leak tightness before commissioning.

The integration of Industry 5.0 technologies offers new opportunities for improving inspection efficiency. Artificial intelligence, machine vision, drones, laser scanning, and digital quality management systems enable continuous monitoring, automatic defect detection, and enhanced traceability. These technologies have the potential to reduce human error, improve productivity, and support predictive quality assurance in future storage tank projects.

Overall, inspection should not be viewed as a final acceptance activity but rather as a continuous quality management process that begins with material procurement and continues until commissioning.

Study Limitations.

This study is primarily based on API 650 and practical field experience.

Experimental validation was not conducted.

AI applications discussed are conceptual.

Findings may require adaptation for cryogenic or pressure storage tanks.

14. Conclusion

Storage tanks are critical assets in the petroleum, petrochemical, chemical, and energy industries. Their safety and reliability depend on strict adherence to recognized engineering standards and systematic quality control throughout construction.

This study developed a comprehensive inspection framework based on the engineering principles of API 650 and practical industrial experience. The framework covers material inspection, hydraulic jacking, fit-up verification, welding quality control, non-destructive examination, dimensional inspection, coating inspection, hydrostatic testing, documentation, and safety management.

Thezstudy concludes that:

- Proper material verification using Material Test Certificates and traceability significantly improves structural reliability.
- Correct fit-up and qualified welding procedures reduce weld defects and minimize repair work.
- Comprehensive NDE ensures that welding discontinuities are identified before commissioning.
- Dimensional inspection, including plumbness, circumference, and nozzle orientation, improves fabrication accuracy.
- Coating inspection and hydrostatic testing enhance corrosion protection and confirm leak-tightness.
- Comprehensive quality documentation ensures traceability and supports future maintenance activities.
- Industry 5.0 technologies, including AI-assisted inspection and digital quality management systems, have the potential to revolutionize storage tank inspection by enabling real-time monitoring and predictive quality assurance.

A systematic inspection program based on API 650 principles not only improves construction quality but also enhances operational safety, extends service life, and reduces lifecycle maintenance costs.

15. Future Scope

Future research should focus on integrating advanced digital technologies into storage tank construction and inspection. Potential areas include:

- AI-based automatic weld defect detection.
- Drone-assisted visual inspection of large storage tanks.
- Robotic inspection systems for confined spaces.
- Digital twins for monitoring tank construction and operation.
- Laser scanning for dimensional verification.
- Machine learning models for predicting welding defects.
- IoT-based sensors for real-time monitoring during hydrostatic testing.
- Risk-based inspection strategies integrated with digital quality management systems.
- Mention 3D Terrestrial Laser Scanning (TLS) specifically for dimensional inspection. TLS rapidly generates point clouds to measure shell roundness, plumbness, peaking, banding, and settlement profiles faster and with higher precision than manual sweep boards.

These developments will contribute to safer, smarter, and more efficient storage tank construction practices.

References

1. American Petroleum Institute (API). (2020). API Standard 650: Welded Tanks for Oil Storage (13th Ed.). Washington, D.C.: API.
2. American Petroleum Institute (API). (2020). API Standard 653: Tank Inspection, Repair, Alteration, and Reconstruction (5th Ed.). Washington, D.C.: API.

3. American Society of Mechanical Engineers (ASME). ASME Boiler and Pressure Vessel Code (BPVC), Section V (Nondestructive Examination) & Section IX (Welding and Brazing Qualifications).
4. American Welding Society (AWS). (2020). AWS D1.1/D1.1M: Structural Welding Code – Steel. Miami, FL: AWS.
5. American Society for Nondestructive Testing. *Nondestructive Testing Handbook*.
6. International Organization for Standardization. *ISO 3834: Quality Requirements for Fusion Welding of Metallic Materials*.
7. International Organization for Standardization. *ISO 17635: Non-destructive Testing of Welds – General Rules*.
8. NACE International. *Corrosion Control Standards for Protective Coatings*.
9. American Petroleum Institute. *API Recommended Practice 577: Welding Inspection and Metallurgy*.
10. American Petroleum Institute. *API Recommended Practice 580: Risk-Based Inspection*.
11. Recent peer-reviewed journal articles on storage tank inspection, welding quality, non-destructive testing, and AI-assisted inspection technologies (2020–2026).
12. Zhang, M., Xu, X., Polzer, J., et al. (2026). Data-driven artificial intelligence methods for real-time welding defect diagnosis: A critical review and future outlook. Journal of Manufacturing Processes, 161, 49–63.
13. Eren, B. (2025). Deep learning approaches for weld defect detection: A comprehensive review of models, applications, and future directions. Computers & Industrial Engineering.
14. Xu, Y., & Wang, Z. (2021). Visual sensing technologies in robotic welding: Recent research developments and future interests. Sensors and Actuators A: Physical, 320, 112551.
15. Parmar, K., Jain, R., et al. (2026). A misclassification-aware explainable hybrid CNN–Vision Transformer framework for radiographic weld inspection. Scientific Reports, 16
16. (2026). Advancements in Intelligent Robotic Arc Welding: A Comprehensive Review of AI and Sensor Integration. China Welding.
17. Zhou, Z. (2026). A Review of the Development and Application of Artificial Intelligence in the Safety Inspection of Chemical Storage Tanks. International Journal of Emerging Technologies and Advanced Applications.
18. Thelen, A., Zhang, X., Fink, O., et al. (2022). A Comprehensive Review of Digital Twin – Part 1: Modeling and Twinning Enabling Technologies.
19. Das, G., Honnavalli, P. B., & Balasubramanyam, A. (2026). Digital Twins for Visual Inspection of Large Structures: A Systematic Review. IEEE Access.
20. Zhou, H. A., et al. (2026). Generative AI in Industrial Machine Vision: A Review. Journal of Intelligent Manufacturing.
21. (2026). Digital technologies for real-time 3D modeling and autonomous UAV inspection in complex distribution networks: A review. Digital Engineering.

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quality assurance and safe construction practices in the petroleum and process industries.