IT INSPECTION TRENDS

AUGUST 2026

THE MAGAZINE FOR MATERIALS INSPECTION AND TESTING PERSONNEL

The Evolution of Welding Automation and Inspection

Eddy Current for Corrosion Detection

Modernizing Documentation and Reporting

PLUS: WHAT WELDING INSPECTORS SHOULD AND SHOULDN'T DO ■ ALLOYING ELEMENTS IN IRON ■ USING AI TO WRITE AND AUDIT WELDING DOCUMENTS

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AWS MISSION STATEMENT: The mission of the American Welding Society is to advance the science, technology, and application of welding and allied joining processes worldwide, including brazing, soldering, and thermal spraying.

Cover Photo: Eddy current testing inspection of a weld on a pressure vessel for water storage. (Credit: Jorge T. Reyna.)

Building a Quality Program from Scratch

BY BILL KOMLOS

I start important projects by taking them apart and rebuilding them from scratch. It's how I distinguish between what is required and what must be done to meet those requirements. Many quality management approval programs are recognized worldwide, and this approach works for any of them. The American Institute of Steel Construction (AISC) 207, *Standard for Certification Programs,* establishes quality management expectations for structural steel contractors in the United States. The organization's technical guidance for crafting robust quality manuals is free and easy to follow. This is how I write a quality program from scratch.

- Use word search or find to seek the first "shall" specified in the standard pertinent to the company.
- Copy the "shall" requirement into the quality manual outline.
- Figure out how the company will accomplish the "shall." Talk with people.
- Tailor compliance procedures. See the paragraph below for more guidance.
- Copy the "how" to address the "shall" into the quality manual outline.
- Repeat until each "shall" has been addressed.

In between each specified "shall," one can be creative. Reading between the lines of AISC 207 and its accompanying commentaries often reveals several opportunities for compliance. The standard defines the requirements; the "how" is up to the contractor.

One area where this approach becomes especially important is the development of quality goals. Once the required procedures are documented, companies still need meaningful ways to measure whether the system is working. One of my customers, a crusty old salt off Utah's West Desert, turned poetic when I asked what his company's quality goal might be.

"Make money!" he proclaimed.

That's always the first answer from an owner. I reminded him that improvements in the balance sheet could become a long-term quality goal. Thinking up a measurable quality goal was not the first thing on his mind. He decided that tracking the date of receipt on the signed delivery ticket would become the company's primary quality goal.

"If we don't make our delivery date, we're out of work," he told me. "And if we don't work, we don't eat!"

Comparing as-bid dates to actual sign-offs is an easy metric to track, but it just didn't feel like quality to me, and I said so.

He backed up the goal with historical data and a collection of well-worn war stories. These were things I didn't know, but I learned. Project schedules are one arena where contractors have some control. The terms in their proposals are reflected in the approved contract documents. Meeting delivery commitments had also become a company symbol for positive teamwork during project execution. Delivery tickets captured that cooperation throughout the company. He was pretty poetic.

Old salt earned approved fabricator status. He went into the audit with the delivery ticket-to-invoice trail and no changes to the quality goal. Meanwhile, I continued exploring my own ideas about quality metrics. There's always a little extra love in something built from scratch. IT

BILL KOMLOS (*bkoz@arctechllc.com*) is a Senior Certified Welding Inspector for Arc Tech LLC, Salt Lake City, Utah. He is also an AWS Counselor and Life Member.

AWS Hosts CWI Nine-Year Seminar

The attendees of the CWI nine-year seminar pose outside of AWS World Headquarters in Miami, Fla.

AWS held a Certified Welding Inspector (CWI) nine-year recertification seminar May 3–8 at its World Headquarters in Miami, Fla. Instructor Rick Suria led the seminar. Suria is an AWS Senior CWI, an AWS Certified Welding Educator, and a Certified Radiographic Interpreter with an ASNT Level III certification. He is also the owner of Industrial Technology & Inspection LLC, Cape Coral, Fla.

The attendees of the seminar were Timothy Bishop, Jason Bishop, Christopher Bistline, Marco Centeno, John Conrad, Mihaly Gosztonyi, Joel Hernandez, Robert Hudson, Daniel Lakadawala, Travis Miller, Norman Newton Jr., Shawn Omersa, James Overberg, Samuel Patterson, Mark Payne, Clay Pike, Daniel Ramos, Rodney Rhodes, Todd Roberts, Russel Smith, Timothy Stenson, Robert Vanderford, and Sheldon Williams.

MISTRAS Group Expands Texas In-House Lab Capabilities

MISTRAS Group, a New Jersey-based provider of industrial asset integrity and testing solutions, has expanded capabilities at its in-house laboratory in Houston, Tex. The upgrades include new equipment and services to help customers in the aerospace and defense industries maintain production schedules and meet demanding quality requirements.

The company's in-house laboratory is fully equipped to provide rapid, turnkey solutions for manufacturing, inspection, repair, and rework requirements. The facility now offers aerospace casting weld repair and rework supported by procedures and personnel qualified to AWS D17.1, *Specification for Fusion Welding for Aerospace Applications*, along with precision grinding, cutting, metal finishing, and component restoration services. Additional investments include dedicated immersion ultrasonic inspection tanks for forgings; advanced 1- to 3-in. and 3- to 5-in. rotary ultrasonic inspection systems for bar, billet, and forging examinations; fluorescent penetrant inspection; and advanced digital radiography utilizing a 320kV x-ray system.

The new solutions complement the lab's established inspection and testing services, including film and computed radiography, 6-MeV linear accelerators, magnetic particle testing, alloy positive material identification, hardness testing, and more, with a 25-ton crane capacity. Providing services for castings, forgings, composites, weld quality, additive manufacturing components, and machined products, the Houston in-house lab maintains ISO 9001 certification, extensive Prime certifications, and ITAR compliance. The lab is also expected to achieve NADCAP accreditation in quality management systems, welding, radiographic testing, penetrant testing, and ultrasonic testing in late 2026.

"These new capabilities significantly expand the range of components and customer needs we can support directly from one location," said Cliff Schaffer, senior vice president of in-lab services at MISTRAS. "From manufacturing support and defect characterization to weld repair, nondestructive testing, and final certification, our goal is to streamline production for our customers with a more complete, efficient, and quality-driven lab experience under one roof."

ASNT Brings Industry to Capitol Hill

The American Society for Nondestructive Testing (ASNT), Columbus, Ohio, brought more than 60 industry professionals to Capitol Hill in May, generating over 150 meetings with congressional offices and federal agencies and elevating the role of nondestructive testing (NDT) in national workforce and infrastructure discussions.

The 2nd annual Day on the Hill marked a significant increase in participation and a shift in engagement. Conversations moved beyond introducing NDT to focused discussions on how it can be integrated into workforce programs, infrastructure policy, and federal initiatives.

"We are seeing a clear shift in how policymakers engage with our industry," said Neal Couture, CEO of ASNT. "These are no longer introductory conversations. There is real interest in how NDT can support workforce development, strengthen infrastructure, and improve public safety."

Meetings with lawmakers and staff focused heavily on workforce challenges, including expanding apprenticeship pathways, increasing awareness of NDT careers, and supporting veterans transitioning into civilian roles. Congressional offices also sought input on how NDT can be incorporated into existing and emerging legislation.

ASNT also met with key federal agencies, including the U.S. Department of Labor (DoL) and the U.S. Department of Transportation, to discuss workforce readiness and regulatory alignment. Conversations with the DoL highlighted shared priorities around expanding registered apprenticeships and scaling earn-while-you-learn models. ASNT is currently developing a national NDT apprenticeship program to increase access to training and strengthen the workforce pipeline.

In parallel, discussions with regulatory agencies emphasized the importance of aligning industry standards with federal frameworks to maintain safety, consistency, and workforce quality across critical infrastructure systems.

As part of its advocacy efforts, ASNT supported multiple pieces of legislation focused on workforce development and industry growth, submitting formal letters and engaging directly with congressional offices.

With momentum building, ASNT will continue expanding its advocacy efforts through sustained engagement on Capitol Hill, deeper collaboration with federal agencies, and the development of a national NDT apprenticeship program to support long-term workforce growth.

North Star Imaging Announces Leadership Transition

North Star Imaging (NSI), Rogers, Minn., a provider of industrial x-ray and computed tomography (CT) inspection solutions and a part of Illinois Tool Works Inc. (ITW), has promoted two leaders within the ITW family of companies.

Rebecca Rudolph, who has led NSI as general manager for the last three years, has been promoted within the ITW family of companies to vice president and general manager, semiconductor, for Brooks Instrument. Brooks Instrument is a provider of precision flow, pressure, vacuum, and vapor-delivery solutions, headquartered in Hatfield, Pa. Before joining NSI, Rudolph worked at COMET Technologies USA Inc. in a variety of leadership roles, including general manager and vice president of global sales.

In connection with Rudolph's move, Vamshi Sarangapani, currently NSI's director of strategic marketing and product management, has been promoted to NSI's general manager. Sarangapani joined NSI in 2025 and has helped shape product strategy and execution across the company's global portfolio of industrial digital radiography and CT solutions, spanning hardware, software, and services. As general manager, he will take full responsibility for the business's profit and loss and lead NSI's continued growth. Prior to NSI, he held general management and product leadership roles at Honeywell and spent 16 years at Cummins Inc., working in roles across product strategy, supply chain, sourcing, engineering, and international operations.

Acquisition Activity Continues across the NDE and Inspection Sector

Mergers and acquisitions remain strong across the inspection, testing, and nondestructive examination (NDE) industries, with buyers looking to expand technical capabilities, broaden geographic reach, and build more comprehensive service and technology portfolios. Recent deals span inspection services, advanced nondestructive testing (NDT) technologies, and software.

■ **Hexagon**, Stockholm, Sweden, signed a definitive agreement to acquire **Waygate Technologies**, Hürth, Germany, a provider of NDT equipment and solutions, from Baker Hughes. Waygate generates approximately $630 million in annual revenue and employs about 1500 people across 25 locations worldwide. The deal expands Hexagon's manufacturing intelligence business into NDT, adding strengths in computed tomography (CT), radiography, and remote visual inspection. The transaction is valued at approximately $1.45 billion.

■ **Certerra**, Las Vegas, Nev., added **Code NDT**, Anaheim, Calif., to its platform as part of its southwest division. The acquisition strengthens Certerra's NDT offerings with capabilities including ultrasonic, radiographic, magnetic particle, visual, and liquid penetrant testing, as well as advanced methods such as phased array ultrasonic testing/time-of-flight diffraction and computed radiography/digital radiography. Niko Svimonoff, former president of Code NDT, has been appointed regional vice president of the southwest division.

■ **ESAB**, North Bethesda, Md., completed its acquisition of **Eddyfi Technologies**, Quebec City, Quebec, Canada, a developer of advanced inspection and monitoring technologies. The deal supports ESAB's strategy to expand beyond fabrication into inspection and asset-monitoring markets. The company said Eddyfi's instrumentation and monitoring technologies enhance its end-to-end workflow offerings.

■ **UTEX Scientific**, Mississauga, Ontario, Canada, acquired **PA-CAT Inc.**, a phased-array corrosion analysis technology business based in Georgetown, Ontario, Canada, from Holloway NDT & Engineering. PA-CAT's patented technology provides quantitative corrosion assessment using phased-array ultrasonic testing and cloud-based analysis tools. UTEX will assume ownership of the technology, licensing program, and future development roadmap.

■ **Industrial Thermal Services (ITS)**, Nederland, Tex., acquired **NDE Inc.**, an NDT services provider serving customers from Louisiana to Florida. The acquisition expands ITS's service portfolio by adding inspection and quality assurance capabilities to its heat treatment and specialty mechanical services.

Bureau Veritas Advances Ultrasonic Weld Inspection for LNG-Fueled Vessels

Bureau Veritas Marine & Offshore, Courbevoie, France, a global ship classification and offshore verification organization, has approved a semi-automated phased array ultrasonic testing (PAUT) solution as an alternative to radiographic testing (RT) for thin-wall austenitic stainless steel piping welds on liquefied natural gas (LNG)-fueled vessels.

Developed by Bureau Veritas France Industry and qualified under Bureau Veritas classification rules, the PAUT procedure was validated through testing on representative weld specimens containing artificial and realistic defects. Bureau Veritas said the method demonstrated detection capabilities comparable to, and in some cases better than, conventional radiography.

The approved approach eliminates the need for radiation sources and associated safety exclusion zones, while providing digital inspection records, traceability, and improved shipyard efficiency. The Brest operational unit of Bureau Veritas France Industry has also been accredited to deploy the method under the company's NR669 NDT supplier framework.

Carestream NDT Receives Two Stevie Awards for Digital Radiography Technology

Carestream NDT, Rochester, N.Y., provider of digital radiography solutions for nondestructive testing, received a Gold Stevie® Award in the Business-to-Business Products category and a Silver Stevie Award for Achievement in Product Innovation at the 24th Annual American Business Awards® held June 9 in New York, N.Y.

The awards recognized the company's HPX-ARC digital radiography detectors. The flexible detectors are designed to conform to curved surfaces, helping inspectors capture high-resolution images in applications where traditional flat-panel detectors can be difficult to use.

The Stevie Awards recognize outstanding workplace performance worldwide and are conferred in nine programs, including the American Business Awards. IT

Corrosion Prevention System Protects Steel and Concrete Structures

The Denso Covercoat™ System is a multilayer corrosion prevention system designed to protect steel and concrete structures, exposed piping, support legs, and column bases in harsh operating environments. Intended for both new construction and maintenance applications, the system can be applied to marginally prepared surfaces in accordance with SSPC SP 2-3 standards, reducing the need for abrasive blasting and extensive surface preparation. The system combines a series of primers, mastics, tapes, reinforcement materials, and coatings to create a durable barrier against corrosion. Its conformable design allows it to accommodate irregular shapes, bolts, joints, and complex profiles while maintaining strong adhesion to the underlying substrate. The materials are UV resistant and can encapsulate existing lead-based coatings, supporting remediation projects while minimizing disturbance of the original coating. According to the manufacturer, the system provides more than 20 years of corrosion resistance with limited maintenance requirements. It is formulated to withstand exposure to acids, alkalis, salts, and other aggressive environmental conditions commonly encountered in industrial settings. Because application can be performed without taking equipment or facilities out of service, the system may help reduce operational disruptions during maintenance activities. The system consists of six components: a petrolatum-based primer that penetrates rust and displaces moisture; a profiling mastic for smoothing irregular surfaces; a high-adhesion petrolatum tape that provides initial corrosion protection; a polyester scrim that adds reinforcement and flexibility; a two-component basecoat that forms a weather-resistant outer layer; and an acrylic topcoat applied in two layers to provide a durable finish. Together, these components create an encapsulating protective system designed to extend asset service life in corrosive environments.

Denso Inc.
densona.com

LED UV-A Inspection Lamp Integrates Ultraviolet and White-Light Illumination

The Nomad-Eclipse LED UV-A inspection lamp provides high-intensity ultraviolet illumination and integrated white light for nondestructive examination and inspection applications. Designed for hands-free operation, the cordless unit combines a compact form factor with a rugged housing machined from military-grade aluminum for use in demanding field environments. The lamp produces a uniform UV-A beam pattern with a 12-in.-diameter inspection spot exceeding 1000 μW/cm² at startup when used at a 12-in. working distance. An integrated white-light source with a 3000 K color temperature offers wide-angle coverage for general inspection and work-area illumination. Weighing 7 oz, the unit carries an IP67 rating for protection against dust and water ingress. A magnetic base and ¼-20 threaded socket support fixed-mount configurations, while included headband and pocket-clip accessories enable hands-free use in a variety of inspection settings. The mechanical switch incorporates replaceable polyurethane membrane seals that help prevent moisture and debris intrusion. Power comes from a 5000 mAh lithium-ion battery, which provides more than 1.5 hours of runtime per charge. The system features a quad-lead threaded battery design that allows battery changes with a single turn. Standard kits include four batteries and two chargers to support extended field operation.

REL Inc.
relinc.com

Eddy Current Flaw Detector Combines Conventional and Array Inspection Capabilities

The NORTEC™ 700 flaw detector integrates conventional eddy current testing (ECT) and, in select models, eddy current array (ECA) inspection capabilities into a single platform for aerospace, defense, manufacturing, and industrial nondestructive examination applications. Available in three models, the instrument supports surface and subsurface flaw detection, bolt-hole inspection, weld inspection, conductivity measurement, coating-thickness measurement, and dual-frequency inspections. Built on the NORTEC 600 platform, the flaw detector features a streamlined user interface with application-based presets that automatically configure inspection parameters for common tasks such as bolt-hole, rivet-line, and surface-crack inspections. The simplified workflow reduces setup time and helps improve consistency across operators. The lightweight instrument weighs approximately 3.95 lb and combines touchscreen operation with hard-key controls to support use in field environments and while wearing gloves. The N700i model combines ECT and ECA capabilities in a single instrument, enabling users to switch between inspection methods without changing platforms. The model also includes automatic layer detection for bolt-hole and multilayer inspections, along with ECA imaging capabilities for defect visualization and data capture. New-generation ECA probes support up to 256 channels and are designed to provide repeatable signal quality and simplified calibration. The instrument maintains compatibility with existing NORTEC 600 probes, batteries, and accessories, helping organizations standardize equipment while protecting previous investments. Inspection data can be reviewed and exported using companion PC software for reporting and documentation purposes.

Evident
ims.evidentscientific.com

Portable Metals Analyzer Expands On-Site Alloy Identification Capabilities

The SPECTROPORT LIBS PXL01 portable metals analyzer performs on-site alloy identification and elemental analysis using laser-induced breakdown spectroscopy (LIBS)-based optical emission spectroscopy (OES). Designed for field and worksite use, the analyzer supports rapid verification of metal composition and measurement of key light elements, including carbon, phosphorus, and sulfur. The analyzer bridges the gap between handheld and larger mobile systems through a split-body design that incorporates two optical systems optimized for different wavelength ranges. This configuration expands elemental coverage and enables analysis of alloys that can be difficult to characterize using conventional handheld analyzers alone. Measurements are completed in approximately 2–6 seconds, supporting alloy identification, grade verification, and pass/fail sorting applications. The system is available with two probe options: a standard probe for routine alloy analysis and a UV-equipped probe for applications requiring measurement of carbon, phosphorus, and sulfur. Both probes feature integrated displays that allow users to view results directly at the point of inspection and can operate with or without argon. For field deployment, the analyzer can be equipped with replaceable batteries and a lightweight argon cartridge housed within the instrument body. Two installed batteries provide up to 4.5 hours of operation and support as many as 120 measurements per hour at a six-second measurement time. The analyzer incorporates Spark Analyzer Pro software for test setup, sample identification, and data management.

SPECTRO Analytical Instruments
spectro.com

BY RACHEL BHEECHAM

CLASS IS IN SESSION

Learn how a welding instructor uses his CWI skills to change students' lives

JD Castillo (far left) with fellow AWS Central Texas members (from left) Michael Hinterlach, Thomas Hinkle, and Daniela Lowry in front of donated metal.

"No one had ever told me this was so fun and addicting," said a student who was enrolled in JD Castillo's welding course but was too scared to grab an electrode holder. That finally changed when Castillo, ever his students' biggest advocate, struck a deal with him. The student would be Castillo's shop foreman during class, but he would eventually have to get certified. They started shielded metal arc welding (SMAW) with 6010 electrodes, and by the end of class, the change was palpable.

Castillo cites experiences with students like this as one of many reasons he became an educator. Now a high school welding instructor, Castillo originally started his career as a carpenter. It wasn't until a family member offered him a job that he had the opportunity to work with extremely knowledgeable, talented, and skilled welders who were willing to help him learn the craft. He learned fabrication, worked turnarounds and shutdowns at plants, and did repair/maintenance work on heavy equipment, tractor-trailers, and anything else that came through the shop doors.

"My first exposure to inspection was for the City of Austin, Tex., where I served as a fire watch for the inspector performing dye penetrant testing, and I was allowed to observe and assist," Castillo recalled.

Soon after, he bought a welding machine, installed it on the back of his truck, and started doing mobile jobs for customers. He eventually started his own business. From there, he transitioned into welding sales, where he kept abreast of what was going on in the welding industry.

His networking and professional relationships led him to Austin Community College (ACC), where an instructor encouraged him to consider teaching. Castillo began teaching continuing education welding classes in Spanish, which he enjoyed so much that, when encouraged by a department head, he did not hesitate to enroll himself in welding inspection courses at ACC.

"Someone once asked whether I wanted to sling iron for the rest of my life or choose a path that would be physically easier but would still allow me to work in the welding industry in a different capacity. I did this by becoming a CWI," he said.

Castillo studied while working two jobs, squeezing in any free second on nights and weekends to work toward his certification. "It was challenging, but learning was easier because it was a subject that I am interested in." He earned CWI status in 2023.

He found a home within qualification, having spent a great deal of time doing inspection welds on buildings with friends.

His favorite inspection method is destructive testing because he's able to witness the welders' and especially the students' reaction to the results of their weld tests. Castillo encourages his students and others to take time to pursue the inspection process if they are interested. "It is not easy, but it is definitely worth achieving."

In his current role, he encourages students to participate in various welding events and emphasizes the importance of networking, going so far as to build professional relationships within the community and with companies that need welders, in hopes of helping his students find employment.

Castillo is straightforward with his students. He shares many real-life experiences from his welding career — unfavorable weather conditions, associated dangers, long hours, and the tales of the people he's met along the way, good and bad — and stresses that the only way to know if welding is for them is to take a class or find a job that exposes them to different types of welding.

"I have found teaching to be the most rewarding part of my career. I hope that by sharing my personal knowledge, I have helped teach my students welding skills that will help change their lives."

For Castillo, there is no better feeling than seeing the light bulb turn on in a student's head, a student's face light up as they finally run a perfect weld bead and position, or a student pass a perfect bend test.

He also highlights all the joys welding has brought him over the years. "There is nothing like reflecting on the interesting jobs I've been a part of and having the satisfaction of saying, 'I built that' or 'I was part of that project.'"

Castillo encourages his students to learn something from everyone they encounter, both in and out of the field. Everyone has something different to offer, and there's always the possibility they may find a different or better way of doing something.

"Knowledge is something that no one can take from you, and the more you know, the more valuable you make yourself. If we don't give back and help teach or mentor the next generation, we are only hurting ourselves."

Castillo hopes that he has made a small difference in the lives of anyone interested in welding.

Castillo's welding students pose in their personal protection equipment.

One of Castillo's students leads a SMAW demonstration.

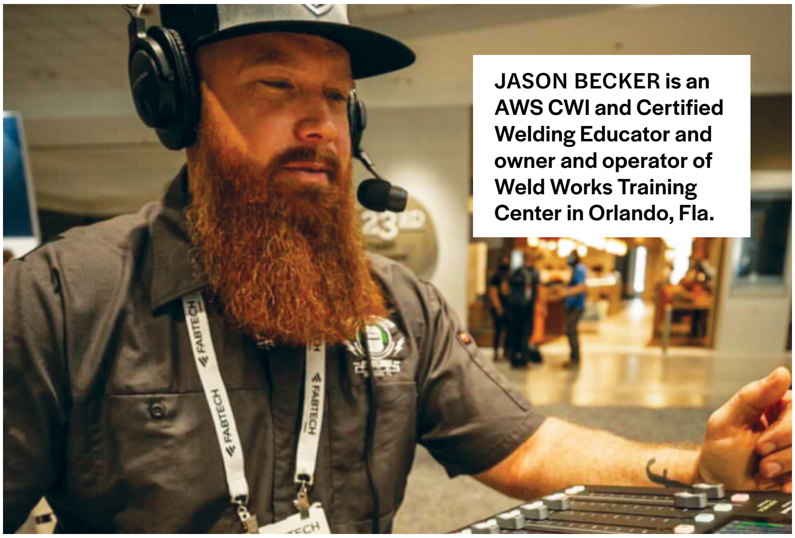
RACHEL BHEECHAM (*rbheecham@aws.org*) is the assistant editor of *Inspection Trends*.

What New CWIs Need to Know after Passing the Exam

A conversation with welding inspection veteran Daryl Peterson on mentorship, ethics, technical growth, and the realities of building a career as a CWI

Passing the Certified Welding Inspector (CWI) exam is a major professional achievement, but it is not the finish line. In the recent *Weld Wednesday* podcast conversation with host Jason Becker, Daryl Peterson (AWS CWI, SCWI, ASNT Level III, API 653, and SSPC PCI Level II inspector), quality manager at Central Maintenance & Welding, Lithia, Fla., emphasized that a new CWI has earned what he calls "a license to learn." The exam demonstrates an inspector has studied the fundamentals, but it cannot provide the judgment, field experience, or code fluency needed to handle every situation encountered on a jobsite.

That distinction matters because many inspectors enter the role after being identified as the best welder in a shop or the person most likely to pass the test. A company may need someone with the credentials quickly, especially when code work, third-party quality requirements, or owner audits begin to appear in the contract. The individual studies hard, passes the exam, and suddenly becomes the person everyone looks to for welding answers. Peterson warns that knowing enough to pass the exam is not the same as knowing enough to work without guidance.



JASON BECKER is an AWS CWI and Certified Welding Educator and owner and operator of Weld Works Training Center in Orlando, Fla.

Understanding the QA, QC, and Authority Roles

One of the first lessons for any new CWI is understanding where authority begins and ends. Peterson drew a clear distinction between quality control (QC) and quality assurance (QA). QC inspectors typically work for the contractor or fabricator and handle day-to-day inspection work, including welder qualification, procedure documentation, visual inspection, and other welding-related quality tasks required by the applicable code and contract. QA, by contrast, often represents the owner or a third party and audits the contractor's compliance.

That difference affects communication. A QA inspector should not direct the welder's work. Peterson advises inspectors in that role to communicate through the proper supervision chain rather than telling a welder to grind, repair, or change technique. The wrong conversation may blur responsibility and create liability. The inspector's job is to observe, verify, document, and report through the correct channel.

The QC inspector's goals are to communicate professionally, identify problems early, and keep the work moving in compliance.

Mentorship Is Not Optional

For Peterson, the most difficult position for a new CWI is being placed in charge without a mentor.

"You don't know what you don't know," he said, and without someone experienced nearby, a new inspector may not even know which questions to ask. That is why he encourages new CWIs to seek out experienced inspectors, attend local AWS Section meetings, participate in professional networks, and build relationships with people willing to answer questions.

Mentorship should also be reciprocal over time. Peterson believes experienced inspectors have an obligation to raise the standard of the profession by helping others improve. The best mentors do more than give answers; they explain why an answer is correct, where it is found in the code, and how it applies in practice. New inspectors should take notes, mark code references, and avoid asking the same question repeatedly. The goal is to build judgment, not dependency.

The Credential Is Yours

Ethics was one of the strongest themes of the discussion. Peterson, who serves on an ethics panel, warned that new CWIs are sometimes pressured to sign for work they did not witness, approve records they did not verify, or accept interpretations that serve a company's schedule rather than the governing requirements. He stressed that the certification belongs to the inspector, regardless of who paid for training, travel, books, or exam fees.

The consequences of unethical conduct can be severe, ranging from reprimand to suspension or loss of certification. More importantly, an inspector's reputation is built on integrity. Becker stressed that while a company may have invested in the credential, it cannot own the inspector's professional judgment. If an employer demands an unethical signature, the CWI must be willing to say no. Losing a job is difficult; losing the credentials and reputation that can support an entire career is worse.

Technical Competency Takes Time

The interview repeatedly returned to the technical depth required of a strong CWI. Peterson discussed metallurgy, preheat, interpass temperature, hydrogen control, aluminum testing, stainless steel heat sensitivity, and the differences between codes. He used practical examples to show how simple assumptions can create problems. Aluminum bend testing, for instance, can fail when specimens are prepared or bent incorrectly. Stainless steel requires attention to maximum interpass temperature. Low-hydrogen electrode exposure limits depend on classification, tensile strength, and governing code requirements.

The larger lesson is that inspectors must resist relying on sayings, shortcuts, or shop folklore. Common rules of thumb may be incomplete, outdated, or wrong in a specific code context. A bend test discontinuity may be acceptable within limits. Undercut acceptance can depend on the loading condition and length. Welder qualification ranges differ among AWS D1.1/D1.1M, *Structural Welding Code — Steel*, the ASME *Boiler and Pressure Vessel Code* (BPVC), Section IX, and other standards. The only reliable answer is the one supported by the applicable code, contract, and procedure.

Read the Contract before the Code

Peterson also urged inspectors and fabricators to read contracts carefully. Codes matter, but the contract identifies which codes, specifications, owner requirements, and inspection hold points apply to the project. A small company may accept work without realizing that a building code references a structural steel standard, which then triggers welder qualifications, welding procedures, and volumetric examination requirements. If those requirements were not understood at bid time, the result can be expensive and disruptive.

For the CWI, contract awareness defines the inspection scope. It can determine whether radiography, ultrasonic testing, coating inspection, pressure testing, dimensional checks, hold points, or owner witness points are required. It also clarifies when third-party testing is needed and which acceptance criteria apply. Peterson's advice is simple: know what the job actually requires before you start making judgments about compliance.

Build Value through NDT and Endorsements

One of Peterson's strongest career recommendations for new CWIs is to gain nondestructive testing (NDT) experience. Working for an NDT company can expose an inspector to structural steel, bridges, piping, pressure vessels, shipyards, and other industries in a relatively short time. Methods such as penetrant testing (PT), magnetic particle testing (MT), radiographic testing (RT), and ultrasonic testing (UT) deepen an inspector's understanding of weld quality and make the CWI more valuable to employers.

Key Takeaways for New CWIs

- **Treat the credential as a starting point.** Passing the exam proves readiness to learn, not mastery of every inspection situation.
- **Find a mentor early.** Experienced inspectors can help new CWIs understand how code requirements apply in the field.
- **Protect your ethics.** Never sign for work you did not witness or records you did not verify.
- **Know your role.** Understand the difference between QA and QC, and communicate through the proper chain of command.
- **Read the contract first.** The contract defines the codes, specifications, hold points, and inspection requirements that govern the job.
- **Document clearly.** Reports should be factual, defensible, and free of unsupported opinions.
- **Keep building value.** NDT experience, endorsements, and related credentials can broaden career opportunities.

Additional credentials can also expand opportunities. Peterson mentioned bolting, coatings, Occupational Safety and Health Administration (OSHA) training, the Mine Safety and Health Administration (MSHA), where applicable, Transportation Worker Identification Credential (TWIC) cards for port access, and AWS endorsements, such as those for welder and procedure qualification. Becker compared this to welding itself: The more processes, materials, and responsibilities a person can handle competently, the more valuable that person becomes. For inspectors, stacking credentials should be part of a long-term plan rather than a random collection of certificates.

Communication and Documentation

Technical knowledge alone does not make an effective inspector. Peterson emphasized communication, conflict management, and report writing as core skills. Inspectors must be able to speak with engineers, supervisors, welders, owners, and managers, often translating between technical code language and shop floor reality. They must also be able to admit when they do not know the answer and commit to verifying it before responding.

Reports should be clear, factual, and unbiased. Photos should be used generously where appropriate, and opinions should be avoided. An inspector's report may be reviewed long after the job is complete, so wording matters. If the report implies that hundreds of welds were inspected when only a small sample was viewed, the inspector has created a serious professional problem. Good documentation protects the client, the contractor, and the inspector.

Don't Hurry into Independence

Both speakers cautioned against launching an independent CWI business too early. Consulting may look attractive, especially when hourly rates sound high, but independent inspectors carry their own liability, insurance, code, tax, equipment, and reputational costs. A missed contract requirement or incorrect inspection decision can quickly become a costly mistake.

The better path for many new CWIs is to work under experienced professionals for several years, gain exposure, learn documentation systems, understand inspection test plans, and develop confidence within a defined scope. Branching out is important, but it should be done deliberately. As Becker put it, do not stay so far in one lane that growth stops, but do not jump into another lane head-on.

A Profession Built on Continuous Learning

Peterson sees inspection as a profession with enormous opportunity for those who stay humble, ethical, and committed to learning. Attend Section meetings. Go to conferences and trade shows. Study codes and commentaries. Ask questions. Teach what you know. Learn from mistakes, but avoid mistakes that come from arrogance or guessing.

For new CWIs, the credential is a starting point. A successful career is built through experience, mentorship, technical study, ethical decision-making, and a willingness to keep improving. Experienced inspectors have a responsibility to help raise others, while new inspectors must learn every day. In welding inspection, every answer should be grounded in the code, every report should be defensible, and every decision should protect the integrity of the work.

BY JEFF NORUK

The Next Evolution of Welding Automation and Inspection

AI-integrated systems are redefining quality, productivity, and inspection

Welding is one of the most universal but unforgiving manufacturing processes in the modern world. From vehicles and bridges to wind towers, pressure vessels, and battery trays, welded joints quietly determine whether structures endure decades of service or fail prematurely. The future of welding depends not on replacing humans but on giving machines the ability to see, learn, and adapt, much like welders have always done.

This article traces the evolution of robotic welding, inspection, and vision systems, showing how today's advances echo lessons learned over more than a century of automation. A palpable conclusion is that blind automation is no longer enough, and intelligence embedded directly into robots and inspection systems is becoming essential — Fig. 1.

Engineering, Automation, and AI

Welding is often mistaken for a single skill or process, but in reality, it is the intersection of many disciplines. Welding engineering blends material science, metallurgy, process selection, automation, inspection strategies, and design for manufacturability. Fewer than 300 welding engineers graduate each year in the United States. Yet, their responsibilities span everything from selecting the appropriate process to designing parts for robotic welding and determining how welds will be inspected.

At the same time, welding itself is extraordinarily diverse. More than 35 welding processes are in use today, performed manually, mechanically, orbitally, or robotically. Each process introduces its own variables, such as heat input, joint geometry, filler wire position, travel angle, shielding gas,

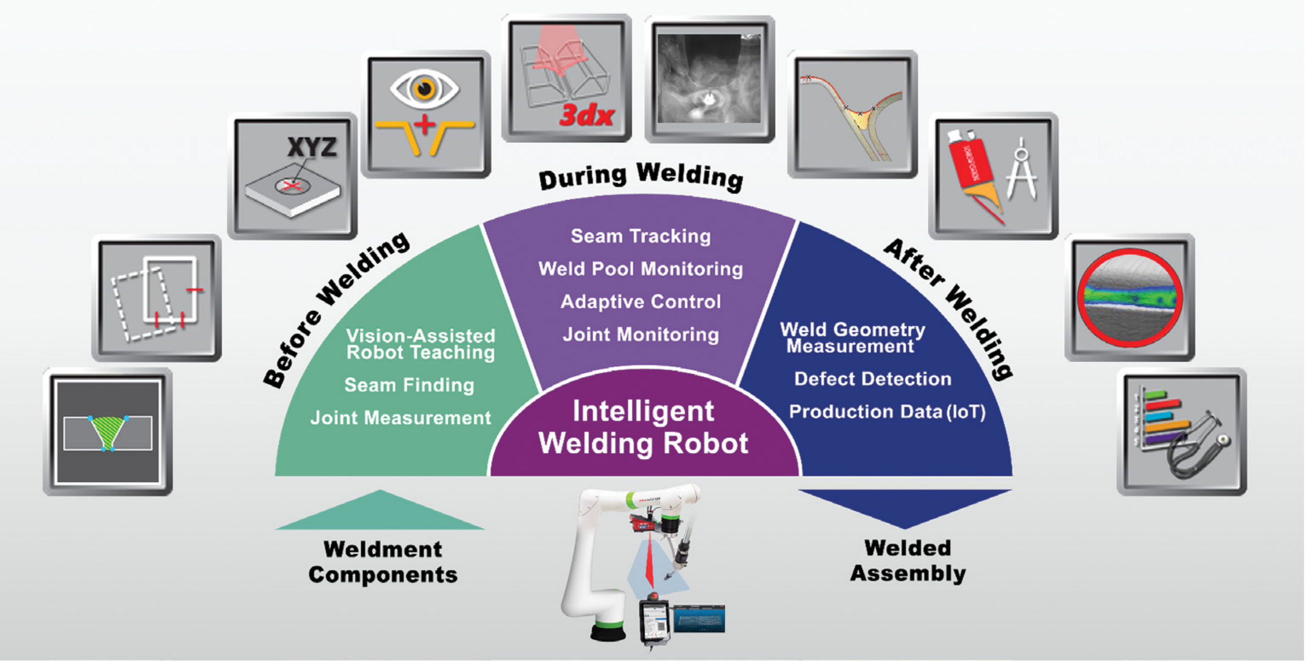


Fig. 1 — A visual representation of how 3D robot vision systems can support the welding process before, during, and after completion.

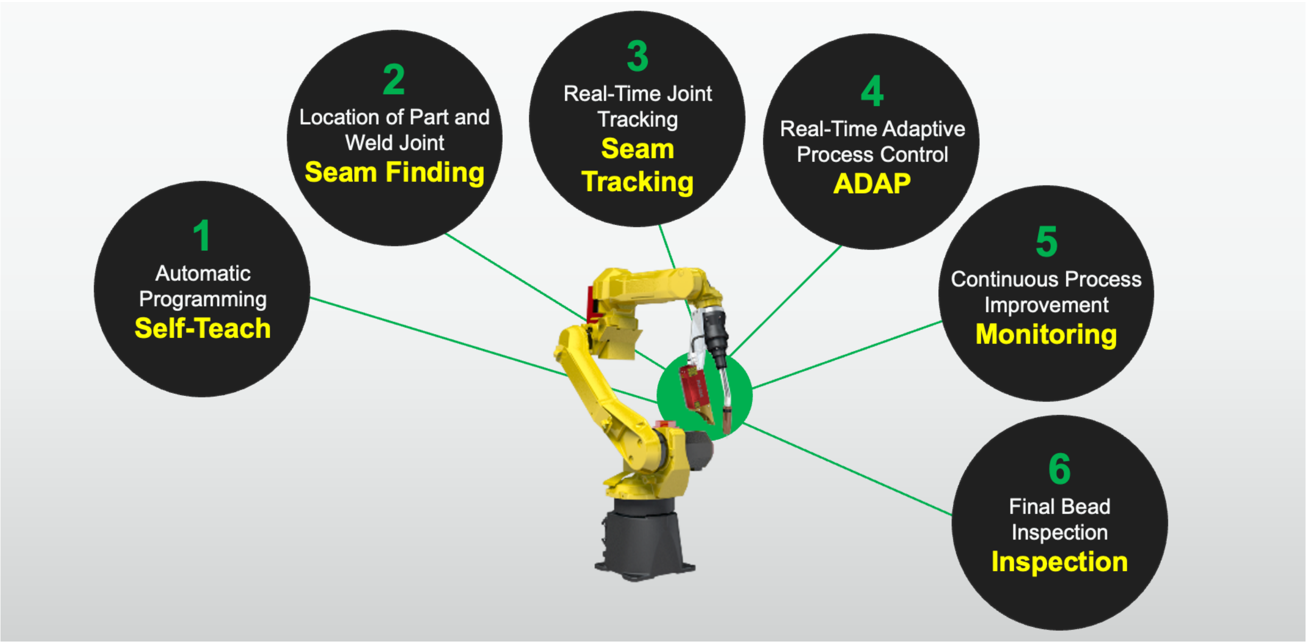


Fig. 2 — 3D robot vision system essential functions.

and surface condition, to name only a few. This complexity is why automation has historically been limited to high-volume, low-mix production environments such as automotive manufacturing; however, that restriction is beginning to disappear.

The roots of industrial robotics stretch back further than many realize. Mechanical riveting machines appeared as early as 1921, while the first industrial robots emerged in the 1970s. Early robotic arc welding systems, including Unimate hydraulic robots, were deployed to weld railroad components and automotive parts. These machines lacked repeatability, vision, and process awareness, making them difficult to scale reliably.

By the 1980s and 1990s, robotic welding had matured in automotive production lines. Companies such as ASEA (now ABB), Hobart, and others deployed robots capable of consistent motion, increasing arc on time and productivity. Yet despite these gains, most systems shared a fundamental flaw: They were blind.

Robots could repeat a taught path flawlessly, but they had no awareness of joint variation, part tolerances, distortion, or real-time process conditions. Any deviation, such as gap changes, misalignment, or heat distortion, could cause the weld to fail.

Welding Robots Should Not Be Blind

A human welder relies on sight, sound, and experience to continuously adjust technique. Subtle changes in arc behavior, pool shape, wire position, or joint geometry trigger immediate corrections. Traditional robots, by contrast, offer accuracy, repeatability, and immunity to fatigue but no perception or decision-making. The consequences can be costly. Even small wire positioning errors can lead to poor bead geometry, excess spatter, incomplete fusion, and wasted material. Without adaptation, robotic welding struggles with part variation, tooling inaccuracies, springback, and thermal distortion — Fig. 2.

Robots must adapt to their environment in real time. Vision and sensing are no longer optional features but are prerequisites for high-quality robotic welding.

Vision Challenges

Another important characteristic of vision systems in welding is their ability to withstand harsh environments. Bright arcs, fume, spatter, magnetic fields, vibration, thermal radiation, and electrical noise all conspire to overwhelm conventional cameras. Reduced access and reflective metal surfaces further complicate sensing.

A solution is modern 3D robot vision systems, which use laser triangulation, hardened housings, military-grade connectors, cooling channels, and replaceable protective windows. Designed for welding, these systems survive where generic machine vision usually fails. The result is reliable vision before, during, and after the welding process.

Seeing the Entire Welding Process

3D robot vision fundamentally changes what robots can do. Before welding, vision systems enable seam finding and joint localization, eliminating time consuming manual programming. During welding, real-time seam tracking enables robots to compensate for joint variations and maintain optimal wire position. After welding, the same sensors inspect the finished weld bead, measuring size, shape, location, and defects.

This unified approach expands the operational window of welding. Vision increases tolerance to part variation, tooling inaccuracies, and process fluctuations, making automation viable even for small and medium-sized manufacturers.

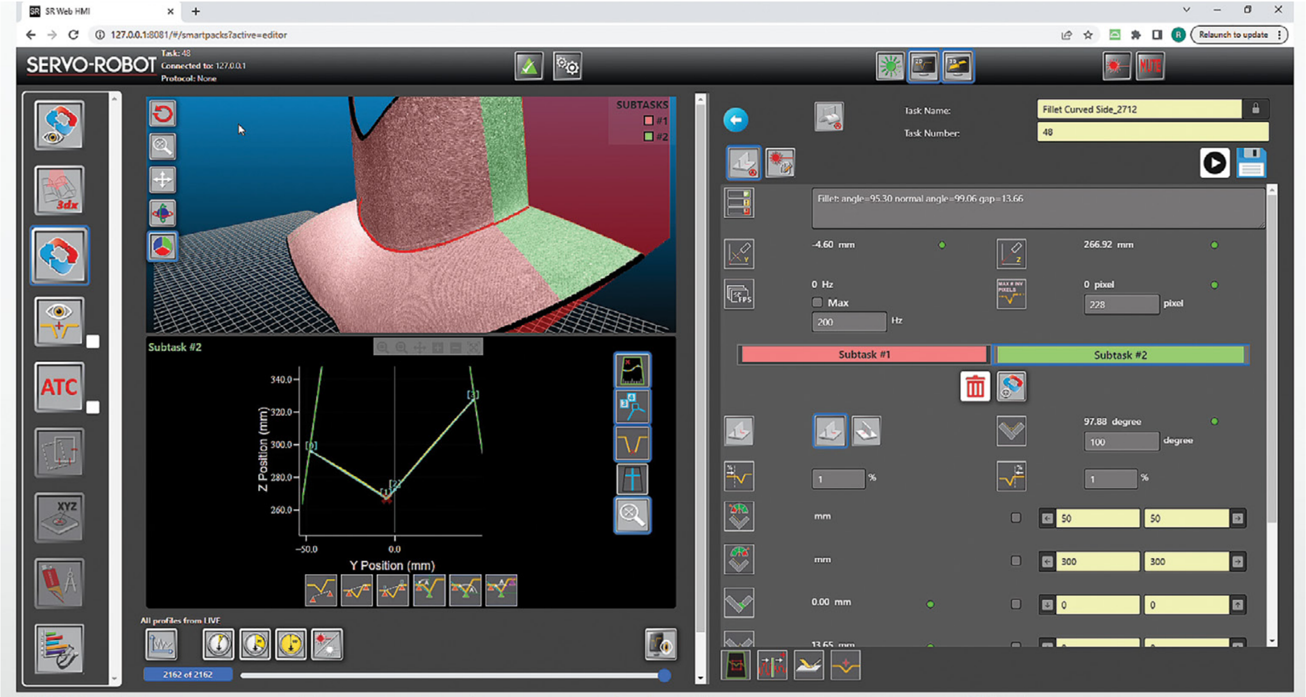


Fig. 3 — Machine learning enables machine vision systems to automatically configure vision tasks from a simple 3D scan of a part, accommodate multiple geometries within the same joint, provide operator-friendly visualization through a web-based interface, and allow fine-tuning when needed.

With proper design for robotic welding, production cells often achieve 85–95% robotic welding rates, a level once reserved for automotive plants. Collaborative robots equipped with vision now bring these capabilities into low-volume, high-mix environments.

Predictive Welding with AI

AI pushes robotic welding beyond adaptation into prediction. Physical AI embeds intelligence directly into robots, welding power sources, and inspection systems.

AI enables automatic joint recognition, self-programming robots, adaptive path correction, and predictive quality control. Instead of relying on fixed thresholds, machine learning models learn what constitutes acceptable and unacceptable welds based on real production data and customer standards — Fig. 3.

This addresses one of welding's most persistent problems: subjectivity. Weld quality assessment often varies by inspector, application, and manufacturer. AI-driven inspection models optimize themselves for specific applications, trained directly on production examples of good and bad welds.

Over time, these systems connect trajectory data, process parameters, geometry, and inspection results, identifying trends and root causes of defects. With enough data, AI systems can predict defects before they occur, turning quality control into defect prevention.

Self-Teaching and Intelligent Interfaces

One of the biggest barriers to robotic welding adoption has been complexity. Programming, calibration, and setup traditionally required specialized skills and long commissioning times.

AI-enabled 3D laser vision changes dynamically. Self-teach functionality allows a robot to scan a part, automatically generate a welding trajectory, and fine-tune the program through an intuitive interface. Automatic joint recognition technology configures vision tasks based on scanned geometry, even when multiple joint types exist in a single part.

These capabilities reduce programming time and make automation accessible to small and mid-sized manufacturers, contract shops, and suppliers facing skilled labor gaps.

Weld Quality Monitoring and Control

Inspection has always been essential to welding, but traditional gauges and visual checks are subjective, time consuming, and limited in scope. Manual inspection cannot provide continuous measurement or automatic documentation.

Automated visual weld inspection changes that equation — Fig. 4. Using robots and laser vision systems, manufacturers can measure weld geometry along the entire joint; detect undercuts, porosity, insufficient material, and other defects; and store the results in sortable databases. 3D surface maps enable intelligent defect detection by comparing nonwelded and welded parts to identify missing or noncompliant welds — Fig. 5.

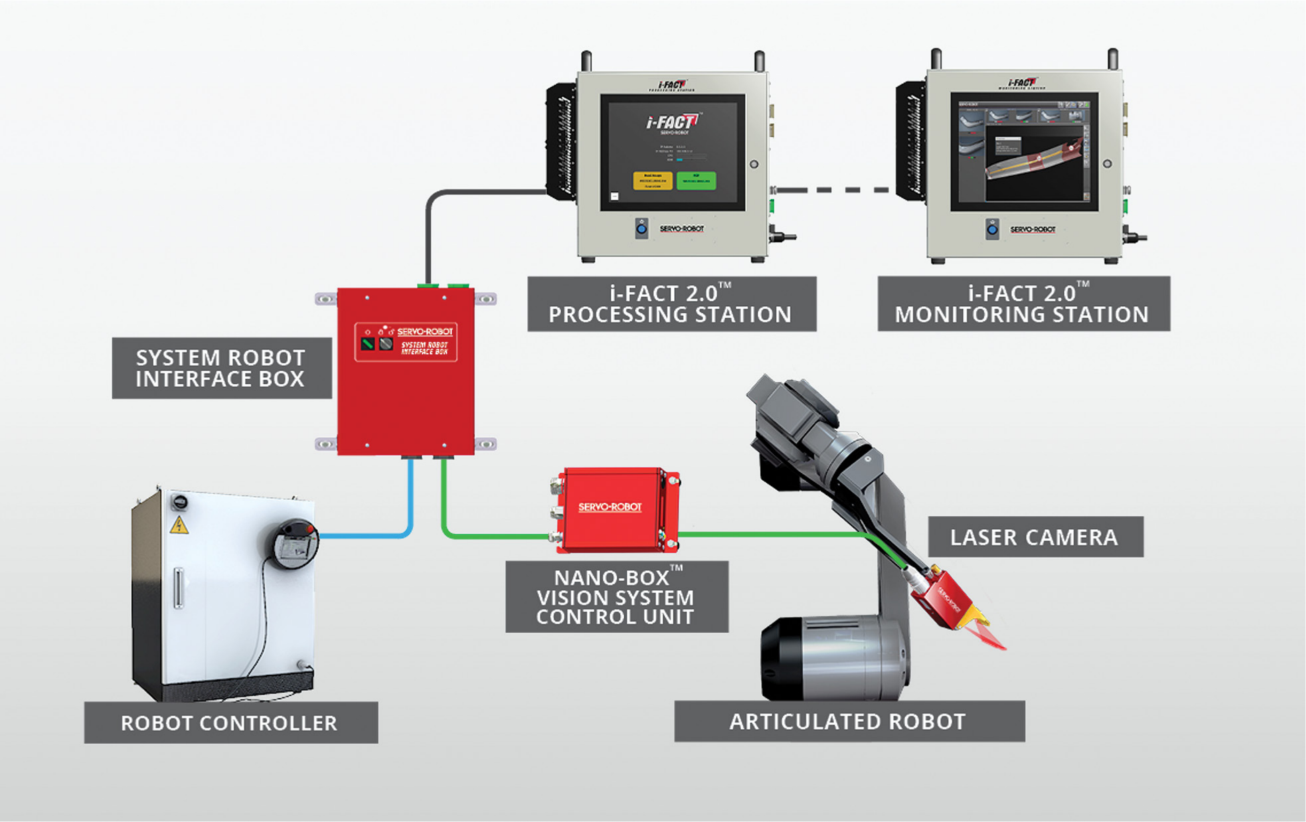


Fig. 4 — An example of an intelligent robot welding quality control system.

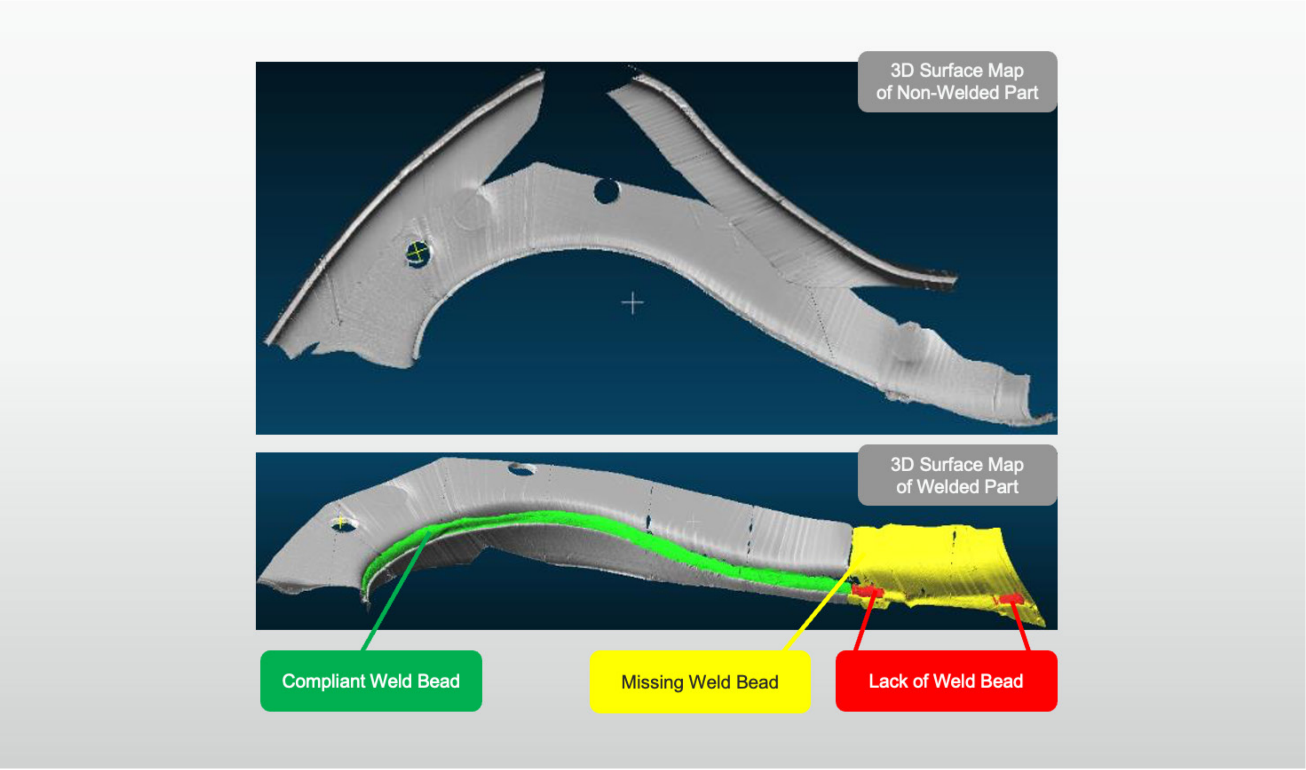


Fig. 5 — An example of 3D surface map, which collects data to achieve intelligent detection of weld defects.

Crucially, effective welding inspection begins before welding starts and continues throughout the process. Studies indicate that good visual welding inspection can detect more than 80% of defects typically associated with expensive nondestructive testing methods.

Digital Record of Every Weld

In modern welding automation, inspection is no longer a final gate; it is an active, data-driven process that shapes quality in real time. Traditional weld inspection relies heavily on manual gauges and visual judgment after the weld is complete. While effective in many cases, these methods can be subjective, inconsistent, and limited to spot checks rather than full-length evaluation.

Advanced robotic inspection transforms that approach. Using laser-based 3D vision, a robot can continuously measure weld geometry across the entire joint, capturing height, width, toe angle, and surface

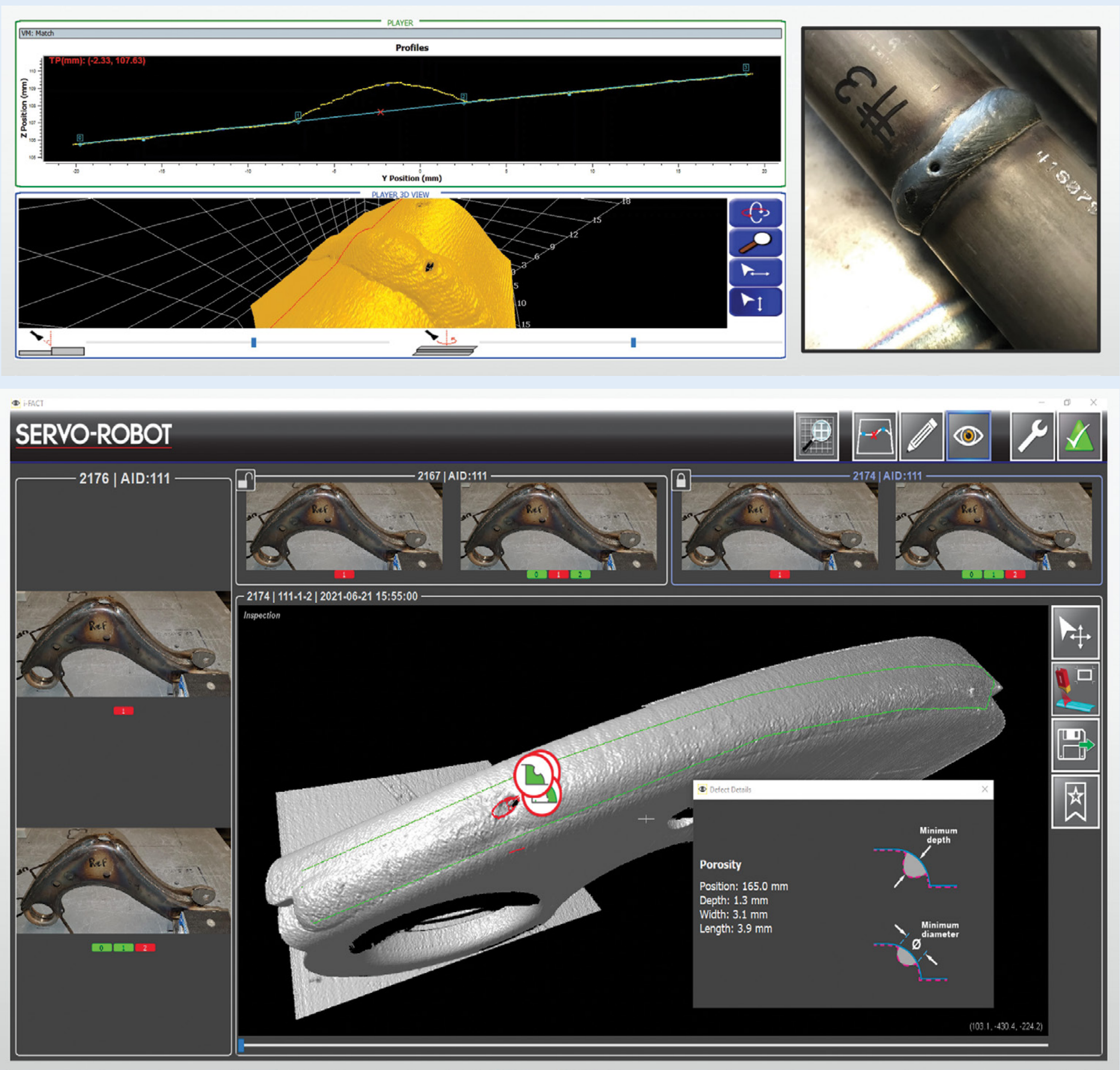


Fig. 6 — Using 3D laser vision, the system can continuously measure weld geometry across the entire joint, capturing height, width, toe angle, and surface defects with quantitative precision.

defects with quantitative precision — Fig. 6. The result is a complete digital record of every weld, not just a pass/fail decision. This shift enables traceability, trend analysis, and faster response when conditions drift out of tolerance.

Even more significant is the convergence of inspection and intelligence. Machine learning models can be trained on real production data to reflect application-specific quality standards, reducing variability between inspectors and facilities. By correlating inspection results with process and trajectory data, manufacturers gain insight into why defects occur, not just where they appear.

Ultimately, automated inspection moves quality control upstream. Instead of finding defects after the fact, manufacturers can identify emerging issues early; proactively adjust processes; and steadily reduce rework, scrap, and risk.

Looking Forward

Despite remarkable technological progress, humans remain central to welding automation and inspection. People program and teach robots, design fixtures, monitor quality, maintain equipment, and make strategic decisions.

Rather than replacing welders, AI-integrated automation elevates them. Skilled professionals transition from repetitive manual tasks to higher-value roles overseeing intelligent systems, interpreting data, and continuously improving processes. The most successful automation strategies recognize that people make the difference.

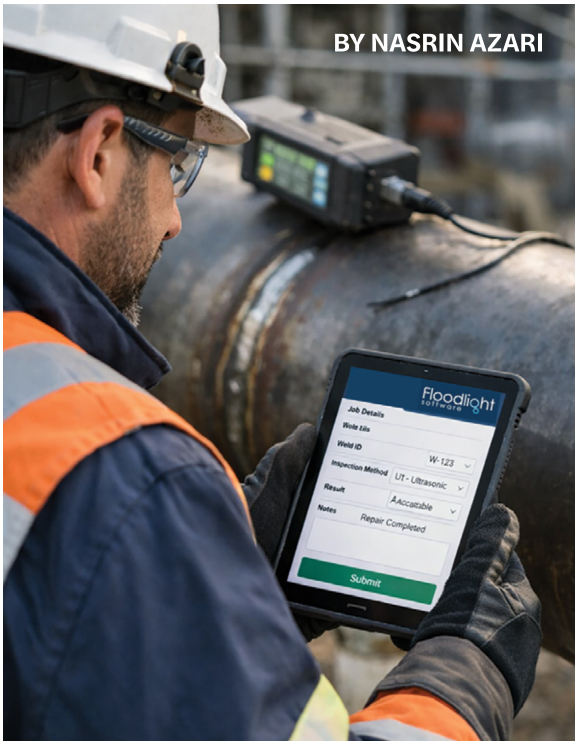
Welding's history shows a repeating pattern. Each wave of automation initially promises full replacement, then reveals new challenges. Progress comes not from eliminating human insight but from carefully and intelligently transferring it into machines.

Today's convergence of robotics, 3D laser vision, data analytics, and AI represents another such moment. The difference this time is clarity. We now understand that automation must see, adapt, and learn.

History usually doesn't repeat itself, but in welding automation, it certainly rhymes. And this time, the rhyme suggests smarter machines, better welds, and a more resilient manufacturing future. IT

JEFF NORUK (*j.noruk@us.servorobot.com*) is president of Servo-Robot Corp., Wauwatosa, Wis.

Modernizing Documentation and Reporting in Welding Inspection



BY NASRIN AZARI

How digital platforms can improve traceability, reporting efficiency, and long-term record management

Welding inspection is an essential part of quality assurance across many industries. Its main challenge is not only verifying weld integrity but also maintaining documentation that supports compliance with codes, specifications, and regulatory requirements.

While welding processes and nondestructive examination (NDE) methods have progressed considerably, many inspection workflows still rely on methods developed decades ago. Paper forms, manual reporting, and disconnected systems remain common across the industry, slowing the shift toward modern documentation.

At the same time, documentation requirements continue to grow. Inspectors must track detailed information about welds, inspection methods, acceptance criteria, repair activities, and outcomes — often across large volumes of work.

Digital technologies are essential to preserving competitiveness, particularly for inspection documentation. Many quality and inspection workflows remain largely manual, so inspection companies are increasingly exploring digital inspection management systems to improve efficiency, improve traceability, and reduce administrative burden.

Traditional Inspection Workflows

In traditional welding inspection workflows, inspectors mostly record results on paper forms or unstructured digital documents. These records are later used to generate reports that may require printing, signing, scanning, and distributing to customers. It's easy to see how documentation can slow the process.

In some organizations, legacy systems are used to generate reports, but these systems often lack modern capabilities such as search, data reuse, or integration with other tools. Documentation workflows are fragmented and labor-intensive across multiple inspection environments.

Inspection companies often describe how their previous process required multiple manual steps to produce and distribute inspection reports, including scanning and reissuing documents when corrections were needed. These types of workflows can greatly increase administrative workload. Quality professionals could spend nearly 30% of their time on documentation and reporting tasks rather than technical inspection work, underscoring the cost of inefficient documentation. For organizations and inspectors performing high volumes of weld inspections, reducing this administrative burden is a key driver for digital transformation.

Beyond administrative inefficiencies, traditional workflows can also result in incomplete or oversimplified inspection documentation. In many welding inspection environments, particularly in construction and infrastructure, inspection reports may reflect only the final inspection status rather than the full sequence of inspection activities.

Field inspections frequently involve multiple steps, including an initial inspection, defect identification, repair activities, and final acceptance. However, when documentation is captured manually or summarized in unstructured reports, these intermediate steps may not always be recorded.

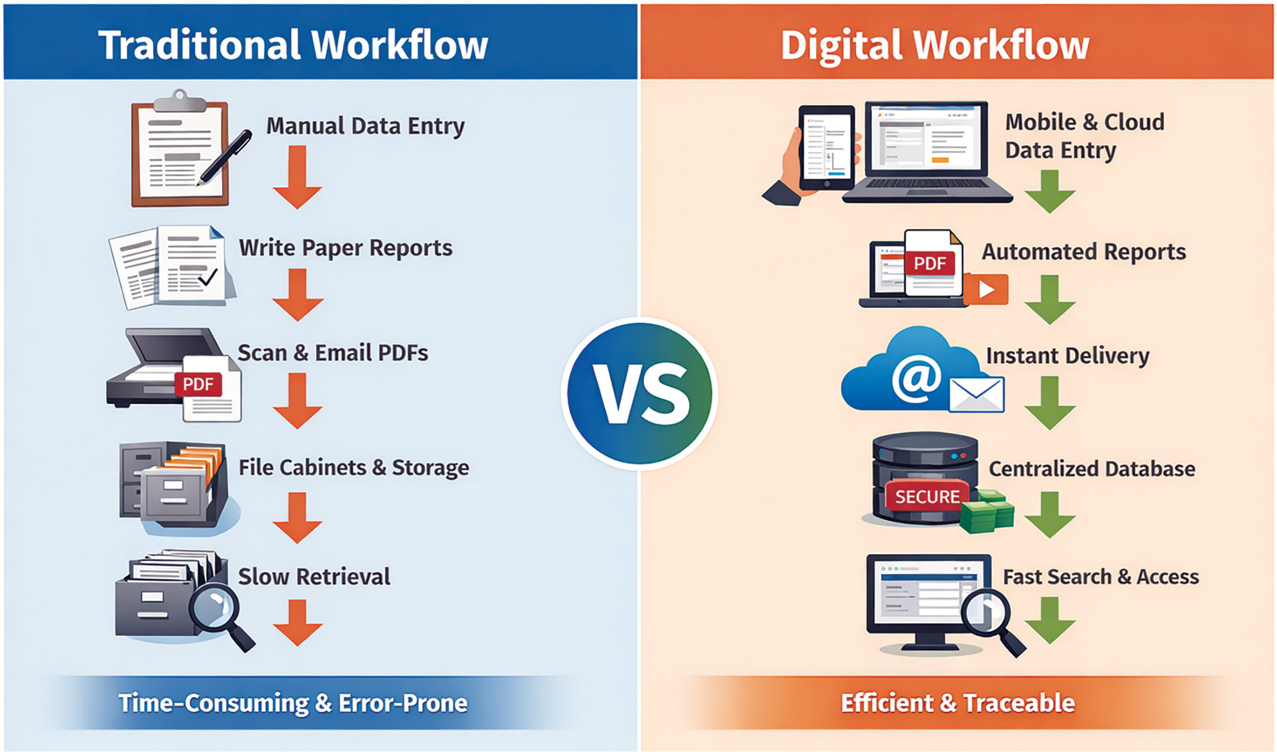


Fig. 1 — Digital inspection management systems can improve efficiency and traceability by leveraging a centralized database that enables fast searches, easy access, automated reporting, and long-term storage.

Welds may undergo multiple repair cycles during a project, but final reports often reflect only the result rather than the full inspection history. This approach can create gaps in traceability, particularly as project owners and regulatory bodies increasingly expect detailed documentation of inspection findings and corrective actions.

As reporting expectations evolve, especially in large infrastructure and government projects, inspection organizations are moving toward more structured and comprehensive documentation practices — Fig. 1.

Traceability and Long-Term Record Management

Traceability is a fundamental requirement in welding inspection. Inspection records must accurately capture part identifiers, inspection methods, specifications, and results in a way that supports long-term retrieval.

In paper-based environments, maintaining traceability can be difficult. Records may be stored in file cabinets, boxes, or off-site storage facilities, which can make retrieval time-consuming.

Even in digital environments, fragmented systems can create challenges. Inspection companies typically use separate tools for scheduling, reporting, and operational tracking, requiring data to be maintained across multiple systems.

In high-volume inspection environments, tracking each weld can involve managing numerous inspection results, photos, repair history records, and associated metadata.

Digital inspection platforms address these challenges by centralizing data in a single system, enabling inspection records to be searched, filtered, and retrieved quickly using partial information, such as weld identifiers, part numbers, or job numbers. This centralized approach improves both operational efficiency and compliance with long-term record retention requirements.

Managing Specifications and Revision Control

Welding inspection processes frequently depend on strict adherence to specifications, procedures, and industry standards that are subject to revision. Managing these revisions while maintaining accurate historical records presents a common challenge in traditional systems.

In some legacy environments, updating a specification can unintentionally affect previously completed reports, requiring manual adjustments to preserve historical accuracy. Inspection companies transitioning to digital systems report considerable improvements in this area.

By associating specific specification revisions with individual inspection records, digital platforms ensure that historical data remains unchanged while new inspections reflect updated requirements. This capability simplifies compliance and reduces the risk of documentation inconsistencies.

Standardization and Efficiency in Inspection Reporting

Consistency in inspection reporting is essential for both internal quality control and customer communication. In some inspection environments, reports were historically generated using basic word processing tools or informal documentation methods. As customer expectations evolve, these approaches can become insufficient.

Inspection companies supporting infrastructure and industrial projects report increasing demand for structured, detailed reporting that clearly documents inspection criteria, methods, and results.

Digital inspection systems address this need by enabling the use of standardized templates that consistently capture all required information. These templates can include predefined acceptance criteria, inspection procedures, and required data fields, ensuring that inspectors capture complete and accurate information.

For companies performing repetitive inspections, templates can also reduce repetitive data entry. Once templates are established, they may be reused across similar jobs, greatly enhancing efficiency. Inspectors could focus on capturing inspection results rather than re-entering standard information for each job.

Inspection Reports and Customer Communication

Inspection reports are the primary means of communicating inspection results to customers.

In traditional workflows, reports are often scanned documents derived from paper forms. These documents can be difficult to read, difficult to search, and susceptible to degradation over time.

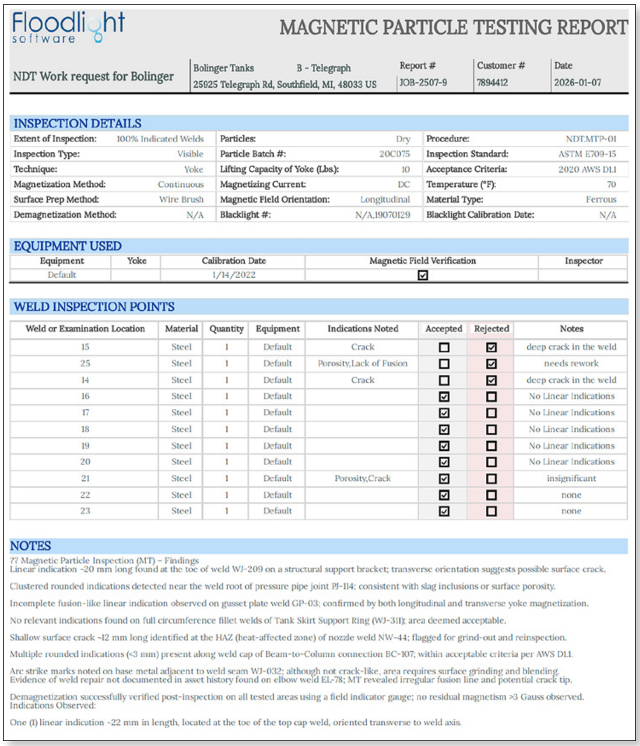
Digital reporting systems generate structured reports directly from inspection data, improving readability and usability. Customers appreciate receiving reports in digital formats that are easier to store, search, and share — Fig. 2.

In addition, digital systems enable faster report delivery and more efficient correction handling, improving overall communication between inspection providers and their customers.

Operational Visibility and Control

As inspection jobs grow in scale and complexity, managing operations across multiple inspectors, projects, and locations becomes increasingly challenging. In some cases, managers rely on phone calls or manual updates to track job progress, inspector activity, and project status.

Digital inspection platforms provide real-time visibility into inspection operations by centralizing job tracking, inspection status, and field activity within a single system.


Floodlight software

MAGNETIC PARTICLE TESTING REPORT

NDT Work request for Bolinger	Bolinger Tanks B - Telegraph 25925 Telegraph Rd, Southfield, MI, 48033 US	Report # JOB-2507-9	Customer # 7894412	Date 2026-01-07

INSPECTION DETAILS

Extent of Inspection:	100% Indicated Welds	Particles:	Dry	Procedure:	NDT.MTP-01
Inspection Type:	Visible	Particle Batch #:	20C075	Inspection Standard:	ASTM E709-15
Technique:	Yoke	Lifting Capacity of Yoke (Lbs.):	10	Acceptance Criteria:	2020 AWS D1.1
Magnetization Method:	Continuous	Magnetizing Current:	DC	Temperature (°F):	70
Surface Prep Method:	Wire Brush	Magnetic Field Orientation:	Longitudinal	Material Type:	Ferrous
Demagnetization Method:	N/A	Blacklight #:	N/A,19070129	Blacklight Calibration Date:	N/A

EQUIPMENT USED

Equipment	Yoke	Calibration Date	Magnetic Field Verification	Inspector
Default		1/14/2022	☑	

WELD INSPECTION POINTS

Weld or Examination Location	Material	Quantity	Equipment	Indications Noted	Accepted	Rejected	Notes
15	Steel	1	Default	Crack	☐	☑	deep crack in the weld
25	Steel	1	Default	Porosity,Lack of Fusion	☐	☑	needs rework
14	Steel	1	Default	Crack	☐	☑	deep crack in the weld
16	Steel	1	Default		☑	☐	No Linear Indications
17	Steel	1	Default		☑	☐	No Linear Indications
18	Steel	1	Default		☑	☐	No Linear Indications
19	Steel	1	Default		☑	☐	No Linear Indications
20	Steel	1	Default		☑	☐	No Linear Indications
21	Steel	1	Default	Porosity,Crack	☑	☐	insignificant
22	Steel	1	Default		☑	☐	none
23	Steel	1	Default		☑	☐	none

NOTES

?? Magnetic Particle Inspection (MT) – Findings
Linear indication ~20 mm long found at the toe of weld WJ-209 on a structural support bracket; transverse orientation suggests possible surface crack.

Clustered rounded indications detected near the weld root of pressure pipe joint PJ-114; consistent with slag inclusions or surface porosity.

Incomplete fusion-like linear indication observed on gusset plate weld GP-03; confirmed by both longitudinal and transverse yoke magnetization.

No relevant indications found on full circumference fillet welds of Tank Skirt Support Ring (WJ-311); area deemed acceptable.

Shallow surface crack ~12 mm long identified at the HAZ (heat-affected zone) of nozzle weld NW-44; flagged for grind-out and reinspection.

Multiple rounded indications (<3 mm) present along weld cap of Beam-to-Column connection BC-107; within acceptable criteria per AWS D1.1.

Arc strike marks noted on base metal adjacent to weld seam WJ-032; although not crack-like, area requires surface grinding and blending.
Evidence of weld repair not documented in asset history found on elbow weld EL-78; MT revealed irregular fusion line and potential crack tip.

Demagnetization successfully verified post-inspection on all tested areas using a field indicator gauge; no residual magnetism >3 Gauss observed.
Indications Observed:

One (1) linear indication ~22 mm in length, located at the toe of the top cap weld, oriented transverse to weld axis.

Fig. 2 — This digital report example includes detailed job and inspection data. Standardized templates help ensure inspectors consistently capture complete and accurate information, including predefined acceptance criteria, inspection procedures, and other essential data points.

The ability to view job progress in real time significantly improves operational awareness, as managers can see which jobs are on schedule, which are delayed, and where issues are occurring without contacting inspectors directly.

This level of visibility supports more active communication with customers and more effective management of inspection resources.

Digitalizing Welding Inspection in the Field

A significant portion of welding inspection takes place in the field. Field inspectors often work under time constraints and must balance inspection responsibilities with documentation requirements. In traditional workflows, inspection data may be recorded in notebooks or informal documents and later transferred into reports. This approach may result in delays in reporting and increased risk of incomplete documentation.

Digital inspection platforms are helping to address these challenges by enabling inspectors to capture data directly in the field. Mobile inspection tools allow inspectors to do the following:

- Record inspection results in real time
- Attach photographs to inspection records
- Document repair activities and follow-up inspections
- Reference inspection procedures and acceptance criteria

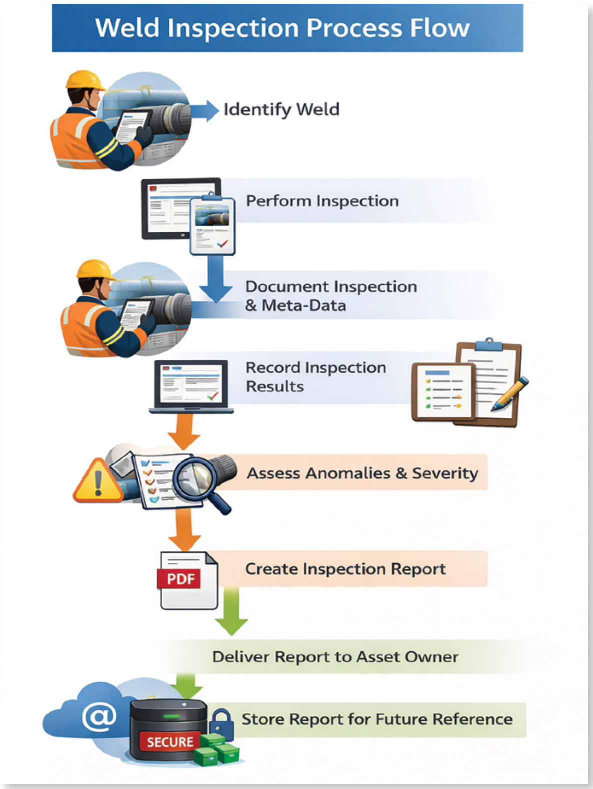


Fig. 3 — As documentation demands and inspection volumes grow, traditional workflows are becoming harder to manage. Digital inspection management systems help modernize these processes efficiently.

Capturing data at the point of inspection helps ensure that all relevant information, including intermediate findings and corrective actions, is recorded accurately. This capability is becoming increasingly important as project owners require more detailed and transparent inspection documentation.

Conclusion

As documentation requirements become more complex and inspection volumes increase, traditional workflows are becoming increasingly difficult to manage efficiently. Digital inspection management systems offer an effective means to modernize these workflows — Fig. 3. By centralizing data, standardizing reporting, and facilitating real-time data capture, digital platforms can reduce administrative workload while improving traceability and operational visibility.

For inspection operations, the transition to digital workflows offers an opportunity to improve efficiency and documentation quality. As the industry continues to evolve, digital inspection is likely to play a critical role in ensuring the accuracy, consistency, and reliability of welding inspection processes. IT

NASRIN AZARI (*nazari@floodlightsoft.com*) is the founder and CEO of Floodlight Software, Raleigh, N.C.

A message from the AWS Certification Department:

Understanding the Updated SCWI Program

In April 2025, AWS introduced a redesigned Senior Certified Welding Inspector (SCWI) program. Individuals seeking to earn the SCWI credential must complete the following four endorsements: Welder Performance Qualifier, Welding Procedure Qualifier, Welding Coordination and QA, and Nondestructive Examination Coordination. These endorsements are not available for initial CWI applicants.

The new path enables in-depth learning and flexibility to pursue endorsements in any order, empowering individuals to tailor their certification journey to their specific career goals and interests.

The SCWI maintenance structure aligns with the AWS QC1:2016-AMD1, *Specification for the AWS Certification of Welding Inspectors* requirements. Under QC1 Clauses 15 and 16, SCWIs must complete renewals at the three-year and six-year marks and undergo complete recertification in the ninth year of their certification cycle.

To renew, as per QC1:2016-AMD1, Clause 15, the SCWI will need to attest that they have had no period of continuous work inactivity exceeding two years in activities described in AWS B5.1, *Specification for the Qualification of Welding Inspectors*, during the previous three years of certification.

To recertify, per QC1:2016-AMD1, Clause 16, SCWIs may recertify using one of three flexible pathways:

- Complete a committee-approved endorsement at any time within the nine-year period.
- Accumulate the required professional development hours (PDHs).
- Attend an AWS 9-Year Recertification Seminar before their certification expiration date.

FEATURE

BY JORGE T. REYNA

Using Eddy Current Testing for Corrosion Detection in Welded Structures

Learn how this testing method helps identify early corrosion around welds in complex industrial structures

In many industrial facilities, corrosion rarely appears randomly across a structure. Instead, inspectors often notice that degradation tends to develop near welded joints. Weld toes, attachment welds, and heat-affected zones (HAZs) are frequently the first locations where corrosion initiates.

Anyone who has inspected pipelines, storage tanks, or offshore structures has likely observed this phenomenon. While coatings may remain intact across large surfaces, localized deterioration may begin around welds where geometry, residual stresses, and metallurgical transitions interact in complex ways.

Traditionally, inspectors evaluate these areas using techniques such as ultrasonic testing (UT) or magnetic particle testing (MT). These methods remain indispensable for weld inspection and structural integrity assessment. However, they are not always optimized for detecting early-stage corrosion or shallow material loss near the surface.

In these situations, eddy current testing (ECT) provides a complementary inspection approach based on electromagnetic interaction with conductive materials.

Electromagnetic Interaction with Welded Materials

Eddy current inspection operates on the principle of electromagnetic induction. When alternating current flows through a probe coil, it generates a changing magnetic field. If a conductive material is placed within this field, circulating electrical currents, known as eddy currents, are induced within the metal.

These induced currents interact with the probe's magnetic field, thereby influencing the electrical impedance of the inspection coil. Any discontinuity that disrupts the flow of these currents produces measurable variations in the signal.

Corrosion near welds can significantly alter the distribution of these currents. Even small material losses, localized pitting, or surface degradation can disturb the electromagnetic field enough to generate detectable signals.

However, welded structures introduce additional complexity. The weld metal, HAZ, and base metal may each possess slightly different electrical conductivity and magnetic permeability due to metallurgical transformations during welding. These variations produce a characteristic signal response that must be understood before corrosion indications can be correctly interpreted.

Frequency Selection and the *Skin Effect*

One of the most important variables in ECT is test frequency. Eddy currents do not penetrate uniformly into a material. Instead, they follow the phenomenon known as the *skin effect*, in which the current density decreases exponentially with depth below the surface.

Higher frequencies concentrate the induced currents near the surface, increasing sensitivity to small discontinuities such as pitting corrosion or shallow material loss at weld toes. Lower frequencies allow deeper penetration and may reveal corrosion that has progressed slightly below the surface or beneath thin coatings.

Selecting the appropriate frequency, therefore, becomes a critical part of the inspection strategy. The choice depends on several factors, including expected corrosion depth, coating thickness, and material electromagnetic properties.

Carbon Steel vs. Aluminum

Material behavior significantly influences ECT performance. Carbon steels are ferromagnetic materials with high magnetic permeability. This property alters the magnetic field distribution and reduces the effective eddy current penetration depth. Additionally, variations in permeability near welds can produce signal changes that resemble corrosion indications if not properly interpreted.

ECT inspection in use to detect cracks in the internal lining of a bearing housing in wind energy equipment during maintenance.

For this reason, ECT of carbon steel welds requires careful calibration and experienced signal interpretation.

Aluminum alloys behave quite differently. Aluminum is nonferromagnetic and has magnetic permeability close to that of free space. Combined with relatively high electrical conductivity, this allows eddy currents to flow more uniformly, producing cleaner and more predictable signals.

These characteristics are among the reasons ECT has long been widely used for inspecting aluminum structures in the aerospace industry.

Complementary Role in Weld Inspection

In welded structures, ECT is rarely used as a standalone method. Instead, it serves as a complementary technique alongside other nondestructive testing methods.

Typical applications include corrosion detection at weld toes in pipelines, inspection of attachment welds in storage tanks, and evaluation of localized degradation in offshore structures.

Because the technique requires no coupling and can often be performed through thin coatings, it offers practical advantages for rapid field inspections.

Conclusion

Corrosion near welded joints remains a persistent challenge in maintaining the integrity of industrial structures. Detecting early-stage degradation in these regions requires inspection methods capable of detecting subtle changes in material condition.

ECT provides a sensitive electromagnetic approach for identifying corrosion in complex welded geometries. When applied with proper understanding of material behavior, frequency selection, and weld metallurgy, it becomes a powerful complementary tool for corrosion assessment.

For inspectors and engineers responsible for the long-term reliability of welded systems, mastering this technique provides another means to assess material condition by observing the invisible flow of electromagnetic currents within the metal.

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ADAPTED FROM A PRESENTATION BY DAVID VIAR

Beyond Credentials: What Welding Inspectors Should and Shouldn't Do

The ethics, the paperwork, and what nobody teaches you

CWI David Viar uses an oxyfuel torch in the shop. Preheating prior to welding is a critical variable that CWIs are responsible for verifying.

In this trade, confidence can get mistaken for competence. You see it when someone tries to win the discussion by quoting clause numbers rather than applying the requirements to the work in front of them. That is not how I approach inspection. I am not an engineer, and I do not use the code book as a debating tool. My responsibility is to verify conformance to the governing code, contract documents, and approved procedures. I'm a welder first, so as a CWI, I level with welders but within the limits of the applicable requirements and acceptance criteria.

Here is the part that many new inspectors learn after certification. The wallet card does not teach you how to run a job in the field. It does not teach you how to write reports that hold up to review, how to document engineering dispositions, or how to handle a request to sign off outside your qualification. Those skills come from structured training, supervision, and repetition in real production conditions.

The Crucial Role of Mentorship

New Certified Welding Inspectors (CWIs) often have strong test preparation but limited exposure to production documentation, inspection hold points, and the day-to-day decisions that must be supported in writing. Without a mentor, a new inspector can miss requirements, misapply acceptance criteria, or create weak records. Any of those can compromise the project and the inspector's credibility.

Early in my career, experienced inspectors corrected my reports and my process before those mistakes became formal nonconformances or audit findings. That supervision mattered. My advice is direct. Find a mentor, and do not wait for a problem to force the relationship. If you are a senior CWI (SCWI), be intentional about mentoring because it reduces risk for the entire organization.

AWS B5.1 vs. QC1

A recurring technical mistake I see is confusion between AWS B5.1, *Specification for the Qualification of Welding Inspectors*, and QC1, *Specification for AWS Certification of Welding Inspectors*. The documents reference each other, so the mix-up is common.

- B5.1 addresses roles, responsibilities, and minimum competencies. I use it as a framework for training plans, task assignment, and qualification matrices. It is not a certification document. It describes what a person should be trained to do and under what level of oversight.

- QC1 governs AWS certification for Certified Associate Welding Inspectors (CAWIs), CWIs, and SCWIs. It defines eligibility, renewal, and the rules for representing your credential. I treat QC1 as a boundary document. It clarifies what the certification does and does not authorize in terms of scope and representation.

B5.1 supports employer training and task assignment across Associate Welding Inspector (AWI), Welding Inspector (WI), and Senior WI (SWI) role descriptions. QC1 defines your certification status. When the two are blended, an inspector can assume they are "certified to do" a task that requires employer authorization, additional training, supervision, or separate certification under a written practice.

B5.1 as a Practical Training Blueprint

If you manage an inspection program or if you are trying to standardize practice in a small shop, B5.1 is a useful blueprint. Auditors ask how employees and inspectors are trained and how competence is verified. B5.1 gives a baseline for knowledge, skills, and tasks by role. When you align internal expectations with a published AWS framework, you improve consistency and defensibility.

Some organizations resist "following a book," preferring internal practices or informal expectations. Audits do not reward that mindset. Using a publicly available, widely understood standard removes ambiguity and gives both the organization and the auditor a common reference point.

Another advantage is access. B5.1 is available at no cost. That matters because it lowers the barrier for building a formal training plan, a task qualification record, and a documented progression model.

B5.1 also reflects an operational reality. A person's demonstrated skill can outpace their title. If the organization determines a person has the capability, it can assign

AWS B5.1 defines inspector capabilities and training guidance, while QC1 governs certification requirements and credentialing.

higher-level tasks. For example, some CWI job descriptions now include bolting, coatings, and sometimes even concrete inspection. As a CWI, I have even been asked to perform bolting inspection.

B5.1 makes it clear that the employer remains the final decision-maker. Qualification to the standard does not automatically make a person suitable for every assignment, and it does not limit the employer's authority to assign work. In practice, that means inspectors may be asked to take on responsibilities outside their primary discipline, and it becomes important to recognize when you may be out of your depth and need help or clarification.

Ethics in Action: What CWIs Must Not Do

When people ask me what a CWI "is allowed" to do, I usually flip it around. The career-saving question is, what should I not do?

1. Don't act like an engineer. A CWI should not change welding procedure specifications (WPSs) or procedure qualification records (PQRs) without qualification. Their role is to verify compliance, not to redesign the process. Substituting filler metals, tweaking essential variables without qualification, or approving procedures outside their qualified range crosses a bright ethical line.

Do not assume authority you do not have. Only the engineer of record, or other designated authority, can make design decisions and code interpretations that change requirements. If I need a disposition, I get clarification and make sure it's documented.

2. Do not perform nondestructive testing (NDT) that you are not certified to perform. A CWI credential does not qualify a person for penetrant testing, magnetic particle testing, ultrasonic testing, radiographic testing, or other NDT methods unless the individual meets the method requirements under the applicable standard and the employer's written practice. When a job requires NDT, I verify technician qualification records and that the procedure and equipment meet the project requirements.

3. Do not ignore documentation. Inspection decisions must be traceable. I keep procedures, inspection reports, correspondence, photographs, and approvals organized. If a dispute arises years later, the record is what supports what was inspected, what was accepted or rejected, and why. If it isn't documented, it didn't happen. Paperwork is part of the job.

Verify before You Call Nonconformance

Passing a CWI exam on one code does not translate to technical competence across all codes. Moving from API work to AWS D1.1, *Structural Welding Code — Steel*, or into aerospace requirements such as D17.1, *Specification for Fusion Welding for Aerospace Applications*, requires deliberate study. These differences are not limited to the codes themselves — they extend to how procedures are written, qualified, and applied. Some codes provide detailed acceptance criteria. Others defer key decisions to engineering judgment, which increases the need for formal interpretations and written dispositions. A professional response is to pause, review the governing requirements, and then respond based on documented criteria.

That principle applies directly in the field, where the governing procedure is the immediate standard for acceptance. On a pipeline job, I once evaluated an in-service sleeve weld and saw a visible tempering (annealing) pass intended to slow cooling. My first reaction was that it was unacceptable. The qualified procedure allowed it. A welder told me to read the procedure, so I did. The takeaway is simple. The procedure controls, and the inspector must verify compliance with the approved procedure before calling a condition nonconforming.

Culture, Confidence, and Saying "No"

Inspection work requires technical confidence and procedural discipline. You have to be willing to stop work when acceptance criteria are not met. You also have to be willing to say "I do not know" when you need time to verify requirements. The inspectors who perform well over time are the ones who build training plans, seek competent review early, and maintain documentation that supports every acceptance decision.

A Career Worth the Discipline

The value of being a CWI is not quoting clause numbers. The value lies in the consistent application of acceptance criteria, documented decision-making, and disciplined control of scope. Use B5.1 to build training programs and task authorization, and use QC1 to define certification boundaries and representation rules. Decline work that requires qualifications you do not have. When you need to verify a requirement, stop and review the governing documents. Then document the basis for acceptance or rejection.

Those habits protect the inspector, and they improve quality outcomes for the entire project team. IT

This article is adapted from a presentation given by **DAVID VIAR** (*viar18@att.net*) at the Inspection Expo & Conference held February 3–4, 2026, in Austin, Tex.

My Field Checklists

When I'm trying to keep myself honest in the field, I come back to a few simple checklists.

BEFORE I ACCEPT THE ASSIGNMENT

- Confirm the governing documents (code, contract requirements, drawings, and referenced standards) and confirm that you can apply the acceptance criteria. If the code is new to you, schedule review time and document the limitation.
- Define inspection scope before mobilizing (welding only or welding plus bolting, coatings, dimensional checks, etc.). If scope extends beyond welding, verify training, method qualifications, and written authorization before accepting responsibility.

PROCEDURE CONTROL

- Do not alter the welding procedure qualification (WPS)/procedure qualification record (PQR) or essential variables without proper qualification and approvals. Your role is verification, not redesign.
- If a WPS appears incorrect or incomplete, request the supporting PQR, involve the procedure owner or responsible engineer, and document the resolution in the job file.

NDT AND SPECIALTY METHODS

- Refuse work you're not certified to perform. Politely cite employer practice and applicable standards. Offer to help arrange a qualified technician.

DOCUMENTATION

- Build a job file: procedures, inspector qualifications, calibration records, reports, photographs, nonconformance notes, and approvals. Save communications that clarify acceptance criteria or engineering judgments.

TRAINING AND MENTORING

- Map company training to AWS B5.1 tasks for AWI, WI, and SWI role descriptions. Use the mapping to track progress, authorize tasks, and support audits.
- Encourage early-career CWIs to pursue structured training and maintain evidence of training, such as WPQ-1, to support controlled expansion of responsibilities under supervision.

BY SETH DAVIS

How to Use AI to Write and Audit Welding Documents

A practical guide to using AI for documentation, audits, and workflow efficiency without sacrificing professional judgment

Welding inspectors and quality managers are spending more time than ever managing paperwork. Today's artificial intelligence (AI) tools, such as ChatGPT, Claude, and Gemini, offer a way to change that by enabling near-instant creation, organization, and review of the technical documents CWIs regularly handle.

This article outlines practical ways AI can assist welding inspectors, quality managers, and business owners in reducing their paperwork burden by streamlining the writing and auditing of welding documents. It also explores current limitations, effective prompt-writing techniques, data security considerations, and the future potential of AI-assisted welding quality systems.

AI in Welding Inspection: What It Actually Does

AI is not yet capable of replacing the judgment of a Certified Welding Inspector (CWI), engineer, or quality manager. However, the pace of development — evident in advanced computational engineering efforts such as Leap71's Noyron model—indicates that the technology is evolving far faster than many anticipated.

At this stage, AI is like a just hired, newly minted CWI, eager to work and full of energy, but still needs direction and supervision to produce high-quality work.

Modern AI systems, commonly known as large language models (LLMs), recognize patterns across enormous amounts of text and generate structured responses based on user instructions.

The first step in working with AI is learning how to give clear instructions.

Writing Better AI Prompts

The quality of AI output depends heavily on the quality of the instructions provided to the system. This process is commonly referred to as prompt engineering.

Avoid vague prompts such as: "Review this welding procedure specification (WPS)."

Instead, provide detailed instructions that define:

1. Who the AI should act as

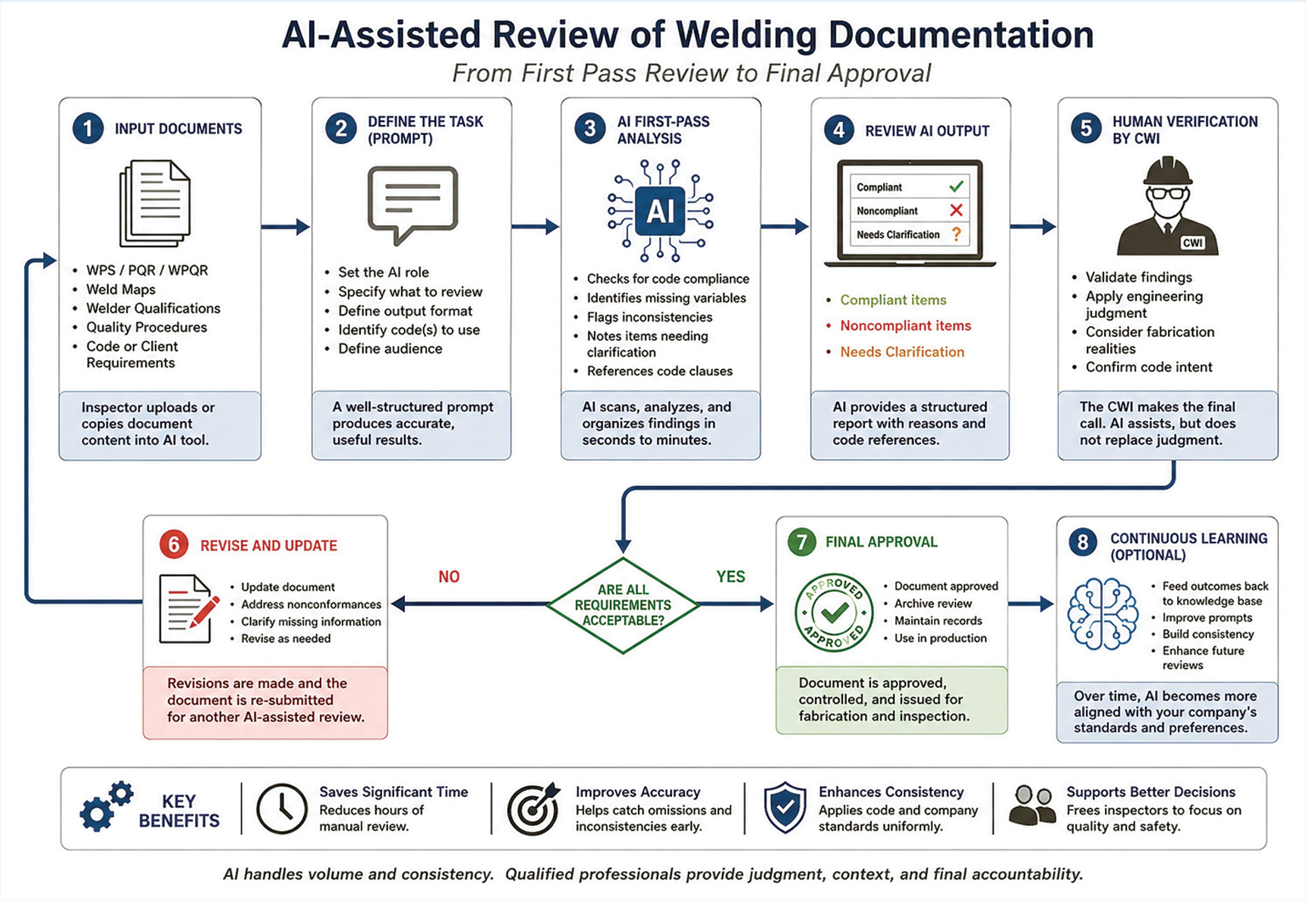
2. What task it should perform

3. How the response should be structured

4. Who the intended audience is

For example:

> "You are a Certified Welding Inspector with expertise in AWS D1.1, *Structural Code—Steel*. Review the following WPS for code compliance. Identify nonconformances, missing variables, and items requiring clarification. Always reference the applicable code clauses. Separate findings into 'Compliant,' 'Noncompliant,' and 'Needs Clarification.'"



Example workflow showing AI-assisted review of welding documentation prior to final inspection approval.

This style of prompting dramatically improves the usefulness of the response.

The key is specificity. AI systems perform best when expectations are clearly defined.

Treat It Like a Conversation

The next thing you need to know is that no matter how well your initial prompt is written, getting what you want out of AI will involve a conversation with multiple clarifications.

Expect to have to review and clarify the AI's work multiple times. Each time you refine your prompt, you get closer to the desired result.

Don't be afraid to challenge the AI to defend its work. Treat it like you would treat a conversation with any other CWI. Challenge it to defend every position it takes from the applicable codes or standards.

You can increase the quality of the output by giving the AI access to applicable drawings and codes in your prompt.

Practical Applications for Welding Companies

One of the most valuable uses of AI is accelerating first-pass document reviews.

For example, a fabrication company preparing for a customer audit can use AI to rapidly identify missing variables, inconsistent terminology, qualification gaps, and conflicting information between procedures before the documents ever reach final review by the CWI.

This allows inspectors and quality managers to focus more on higher-level technical decisions rather than repetitive clerical review.

AI can also help smaller fabrication shops that may not have dedicated quality departments by improving documentation consistency and reducing administrative workload.

Understanding the Current Limitations of AI

Despite its strengths, AI has significant limitations that welding professionals must understand.

First, just like many of us, AI systems can confidently provide incorrect information. This issue is commonly referred to as hallucination. The system may generate nonexistent code clauses, inaccurate interpretations, or incorrect technical recommendations. Because of this, AI-generated content should not be accepted without human review.

Second, AI systems do not truly "understand" welding codes in the same way an experienced inspector does. They recognize statistical language patterns rather than applying engineering judgment.

A skilled CWI understands:

- Intent behind code language
- Practical fabrication realities
- Historical interpretations
- Field conditions
- Safety implications
- Customer expectations

AI currently lacks this contextual understanding.

Third, AI is not liable for mistakes. If AI-generated documentation contains errors, responsibility still falls on the company and the qualified personnel who approved the documents.

For these reasons, AI should be viewed as an assistant, not a replacement for qualified welding professionals.

Data Security and Confidentiality

One easy-to-overlook aspect of AI adoption in welding is data security.

Many public AI systems store or process user input externally. This means that welding documentation containing proprietary information may be exposed to the public.

Before uploading documents into any AI system, companies should understand:

- Who owns the uploaded data
- Whether data is retained
- Whether information is used for model training
- How the provider handles encryption and access control

Basic best practices include:

- Removing sensitive customer information
- Avoiding export-controlled data
- Using enterprise-grade AI platforms when possible
- Implementing access controls
- Maintaining document traceability
- Reviewing company cybersecurity policies

Organizations considering large-scale AI integration should involve both quality and IT personnel in deployment planning. Many of the security concerns associated with using external AI can be addressed by building your own in-house system.

Building Internal AI Systems

A great path forward is for each company to build its own in-house AI.

While high-end systems can cost hundreds of thousands of dollars, a small shop can get started with something as simple as a $500 Mac Mini and the download of an open-source AI like Ollama, paired with an agent like OpenClaw.

Developing these systems typically involves:

1. Defining the specific problem to solve

2. Gathering and cleaning quality data

3. Selecting an appropriate AI model

4. Testing and validating outputs

5. Continuously refining performance

The Future of AI in Welding Inspection

AI tools are improving at an extraordinary pace. What seems impressive today will likely appear primitive in only a few years.

Welding professionals and companies who understand how to use AI will gain significant advantages in productivity and profit.

For now, the most effective approach is a collaborative one where AI handles repetitive, document-heavy tasks, while human experts continue to provide judgment, oversight, and accountability.

Those who begin learning and using these tools now will be better positioned to adapt as the technology evolves.

Conclusion

In its current form, AI is a powerful tool that can help professionals work faster, improve consistency, and reduce administrative burden.

The best way to learn AI is to use it. Go online right now and start talking to any of the many available AI programs so that you can get a feel for how they work and how best to communicate with them. IT

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THE ANSWER IS

BY ALBERT J. MOORE JR.

Q I passed my Certified Welding Inspector exam recently, but I'm having a difficult time understanding exactly how alloying elements interact with iron, and how they influence the properties of metal. Can you provide an overview of the basics of alloying steels?

A The study of metallurgy and the effects of alloying elements on iron have been ongoing for many years. It is still a subject of study by folks far smarter than me, but I'll share what I know.

During your studies for the Certified Welding Inspector (CWI) examination, you learned that steel is a combination of iron and carbon. Carbon is the primary alloying element added to pure iron to make steel (see Table 1). While that might sound simple, the process is complicated because carbon can either remain in solid solution or form a chemical compound.

While we are familiar with a solid dissolve in a liquid, metals are unique because they can dissolve into one another to form solid solutions. As a youngster, you probably noticed that you could dissolve more sugar in hot water than in cold water. Similarly, carbon is more easily dissolved in iron when the iron is at a high temperature than when the iron is at room temperature.

As the hot water cools, the excess sugar is rejected from the water as sugar crystals. In a similar manner, as the hot iron cools, the excess carbon is rejected. The excess carbon can be rejected as a chemical compound called cementite (Fe_3C). Let's talk about it.

When the iron is at a high temperature, it is said to be austenitized. At this temperature, the solubility of carbon is relatively high, about 2.14% by weight when the iron is heated to around 2000°F. The solubility of carbon in iron at roughly room temperature is only about 0.005% by weight. Just like sugar dissolved in water, the solubility of carbon is dependent on the temperature of the iron. Solubility increases with increasing temperature and is reduced as the temperature drops.

Carbon is considered to be the most influential alloy addition to iron as very small additions of carbon to iron produce steel that is harder and stronger than pure iron, but at the expense of ductility and reduced weldability. That's the starting point in this conversation.

For ease of welding, we limit the amount of carbon added to iron to less than 0.3%. There are steels containing higher amounts of carbon, but they can be difficult to weld and require high preheat before welding, they require the maintenance of high interpass temperatures until the welding operation is completed, and they require low-hydrogen welding practices.

To complicate matters, even without changing the concentration of carbon, steel can be heat treated to modify the properties of steel.

Let's assume we start with a eutectoid steel, i.e., one that contains 0.76% carbon. The mechanical properties can be modified simply by controlling the cooling rate from the austenitizing temperature.

If we heat the steel to a high temperature, that is, we austenitize it, and then cool the steel very slowly in a furnace such that it cools to room temperature over the course of 24 hours or so, we say it is annealed. The excess carbon comes out of solution as cementite (Fe_3C) in the form of coarse laths surrounded by ferrite, i.e., iron with very little carbon. We call that microstructure coarse pearlite, because it resembles mother of pearl when viewed under high magnification. It is soft, ductile, and easily formed into shapes.

If the same steel containing 0.76% carbon is heated to the austenitizing temperature, such that all the carbon in solution, and is then cooled in still air, the solubility of carbon in iron is again reduced. The excess carbon is rejected, but because the cooling rate is increased, i.e., it is cooled faster, the laths of cementite (Fe_3C) do not have a chance to grow as large. As a result, we now have fine-grained pearlite formed. The steel is stronger than it is in the annealed condition. It is not as ductile, but it still has reasonable toughness at room temperature.

If we take the steel, still with 0.76% carbon, and heat it until it is austenitized, then cool it fairly quickly to 1000°F, and hold it at that temperature for a short while before quickly cooling it to room temperature, we get a multiphase microstructure called bainite. It is hard and strong, but it has relatively good toughness and limited ductility.

Now to wrap up this subject, if we reheat the eutectoid steel containing 0.76% carbon to the austenitizing temperature and cool it very fast, i.e., quench it in water or oil, the excess carbon doesn't have time to form cementite. The excess carbon is accommodated in the body-centered ferrite by forming an interstitial solid solution. We call it the diffusionless decomposition of austenite because the carbon doesn't have sufficient time to form cementite, instead causes the body-centered cubic ferrite to elongate into a shoebox-shaped unit cell called body-centered tetragonal. We have a special name for that microstructure: martensite. Martensite is characterized as hard and strong, but with low toughness, and it is brittle.

The preceding discussion used a eutectoid steel containing a relatively high carbon content, too high to be considered easily welded, to illustrate that alloy content alone doesn't determine the mechanical properties of steel. One must also consider the steel's thermal history.

There are other elements that can be added to steel that enhance its properties in a similar way that carbon does, but they do not degrade weldability (ease of welding) to the same extent that carbon does. Some alloy additions also have other benefits besides increasing the strength of steel.

What are some of the other benefits? Chromium increases strength, and it can improve corrosion resistance if added in sufficient amounts. We see a slight improvement in corrosion resistance when the chromium content exceeds 4.5 to 5%, but corrosion resistance is noticeably improved when the chromium content exceeds about 11%.

Small additions of nickel, on the order of 1 to 3%, can improve strength and low-temperature toughness.

Manganese performs several important functions when added to iron. Up to about 1%, it acts as a deoxidizer to prevent porosity while making steel or depositing a weld. When there is sulfur, we typically increase the manganese to about ten times the sulfur content so that it chemically combines with the sulfur to form rounded manganese sulfide inclusions that mitigate the tendency of the weld to crack during solidification. Manganese in amounts in excess of that needed for deoxidation or to counter the effects of sulfur acts as a strengthening agent. Manganese added to iron in roughly 11 to 14% produces Hadfield steel, which work hardens when subjected to repeated blows. It sees applications in mining, quarry, and excavation equipment.

Table 1 — Effects of Alloying Elements on Steel

Effect	Coefficient C_{eq}	Hardening/ Strength	Corrosion Resistance	Low-Temp. Toughness	High-Temp. Creep	Deoxidize	Combine with Sulfur
Carbon	1	X	$\downarrow$				
Chrome	5	X	$\uparrow$				
Molybdenum	5	X			$\uparrow$		
Vanadium	5	X					
Manganese	6	X				$\uparrow$	$\uparrow$
Silicon	6	X				$\uparrow$	
Nickel	15	X		$\uparrow$			
Copper	15	Improved weathering characteristics but increased crack sensitivity					

Note: The table shows the primary functions of the alloying elements added to steel and is not intended to be all inclusive.

Molybdenum improves strength at high temperatures (improving creep resistance). Some alloy additions can influence more than one property of steel, but never forget that any increase in strength and hardness is accompanied by a reduction in ductility.

Other alloy additions act similarly to carbon to a limited extent. To compare the effects of those elements to the effects of carbon, researchers have developed several carbon equivalent formulas. The carbon equivalent formulas are derived from empirical data collected from numerous experiments. The formulas are useful over a certain range of alloy compositions but lose relevance if the value of the carbon equivalent exceeds a certain threshold.

One carbon equivalent equation included in AWS and ASTM standards is as follows:

$$C_{eq} = C + \frac{Si}{6} + \frac{Mn}{6} + \frac{Mo}{5} + \frac{Cr}{5} + \frac{V}{5} + \frac{Ni}{15} + \frac{Cu}{15}$$

It is useful up to a carbon equivalent of about 0.6. This upper limit is appropriate for most steels commonly used in construction of buildings, bridges, and ships. It shows how influential the alloying elements found in those steels are relative to carbon. Simplified, the equation indicates that it would take 5% chromium to produce the same hardness as 1% carbon, whereas it would take 15% nickel to produce the same hardness as 1% carbon.

That may be an oversimplification, but you can see that both chromium and molybdenum have a smaller effect on hardness than carbon, whereas nickel is not nearly as effective as chromium or molybdenum as a hardening agent. So, to attain the same strength, elements other than carbon can be added to steel without dramatically increasing the carbon equivalent or reducing weldability, but at a higher cost. The lower the carbon equivalent, the less likely delayed cold cracking will be a problem. So, we have alloy steels that retain ease of welding, yet have high strength, good high-temperature properties, or low-temperature properties without the problems we would expect if we were welding steels alloyed with carbon alone. IT

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