



INSPECTION TRENDS

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Audits as Allies

Amusement Park Inspection

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Five Things a CWI Should Know about Coatings

The rise in value-added services has reshaped how inspection companies market themselves. Companies often promote the idea of the dual-certified inspector — someone to cover both welding and coatings. The idea seems efficient: one well-rounded professional who can streamline oversight, reduce labor costs, and deliver more-thorough inspections. But behind that convenience lies a tougher reality for welding inspectors. Many are not offered hands-on training but are suddenly expected to step into a role with extra responsibilities. Here are five things a welding inspector should know about coatings.



BY LUCY DRAUS


1. Know industry standards and specifications. Many surface preparation and coatings standards referenced in job specifications are published by the Association for Materials Protection and Performance (AMPP, formerly NACE and SSPC), ASTM International, and the International Organization for Standardization (ISO). Certified Welding Inspectors (CWIs) stepping into the inspection of coatings should become familiar with these organizations' publications since their standards define surface cleanliness, surface profile, coating thickness measurement, and inspection procedures.

2. Surface preparation is critical. Poor surface preparation is the leading cause of premature coating failure. Inspectors should verify cleanliness and surface profile before painting. Tools include replica tape and micrometers for nondigital verification or digital depth micrometers for faster measurements. Visual standards such as SSPC-VIS 1, *Guide and Reference Photographs for Steel Surfaces Prepared by Dry Abrasive Blast Cleaning*, provide side-by-side comparisons to confirm the required level of preparation.

3. Monitor environmental conditions. Every coating's chemistry reacts differently to its surroundings during application and curing. The ambient temperature, wet bulb temperature, humidity, dew point, and substrate surface temperature must be measured before and during coating. Digital dew point meters with surface temperature probes simplify this process, while a sling psychrometer (with psychrometric charts) and a surface temperature gauge remain reliable nondigital options. These readings confirm whether conditions meet the coating manufacturer's requirements.

4. Check the application and thickness. Each coat of paint has a purpose and recommended thickness. Inspectors should evaluate the application for discontinuities, which can compromise performance. The dry film thickness (DFT) is measured per SSPC-PA 2, *Procedure for Determining Conformance to Dry Coating Thickness Requirements*, to verify that results fall within specification. Electronic DFT gauges are the most common choice, while nonelectronic gauges are less expensive and less accurate. Use certified coated standards to verify instrument accuracy.

5. Observe and document. Document environmental conditions, coating batch numbers, expiration dates, surface preparation times, application times, inspection results, and nonconformances.

Basic coatings awareness can make a significant difference even without a full coatings certification. CWIs who juggle both roles often switch between two sets of standards, equipment, terminology, and procedures. Yet this additional work is frequently overlooked in project planning and employee compensation. For those thrown into coatings without much preparation, starting with the fundamentals can make the work more manageable. 

LUCY DRAUS (ldraus@drausinspection.com) is the owner of Draus Inspection, Conneaut Lake, Pa. She is an AWS CWI and AMPP Senior Certified Coatings Inspector.



Ray Wilsdorf Honored with CWI Lifetime Achievement Award



Ray Wilsdorf (right) accepted his CWI Lifetime Achievement Award from AWS President Richard Holdren at FABTECH 2025.

Ray Wilsdorf received the Certified Welding Inspector (CWI) Lifetime Achievement Award on September 8 during the AWS 106th Annual Business Meeting at FABTECH in Chicago, Ill. He was recognized with a plaque and a medallion.

“I’m humbled and very honored to receive the award,” Wilsdorf said. “It’s very special and probably the most significant award I’ve received in my entire career. So, thank you very much.”

Wilsdorf was recognized for nearly 50 years of distinguished service as a CWI. His accomplishments include pioneering quality control initiatives at Flint Steel Corp. and contributing to the development of the electro-slag and strip-overlay welding processes. He joined AWS as a Student Member while attending LeTourneau University in Longview, Tex. He has been an active member of the AWS Tulsa Section for 58 years and has supported the welding industry through mentoring, teaching, publishing, and board service.

He taught CWI classes at the Tulsa Technology Center, Tulsa, Okla., for five years and currently serves as an Oklahoma state welding inspector. In that role, he oversees witness and testing for students certifying for their Oklahoma Welder Certification License at Indian Capital Technology Center in Muskogee, Okla.

Wilsdorf is also a consulting quality control manager for Zentech, Tulsa, Okla., and provides welding engineering consulting services to the petrochemical and heavy metal industries throughout the region.

AWS Holds CWI Seminar

AWS hosted a Certified Welding Inspector (CWI) seminar July 13–28 at its World Headquarters in Miami, Fla. Tim O’Neill, a Senior Certified Welding Inspector and owner of O’Neill Technical Services, led the course.

Attendees included Kyle Albrecht, Asdrú Arana, Damen Bircher, Jason Geldner, John Ingram, Travis King, Quinton Llewellyn, Jesse Memmott, Erik Pfief, Felix Robles, Leonardo Roque, and Adrian Steele.



The attendees of an AWS CWI Seminar pose for a photo in front of AWS World Headquarters in Miami, Fla.

ASNT Foundation Invests in NDE's Future through Research and STEM Outreach

The American Society for Nondestructive Testing (ASNT) Foundation, Columbus, Ohio, is advancing non-destructive examination (NDE) through a dual effort: launching a national study to quantify NDE's economic impact and expanding STEM outreach with hands-on learning for middle school students.

The research initiative will measure and communicate the economic value of NDE across U.S. industries. In partnership with the global research firm Frost & Sullivan, the study will assess NDE's role in job creation, cost savings, risk mitigation, and workforce needs in sectors such as aerospace, energy, manufacturing, construction, and transportation.

"By putting hard data behind NDT's [nondestructive testing's] impact, we can show its vital role in safety, innovation, and workforce growth," said Heather Cowles, executive director of the ASNT Foundation. "This study will provide industry leaders, educators, and policymakers with the insights they need to prepare for the future."

This research will impact workforce development, funding, and policy decisions that shape the U.S. NDE industry. The foundation views this project as a critical step in elevating awareness of the NDE industry and ensuring the industry's contributions in the United States are fully recognized. The findings will offer valuable insights to guide workforce initiatives, industry advocacy, and long-term strategic planning by providing the first comprehensive picture of NDE's economic and workforce impact. A final report will be released in early 2026.

The ASNT Foundation has also been awarded a STEM Innovation Grant from Battelle, which recently announced a \$1.2 million investment in Central Ohio nonprofit organizations dedicated to STEM education.

The grant will help the foundation expand educational programs in NDE. This pilot initiative will distribute 500 Ultrasound in a Box kits to after-school and weekend clubs, giving middle school students, particularly first-generation and underserved learners, an early introduction to NDE and its in-demand career opportunities.

"This grant provides the resources to expand our reach, introducing students and educators to a critical and in-demand career pathway in NDT," said Alex Rios, fundraising manager at the ASNT Foundation. "It's an investment in the future of a highly skilled NDT workforce essential to keeping our world safe."

Previa Restructures Eddyfi Technologies and NDT Global as Independent Companies

Previa, Quebec, Canada, has initiated a strategic realignment that will establish Eddyfi Technologies and NDT Global as two independent and autonomous entities. The move is intended to support each organization's distinct business model, industry focus, and operational needs.

With separate leadership teams, tailored strategies, and individual balance sheets, both companies will operate independently while continuing to serve their respective markets in advanced inspection and nondestructive examination technologies.

"This is an exciting moment for our group," said Martin Thériault, founder and CEO of Previa. "By empowering



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Eddyfi Technologies and NDT Global to operate independently, we are enabling each to pursue their own focused growth strategies, including executing on their attractive innovation pipelines, capitalizing on M&A opportunities, and better serving their respective customers and markets.”

Most of Previa’s corporate staff will remain with Eddyfi Technologies or NDT Global. Both businesses are expected to be fully standalone by the end of 2025.

Turner Industries Expands with New Facility in Salt Lake City, Utah

Turner Industries has opened a new operations facility in Salt Lake City, Utah, to support regional projects and client services.

The office will serve as a strategic base for expanding the company’s industrial services, including rope access and nondestructive examination and inspections. The facility will also support ongoing site and project operations and serve as a center for hiring and training to improve efficiency and provide dedicated local resources.

“We are excited to officially open our doors in Salt Lake City,” said Stephen Toups, CEO of Turner Industries.

“This new facility represents a natural progression of our long-standing presence in the Midcontinent region. It allows us to further strengthen our partnerships, better respond to the unique needs of this market, and deliver even greater value to our clients by providing a permanent local presence and dedicated support.”

NDI Team Expedites B-52 Inspection at Edwards Air Force Base

The 412th Maintenance Squadron’s nondestructive inspection (NDI) team at Edwards Air Force Base, Calif., recently finished an x-ray evaluation of a B-52 Stratofortress 17 days ahead of schedule, demonstrating the unit’s ability to support high-priority aircraft readiness with precision and speed.

NDI technicians applied multiple evaluation methods, including radiography, ultrasonic testing, and oil analysis, to assess the bomber’s structural integrity without disassembly. The B-52’s size and complexity required coordination, with teams working across shifts to complete the inspection safely and effectively.

Staff Sgt. Brandon Tate noted that the project provided rare hands-on experience with a legacy platform. “It’s not



Jannet Diaz, 412th Test Wing Maintenance Group, demonstrates the procedures the nondestructive inspection team uses to identify damage to aircraft at Edwards Air Force Base. (Air Force photo by Daniel Kelley.)

every day you get to perform this type of in-depth inspection on a B-52. It was a great opportunity to hone our skills and contribute directly to the aircraft's continued operational readiness," he said.

By completing the inspection ahead of schedule, the NDI team enabled the aircraft's early return to service for ongoing test and mission operations, reinforcing the unit's critical role in sustaining the Air Force's bomber fleet.

AIMM Center Launches, Offering Advanced Aerospace NDE Services

The Advanced Inspection Methods and Materials (AIMM) Center has opened in Ogden, Utah, focused on next-generation nondestructive examination (NDE) services for aerospace and defense manufacturing.

Formed through a partnership between Composite Inspection Consulting and Non-Destructive Testing (CICNDT) and Omni NDE, the AIMM Center provides inspection capabilities emphasizing automation, digital imaging, and scalable service delivery.

The center's offerings include cobot-assisted inspections for data collection; digital x-ray and computed tomography for internal structural evaluation; ultra-

sonic and laser shearography testing for composites and bonded assemblies; bond testing to identify delamination, disbonds, and adhesion failures; phased array for multi-angle inspection of complex geometries; laser ultrasonic testing for high-resolution, noncontact evaluation of large parts; and a Scan-as-a-Service (SaaS) model providing on-demand inspection without in-house NDE staffing.

These services help manufacturers detect defects early and maintain production schedules without compromising quality.

The facility combines CICNDT's decades of NDE expertise with Omni NDE's applied knowledge in robotics and inspection integration. Their collaboration has resulted in a facility that not only performs inspections but also advances modern NDE methods. Through training offerings and integrated inspection systems, AIMM supports evolving industry needs in aerospace manufacturing.

Located near Hill Air Force Base, AIMM benefits from Utah's established aerospace infrastructure and innovation ecosystem, including support from 47G, the state's deep tech development network. Through collaboration with defense contractors, startups, and educational institutions, AIMM makes high-end inspection services accessible to small suppliers, enabling quality control without large capital investment. [IT](#)



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A Chance Discovery Turns Sparks into a Career



A canceled jewelry class sets Daniela Lowry on an unexpected path

Earlier this year, Daniela Lowry stood in front of a monorail where new heat recovery steam generator panels, seen hanging against the stairs, were waiting installation.

If you want to be inspired by a remarkable Texan who found welding by chance, turned learning the trade and inspection into an impressive career, look no further than Daniela Lowry. She became a Certified Welding Inspector (CWI) and world traveler.

"I found welding by accident," Lowry recalled. "Being completely rudderless as a youth, I signed up for blacksmithing, art metals, and introduction to jewelry at Austin Community College [Austin, Tex.]. My jewelry class was canceled [in] the first week of class, and I filled it with the only available course — introduction to shielded metal arc welding [SMAW]. The second I saw the professor strike an arc, I was 100%

sold. Working with molten metal was the coolest thing I'd ever seen."

She went on to take every welding class she could, including orbital tube welding, and her positive experiences in those classes led to many meaningful professions.

Inspection Attention Leads to Rewarding Work and Degrees

Lowry's SMAW professor, Dr. Warren Donworth, encouraged her to take his nondestructive examination (NDE) courses, including ultrasonic testing (UT) and CWI preparation.

"In these classes, I was able to combine my love of books and [my] critical eye and apply them to the world of welding. I could never have imagined a happier fit," Lowry said.

Her first job in welding was as an inspector at a semiconductor fabrication facility, inspecting orbital tube welds. "I got to climb a maze of piping every day and apply

all that I was learning in school," Lowry recalled. "The physical nature of the work along with the mental requirements of applying drawings, specifications, and standards made it the most rewarding job I had ever had."

She enjoyed working so much that completing an associate in applied science (AAS) in welding technology/code welding degree took a while, but she achieved that distinction, followed by an AAS in welding technology/welding inspection, both from Austin Community College.

Mentoring Helps on the Way to CWI Success

When asked about her path toward becoming a CWI, Lowry said, "I am a book nerd. I've always enjoyed identification books, applying descriptions and pictures to identify and learn about the natural world. I found code books to be a continuation of this hobby."

Lowry's advice for individuals considering joining the inspection industry?

“I encourage you to find someone in your life who thinks you are a better person than you are, prove them right, and then strive to become better than that. Make them and yourselves proud of your actions and outcomes.”

Dr. Donworth welcomed Lowry into the welding world, and each of his classes fascinated her. Professor Tim Strouse also motivated her not to stagnate as a student and encouraged her to join the workforce as soon as possible. Their courses, leadership, and guidance springboarded her into the industry, and she gained the experience and tenacity necessary to take the CWI exam, which she passed in December 2008.

She became a NACE Level I coating inspector and UT/magnetic particle testing/liquid penetrant testing Level II certified technician.

Career Accomplishments

Through the years, Lowry has had the pleasure of inspecting a wide variety of projects.

She later worked for a failure analysis firm as a laboratory technician and manager. There, she analyzed failed and intact samples; worked in a machine shop and wet lab dissecting and analyzing metal components from different industries; and conducted field visits to pulp and paper facilities, electric utility plants, and chemical plants for in-situ replication and inspections. She also climbed inside boilers, tanks, and drums to understand where laboratory samples were sent from and later became a quality assurance manager at a steel pole manufacturer, where she administered the quality management system and AISC certification.

Present-Day Practices

During the past eight years with Austin Energy — which has more than 1900 employees serving over 500,000 customers and two local power plants — Lowry has been involved with a wide range of projects. For the company's electric service delivery department, she has inspected transmission poles in the black and galvanized conditions. She has also overseen steam turbine eddy current and wet fluorescent magnetic particle testing. In addition, she has inspected numerous large-scale replacements, including heat recovery steam generator panels with hundreds of finned tubes, headers, and collectors, steam drum safety valves, and routine boiler tube repairs, and has recently planned and inspected gas turbine exhaust silencer baffle repairs and boiler external high-energy piping assessments.

“While I love all NDE methods, my favorite is visual inspection. I have found it to be the most vital to ensuring good results — especially when used properly — before, during, and after welding,” Lowry said.

Currently, she's a program consultant at Austin Energy. Her responsibilities include performing inspections on new and existing equipment, recommending repairs and setting reinspection intervals, planning inspections and welding projects, and overseeing in-house and contracted labor. She also creates and reviews documentation,


including contracts, drawings, procedures, and specifications from internal and external engineering groups as well as vendors and contractors, and travels to repair shops and fabrication facilities to oversee and audit work on new or existing equipment.

Looking Ahead

Lowry is always excited to learn new things and consider the next steps to take in her career. She hopes to pursue phased array and radiography and is also interested in certifications such as the National Board Pressure Equipment Inspector, API 510, and API 570.

When Lowry's not working or participating in AWS Central Texas Section activities, she has a host of hobbies, including landscaping, traveling, scuba diving, hiking, reading fiction, bird watching, snorkeling, and making new connections. So far, she's been to 21 countries and 49 U.S. states. Scuba diving in Okinawa, Japan, and hiking Mount Fuji are among a couple of bucket list items she will be completing by the end of 2025.

Lowry's advice for individuals considering joining the inspection industry?

“I encourage you to find someone in your life who thinks you are a better person than you are, prove them right, and then strive to become better than that. Make them and yourselves proud of your actions and outcomes.” 

KRISTIN CAMPBELL (kcampbell@aws.org) is managing editor of *Inspection Trends*.



Bendable Digital Radiography Detector Captures Images around Curved Surfaces

The INDUSTREX HPX-ARC 1025 PH bendable digital radiography (DR) detector enables next-generation digital imaging that supports streamlined workflows and immediate acquisition of high-quality images. With a flexible form factor, the detector is lightweight and adaptable to a range of applications and features a 4 × 10-in. capture area optimized for common nondestructive examination tasks. The DR detector can curve from a flat position to wrap around objects with diameters as small as 2 in. It supports high-resolution imaging close to the detector's edge, enabling detailed inspection of curved or irregular surfaces. Instant image access allows for rapid analysis during examinations and helps minimize the need for repeat scans. Compared to conventional rigid detectors, this flexible model incorporates digital enhancements that support immediate image processing and reduced radiation dosage. These features contribute to faster inspection cycles and improved workflow efficiency, particularly in applications such as welding inspection. The detector is compatible with INDUSTREX digital viewing software, allowing for streamlined integration into existing inspection workflows. This compatibility supports unified use of both computed radiography and DR within a single software platform.



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Report Indicates NDE and Inspection Market Worth \$22.34 Billion by 2030

The nondestructive examination (NDE) and inspection market is projected to grow from \$14.99 billion in 2025 to \$22.34 billion by 2030, a compound annual growth rate (CAGR) of 8.3%, according to *NDT and Inspection Market by Technique, Service, Method, Vertical, Application and Region – Global Forecast to 2030*. Growth will be driven by stricter safety regulations to ensure public safety, asset integrity, and product quality across industries such as oil and gas, aerospace, and power generation. Emerging technologies, including artificial intelligence, Internet of Things, and digital twins, are improving inspection

accuracy, enabling real-time monitoring, and minimizing downtime. Rising demand for structural health monitoring of aging infrastructure and advances in portable, miniaturized NDE devices are also expanding market opportunities. Infrastructure development across Asia Pacific, Europe, and South America, along with growth in power and renewable energy sectors, is accelerating the adoption of advanced NDE solutions. The other services segment, which includes training, certification, consultancy, and maintenance and repair services, is projected to register the highest CAGR. The oil and gas sector is anticipated to hold the largest market share, while North America is projected to lead regionally.

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ViewTech Borescopes
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INSPECTION INSIGHTS

A summary of selected AWS Weld Wednesday podcast episodes hosted by Jason Becker. Visit weld.ng/podcasts for more episodes.



Resources for New Welding Inspectors

Insights from industry leaders on bridging the experience gap, mastering code navigation, and building professional networks for long-term success

The journey from certification to qualification in the welding inspection industry presents numerous challenges for new AWS Certified Welding Inspectors (CWIs). In this podcast episode, CWI and industry veteran Scott Witkowski, vice president at Republic Testing Labs, Houston, Tex., and host Jason Becker revealed critical insights about the gap between certification and true qualification, the importance of mentorship, and how to navigate complex industry codes.

The Certification vs. Qualification Dilemma

One of the most significant challenges facing new CWIs is understanding the difference between certification and qualification. Witkowski explained, “Certification means you’ve got documentation . . . you’ve taken some exam or test. But are you qualified? There’s a big difference.”

Many organizations view the CWI certification as a checkbox that indicates readiness for complex inspection

responsibilities. However, certification alone doesn’t guarantee that an inspector can make sound decisions without oversight. New inspectors often find themselves in positions where they’re expected to perform at the level of senior inspectors despite lacking the necessary experience.

“I was 21 years old when I got my CWI,” Witkowski shared. “I was not qualified to have a CWI credential. I met the requirements, but that does not mean that I needed to go out on my own and be responsible enough to make sound decisions without somebody looking over my shoulder.”

The Critical Role of Mentorship

Both experts emphasized that finding a mentor is perhaps the most valuable step for a new inspector. The welding inspection field is built on accumulated knowledge and experience that cannot be gained from textbooks alone.

“The biggest benefit to me once I got my CWI was finding a mentor,” Becker noted. “These are the folks that I look up to and have kept me out of a lot of hot water. I know I can call them if I run into a problem.”

For a CWI who may be the only inspector at their company, connecting with experienced professionals becomes even more crucial. Attending local section meetings, conferences, and industry events provides invaluable networking opportunities with potential mentors.

Navigating Complex Code Books

A significant hurdle for new inspectors is effectively navigating and applying code books. As Witkowski explained, “In the welding world and inspection, it’s hard to study because the way the code books are written . . .



you have to have a question to find an answer. You can't just start on page one and work through the book."

The experts noted that many certification programs don't teach individuals how to effectively read and navigate code books. Understanding how to move from one section to another or knowing which portions apply to specific situations typically comes from experience or guidance from a mentor.

"If they were just taught that earlier in their career, it provides so much insight and makes these big books look much smaller," Witkowski explained. "It's not intended for you to read the whole book to get an answer to a question."

Expanding Knowledge Beyond Certification

The conversation highlighted the value of expanding knowledge beyond the initial certification requirements. Attending section meetings for organizations like AWS, the American Society for Nondestructive Testing (ASNT), and the American Society of Mechanical Engineers (ASME) exposes inspectors to different perspectives and broadens their understanding of interconnected fields.

"If you're out in the field and there's an issue with quality and something's going wrong, hopefully you know a little bit about welding to help troubleshoot the situation, or you're just another warm body in the way," Witkowski noted, emphasizing that good inspectors need practical knowledge beyond the certification requirements.

Building a Professional Network

Both experts stressed the importance of building a professional network through industry associations, conferences, and social media platforms. These connections provide resources when inspectors face challenges on the job.

"When you run into a situation, you've got another number of a person you can call and say, 'Hey, I need help. Have you ever gotten into this?'" Witkowski explained. "Can you steer me in the right direction? Is there a code book, a standard, or a specification that may give some light on the situation so I can better do my job?"

The Importance of Soft Skills

Beyond technical knowledge, successful inspectors need strong interpersonal skills. Effective communication with various stakeholders — from welders to engineers to project managers — is essential.

"You have to have people skills because you are going to interact with lots of different people, a lot of different personality types," Witkowski noted. New inspectors must be approachable and willing to ask questions, even when stepping outside their comfort zone.

Leveraging Technology Appropriately

While new technologies can enhance inspection efficiency, both experts cautioned against overreliance on automated tools. Understanding traditional inspection methods provides a foundation that ensures inspectors can still perform their duties when technology fails.

"It's important when you're teaching people how to use those devices that they understand how to do it the old-fashioned way," Witkowski advised. "It doesn't matter if that machine's going to break. It's when."

Continuing Education and Resources

The conversation highlighted numerous resources available to inspectors seeking to expand their knowledge:

1. Code books and standards from organizations like AWS, ASME, American Petroleum Institute (API), and American Society for Testing and Materials (ASTM);
2. AWS section meetings, which often have libraries of code books available;
3. Industry publications like *Welding Journal* and *Inspection Trends*;
4. Online resources, such as the AWS Member Network and Forum, and social media platforms where professionals share insights; and
5. Conferences and expos like the AWS Inspection Expo and Conference (IEC) and FABTECH.


Commitment to Ethics

The experts emphasized the importance of ethics in the inspection profession. Witkowski noted that inspectors who sign and stamp documents need to understand the ethical responsibilities of certification. Understanding the rules and requirements associated with certification is essential to maintaining professional integrity.

Conclusion

For new CWIs, the path from certification to true qualification requires more than passing an exam. It demands practical experience, mentorship, continuous learning, and professional networking.

As Becker summarized: "The biggest thing is to find yourself a mentor." This connection to experienced professionals provides the guidance, context, and support that transforms a certified inspector into a qualified one capable of making sound decisions in complex situations.

By embracing these insights from industry veterans, new CWIs can more effectively navigate their profession's challenges and contribute to maintaining quality and safety standards across the welding industry. 



Welding Procedure Qualifier Endorsement

Explore the requirements and testing details for this key AWS CWI/SCWI credential

AWS QC1, *Specification for AWS Certification of Welding Inspectors*, allows endorsements to be added to the AWS Certified Welding Inspector (CWI) and Senior Certified Welding Inspector (SCWI) certifications. Endorsements indicate additional knowledge, skill, or ability documented in writing and added to an individual's certification credential(s).

This endorsement provides an additional credential to CWIs and SCWIs in qualifying welding procedure specifications (WPSs). Given the technical specifications or a drawing, the holder of the endorsement should be able to utilize language from AWS D1.1/D1.1M, *Structural Welding Code – Steel*, and AWS B2.1/B2.1M, *Specification for Welding Procedure and Performance Qualification*, and be able to:

1. Implement the organization's responsibilities.
2. Work with an engineering specification or drawing to determine which base material and filler metal combination would be appropriate for procedure qualification testing.
3. Evaluate welding processes required for the application and determine the essential variables impacting the qualification process.
4. Determine if a WPS is required to be qualified by testing, is suitable for prequalification, or if there are alternative WPSs that could be utilized.
5. Determine the equipment needed for preparing and taking required measurements to be recorded during welding of the test plates.
6. Perform oversight of the welding of the weld test.

7. Determine the requirements of the weld test's final nondestructive testing (NDT).
8. Determine the destructive mechanical testing required per the governing standard(s).
9. Correctly prepare the test specimens from the test coupons.
10. Evaluate the test results.
11. Document the actual variables used during welding of the weld test and the test results on a procedure qualification record (PQR).
12. Assist with the determination of weld test failures.
13. Finalize the WPS.

Endorsement Candidate Eligibility Criteria

Any CWI or SCWI who wishes to obtain a credential that documents their knowledge, skills, and abilities to conduct welding procedure qualifications.

For existing CWIs or SCWIs, successful completion of this endorsement satisfies the examination requirements for a nine-year recertification, provided that the endorsement is taken during the immediate nine-year period.

Training and Examination Requirements

This endorsement has no mandatory training requirements. Candidates are encouraged to attend an AWS

Domain	Subdomain	Percent of Questions on Exam
Domain 01 Planning	0101 Assessment of Project Requirements	30%
Domain 02 WPS Qualification and Testing Requirements	0201 General	40%
	0202 Process Variables	
	0203 Evaluation of Mechanical Testing	
	0204 Evaluation of NDT	
	0205 Prepare PQR and other documents	
Domain 03 Finalization of WPS	0301 Establishing Ranges for Prequalified WPS	30%
	0302 Establishing Ranges for WPS Qualified by Testing	
	Total	100%

Table 1 – Test specifications are shown.

seminar or to perform self-study to become familiar with welding procedure qualification.

Candidates who hold an AWS CWI or SCWI wishing to take this examination to add as an endorsement to their AWS credentials need to be current in their AWS certification status. Successful candidates must correctly answer 66% of the questions to receive this endorsement.

Test and Examination Details

Test specifications include a breakdown of exam content areas and the proportion of the exam devoted to each content area – Table 1.

The open-book examination consists of 50 scorable questions and five unscorable questions. The unscorable questions are pretest questions. The examination will consist of traditional multiple-choice items.

Pretesting

The unscored questions are referred to as “pretest” questions. Including a small number of unscored test questions is common practice within the high-stakes testing industry. It allows AWS to evaluate new items for both content validity and statistical performance. Items that perform well may be used in future examinations, further helping future examination versions have equivalent levels of difficulty and overall quality.

These questions are not scored and will not impact whether a candidate passes. These items are randomly placed within the examination and will not be identifiable as pretest items during testing.

Exam Delivery and Computer-Based Test Exam Timing Information

The examination is a computer-based test delivered at a Prometric test center. From check-in to check-out at the test center, the seat time allotted is 210 minutes (3.5 hours). The time that can be used to answer questions is 180 minutes (3 hours) – Table 2.

Section of Testing	Time in Minutes
Candidate Confirmation Page	2
Non-Disclosure Agreement (NDA)	2
Introduction & Tutorials	10
Exam Question Answering	180
Survey	15
Finish Page	1
Total Duration	210

Table 2 – Exam timing is highlighted.

Examination Reference

Most exam questions can be directly answered from the two reference documents below. Candidates can either answer from memory and experience or use the electronic copy of the document provided on the testing computer:

1. AWS D1.1/D1.1M: 2020, *Structural Welding Code – Steel*
2. AWS B2.1/B2.1M:2021, *Specification for Welding Procedure and Performance Qualification*

Endorsement Fee Structure and Endorsement Credential

For candidates in the United States and Canada, exam fees are due at registration and are paid directly to AWS. For the AWS exam price list, visit aws.org.

For international (outside of the US and Canada) candidates, exam fees are due at registration and paid to the International Agent representing AWS. Agents can provide pricing information regarding international exams.

Endorsements earned will be updated in the AWS certification profile. Status can be checked via the QR code on the back of the CWI wallet card or via the Quick-Check at aws.org.

Endorsement Renewal and Professional Development Hours


This endorsement does not require renewal. It will automatically be renewed at each CWI renewal or recertification. The endorsement will continue to be listed in an approved manner.

Candidates who successfully complete pre-exam training to prepare for the Welding Procedure Qualifier endorsement examination may gain professional development hours (PDHs) in accordance with AWS QC1, clause 16.5. Candidates who successfully pass the Welding Procedure Qualifier endorsement examination and desire to gain PDHs should contact the AWS Certification Department.

Informative References for Self-Education

The following is a list of documents that have requirements for qualifying WPSs and may be of value for candidates wishing to understand better how governing standards affect the qualification of WPSs:

1. AWS Publication, *The Practical Welding Engineer*
2. AWS *Welding Handbook*, Volume 1, Chapter 15
3. AWS B2.1/B2.1M, *Specification for Welding Procedure and Performance Qualification*
4. AWS D1.1/D1.1M, *Structural Welding Code – Steel*
5. AWS D1.2/D1.2M, *Structural Welding Code – Aluminum*
6. AWS D1.4/D1.4M, *Structural Welding Code – Steel Reinforcing Bars*
7. AASHTO/AWS D1.5M/D1.5, *Bridge Welding Code*
8. AWS D1.6/D1.6M, *Structural Welding Code – Stainless Steel*
9. AWS D9.1/9.1M, *Sheet Metal Welding Code*
10. AWS D17.1, *Specification for Fusion Welding of Aerospace Applications*
11. API 1104, *Welding of Pipelines and Related Facilities*
12. ASME *Boiler and Pressure Vessel Code*, Section IX: Welding, Brazing, and Fusing Qualifications
13. ISO 5173, *Destructive Tests on Welds in Metallic Materials – Bend Tests*
14. ISO 15607, *Specification and Qualification Testing of Welding Procedures for Metallic Materials – General Rules*
15. ISO 15609-1, *Specification and Qualification Testing of Welding Procedures for Metallic Materials – Welding Procedure*
16. *Welding Procedure Development for Non-Welding Engineers*

Thinking of becoming a SCWI? This endorsement can be used as one of the four required endorsements: Welder Performance Qualifier, Welding Procedure Qualifier, Welding Coordination and QA, and Nondestructive Examination Coordination. 

Discover the Value of CWI/SCWI Endorsements

AWS CWI and SCWI endorsements represent a pinnacle of achievement for inspectors seeking to deepen their knowledge, skills, and abilities and add to their credentials in the welding industry.

These specialized credentials symbolize your commitment to excellence and continuous learning and serve a strategic purpose for CWI and SCWI recertification.

In addition to the Welder Performance Qualifier endorsement, the other 13 endorsements AWS currently offers are as follows:

Welder Performance Qualifier

(required for the SCWI credential)

Showcase your knowledge, skill, and ability to conduct welder performance qualification tests.

Welding Coordination and QA

(required for the SCWI credential)

Validate your specialized knowledge in welding quality assurance and coordination and position yourself as a valuable asset to organizations seeking to optimize their welding quality processes.

Nondestructive Examination Coordination

(required for the SCWI credential)

Demonstrate an understanding of NDE qualification and certification programs, core NDE testing methods, and key NDE coordination components and activities.

D1.1 Structural Steel

Demonstrate your knowledge in structural steel welding, covering material and design, fabrication, inspection, and qualification in the industry.

D1.2 Structural Aluminum

Demonstrate your knowledge in aluminum welding, covering material and design, fabrication, inspection, and qualification.

D1.5 Bridge Welding

Showcase your knowledge of bridge welding standards, including material and design, fabrication, inspection, and qualification.

D15.1 Railroad Welding

Demonstrate your expertise in welding railroad cars and locomotives, covering material and design, fabrication, inspection, and qualification.

D17.1 Aerospace Welding

Demonstrate your knowledge in aerospace welding, encompassing the specific requirements and standards for materials, design, fabrication, and inspection within the aerospace industry.

ASME BPVC, Section IX, Power B31.1 and Process B31.3 Piping

Showcase your proficiency in welding power and process piping systems, aligning with the rigorous standards of ASME codes.

API 1104 Pipeline Welding

Demonstrate your knowledge in pipeline welding, covering material and design, fabrication, inspection, and qualification in the industry.

This credential enhances your professional value, positioning you as a crucial asset to companies in the pipeline industry. Invest in career advancement and elevate your welding credentials with the API 1104 endorsement.

Magnetic Particle Testing of Welds

Demonstrate your knowledge in conducting magnetic particle testing of welds.

Penetrant Testing (PT Type II – Method C)

This endorsement signifies proficiency using the solvent-removable method for visible penetrant testing of welds on ferrous and nonferrous materials.

ISO Welding Standards

Demonstrate your knowledge of ISO welding standards, including material and design, fabrication, inspection, and qualification.

For more information about these endorsements, visit aws.org/certification-and-education, or contact the AWS Certification Department at (800) 443-9353 or aws.org/contact-us.



Audits as Allies

Rethinking the role of audits and transforming evaluation into opportunity

Audit. A word that seemingly instills fear and panic in welding shops everywhere. Just uttering that word has probably raised the blood pressure of a quality manager or project manager somewhere. I admit that the thought of having someone else swoop in and check up on me didn't always give me the warm fuzzies either.

I had a misconception that the purpose of an audit was to find what I was doing wrong. That misconception left me, like most, with an unfounded and irrational fear of being audited.

Several years (and countless audits) later, I came to appreciate those checkups from outside sources. I learned to walk into an audit with an open mind, heeding the advice and suggestions rather than being defensive and closed-minded.

Opportunity for Growth

If you allow it, an audit is an excellent opportunity for your operation to grow. It lets you showcase how effectively your current systems function. Audit findings can also allow you to improve and streamline your operations. It is easy to believe your current systems are flawless and your operation is as seamless as possible. I mean, you do this stuff every day, so why wouldn't it be, right?

Sometimes we get so inundated with our daily operations that we can't see the forest for the trees, as

they say. This is where auditing, whether it be internal or third-party, can become our best friend.

Auditing brings in a fresh set of eyes and gives us a look from a different perspective. It allows our procedures and operations to be surveyed without bias.

Evaluate Efficiency

From a welding perspective, auditing offers insight into the efficiency and effectiveness of our process selection, filler metals, and postweld activities.

It's no secret that welding isn't cheap. Power sources, electrodes, filler metals, and abrasives are all expensive. And, of course, labor only adds to the costs. Audits present us with the opportunity to evaluate the efficiency of all these factors. For example, let's say we are welding an out-of-position joint with short-circuit gas metal arc welding (GMAW) then sanding weld spatter off the adjacent base metal. This quickly becomes costly. We are paying to weld the joint, sand off spatter, and then adding in the cost of abrasives.

If we audit the procedures, switching to pulsed-spray GMAW welds the joint faster (producing a better bead profile), reduces spatter by up to 90%, and, theoretically, eliminates the need to use abrasives to remove the spatter. This change reduces the time and materials used to produce the same product.

Reducing time and materials keep money in our pocket, and that is with just one small change. If we audit more areas, we could find more areas for improvement. As someone who has been on both sides of audits, I can attest that the costs and time associated with auditing are easily recouped. As in our example, one minor but significant change can revamp an operation. I've seen several audit findings turn out to be the small change needed to keep a shop profitable.

Learning from Experience

Early in my self-employment, I was given an opportunity (via a former coworker) to audit a large repair shop for underground mining equipment. This was when the coal market was getting soft, Illinois Basin mines were closing, and repair facilities feared meeting a similar fate.

This shop was rebuilding coal shearer drums, replacing the bearing housings and welding up bit blocks with low-hydrogen shielded metal arc welding electrodes. As a self-employed welder, I had already faced the trials and tribulations of cutting costs to stay alive in the coal fields and had recently changed nearly all my welding operations to flux cored arc welding (FCAW). It was a no-brainer to change this shop to FCAW as well. We changed the process and watched the shop go from scraping by (under the ever-looming fear of layoffs) to holding steady in a plummeting market. Who knows how that would have turned out without a simple audit from an outside source?

On the opposite side of the coin, I remember another shop with a hardheaded foreman rebuilding earthmoving equipment. This shop was overworking three welders to keep up production while cutting costs. The owners brought in a consultant (a young kid who worked for the largest equipment manufacturer in North America. What could he know, right?) to audit the shop, and after less than two hours of watching us in action, he told us to hire two more guys. How could a shop on the verge of closure justify hiring two more welders? The owners took his advice and hired two more welders (whom I swore we couldn't afford). Lo and behold, the kid was right. The workflow improved, employees were more productive because they weren't being overworked, and shop availability increased, allowing more work to come in. In less than two hours, an outside auditor put fresh eyes on the operation, realized the bottleneck, and solved the issue. That shop would have closed in less than a month without the audit. That was the moment I changed my view on audits.

Since then, I have become a die-hard advocate of auditing, whether they are internal audits, audits by accrediting bodies, or outside audits by consultants. They are beneficial and nothing to fear.


“One minor but significant change can revamp an operation. I’ve seen several audit findings turn out to be the small change needed to keep a shop profitable.”

Audit Recommendations

Audits and auditors help maximize an operation's potential while minimizing waste. A successful audit doesn't have to be extravagant. Simple, periodic reviews of an operation can be highly successful. I am a fan of a system comprising frequent internal reviews followed by an annual outside audit. I like to perform these internal reviews either monthly or quarterly, depending on the size of the operation. These are typically conducted in-house, which also helps keep costs down. Although they impose an increased cost, annual outside audits give you an unbiased look into the workings of your operation. They also offer unique insights and new points of view. An audit system of this type keeps operations efficient with frequent internal reviews while allowing an outside perspective at reasonable intervals.

For operations with quality systems already in place, allowing an outside consultant to perform a periodic audit can be an excellent method of keeping your quality system from getting stale. For smaller operations, I highly recommend setting up an audit system even if you don't think you need it.

Conclusion

In the world of competitive bidding and lean manufacturing, efficiency is everything. Bringing people in to observe and evaluate is a good thing. I've learned over the years that no one knows everything and everyone knows something. Audits are opportunities, not obstacles. Use them to your advantage. There's an old saying in the coal fields, “No matter how good you think you are, you can always be gooder.” Audits make us better. 

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Conventional and Emerging NDE Techniques for Amusement Parks

From visual testing to eddy current, various NDE methods for structural defects are explored

BY THOMAS R. HAY

Nondestructive examination (NDE) of amusement park infrastructure is critical to safely operating the broad spectrum of rides. Most amusement park infrastructure is fabricated from structural steel to AWS D1.1, *Structural Welding Code — Steel*, or comparable ride manufacturer specifications. Amusement park infrastructure includes everything from massive roller coaster to smaller lap bars and pins. Many components are coated with very thick coatings and foams, preventing direct visual testing (VT). Additionally, many

components, like gears and pins, are coated with grease, inhibiting NDE. Consequently, NDE of amusement park components often requires the removal of coating or foam and degreasing before performing VT, magnetic particle inspection (MT), and liquid penetrant testing.

Some advanced NDE techniques, such as eddy current testing (ET), eddy current array (ECA) testing, and alternating current field measurement (ACFM), show potential for inspection with limited surface preparation.

Qualified personnel perform NDE on chassis, axles, bogies, and tracks. The inspection objectives are to identify in-service cracks and metal loss due to wear or corrosion, and NDE professionals accurately locate and quantify the extent of discontinuities and material defects — Fig. 1.

Visual Testing

VT is the first line of defense for all amusement park infrastructure, including welds, small, redundant parts, and large, complex components. Based on over 15-plus years of amusement park NDE experience, I have found that more than 80% of all indications can be identified through thorough VT. A NDE inspector can identify most of the damage mechanisms encountered on the amusement industry's many components by using adequate viewing angles, lighting, and magnification. VT is a great starting point, but poor technique, inadequate lighting, and dirty components tend to mask indications from the naked eye. NDE is performed in accordance with the ASME *Boiler and Pressure Vessel Code* (BPVC), AWS D1.1, and ride manufacturer guidelines.

Wet Fluorescent Magnetic Particle Testing

The most common supplement to VT in the amusement industry is MT. Both dry and wet MT are common, with the latter being used more often because it is more efficient. This technique is made possible by exploiting the predictable nature of magnetic fields. Magnetic fields are introduced into the test part using standard yokes and coils. Magnetic flux leakage fields are generated around surface cracks. This leakage field attracts small iron particles to cracks, narrow weld undercuts, and places with incomplete fusion. In contrast to the dry technique, the fluorescent technique highlights the area of concern when viewed under adequate ultraviolet lighting.

Wet fluorescent MT is the preferred technique to detect dry particles due in part to its comparably higher sensitivity to more minor flaws — Fig. 2. The higher sensitivity is driven by higher MT particle mobility and the peak sensitivity of the human eye to the green-yellow emitted by the wet MT bath. While the probability of detection is high, depth quantification of indications is impossible, and MT does not detect subsurface indications.

Eddy Current Testing and Alternating Current Field Measurement

ET is an electromagnetic testing technique digitized and quantified through a simple bridge circuit and pre- and post-signal amplifying processes. ACFM is a derivative of ET, developed in the oil and gas industry to inspect

underwater infrastructure welds. The main advantage of ACFM is its ability to detect depth-size cracks underneath coatings as thick as 0.10 in. ET's and ACFM's electrical output is zero when the signal is balanced, causing no onscreen impedance plane deflection.



Fig. 1 — In-service crack on a welded repair.



Fig. 2 — In-service crack on a critical member of a carousel-style ride using wet fluorescent MT.

ACFM differs from conventional ET in that it deploys a dual coil configuration and monitors for direction-specific variation in magnetic fields generated by surface cracks. The ACFM array is scanned parallel to the weld toe and measures two orthogonal magnetic field components generated by surface-breaking cracks. The two components measured are the B_x , corresponding to the crack length, and B_z , which provides depth information.

Standard ET can be performed to validate VT and MT, but it is not commonly used as a primary crack detection method. NDE personnel use ET to verify and help quantify the depth of in-service surface-breaking cracks. Since ET is such a sensitive testing method, many factors can skew the inspector's interpretation. It is nearly impossible to determine the type of damage mechanism viewed on the display without magnified VT when viewing tiny indications. In addition, other geometric and metallurgical variances can influence the results and interpretation of testing results. The most common cause of dot drift is called the edge effect. This is when the magnetic field produced by the coil meets the edge of the part, causing flux lines to scrunch up, similar too a slinky. This process affects the part's primary and secondary magnetic fields, affecting the voltage (the eddy current) produced by the conflicting magnetic fields, causing the dot to drift on the screen. Another significant drawback to ET is the speed and depth of inspection. This testing method requires a painfully slow scanning speed to ensure proper probe angle and part contact to obtain accurate and usable deflection readings. The eddy current depth of penetration, or skin depth, is influenced by the material properties and frequency range of the probe and the type of material.

Eddy Current Array

Eddy current array (ECA) is another advanced nondestructive examination technique that shows promise in the amusement park testing market. The basic working principles of ECA are the same as those of conventional ET except that multiple coils are contained in the array probe. ECAs are constructed using a multilayer printed circuit board coil, a multilayer configuration dedicated to a cross-wound array on the lower layer, and a reflection coil probe on the upper layer. The eddy current reflection probe provides dynamic lift-off compensation for rough surfaces and weld reinforcements — Fig. 3. In this configuration, eddy-current signal polarity can correlate direction to crack orientation relative to the coil axis.

The primary use of ECA is to evaluate inside diameter/outside diameter corrosion on tubing and piping. This applies to a multitude of structures found in amusement parks. From square/round track tubing to pitting on axles, ET provides a quantifiable evaluation of corrosion, ero-

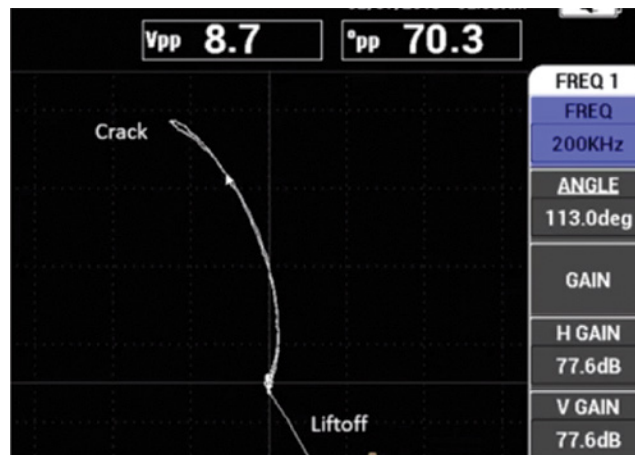


Fig. 3 — 180-lag between the stainless-steel surface crack and lift-off using a cross-wound coil.

sion, and service wear experienced by these structures. ECA is a sensitive method that has the same issues as conventional ET, the main problem being that the method is susceptible to permeability changes. For this reason, weld inspection with ECA is difficult due to the varying heat input changes during the heat treatment and welding process. The different temperatures throughout the weld material and heat-affected zones typically decrease magnetic permeability (how susceptible a material is to an external magnetic field). The significant advantage of ECA is maximizing the penetration depth of the usable eddy current field. **IT**

References

1. ASTM F1193-18a, *Standard Practice for Quality, Manufacture, and Construction of Amusement Rides and Devices.*
2. ASTM E1444-05, *Standard Practice for Magnetic Particle Testing.*
3. ASTM E2261/E2261M-17, *Standard Practice for Examination of Welds Using the Alternating Current Field Measurement Technique.*
4. ASTM E3052-21, *Standard Practice for Examination of Carbon Steel Welds Using An Eddy Current Array.*

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Case Study: Steam Turbine Casing Repair

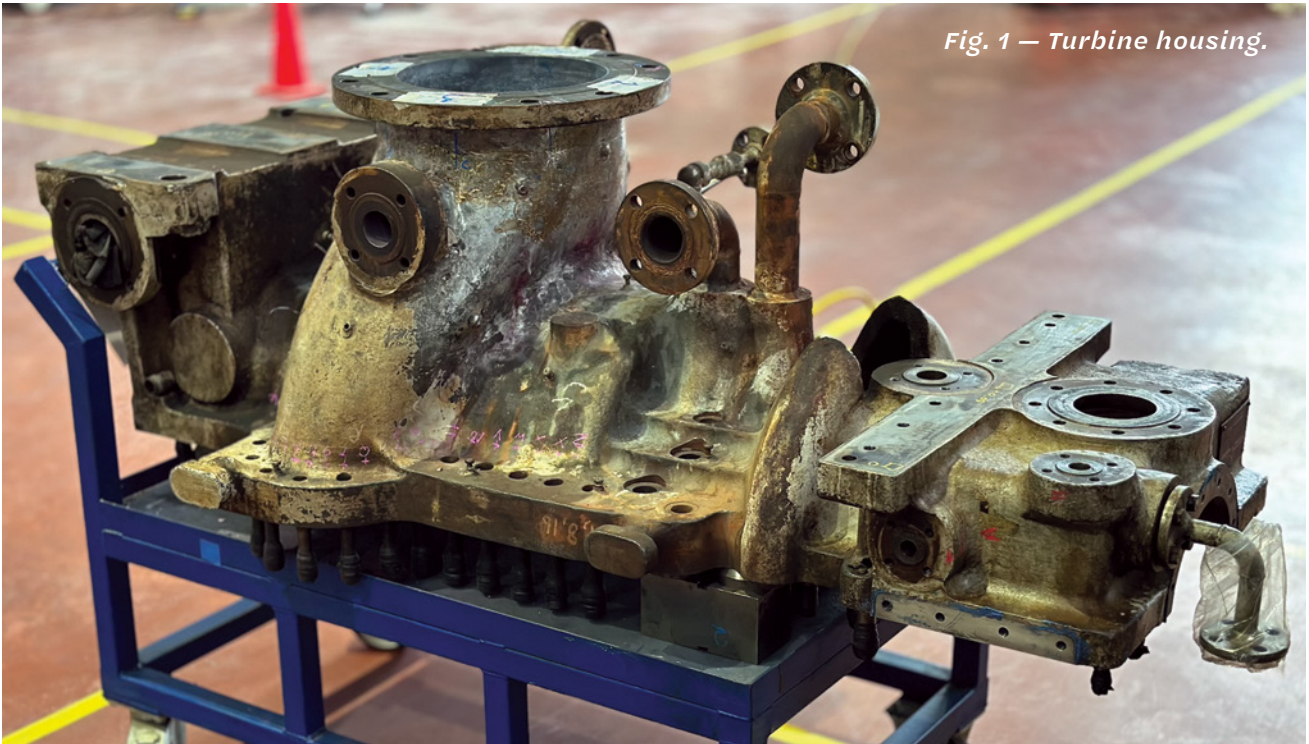


Fig. 1 — Turbine housing.

An overview of the pulsed laser beam welding process and the qualification and inspection procedures used in this refurbishment

BY STEPHAN THIEMONDS

Gas compressor turbines are key equipment in the oil and gas industry, power plants, and many industrial applications. This refurbishment project was initially prompted by a routine inspection of the turbine's inside housing using an endoscope — Fig. 1. The inspection was conducted six months ahead of a scheduled plant shutdown to determine whether repair work was necessary.

Previous inspections and overhauls had already revealed gradual erosion-

induced wear of the inner wall surface, which was now very advanced in some areas. Notably, the section around the gas outlet nozzle was most affected. A critical approach to the calculated minimum wall thickness was localized at some spots. If these minimums were not met, the turbine would need to be taken out of operation immediately, and the entire production plant would have to be shut down.

Partial deposition welding, primarily in areas where the erosion was most advanced (Fig. 2), was considered as a repair method to prevent the worst-case scenario of an imminent plant shutdown. Based on an original wall thickness of 30 mm, the wear profile in the selected repair areas was between a minimum eroded depth of 4 mm and a maximum of 11 mm.

Welding Process Selection

Instead of selecting a classic arc welding process, which would have required additional work, pulsed laser beam welding (PLBW) technology was used due to its specific benefits. The PLBW repair was carried out by DSI Laser Service (Thailand). The choice of this process was directly connected to the tight schedule because it does not require any reworking related to the base material during or after the welding process. The total plant shutdown was scheduled for 18 days; five days were planned for the repair, including the necessary preparations and an extensive quality control plan.

Some of the advantages of PLBW are faster welding start times (under 25 ms), no pre- or postheat treatment at room temperature, a very thin (about 0.2 mm) heat-affected zone (HAZ), no critical microstructure changes, no coarse grain formation (which weakens the metal structure), very low heat input (because of welding with pulsed light and its speed, there's no HAZ of the base material), and almost no distortion.

The fusion line showed that the base material and the filler material were fully joined together. This strong bond made the final material almost as strong as the original base material even without needing extra heat treatment afterward.

PLBW Qualification Procedures

To carry out the work, the welding repairs were preceded by extensive qualification procedures using welding procedure specifications (WPSs) and procedure qualification records (PQRs). These were used to qualify the PLBW process and the welder, who also operated the machine. The qualification and certification procedures were carried out by DSI Thailand Laser Welding Academy in cooperation with the authorized third party, KINGWELD (Bangkok).

The WPS and PQR followed AWS C7.4/C7.4M:2017, *Process Specification Operator Qualification for Laser Beam Welding*, and AWS D14.6/14.6M:2012, *Specification for Welding of Rotating Elements of Equipment*. The latter was used due to the customer's special request, even though the component to be welded was not the rotating turbine rotor but only its static housing.

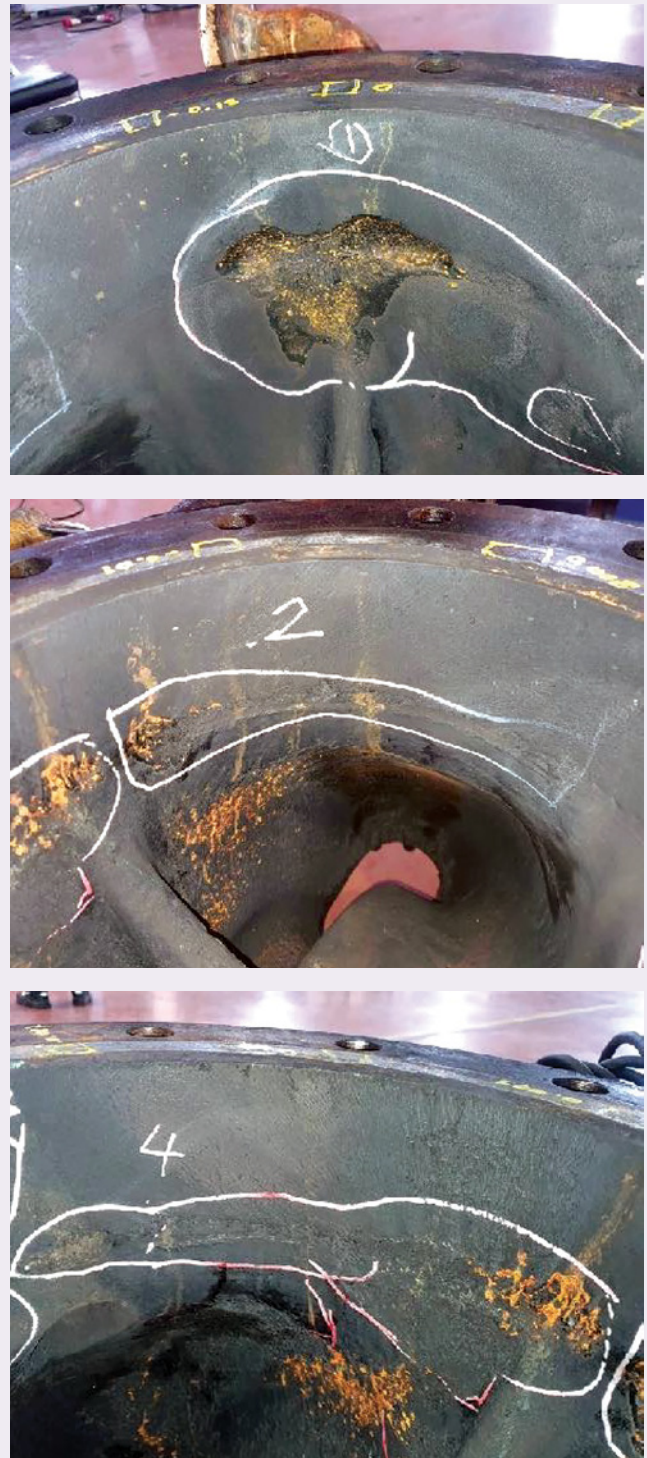


Fig. 2 — Eroded areas.



Fig. 3 — Distortion control setup during welding.



Fig. 4 — PLBW workpiece and machine setup.

Repair Preparation

The repair procedure entailed determining the actual housing dimensions and considering the form and position tolerances, particularly the flanges and the alignment of reference surfaces.

Planning for PLBW included mechanical surface preparation of the designated welding areas by hand grinding.

Measuring equipment (i.e., dial gauges) was set up for continuous distortion monitoring during the ongoing welding process — Fig. 3. Four dial gauges, staggered by 90 deg, were installed around the turbine exhaust flange (one at the outer edge and one at the lower edge).

PLBW Process

The deposition of designated areas ranged between 4 and 11 mm. For the base material, A216 WCA / ASTM 216, the selected filler material was DSI M NICK625 (Inconel 625), with a diameter of 1.2 mm.

Welding was done with an AL Flak 1200 F fiber laser machine, and the operator used a joystick to control welding direction movements. At the same time, the filler metal was fed in manually. At 1200 watts of pulsed laser power, the molten pool had a diameter of 5.2 mm — Fig. 4.


Inspection and Quality Control

The intermediate quality control procedures during welding included visual testing (VT) and liquid penetrant testing (PT) after every 3 mm of deposition. Continuous distortion control was monitored via dial gauges (see Fig. 3). The maximum distortion observed was 0.025 mm.

Final inspection after welding included VT, PT, and magnetic particle testing — Fig. 5. Additionally, radiographic testing and ultrasonic testing were performed — Fig. 6.

Conclusion

This case provided a noteworthy example of the benefits of PLBW, which achieved complete metallurgical bonding without any welding discontinuities or defects (cracks, incomplete fusion, or porosity) while providing benefits that conventional arc welding methods typically cannot — Fig. 7.

The comprehensive inspection and quality control plan provided thorough verification and satisfactory results. 

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Fig. 5 – Magnetic particle testing.



Fig. 6 – Ultrasonic testing.

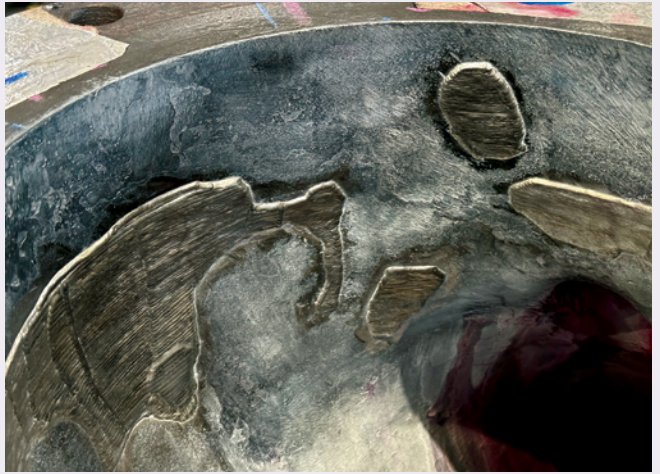
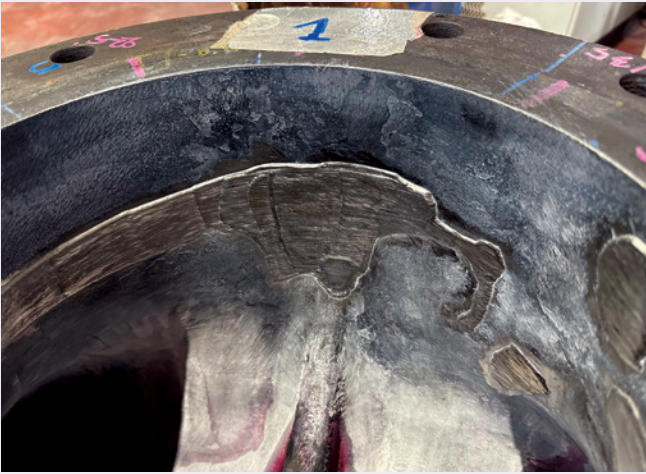


Fig. 7 – Finished repair.



This is the second part of my response to the inquiry about reducing elongated porosity in welds made using the flux cored welding process. Part 1 appeared in the August 2025 Inspection Trends. This installment focuses on setting welding parameters to achieve the best possible results.

A quick review of the construction of flux cored electrodes and the functions of the flux is a good starting point. These electrodes consist of a tubular wire formed from a strip of sheet metal filled with the proper amount of flux. The flux inside the electrode sheath provides improved deoxidation compared to the bare wire used for gas metal arc welding. Similar to the covered electrodes used in shielded metal arc welding, the flux produces copious volumes of carbon dioxide smoke, which displaces the air around the molten weld pool. It also supplies the elements needed to form a slag cover and improves the weld profile. Additionally, the flux can serve as a vehicle for alloying elements to tweak the chemistry of the weld deposit. However, the limited volume of flux in the electrode core makes the welding process somewhat sensitive to welding parameters.

There are two types of flux cored arc welding (FCAW) electrodes: gas shielded and self shielded. Typically, small-diameter electrodes cannot produce sufficient carbon dioxide to properly shield the molten weld pool, so additional shielding gas is required to supplement the carbon dioxide produced by the electrode. Larger-diameter electrodes, which contain more flux, may be able to produce larger volumes of carbon dioxide and therefore do not require additional shielding gas. The supplemental shielding gas usually consists of carbon dioxide or a mixture of carbon dioxide and argon in varying proportions. Mixed gases with higher argon content tend to reduce weld spatter and increase tensile and yield strength, often at the expense of ductility.

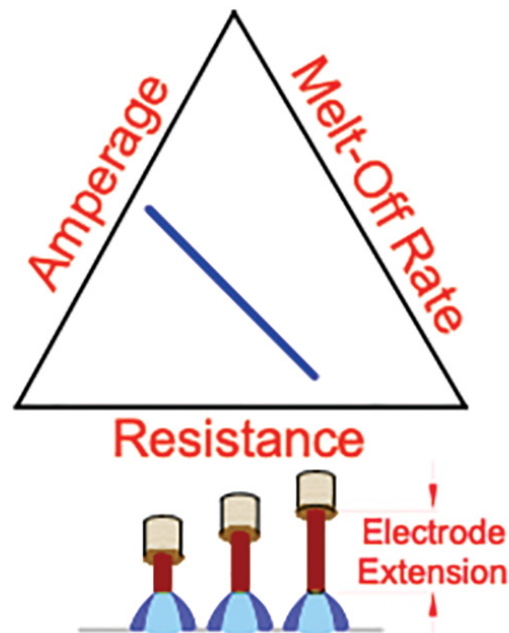
Electrode manufacturers have wide latitude in the composition of the flux and the fill factor (i.e., the amount of flux in the electrode core)

as long as they can demonstrate the requirements of the filler metal specification and classification are met. In other words, not all FCAW electrodes are created equal. To achieve optimal mechanical properties and performance, proper welding parameters must be used. Considering each electrode manufacturer has complete control over the chemistry of their electrodes, it should come as no surprise that the parameters producing excellent results for one brand may not yield the same performance with another even when

both electrodes carry the same AWS classification.

There are four key welding parameters that must be controlled to achieve acceptable results: arc voltage, wire feed speed, welding current, and electrode extension. Each of the parameters must fall within a tight range to get the right balance for optimal performance. While your employer could determine the ideal parameters through endless trial and error, and if they have deep pockets and plenty of time, they're welcome to do so. My question is: Why replicate what the manufacturer has already done?

Most manufacturers list recommended parameters for optimum results on their websites. If the manufacturer doesn't provide that



This image depicts the relationship between resistance (electrode extension), amperage, and melt-off rate. The shortest electrode extension (left figure) results in the highest amperage, which produces the highest melt-off rate. The longest electrode extension (right figure) results in the lowest amperage, which produces the lowest melt-off rate.

Table 1 — Recommended Parameters from Manufacturer A for Its E71T-1M Electrode

Voltage	WFS (in./min)	TTW (in.)	Amperage
23/26	150/260	1/4-3/8	135/205
25/27	260/380	3/8-5/8	205/230
26/30	380/520	5/8-7/8	230/265

Table 2 — Recommended Parameters from Manufacturer B for Its E71T-1M Electrode

Voltage	WFS (in./min)	TTW (in.)	Amperage
21/23	236	5/8	160
23/24	295	5/8	190
24/26	354	5/8	220
28/30	525	5/8	275

information, look for a different manufacturer.

Let's look at the four parameters I listed and how they influence the welding operation:

■ **Arc Voltage:** This is the voltage drop across the welding arc while welding. A longer arc length results in a higher arc voltage, while a shorter arc length results in a lower voltage. The welding machine (i.e., the power supply) is typically a constant potential power supply, which, by the way, is exactly the same as a constant voltage power supply. These welding machines are said to be self-regulating, meaning other parameters will respond in a manner that will cause the arc length to return to the arc voltage set by the welder. We can say that once set, arc voltage (and therefore arc length) remains constant.

■ **Wire Feed Speed:** This refers to the length of electrode wire fed through the contact tip over a given period of time. Wire feed speed (WFS) is usually measured in inches per minute (in./min) or millimeters per second. The WFS does not vary once it is set by the welder until the welder changes

it. Whether the gun is pointed straight up or aimed at the weld pool, X inches of electrode is going to spit out the contact tip every minute until the welder changes it.

■ **Electrode Extension:** This is the distance from the end of the contact tip to the end of the electrode. Some refer to it as contact tip-to-work distance or tip to work, but the standard term is electrode extension (EE). It is what it is; we can't put everyone who calls it "MIG welding" in jail, and we certainly can't lock up everyone who uses the term contact-tip-to-work distance. Why is EE important? It's simple. The longer the EE, the higher the electrical resistance. The higher the resistance, the lower the amperage. Ohm's Law is not a recommendation, it's the law.

$$\text{Amperage} = \text{Voltage} / \text{Resistance}$$

Since we can assume that the arc voltage provided by the power supply is constant, and the EE is also constant if the welder doesn't vary it during welding, the amperage becomes inversely proportional to the EE. The sketch on the previous

page shows the relationship between arc voltage, EE, and amperage. Because the contact tip is where the electrode becomes electrically energized, we can ignore the internal circuitry of the welding machine. The electrical resistance is directly proportional to the EE. If the welder doubles the EE, the resistance also doubles. And if the resistance doubles, the amperage is reduced by a factor of two. In other words, the amperage becomes half of what it was.

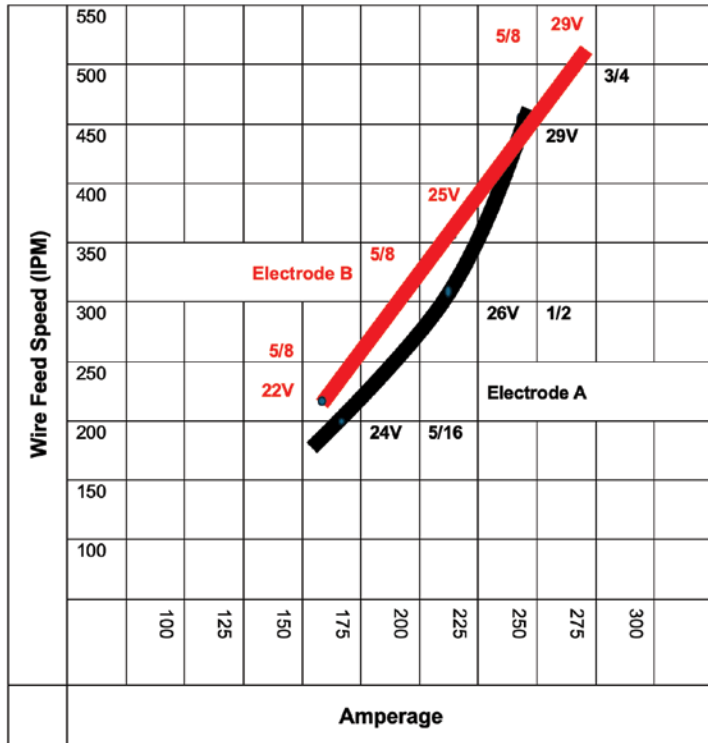
■ **Amperage:** Amperage is dependent on the EE. It will vary if the welder allows the EE to change as the welding gun moves along the joint. The amount of weld spatter produced is influenced by the amperage. The partial pressure of carbon dioxide, produced by the decomposition of the flux, increases in proportion to the amperage. The higher the amperage, the more spatter is produced.

The bottom line is that there are three constants easily controlled by the welder: arc voltage, wire feed speed, and electrode extension. The one parameter that is not a constant is amperage. It's important to recognize that the welder can dial in the voltage, and it will remain virtually unchanged during welding. The welder can also dial in the WFS, which will not change while welding. EE can be visually monitored and adjusted by the welder in real time during welding.

I have not addressed the effect of the shielding gas selected. Since the shielding gas isn't changed while the welder is welding, I'm skipping over it — for now. Maybe that's a subject for another article.

In my opinion, the typical way welding parameters are presented in a welding procedure specification leaves something to be desired. Tables 1 and 2 are offered for comparison. Both use the same electrode diameter and the same shielding gas mix.

One can see that the recommended welding parameters for the E71T-1M electrode from Manufacturer A are not the same as those recommended by Manufacturer B. If the welder assumes that the same parameters can be used for both, the results will prove otherwise.



Both gas-shielded FCAW electrodes are shielded with SG-AC25.

min, voltage at 26 V, and an EE of 3/8 in. Using Electrode B as an example, the starting point is a WFS of 300 in./min, voltage at 25 V, and an EE of 5/8 in.

The decomposition of the flux within the electrode produces carbon dioxide gas. The partial pressure of the carbon dioxide is proportional to the current. At very high amperage, the pressure of the carbon dioxide is sufficient to produce excessive weld spatter. IT

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On this page is a graphical presentation of the manufacturers' recommendations. From this, the welder can immediately see how the welding machine should be set. The starting point is to set the WFS at midrange.

The voltage would correspond to the recommended value based on the WFS. The EE would also depend on the selected WFS.

Using Electrode A as an example, the starting point is a WFS of 325 in./



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