IT
INSPECTION TRENDS
FEBRUARY 2025
THE MAGAZINE FOR MATERIALS INSPECTION AND TESTING PERSONNEL

Laser Vision Inspection

NDE Personnel Qualification and Performance to AWS Codes

AWS®

IN THIS ISSUE: QUALITY: AIM HIGHER! ■ CWI CORNER ■ CHARPY V-NOTCH TEST

CONTENTS

[**FEBRUARY 2025** | VOLUME 28 | NUMBER 1]

[FEATURES]

[DEPARTMENTS]

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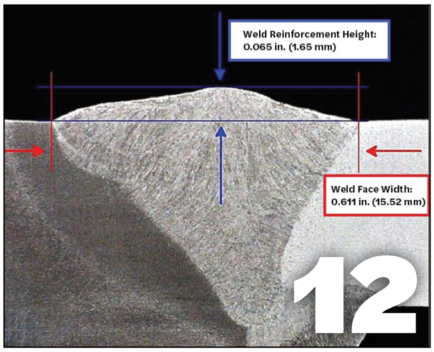
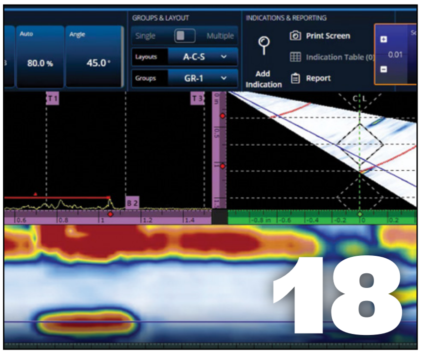
AWS MISSION STATEMENT: The mission of the American Welding Society is to advance the science, technology, and application of welding and allied joining processes worldwide, including brazing, soldering, and thermal spraying.

COVER PHOTO:
A technician performs a laser vision scan of a fillet weld. (Credit: Servo-Robot Corp.)





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Qualification Thoughts

CURT GREEN

Welder performance qualification testing is an increasingly vital aspect of our role as Certified Welding Inspectors (CWIs). As the industry continues to evolve, performance qualification testing is becoming more integral to ensuring welders have the necessary skills and capabilities. Proper qualification is a key frontline approach to maintaining high standards of quality in welding practices.

As CWIs, we are at the forefront of much of this work, yet performance qualification testing is still somewhat unfamiliar territory for many CWIs. There are many CWIs who are competent and knowledgeable but just haven't had the opportunity to gain experience with performance qualification. This disparity can be problematic as the demand for qualification testing increases. As demand increases, many less experienced CWIs are being called upon to conduct performance qualification testing. This often creates anxiety for the inspector, who may feel pressured to achieve high pass rates when testing welders. In some cases, this pressure can lead to inexperienced inspectors overstepping their bounds. As the inspector, or qualifier, our job is to observe, evaluate, and document. We observe the welder perform the test, evaluate the finished weldment and test specimens, and document the results. Nothing more, nothing less. Many times, I will get questions from the welder about machine settings or technique. To answer these questions, I point them to the welding procedure specification (WPS). I always begin the qualification test with a review of the WPS the welder will be following and the acceptance criteria to which the weldment will be evaluated. It is not the CWI's job to coach a welder through the test. It is the CWI's job to unbiasedly assess and document the welder's abilities.

I find it best to be upfront with welders. Prior to striking an arc, welders are given the acceptance criteria, and it is explained that this criteria is not my opinion of a good weld. The criteria comes directly from the applicable governing document. Being forward and upfront about expectations greatly reduces confusion, misunderstandings, and even the potential for conflict. When evaluating test specimens, adherence to the acceptance criteria is crucial. Every welder you qualify carries your stamp of approval and, in turn, possesses the ability to influence your reputation. It isn't always glamorous, but unwavering compliance to the governing documents will help to solidify your reputation as a creditable inspector. It is up to us, as CWIs, to uphold the prestige of this credential. We have all dedicated countless years to earning and achieving the title of Certified Welding Inspector and the respect that comes with it. I, for one, do not take that lightly. The title of CWI not only carries great respect in the industry; it also carries the burden of great responsibility. It is our responsibility to ensure standards are met and upheld and, in the case of qualification testing, to ensure the abilities of the welders are up to par for the tasks they are given. IT

CURT GREEN (*curtis.green@kctcs.edu*), **an AWS SCWI, AWS CWE, and ASNT NDT Level III, is the associate professor of welding technology at West Kentucky Community & Technical College, Paducah, Ky., and owner of AccuWeld LLC, Golconda, Ill.**

ASNT 2024 Breaks Attendance Record with NDE Event in Las Vegas

The ASNT booth served as a key hub for networking and information sharing during the ASNT 2024 conference.

The American Society for Nondestructive Testing (ASNT) hosted the ASNT 2024 annual conference on October 21–24, 2024, at Caesars Forum in Las Vegas, Nev. With more than 2100 guests, the event broke an all-time paid attendance record for the organization. Themed "Engage," the conference featured advancements in nondestructive examination (NDE), innovative discussions, and celebratory moments.

The conference showcased over 200 exhibitors in the exhibit hall along with more than 100 technical presentations, open discussion sessions, and new events, like the Cool New Ideas competition, which involved six companies competing to decide who has the best new technology, and the AWS Visual Testing Competition.

The Annual Meeting of the Members, held on October 21, featured John Z. Chen, PhD, ASNT board chair, emphasizing ASNT's strategic goals and ASNT CEO Neal J. Couture, highlighting the organization's growing impact on the NDE profession. Other noteworthy events included keynote speeches from engineer Tamara Robertson and futurist Dr. Shawn DuBravac, panel discussions on digitalization in NDE and workforce development, and ASNT's annual Ultrasonic Testing Competition, where Theo Young won first place.

The ASNT Foundation raised substantial funds through auctions, sponsorships, and a commemorative pin campaign. The gala event, ASNT Celebrates!, honored industry achievements with prestigious awards and featured the Las Vegas Raiders' house band, Pop40, performing at the after-party.

ASNT 2025 is scheduled for October 2025 at Disney's Coronado Springs Resort in Orlando, Fla., where industry professionals will gather for another comprehensive NDE event.

AWS Sponsors First VT Competition

AWS held its first annual Visual Testing (VT) Competition on October 22 and 23, 2024, at the ASNT 2024 conference in Las Vegas, Nev. The competition assessed the visual testing skills of Certified Welding Inspectors (CWIs) or Senior Certified Welding Inspectors (SCWIs) on welded connections.

AWS VT Competition winner Lazarao Magaña Martinez (right) holds up one of his prizes.

Six CWI and SCWI competitors were provided weld samples, visual inspection gauges, and AWS D14.0, *Machinery and Equipment Welding Specification*, visual inspection requirements. Through a series of multiple-choice questions over three rounds, they were tested on their ability to interpret the code, measure characteristics of the samples, and analyze and evaluate indications to the acceptance criteria.

Lazarao Magaña Martinez from Ixtlahuacán, Mexico, won first place, and Danfer D. Carrasco from Lima, Peru, took second. Both VT winners were awarded a visual inspection gauge and mirror kit, wall plaque, and desk awards. The first-place winner was also shipped AWS's complete *Welding Handbook* five-volume set.

AWS Hosts CWI Seminars at Headquarters

AWS held several Certified Welding Inspector (CWI) seminars at its World Headquarters in Miami, Fla., during the last two quarters of 2024.

A CWI seminar taught by Instructor John Yochum took place September 29–October 4. Yochum is a CWI and a construction, engineering, and inspection (CEI) inspector with more than 15 years of experience in the construction industry. His teaching experience includes more than 25 years as a welding and engineering instructor in South Florida public education and technical schools and state college programs.

CWI seminar students pose for a photo in front of AWS World Headquarters.

Nine-year seminar attendees gather for a photo.

The attendees of the CWI seminar were Nathanael Adler, Austin Blackburn, Kane Cortellese, Joshua Disher, Alexander Djassemi, Shawn Drummond, John Gusich II, Jeff Gutierrez, Rebecca Kanipe, Jacob Powell, Jacob Reese, Justin Spanos, Scott Thompson, Roman Titov, and Yusuan Valdes.

Additionally, instructors Rick Suria and Yochum held a nine-year recertification seminar from December 1 to 6. Suria is an AWS Senior Certified Welding Inspector (SCWI), Certified Welding Educator (CWE), and Certified Radiographic Interpreter with an ASNT Level III certification. He is also the owner of Industrial Technology & Inspection LLC, Cape Coral, Fla.

The nine-year seminar attendees were John Biggs III, Calvin Chan, Delbert S. Evans, Brian Fox, Garry Gilliam, Michael Jeeninga, Fabio Madeira Pereira, George Martin, Trenton G. Mauk, Arthur McFate, Michael Palin, Drew Payne, Igor Petrenko, Garrett Reynolds, Christopher Selvoski, Daniel Steele, Leland Tennant, Nathaniel D. Vanderhoof, Christopher Wimmer, Ryan Yoder, Billy Young, and Long Xiao.

Finally, a two-week seminar took place December 2–14 and was combined with a part B seminar on December 11–14. The instructors were Rich Campbell and Vince Casella. Campbell is a SCWI, CWB Level 2 Welding Inspector, ASNT Level III VT inspector, and a Bechtel Fellow. Casella is a CWI and CWE, ASNT Level II VT inspector, and welding instructor and ATF supervisor at Lincoln Electric.

The 12 attendees of the two-week seminar were Ankit Awasthi, Ronnie Blount, Alexis Castillo, Joseph Costello III, David Decker, Silvino Guijosa-Bernabe, Heath Knight, John Mi, Jose Miro Mendoza, Joshua Rupert, Joseph Shinault, and David Vlasyuk.

The part B participants were Kyle Benson, Jarrad Brayford, Alberto Camargo, Kyle Daggett, Melvin Djojosentono, Thomas Farmer, Avinash Girdhari, Michael Goglia, Kenneth Grant, Joe Hernandez, Matthew Holliday, Robert May, Stephen Miller, Alex Momo Atemkeng, Johan Puchi Molina, Brandon Rawlins, Porter Ritchie, Thomas Smith, Kyle Yoho, Kathleen Reidl, and Vernon Bernier.

The two-week and part B seminar attendees take a combined photo outside AWS World headquarters.

Industrial Welding Inspection Expands NDE Services to Long Beach

Industrial Welding Inspection, a provider of welding inspection and nondestructive examination (NDE) services in Mesa, Ariz., is expanding its NDE offerings to Long Beach, Calif., and neighboring cities.

Magnetic particle testing on an above-ground storage tank in Long Beach, Calif.

The company's expanded services in Long Beach include a wide array of NDE techniques, ensuring comprehensive quality control for welding projects of all sizes. The company's AWS Certified Welding Inspectors are equipped to perform visual, magnetic particle, dye penetrant, ultrasonic, and radiographic testing.

"Our goal is to ensure that every weld we inspect meets or exceeds the required standards," said Matthew J. Behlen, owner of Industrial Welding Inspection. "We understand the critical role that welding plays in the safety and reliability of structures and equipment. Our expanded services in Long Beach allow us to contribute more significantly to the region's industrial safety and quality assurance."

As Industrial Welding Inspection establishes a stronger presence in Long Beach, the company is poised for further growth and expansion. Plans are underway to increase the local workforce, invest in additional advanced NDE company equipment, and develop partnerships with local educational institutions to nurture the next generation of welding inspectors.

TRIGO ADR Americas Partners with NDT Solutions and NDE Labs

TRIGO Aerospace, Defense, and Rail (ADR) Americas, Auburn Hills, Mich., the American subsidiary of TRIGO Group, has partnered with NDT Solutions, New Richmond, Wis., and NDE Labs, Benbrook, Tex. This collaboration enhances TRIGO's portfolio by integrating advanced nondestructive examination (NDE) capabilities to address critical needs in North America's infrastructure sectors.

The partnership leverages NDT Solutions' and NDE Labs' specialized expertise in NDE for high-stakes components across aerospace, defense, and space exploration, along with NDT Solutions' testing technologies. The goal is to provide comprehensive services, including training, consulting, audit-

TRIGO ADR Americas collaborates with NDT Solutions and NDE Labs to enhance its NDE services, supporting critical infrastructure sectors such as aerospace, defense, and space exploration.

ing, onsite inspections, and testing equipment. These services support lifecycle reliability and regulatory compliance for key industries.

"Our partnership with NDT Solutions and NDE Labs significantly strengthens our position in the aerospace, defense, and rail sectors, alongside with our capabilities and responsiveness in NDT," said Steffen Spell, president of TRIGO ADR Americas. "NDT Solutions holds specialized qualifications, making them a valuable partner as we broaden our reach in high-stakes quality management cases."

Together, the three companies will expand audit and inspection services, ensuring suppliers meet stringent quality standards across production and operation stages.

The three companies will expand audit and inspection services, ensuring suppliers meet stringent quality standards across production and operation stages.

Conair Increases In-House NDE Capability, Critical for Safe Aerial Firefighting Operations

Conair Group Inc., Abbotsford, British Columbia, Canada, has expanded its in-house ability to perform nondestructive examinations (NDEs) on its fleet of over 55 aerial firefighting aircrafts.

This expansion mitigates the need to rely on third-party providers, enabling the company to schedule and complete inspections between fire season contract periods, ensuring bird dog lead planes, air tankers, and water scoopers are available to government agencies when needed.

"NDT [nondestructive testing] is split into surface and subsurface techniques," said Alfred Modino, Conair's Component Shop Level 3 NDT Technician. "Conair is now fully equipped to support the fleet using both technique types, performing inspections utilizing eddy current, ultrasonic, liquid penetrant, and magnetic particle testing."

The company employs six accredited NDE technicians and a two-person team dedicated to executing inspections performed to original equipment manufacturer (OEM) standards.

"In the future, we plan to develop the NDT program further, performing inspections on our U.S. subsidiary's fleet, located at Aero-Flite in Washington state. And we are investigating adding digital x-ray capability," Modino said.

This essential service is necessary to secure the continued airworthiness of the aerial firefighting fleet, ensuring safe missions and ongoing response. Each Conair aircraft undergoes a thorough period of heavy maintenance once a fire season contract with a government agency has closed, typically taking four to six weeks to complete.

A Conair NDE technician performs eddy current testing on the interior of an aerial firefighting aircraft.

BY KRISTIN CAMPBELL

Meet Chris Morr

This successful business owner applies his knowledge and experience to teach the next generation of CWIs

Chris Morr has been a CWI since 2007.

While participating in a three-year high school welding program, Chris Morr got drawn into the trade and never looked back.

"I soon realized that I enjoyed the welding field," said Morr.

The Kendallville, Ind., native also showed appreciation toward trades teacher and mentor Jim Deetz. "He was a great instructor and even better person. By my senior year, I was his classroom assistant for the underclassmen. This is when I realized that I liked to teach others how to weld."

Morr continued his education, attending the Hobart Institute of Welding Technology (HIWT), Troy, Ohio, in February 1991. This article shares his story and words of wisdom.

Provide more about your background, including becoming a Certified Welding Inspector (CWI).

From 1991 to 2002, I held a couple of different welding jobs until I found my home at Colbin Tool, Syracuse, Ind., a maker of stainless steel and aluminum boat rails and ladders, where I was a stainless steel welder. I was responsible for training all the new welders and eventually worked my way to production manager in 1996. In 2003, I landed a job teaching at the Warsaw Area Career Center (WACC), Warsaw, Ind. Around 2005, I noticed a growing number of instructors becoming CWIs so they could certify their students. I made the push to my administrator about this for me, too, and he agreed. In 2007, I was able to get the funding and make it happen. I returned to Hobart for their CWI preparation course, took the test, and passed.

Another goal I had was to make WACC an AWS Accredited Test Facility (ATF). Around 15 years ago, we passed the audit to make WACC one of only two high school ATFs in the state at that time. I also used my summers and evenings to pick up some CWI work with private companies, using visual and destructive techniques, and taught some college courses covering basic to advanced welding with certification offerings at the conclusion of the class. I also became an AWS Certified Welding Educator.

After all these years, my favorite testing method is still destructive testing. I love to watch a weldment get destroyed and then see how the weld holds up.

Why did you open your own business?

In 2019, I became seriously ill and decided I should not continue teaching once I recovered. Because I had some connections in education and the private industry from my teaching days, I knew there was a huge need for certifications in our area, and during some downtime, I worked on my website and other things needed to start a business.

In 2021, Morr Weld Inspection and Certification Inc. (MWIC, *mwic.us*) in Kendallville, Ind., officially opened. I quickly made

Chris Morr (left) and his son Devon prepare to bend parts during an AWS ATF audit. Sample test parts are also shown.

Devon Morr (right) looks at pipes on a job site.

The father-and-son team are shown at their table during a welding competition, representing Morr Weld Inspection and Certification.

"It's amazing to have your son follow in our footsteps, but to be able to work with him for our own company is even better."

the move to turn MWIC into an ATF, and in 2022, we received that status. High schools that did not have a CWI on staff were pursued, and some were very receptive to the idea of having their students achieve an AWS certification. Also, the state requires they earn one for their pathways technical diploma. We now test six high school programs, mostly to AWS D1.1, *Structural Welding Code — Steel*, but we also do a lot to AWS D9.1, *Sheet Metal Welding Code*. The medical industry in our area makes a lot of orthopedic hardware as well, like knee and hip implants, and tools for doctors. These companies use AWS D17.1, *Specification for Fusion Welding for Aerospace Applications*, so we do a lot of that as well.

What's it like to run your own business and operate as a father-son duo?

In May 2024, I hired my son, Devon Morr, as a full-time employee. He also went to HIWT after high school. In the summer of 2024, he went back to Hobart for CWI training and ultimately passed the test. We now have two CWIs on staff and do welder training and certification, including on ASME pipe, and writing procedure qualification records and welding procedure specifications, holding classes at Steel Dynamics steel mill for the past year, as well as CWI work consisting of pipe inspection. When we face challenges, they're overcome by hard work and a deep dive into the code book because the answer is usually in there. You just have to find it.

It's amazing to have your son follow in your footsteps, but to be able to work with him for our own company is even better. In the future, we're looking forward to achieving a good customer base and growing the company. My ultimate goal would be to start a small, full-time welding school here in northern Indiana. We're also both members of the local AWS Section, Johnny Appleseed. I am the certification committee chair, and Devon serves on the committee with me. I felt honored to have recently received the Dalton E. Hamilton Memorial CWI of the Year Section Award as well.

Do you have any advice you'd like to give?

If you're an AWS member and not part of your local Section, please do join; you'll enjoy many benefits, including networking with fellow colleagues.

My recommendation to individuals wanting to be a CWI is don't get discouraged. The test is very hard for anyone. Try to find a mentor CWI and never try to take the test without a preparation course.

I hope you've enjoyed reading about my career, and if it's been inspiring to you, then please reach out and let me know (*cmorr2019@gmail.com*). I'd very much like to hear from you, and if I can share more wise words, I will. IT

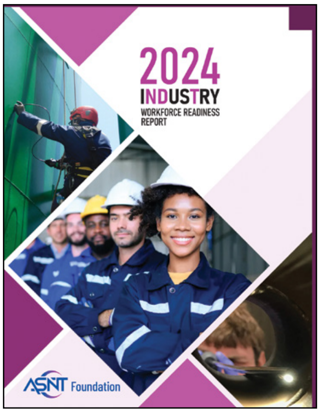
KRISTIN CAMPBELL (*kcampbell@aws.org*) is managing editor of *Inspection Trends*.

Flaw Detector Offers Advanced Imaging and Fast Results for Infrastructure Inspections

The OmniScan™ X4 phased array ultrasonic flaw detector identifies and characterizes damage in critical infrastructure. Designed for field use, this portable instrument incorporates multiple ultrasonic testing technologies to ensure precise and reliable results. All X4 models feature advanced imaging methods, including total focusing method (TFM), phase coherence imaging (PCI), and plane wave imaging, which enable efficient detection of complex flaws. With enhanced processing power and optimized software, it delivers near-instantaneous imaging results, boosting productivity in the field. Equipped with a lightweight design, the tool is suitable for solo inspections and can be quickly configured using intuitive presets. These settings streamline workflows, minimize postprocessing time, and ensure consistent, accurate data acquisition. The device can simultaneously display TFM and PCI results to clearly examine challenging flaws. With the 1-terabyte storage drive and expanded RAM, inspectors can handle larger datasets without interruptions. The flaw detector is designed to evolve, with regular software updates adding new features tailored to industry needs. Ideal for infrastructure applications, this all-in-one inspection solution supports users of all experience levels, providing accurate flaw detection, advanced imaging, and a simplified inspection process.

Evident
olympus-ims.com

NDE Workforce Reports Provide Key Insights on Readiness and Compensation Trends



The *2024 Industry Workforce Readiness Report* and *2024 Industry Compensation Report* provide comprehensive information on the nondestructive examination (NDE) workforce in the United States. The reports offer insights into practitioner demographics, emerging trends in hiring, and practitioner preferences and behaviors. They also deliver actionable data to guide strategic decision-making and foster sustainable growth within the NDE workforce. Designed as primary references, they equip NDE professionals, employers, hiring managers, and human resources professionals with data to address industry gaps, plan for future workforce needs, and stay competitive in a changing landscape. The *2024 Industry Workforce Readiness Report* contains an assessment of critical skills by practitioners and an assessment of those same skills by hiring managers and recruiters. The report also includes practitioners' perspectives of the field, including fairness of compensation and benefits and job satisfaction. The *2024 Industry Compensation Report* includes practitioner demographics and salary differences based on job role, work environment, certification, professional tenure, industry, and supervisory responsibilities. This report enables industry employers to understand their compensation package compared to industry standards.

ASNT Foundation
foundation.asnt.org

Bendable X-Ray Detector Scans Pipes up to 12 Inches in Diameter

The NOVO 18BN portable detector enhances radiography capabilities with its bendable functionality. The detector is engineered to accommodate curved surfaces, including pipes with diameters up to 12 in., while also adaptable for use in flat mode. It is thin, light, and can be easily positioned in tight spaces, making it ideal for challenging inspection environments. The detector achieves a high resolution of 99 microns, meeting ISO17636-2, *Non-destructive testing of welds — Radiographic testing — Part 2: X- and gamma-ray techniques with digital detectors*, Class B standards for materials 4 mm (0.16 in.) thick and above. The included proprietary bendable mount saves time by streamlining setup and ensuring rapid deployment, allows for repeatable positioning, and prevents overflexing to prolong equipment life. The detector is fully compatible with NOVO's previous generation systems, providing seamless integration for current users.

NOVO DR Ltd.
novo-dr.com

Report Examines Driving Forces in the NDE Equipment Market

The *Non-Destructive Testing (NDT) Equipment Market* report projects the industry to grow at a compound annual growth rate of 6.2% from 2022 to 2032, reaching a value of $31.5 million by 2032. This report delves into key drivers propelling this growth, including increasing safety regulations, technological advancements, and heightened demand across diverse industries like aerospace, automotive, and construction. Demand for nondestructive examination (NDE) equipment is linked to the rising importance of ensuring material integrity and machinery reliability, particularly in high-stakes sectors such as power generation, petrochemicals, and manufacturing. The report highlights the market's competitive landscape, noting key players like General Electric, Olympus Corporation, and Mistras Group, and outlines emerging opportunities for innovation and technological advancements in automation and laser-based testing systems. Regional growth is equally promising, with North America and Europe expected to hold significant market shares due to growing industrial infrastructure and power generation activities.

Future Market Insights Inc.
futuremarketinsights.com

AWS Updates Welding Inspector Specification

AWS B5.1:2025, *Specification for the Qualification of Welding Inspectors*, establishes the requirements to qualify welding inspectors and defines the body of knowledge applicable to welding inspection personnel. The qualification requirements for visual welding inspectors include experience and satisfactory completion of an examination, which includes demonstrated capabilities, and proof of visual acuity. The examination tests the inspector's knowledge of welding processes, welding procedures, nondestructive examinations, destructive tests, terms, definitions, symbols, reports, welding metallurgy, related mathematics, safety, quality assurance, and responsibilities.

AWS
aws.org

BY WALT BYLSMA AND JEFF NORUK

Laser Vision Scanning of Welds

Could this technology become the new benchmark for visual welding inspection?

The November 2020 *Inspection Trends* featured an article titled "Using Portable Laser Vision to Improve Weld Quality," written by myself, a Certified Welding Inspector (CWI) at Crown Equipment Corp., New Bremen, Ohio, and Jeff Noruk, president of Servo-Robot Corp., Wauwatosa, Wis., which explained the foundational benefits of incorporating portable laser vision inspection into a weld quality control program. Crown Equipment Corp., one of the world's largest forklift and material handling companies, acquired this technology to enhance its manufacturing while producing robust, ergonomic, and safer equipment.

Fast-forward over three years and we have experienced additional benefits that have been realized over time. The rapid evolution of welding technology demands an equal progression of quality control, measurement accuracy, and digital data output that can only be captured and realized by laser technology, using, for example, a handheld laser vision scanner and weld quality system — Fig. 1.

Backstory

Having personally welded for 20 years at many large and small organizations, then progressing to weld inspection for over 20 years at Crown, I acquired the experience of being very up-close and personal with tens of thousands of welds on both sides of the manufacturing aisle. Understanding that each weld in the world is unique

Fig. 1 — WiKi-Scan™ weld inspection system.

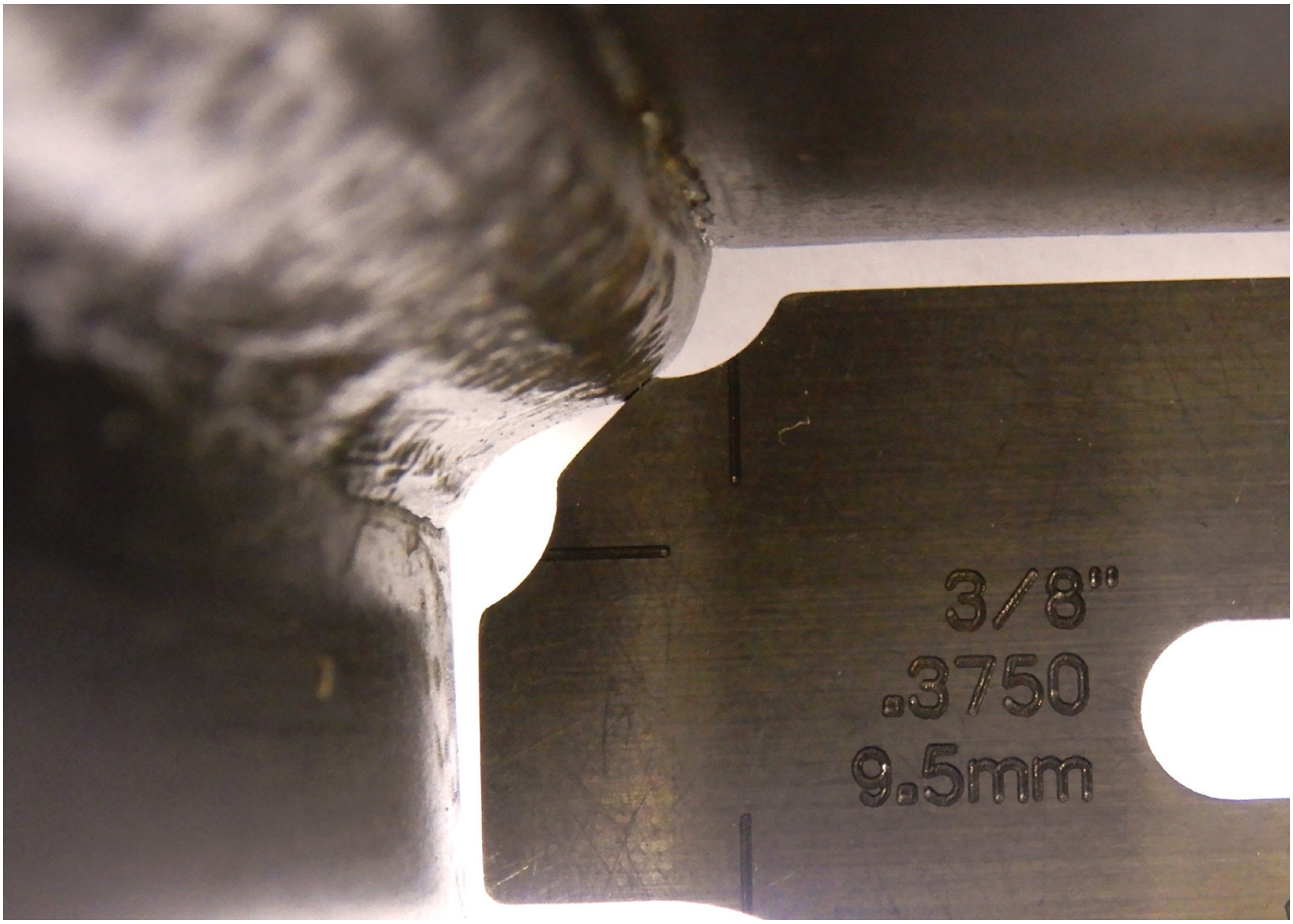


Fig. 2 — Inspecting a fillet weld utilizing the weld leg size corner of a traditional fillet weld gauge.

and distinct brings with it a sense that there must also be an equally distinguishing method to validate a weld's conformance to applicable standards and codes. With the ever-increasing changes in the manufacturing world, whether due to ergonomics, economics, or other factors, welding and welding joints are continuously evolving. I found a need for a more versatile and reliable method of visual weld inspection, such as laser vision.

The November 2020 *Inspection Trends* article touched on general weld inspection. In the article, laser vision scanning was compared to the traditional manual weld gauges, and inspecting unconventional weld types, such as skewed T-joints, was discussed. Weld features that are difficult to quantify were also considered, such as reentrant angles (at the weld toes) and undercut depths. The article also discussed the safety benefit of laser vision inspection due to its ability to measure hot parts without contact and its intuitive reporting capabilities, including digital data, vivid images, and cross-sectional graphics.

Discovery

I would like to highlight the accuracy of laser scanning by comparing it to the more traditional methods of inspecting welds using conventional, manual weld gauges. We'll start with a story about my real-world experience.

During an audit I performed to validate weld sizing and quality on robotically welded test samples, I inspected a fillet weld produced in the horizontal position (2F) with the specified weld size of 0.375 in. (9.53 mm). As you may know, welds deposited in the horizontal position, or any position that deviates from true flat, generally exhibit some gravitational sag. Proficient manual welders or robotic programmers can mitigate some of this sag through equipment settings and welding techniques, but eliminating it isn't easy. Gravity is ubiquitous and causes weld face profiles to deviate from the desired flat profile, even to a small degree.

To inspect this fillet weld, I utilized the weld leg size corner of a traditional fillet weld gauge. The horizontal and vertical weld legs met the minimum weld leg size. Turning the gauge appropriately to validate the theoretical weld throat with its center tab revealed that it met the minimum required size. Or did it? — Fig. 2.

The center tab contacted the face of the weld, which typically validates that the theoretical weld throat meets the minimum size specification. However, I was curious about the concave area between the center of the weld and the vertical weld toe. Typically, the fillet weld size for equal leg fillet welds is defined as the leg lengths of the largest isosceles (two legs of equal length) right-angle triangle that can be inscribed within the fillet weld cross section. I wondered what the calculated fillet weld size would be. Fortunately, I had access to laser technology that would provide quantitative digital values to validate the results of the manual gauge inspection.

Plan

Without laser vision scanning, I would have had to cut this sample and examine it closely under magnification (macroetching). Because I had access to laser scanning, I used both methods to evaluate this weld. If the inspection equipment performed as claimed — that is, to automatically inscribe the largest isosceles right-angle triangle by the incorporated algorithm — I would be able to compare and validate laser scanning and magnification results for accuracy.

I started with the laser scanner. After reading the operation manual and familiarizing myself with its software, I created a program for a 0.375 in. fillet weld and measured it. There were a few graphical icons that turned red (revealing nonconformance). Most were green. These results tentatively supported my suspicion about the quality of this weld. Next, I needed to validate this by sectioning and macroetching the part in the same area. I was excited, thinking that now we might have a way to substantiate and validate what, up until now, was mere suspicion on our part. I sectioned the sample, performed a macroetch, and measured the weld. The results can be seen in Fig. 3.

Accuracy

The laser profile graphic in the upper right corner of Fig. 3 is a cross-sectional graphic showing the laser scanning results. The yellow line represents the profile of the weld face utilizing a 2D point line. The blue, large isosceles right-angle triangle inscribed within the weld touches the weld face at the lowest point of concavity. This represents the adjusted, or actual, true weld size. The laser output data section displays what is being measured along with the numerical results. The large macroetched view on the left in Fig. 3 was measured by alternate, dedicated weld inspection equipment after the part was sectioned and acid etched.

Table 1 shows the results of five key measurements made using two different validation techniques, sectioning and macroetching versus laser scanning. The colors indicated correspond to those shown in Fig. 3.

All measurements using the two methods were comparable to within 0.003 in. (0.08 mm). This is exceptional and falls within the measurement precision of 0.005 in. (0.13 mm) for the laser scanning unit that was used.

The laser scanner automatically calculated the adjusted weld size with the incorporated algorithm based on the theoretical weld throat. This resulted in a final adjusted weld size of 0.365 in. (9.27 mm), which fell short of the required minimum weld size of 0.375 in. (9.53 mm). You may have noticed that the horizontal and vertical weld legs were swapped for the laser scanner results. This was caused by the orientation of the scanning device to the weld, but it did not affect the overall test result.

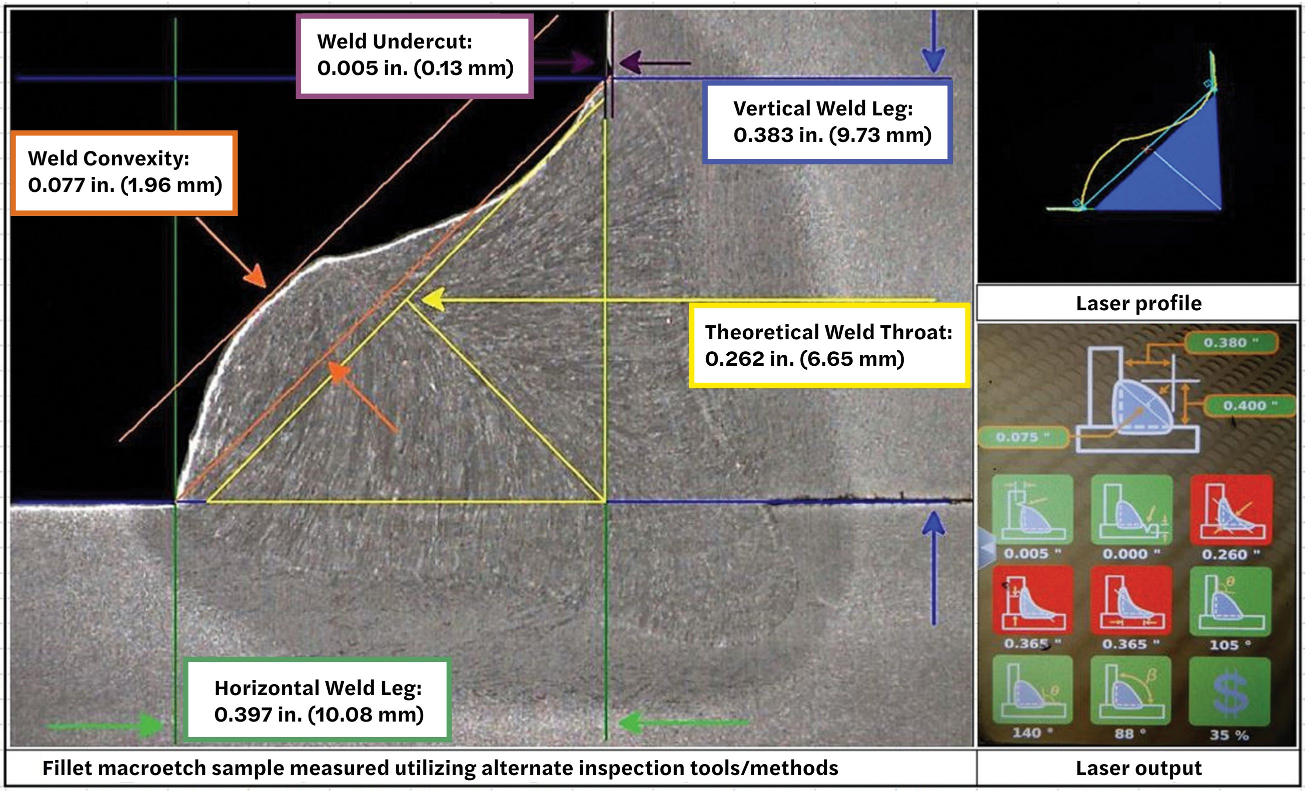


Fig. 3 — Laser scanning results of a fillet weld.

Table 1 — Horizontal Fillet Weld

Measurement Type	Sectioning/Macroetching Measurement	Laser Scanning Measurement	Laser Scanning Test Result
Horizontal Weld Leg (Green)	0.397 in. (10.08 mm)	0.400 in. (10.16 mm)	Pass
Vertical Weld Leg (Blue)	0.383 in. (9.73 mm)	0.380 in. (9.65 mm)	Pass
Theoretical Weld Throat (Yellow)	0.262 in. (6.65 mm)	0.260 in. (6.60 mm)	Fail
Weld Convexity (Orange)	0.077 in. (1.96 mm)	0.075 in. (1.91 mm)	Pass
Weld Undercut (Purple)	0.005 in. (0.13 mm)	0.005 in. (0.13 mm)	Pass

Supplemental data captured and displayed by the laser scanner included the angle between the base metal plates (88 deg) and the angles between the weld faces and the adjacent base metals at the weld toes (105 and 140 deg). These measurements also helped validate that the base material angles met specifications and revealed overlap or toe angles that might meet more stringent specifications per applicable code. It also outputted an over-welding percentage (dollar sign icon showing 35% below it) based on the minimum leg size tolerance set and zero convexity, which could help identify opportunities for cost savings.

While this example suggests that the slightly undersized weld was a cause for rejection, there are many factors considered in the pass/fail disposition of a weld. The weld size needs to be assessed for the entire weld length. Each discontinuity along that length must also be incorporated into the decision matrix to determine if it is a rejectable defect. Your company's code associated with this weld will provide guidelines for pass/fail criteria, with specific tolerances for weld size and the number of variations allowed within the length of the weld.

With such stringent requirements and specifications, using an equally capable inspection method is even more imperative. Inspection with manual weld gauges has its place, and the tools used are always improving. However, there are cases where manual inspection cannot attain the accuracy that newer technologies achieve, especially as companies continue to refine their codes. Laser scanning can achieve this level of accuracy and provide the digital data to support it.

Another Test Example

To help validate the experience of the first test above, I performed the same comparison testing for groove and skewed T-joint welds, as shown in Fig. 4. Pass/fail tolerances were not programmed into the laser scanner in this example.

For the groove weld, the laser scanner's weld profile graphic reveals the cross-sectional shape of the weld face. The blue triangulation noted above is not utilized with groove welds, so it is not part of these results. Two measurements were chosen to be evaluated through macroetching. Laser scanning captured these results; the additional measurements are shown in Table 2. The two measurements taken by both methods were comparable to within 0.001 in. (0.03 mm).

A similar comparison was also conducted for a skewed T-joint weld. In the laser's profile graphic, the blue triangulation is no longer a right-angle triangle but is still an isosceles triangle. Note that in the case of a specified unequal leg fillet weld, there is the option to inscribe the largest nonisosceles triangle within the weld cross section to facilitate correctly calculating the weld size and theoretical throat measurements. Notice that the weld leg on the vertical base material member is longer than the horizontal member's. These cross-sectional graphics are easily understood and can be a good way to present ambiguous concepts and data to manufacturing personnel for process improvements.

Again, five measurements are specified and displayed in Table 3. All five measurements match to within 0.003 in. Supplemental data captured via laser scanning included weld toe angles and joint angle.

These tests made it clear that laser scanning could produce results similar to sectioning and macroetching but with more speed and accuracy and the ability to capture additional supplemental data. This capability assists our operations in tracking processes and trends and informing continuous improvement plans designed to achieve and maintain Six Sigma weld quality.

Additional Attributes of Laser Scanning

Laser scanning may help an operator better locate the weld position. Laser imaging utilizes a set of breakpoints that the laser searches for that best represent the base metals and what it sees as the weld toes and weld face profile. In some instances of nonstandard welds, the scanner may not properly represent the weld's cross section. This is usually discernable directly after having performed an inspection by viewing the profile graphic and roughly assessing weld toe locations. Moving the

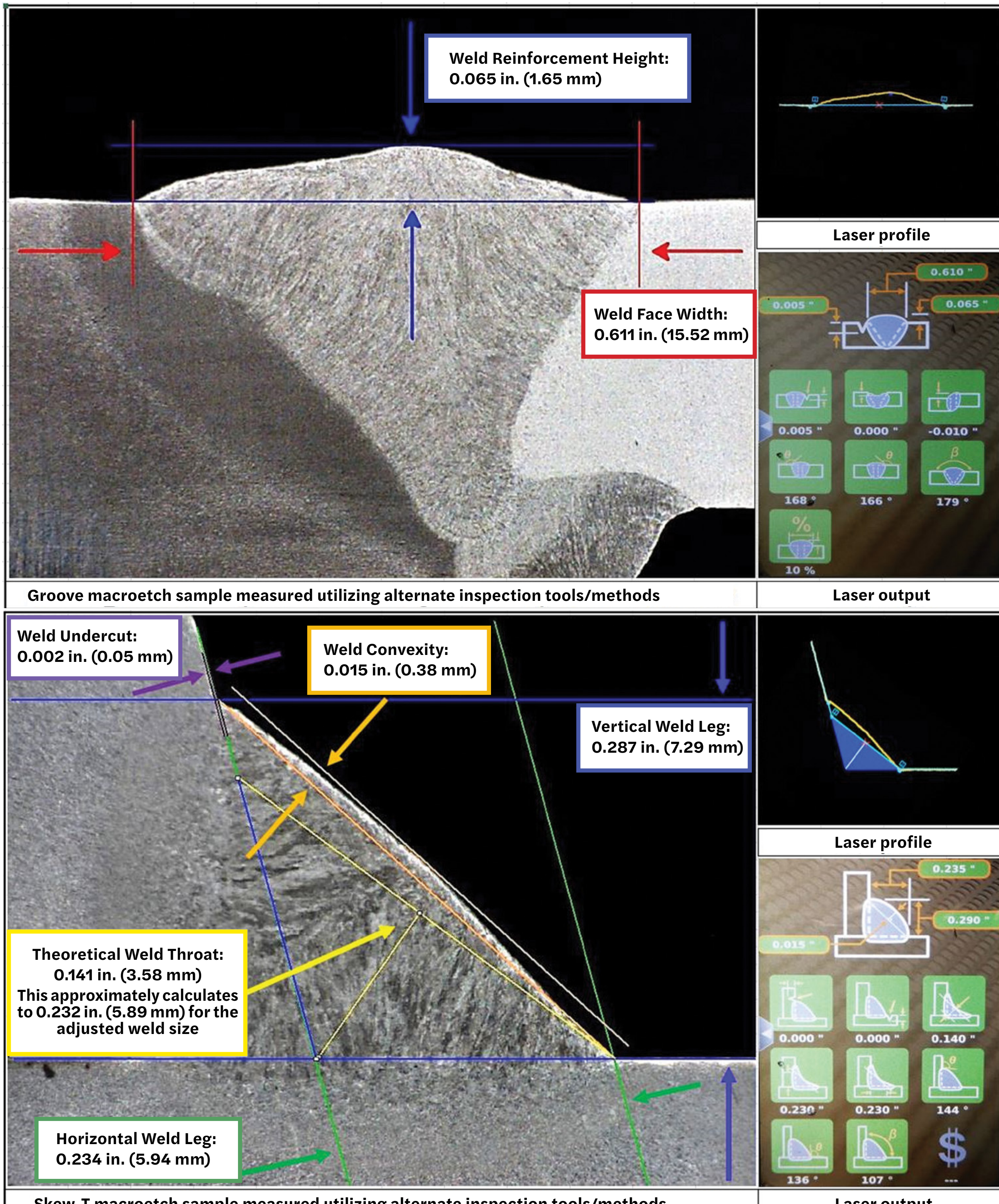


Fig. 4 — Comparison testing of groove and skewed T-joint welds.

Table 2 — Groove Weld

Measurement Type	Sectioning/Macroetching Measurement	Laser Scanning Measurement
Weld Face Width (Red)	0.611 in. (15.52 mm)	0.610 in. (15.49 mm)
Weld Reinforcement Height (Blue)	0.065 in. (1.65 mm)	0.065 in. (1.65 mm)
Undercut at the Right Weld Toe	N/A	0.005 in. (0.13 mm)
Groove Underfill	N/A	0.000 in. (0.00 mm)
Base Material Mismatch	N/A	-0.010 in. (-0.25 mm)
Weld Toe Angles	N/A	166 and 168 deg
Joint Angle	N/A	179 deg
Reinforcement Height Size/Ratio	N/A	10%

Table 3 — Skewed T-Joint Weld

Measurement Type	Sectioning/Macroetching Measurement	Laser Scanning
Horizontal Weld Leg (Green)	0.234 in. (5.94 mm)	0.235 in. (5.97 mm)
Vertical Weld Leg (Blue)	0.287 in. (7.29 mm)	0.290 in. (7.37 mm)
Theoretical Weld Throat (Yellow)	0.141 in. (3.58 mm)	0.140 in. (3.56 mm)
Weld Convexity (Orange)	0.015 in. (0.38 mm)	0.015 in. (0.38 mm)
Weld Undercut (Purple)	0.002 in. (0.05 mm)	0.000 in. (0.00 mm)
Weld Toe Angles	N/A	136 and 144 deg
Joint Angle	N/A	107 deg
Adjusted Weld Size	0.232 in. (5.89 mm)	0.230 in. (5.84 mm)

breakpoints to the proper locations, using the available magnification levels, if necessary, helps to locate the best breakpoint placement. In addition, weld features are updated automatically.

Conclusion

In today's highly automated and technologically developed world, we can live on the 52nd floor of a new high-rise, drive on a quarter-mile-high suspension bridge, and dive into the ocean depths in a submarine. What do these things have in common? They all require welding.

No matter the activity, we expect and deserve to be safe. Manufacturing codes were created to help keep us safe. Technologies have been developed to help ensure we are safe. Laser scanning is one of these technologies designed to ensure that the things we live in, drive on, and dive in are structurally safe and secure.

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IT FEATURE

BY THOMAS R. HAY

NDE Personnel Qualification and Performance to AWS Structural and Bridge Welding Codes

The relationship between NDE performance demonstration and these codes is explored

Nondestructive examination (NDE) personnel are qualified to perform inspections based on accumulated in-person or remote classroom training, in-person practical training, written and practical exams, and, in some cases, demonstration or qualification exams.

Performance demonstration (PD) and inspection qualification (IQ) are interchangeable. NDE, PD, and IQ are supplemental to the core certification process that verifies the competency skills of an NDE technician. It demonstrates that the technician can follow an NDE procedure to perform an examination for a specific application and deliver acceptable results within the capability of the NDE method or technique utilized.

Introduction to NDE Performance Demonstration in Compliance with the AWS D1.1 and AWS D1.5 Codes

NDE of steel structures and steel bridges using ultrasonic testing (UT) and phased array ultrasonic testing (PAUT) is described in AWS D1.1/D1.1M, *Structural Welding Code — Steel*, and AWS D1.5M/D1.5, *Bridge Welding Code*. The core NDE certification requirements are well-defined and referenced in the American Society for Nondestructive Testing (ASNT) Recommended Practice No. SNT-TC-1A: *Personnel Qualification and Certification in Nondestructive Testing*, and ASNT CP-189, *Standard for Qualification and Certification of Nondestructive Testing Personnel*. The qualification process for UT Level II requires at least 80 hours of formal classroom training and 630 hours of on-the-job supervised practical experience. To qualify for PAUT Level II, an additional 80 hours of training beyond UT Level 2 is required. In addition, 320 hours of supervised on-the-job practical experience is required.

The codes present PD or IQ in compliance with AWS D1.1 and D1.5 but with limited detail. AWS D1.8, *Structural Welding Code — Seismic Supplement*, does provide a detailed examination structure and grading scheme. This code is often used to evaluate the skill of UT Level II technicians before they are approved for a project. In most cases, the entity administering the examination is independent of the NDE technician employer.

Overview of AWS D1.8 Performance Qualification Exam

AWS D1.8 outlines a performance qualification exam for ultrasonic technicians. The exam consists of at least 20 indications across multiple test specimens. An example test specimen is shown in Fig. 1. The test specimen is a bridge girder flange simulation with two artificial discontinuities inserted into the weld. The first is a mid-wall incomplete fusion approximately 0.50 in. long. The second is the lack of root fusion, which is also 0.50 in. long.

The NDE candidate must accurately assess the AWS D1.1/D1.5 indication rating (IR) decibels, weld flaw length, axial location relative to the reference edge, and depth in the weld relative to the top surface. Two ASNT Level III UT inspectors must confirm the actual metrics cited above.

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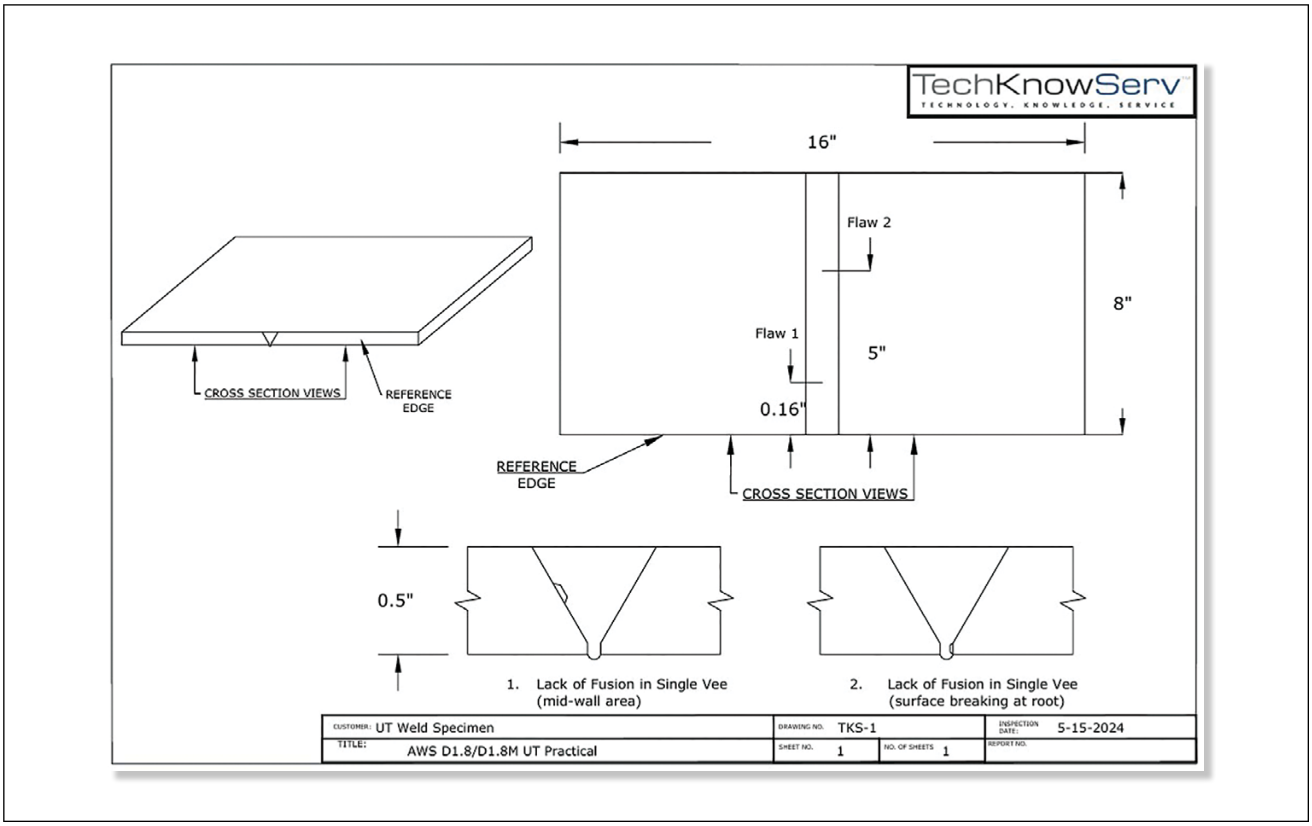

Fig. 1 — AWS D1.8 bridge flange transition weld with two simulated weld flaws for performance demonstration examinations. (Credit: TechKnowServ Corp.)

The following metrics are used to assess the participant's performance:

- The IR must be within ± 6 dB
- The indication length must be within +1 in. to –0.5 in.
- The indication depth must be within ± 0.25 in.

For a flaw to be considered detected, the candidate must satisfy at least two of the above metrics. Weld flaws detected with UT are passed on the overall rating assessment, R. The overall rating considers detected flaws "D" and false indication "F." The following calculation is used:

$$R = ½ (1 + D – F)$$

To pass the exam, the overall rating of R must be 0.90 or higher, the detection rating, D, must be 0.87 or higher, and the false rating, F, must be 0.15 or less. The candidate will pass the test if the detection rate is sufficient while the rejection rate is minimal.

PAUT Inspector Qualification to AWS D1.1 and AWS D1.5 Codes

PAUT is a more-advanced form of UT. It utilizes an array of electronically controlled ultrasonic transducers to produce and receive ultrasonic waves at various angles and focal lengths. This allows for more-precise and detailed inspections of welds and materials, including the ability to detect and size defects with greater accuracy. PAUT is often preferred for its versatility, speed, and ability to provide real-time imaging of the inspected area.

Personnel qualification requirements for UT Level I, II, and PAUT Level II are outlined in ASNT SNT-TC-1A. The candidate must reach the required hours per level to receive these levels. Along with the hours, the candidate must pass the appropriate practical exam administered by a UT Level III or PAUT Level III instructor. The hours required are as listed: UT Level I 40 training hours and 210 method hours and UT Level II has 40 more training hours and 630 method hours. To take the PAUT Level II exam, the candidate must be certified at UT Level II. PAUT Level II requires an additional 80 training hours with 320 method hours. These apply to AWS D1.1, AWS D1.5, and AWS D1.8.

The minimum personnel qualification requirements for practical examinations are outlined in AWS D1.5M/D1.5 for PAUT. The exam consists of two welded joints (e.g., butt, T, corner) that have real or artificial discontinuities. These joints need to be examined using a PAUT procedure written in accordance with AWS D1.5M/D1.5 Annex J.

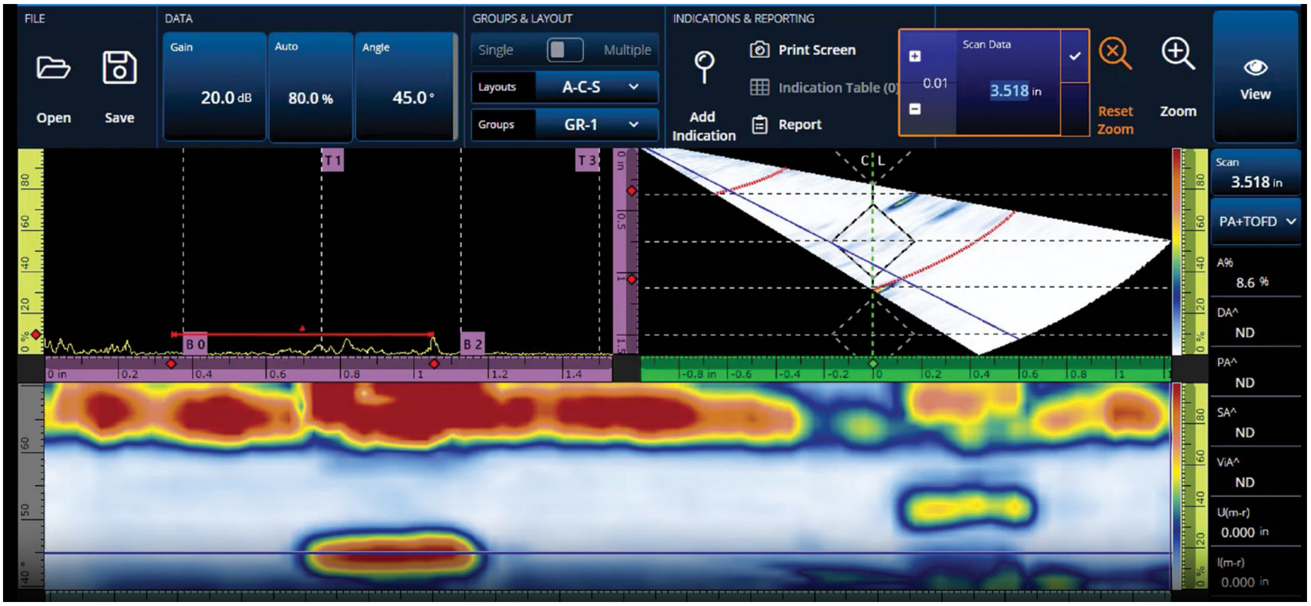

Fig. 2 — Example PAUT testing for AWS NDE personnel qualification exam. (Photo credit: TechKnowServ Corp.)

Figure 2 shows an example of PAUT data. The typical Olympus X3 encoded scan display shows the A-scan in the top left, the S-scan in the top right, and the C-scan across the bottom. The displayed PAUT A-scan is selected using the S-scan data cursor, and the PAUT S-scan displayed depends on the C-scan data cursor.

UT and PAUT use the same principles, but when evaluating indications, they use different premises. For UT, the indication rating should be calculated. For PAUT, three levels are set to evaluate whether to accept or reject an indication. The indication rating described in AWS D1.1 is the algebraic decibel difference between the indication level and the reference level corrected for attenuation. Indication rating = d, attenuation factor = c, indication level = a, and reference level = b. The formula if the instrument has gain in dB is $a - b - c = d$.

For PAUT evaluation, the three different levels are automatic reject level (ARL), standard sensitivity level (SSL), and disregard reject level (DRL). These levels can change based on the acceptance criteria — Fig. 3. However, for this example, I will pull from AWS D1.5. The SSL will be aligned with the primary reference level dB at 50% ± 5% of full screen height. The ARL is defined as 5 dB over SSL, and the DRL is defined as 6 dB under the SSL. All of these will be displayed on the A-scan of the PAUT unit. These levels break the A-scan into four classes: A, B, C, and D. Class A is anything above the ARL; Class B is between SSL and ARL; Class C is between DRL and SSL; and Class D is anything below DRL. These classes correlate to the AWS D1.5 Table J.3, PAUT Acceptance Criteria, as shown below.

Summary

NDE performance demonstration exams are emerging as important milestones for NDE inspection personnel across many different fabrication codes, including AWS, the American Society of Mechanical Engineers (ASME), and the American Petroleum Institute (API). Coincidentally, the latter two demonstration exams are comparable or more stringent. IT

Table J.3
PAUT Acceptance Criteria (see J10.2)

Maximum Discontinuity Amplitude Level Obtained	Maximum Discontinuity Lengths by Type of Loading	
	Compression	Tension
Class A (> ARL)	None allowed	None allowed
Class B (> SLL, ≤ ARL)	20 mm [3/4 in]	12 mm [1/2 in]
Class C (> DRL, ≤ SLL)	50 mm [2 in]	Middle half of weld: 50 mm [2 in] Top or bottom quarter of weld: 20 mm [3/4 in]
Class D (≤ DRL)	Disregard	Disregard

Fig. 3 — Table J.3 from AWS D1.5M/1.5:2020, *Bridge Welding Code*.

POINT OF VIEW

Aim Higher!

Quality is the cornerstone of the welding industry

BY SETH DAVIS

Company owners, welding supervisors, welding teachers, and welders often tell me weld quality is important to them, but they struggle to define what it means. I've been told that a quality weld is one that is certified, meets a code, looks good, or doesn't break. But to truly define a quality weld, one must be more specific.

What Is a Quality Weld?

What measurable characteristics of a weld make it look good or indicate that it won't fail? How specifically do you measure quality? Some might say the weld has to meet the requirements of whatever code you are working under. But is a weld that meets the requirements outlined in any given code or standard a quality weld?

I invite you to remember your high school days to answer that question. What letter grade did you have to earn in high school to pass a class? In most schools, it was either a C or a D. To put it another way, a C or D was the minimum acceptable standard.

Keep that in mind as I make the following observations:

1) Any welding code or standard is, by default, a minimum standard;

2) Welding codes and standards set the baseline for what is considered acceptable practice; and

3) Producing a weld that meets the code minimum requirements can be seen as meeting the basic standards, but there is always room for further improvement in terms of craftsmanship and performance.

While passing a class with a C or a D indicates that the requirements were met, it doesn't reflect the highest quality of work. Similarly, a weld that passes the code, while perfectly acceptable, doesn't necessarily represent the highest quality. To return to my original question, what measurable characteristics of a weld indicate quality, and how are those characteristics defined?

The Minimum Acceptable Standard

While codes may be the minimum acceptable standard, they do give us a starting place.

To claim that a weld is high quality, it should exceed the standard outlined in the code in some measurable way.

Some measurable examples are as follows:

If a code says . . .	A quality weld should have . . .
Undercut should not exceed 1/32 in.	No undercut
Reinforcement should not exceed 1/8 in.	Control of reinforcement on the root or cap to within 1/32 in. of a specified number, never to exceed 1/8 in.
Weld width — Not defined	Weld width at cap no more than 1/16 in. wider than groove
Weld profile consistency — Not defined	No more than 1/16 in. variation between the highest point on the weld and the lowest point on the weld
Large deviations in fillet weld leg size allowed	The ability to hold a fillet weld to within 1/32 in. of the required leg size without being undersized at any point
Some porosity allowed	No porosity

Many of you who are reading this list might think that it's impossible. No one can do that consistently, or it's too costly to enforce.

Let's say you are right — no one can do what I have described. That still does not change the definition of a high-quality weld. If one sees the gold standard of high-quality work as the code minimum, then the code minimum is what one will produce on their best day at work. The code minimum should be the kind of work one produces on their worst day at work. To consistently achieve high-quality results, one should aim for a level that goes beyond the minimum.

Strive for Excellence

A welder's skill should be defined by the degree of their control over any dimension or aspect of a weld. The level of quality you hold yourself to should make you uncomfortable and force you to work harder to improve yourself every time you strike an arc. Your personal standard should be higher than any external code, company, or school standard you encounter. Your standard must also be measurable, and you should possess the tools to measure it. If weld quality is important to you, pull out your V-Wac gauge or fillet weld gauges and show me how you use them.

What do I want to say when someone tells me that weld quality is essential to them? First, show me the numbers and tools you use to define and measure quality. Second, if you aim for the code minimum, you will sometimes barely hit it. Aim higher!

SETH DAVIS (*seth.davis@weldingaudits.com*) is an AWS CWI and owner of Welding Audits LLC, Ordway, Colo.

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

Unlocking Success: Certification and Mentorship

Jason Becker, host of the *Arc Junkies* podcast, welcomed guest Andy Provost, an AWS Certified Welding Inspector (CWI) with numerous endorsements and certifications. Their conversation delved into Andy's career, the significance of certifications, the role of mentorship, and the evolving demands of the welding inspection industry.

Jason Becker (left) and Andy Provost at FABTECH 2024 in Orlando, Fla.

Andy's Career and Certifications

Jason and Andy's professional relationship began years ago, when Andy inspected Jason's welds at theme parks. Over time, Andy became both a mentor and a friend to Jason. Andy is highly respected for his vast collection of AWS endorsements, including D1.2, *Structural Welding Code — Aluminum*, D1.5, *Bridge Welding Code*, Welder Performance Qualification, and more. These certifications have been integral to his work, from his early days with American Institute of Steel Construction-certified fabricators to his current role in an engineering consulting firm.

Andy emphasized that he actively uses all his certifications, which proves their practical value. Inspired by Andy, Jason pursued his advanced certifications, including the Welder Performance Qualification, which has been vital for running an Accredited Testing Facility.

Importance of Endorsements and Ongoing Education

Endorsements serve multiple purposes in the welding industry: They expand technical knowledge, fulfill continuing education requirements, and prepare professionals for specific roles. Andy noted that endorsements like Welder Performance Qualification and D1.1, *Structural Welding Code — Steel*, address unique industry needs. Preparation for these exams involves understanding the layout of codebooks and knowing how to locate key information rather than memorizing content.

Andy and Jason discussed D1.3, *Structural Welding Code — Sheet Steel*, as one of the most challenging codes due to its strict requirements. Jason initially underestimated its complexity, but Andy's mentorship helped him navigate its nuances.

Both Jason and Andy stressed the value of continuing education and networking. Andy explained that attending seminars and conferences lets him stay current with industry developments and learn from others' experiences. He views learning as a lifelong process

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and encourages welding professionals to embrace growth opportunities. Jason reflected on how mentors have motivated him to pursue further certifications. His next goal is to earn the Welder Procedure Qualification endorsement.

Andy explained his company's approach to helping CWIs maintain their certifications, including offering opportunities for continued education and preparatory courses for nine-year recertifications. For older inspectors who may not test well, attending classes and presenting project experience provides a practical alternative. Andy advised younger inspectors to pursue endorsements or log sufficient hours early in their careers to avoid future challenges.

Common Mistakes by New CWIs

Andy identified frequent errors among young CWIs, such as failing to ensure welds are thoroughly cleaned before inspection. He underscored the importance of proper lighting and attention to detail to avoid overlooking flaws like cracks or inclusions. Jason shared a personal story about painting welds to prevent rust, only to be told by an inspector to remove the paint because coatings can obscure welds.

Jason and Andy emphasized the need for clear communication and education to reduce errors and ensure compliance. Andy encouraged supervisors to audit inspectors regularly and offer constructive feedback to improve their performance.

Industry Trends and Certification Demands

The demand for certified welders and compliant welding procedures is growing, with employers increasingly requiring certifications like D1.1 for structural steel and D1.3 for sheet metal. Andy attributed this trend to project specifications and highlighted the need for proper training to ensure inspectors and contractors adhere to code requirements.

Jason and Andy also discussed procedure qualification records and welder procedure specifications. Andy explained the importance of strict compliance with testing standards to maintain structural integrity, particularly for critical applications.

Mentorship and Knowledge Sharing

Mentorship plays a crucial role in professional development. Andy reflected on how his mentors shaped his career, and Jason appreciated how Andy's constructive feedback helped him improve his skills. Both agreed that inspectors should educate clients and welders rather than simply pointing out errors. This approach fosters understanding, improves quality, and ensures long-term compliance.

Andy also encourages his team to attend conferences and training sessions, describing events like the Inspection Expo & Conference as valuable opportunities to connect with industry professionals and share expertise. Jason highlighted how feedback from experienced inspectors like Andy has enriched his knowledge.

Codes, Standards, and Resources

Understanding and utilizing industry standards is essential. Jason stressed that companies must own and refer to codebooks like D1.1 and D1.3 to train welders and ensure compliance. Standard Welding Procedure Specifications from AWS offer a cost-effective way to meet code requirements.

Andy mentioned AWS B2.1, *Specification for Welding Procedure and Performance Qualification*, as a lesser-known but valuable resource for certifications like Welder Performance Qualification. He also highlighted compiling relevant standards into a comprehensive reference book, streamlining compliance efforts.

Conclusion

Jason and Andy concluded by emphasizing the importance of mentorship, education, and collaboration in the welding industry. They encouraged professionals to attend seminars, pursue certifications, and share knowledge to elevate the quality of work and foster a supportive industry culture. Andy's final advice is always to remember those who helped you along the way and to pay it forward by mentoring the next generation. IT

Certification QuikCheck

You can easily verify whether someone is a Certified Welding Inspector by using AWS's free online certification verification services. Go to the AWS website at *aws.org* and click on "Certification & Education" at the top of the homepage. Click on QuikCheck, then type in the person's certification number and last name.

BY ALBERT J. MOORE JR.

Q We are trying to qualify a welding procedure specification with notch toughness requirements. We aren't having any success. What factors should we consider to improve our chance of welding a successful test plate? The engineer specified the base metal, but we were tasked with selecting the filler metal and welding process. We have welded two test assemblies so far, and neither has passed the notch toughness requirements. All the other tests, nondestructive examination, and mechanical properties have passed the AWS D1.1, *Structural Welding Code — Steel*, requirement. It is only the Charpy test results that are too low at the test temperature.

A You asked a question that has been known to drive inspectors out of their minds.

Welding is a lot like baking. If the goal is to bake a batch of brownies, one doesn't throw ingredients haphazardly into a mixing bowl. Instead, one must have a recipe that tells the cook everything needed. Most cookbooks don't assume the person following the recipe is a professional baker (if they were, why would they need the cookbook?). The recipe walks the reader through the process of making a batch of brownies. It will direct the reader to preheat the oven, gather all the ingredients, mix the dry ingredients in the correct proportions, mix in the right amounts of the wet ingredients, and pour the batter into a greased pan. Then, the batter must be baked in the oven at the correct temperature and for the right length of time. If you jigger the proportion of dry or wet ingredients, the batch of brownies isn't going to turn out exactly the way you expected. The taste may be off, or the brownies might not bake properly, and they could even come out of the oven like a dense brick. If the temperature is too low, the batter might be undercooked. If the oven's temperature is too high, the bottoms of the brownies might be scorched. Turning the temperature from 325° to 650°F doesn't mean the brownie batter will cook twice as fast.

Again, welding is a lot like baking. You must have the correct ingredients (base metal, filler metal, and shielding gas if required), and the heat input (arc voltage, welding current, and travel speed) must be sufficient to achieve proper fusion but not so high as to adversely affect the properties you are shooting for.

When attempting to qualify a welding procedure specification (WPS), the welder should be provided with a recipe (a preliminary WPS) developed by someone who understands what they are doing. Otherwise, it's like creating a recipe for brownies from scratch without ever seeing or tasting a real brownie. If the preliminary WPS isn't correct, there is a slim chance the resulting weld will produce the required mechanical properties. Let's look at the factors (ingredients) that play a part in developing acceptable mechanical properties.

The family of base metals categorized as steel is very large. To simplify the discussion, let's narrow it down to carbon steel.

There are several factors to consider. Let's look at the effects of temperature on the mechanical properties of steel. A round bar will stretch when subjected to a tensile load. The amount of stretch is called strain. At elevated temperatures, the amount of strain will increase over time, even if the tensile load is unchanged. This phenomenon is called creep. As the bar stretches longer and longer, the cross section of the bar gets smaller and smaller until the unit stress (load/area) exceeds the tensile strength of the heated bar, at which point the steel ruptures. When the bar fails under such conditions, it is termed creep rupture. Steel operating at high temperatures is often alloyed with molybdenum to improve resistance to high-temperature creep.

At room temperatures, let's say 68°F and slightly higher, the round steel bar will stretch as adjacent atoms are separated ever so slightly by the tensile load. The strain is proportional to the load as long as the unit stress is below the yield strength of the steel. The amount of strain will not change unless the magnitude of the load changes. If the load is removed, the amount of strain is reduced such that the bar returns to its original length. In such a case, the bar is said to exhibit elastic behavior. If the load increases sufficiently, the unit stress exceeds the steel's yield strength, the atoms slip past each other, and the steel bar undergoes permanent deformation. When the load is removed, the bar is longer than before it was loaded. When the round bar is permanently deformed, the bar is said to exhibit plastic behavior. If the bar is loaded to failure, the steel exhibits permanent deformation in the area surrounding the failure. The failure is said to be a ductile failure because there is substantial deformation.

At low temperatures, the steel can fail without appreciable deformation. The failure can be sudden and catastrophic. This failure mode is said to be a brittle failure. Nickel can be added to steel to ensure the steel retains its ductility at a lower temperature. However, if the temperature is lowered even further, the steel will fail suddenly without exhibiting significant deformation. The mode of failure is a brittle fracture.

Engineers prefer the mode of failure to be ductile, where there are indications of excessive bending, twisting, etc. before failure occurs. The engineer or owner can take steps to prevent ductile failure by reducing the magnitude of the load or adding supports before failure occurs. However, there is a scant opportunity to take measures to avoid catastrophic failure when the steel is not ductile. At low temperatures, steel with insufficient ductility and toughness can suffer brittle fracture.

As a means of assessing the properties of the steel, the engineer performs a standardized test to determine the toughness of the steel. The results of toughness testing provide the engineer with direct evidence of the expected failure mode, whether it will be ductile or brittle. The toughness test aims to verify if the base metal, weld, and heat-affected zone (HAZ) have sufficient toughness at a temperature slightly below the design temperature to ensure the mode of failure, should it occur, is ductile. The goal is to avoid a catastrophic brittle failure. The toughness test frequently used is the Charpy V-notch (CVN) test.

The CVN test apparatus consists of a heavy pendulum that is placed into the horizontal (cocked) position and then released. The pendulum swings downward through an arc and strikes a test specimen on the side directly opposite a machined notch. The difference between the pendulum's starting height and the pendulum's final height represents the energy absorbed by the test specimen. A material with good toughness will absorb much of the energy before breaking and will undergo considerable deformation. A material with poor toughness will absorb little energy and cleave cleanly with little deformation.

The temperature at which the test is performed is a determining factor in the amount of energy absorbed. Therefore, the engineer or the applicable fabrication standard will specify the test temperature. The specimen is cooled by immersing it in a liquid bath and quickly placing it into the test position. As soon as possible, the impactor (pendulum) is released from its cocked position. The test is completed in a couple of seconds.

The thickness of the steel is also a determinant that must be considered. Thin rolled material typically exhibits fine grain (i.e., small grains), whereas thick rolled steel often exhibits coarse grain (i.e., larger grains). One hypothesis is that fine-grain steel presents a more torturous path for crack propagation, which inhibits crack growth and, therefore, greater toughness at lower temperatures. Thick rolled steel typically exhibits coarse grains with low toughness where a crack can propagate more easily (i.e., the crack propagates by following a straighter, less torturous path). Steel manufacturers can control the grain size of the steel by controlling the chemistry, rolling practices, and heat treatment.

The alloy content of the steel influences the toughness of the steel. With plain carbon steel, carbon is added to increase the hardness and strength of the steel. As the hardness increases, there is a corresponding increase in strength at the expense of ductility. The area under the stress-strain curve often represents static toughness. As it turns out, low-carbon steel typically exhibits better toughness than high-carbon steel. While the hardness and strength increase with increased carbon content, it is usually at the expense of ductility and toughness. The ease of welding also declines with an increase in carbon content. To ensure weldability, it is preferable to keep the carbon content between 0.2 and 0.3%.

The factors that influence the toughness of steel include thickness, chemistry, temperature, and processing (i.e., casting, forging, hot forming, cold forming, machining, welding, etc.).

Thickness — Thicker sections undergo less mechanical work while rolled and typically have larger grains associated with reduced toughness. Thin sections pass through the rolls a greater number of times (compared to thick sections), producing a greater degree of grain refinement (smaller grain size); smaller grains typically exhibit better toughness. Forged sections also undergo grain refinement if the cross section is reduced sufficiently and thus exhibit better toughness when compared to a casting or a machined part. Machining generally has no effect on toughness because it does nothing to reduce grain size.

Chemistry — Elements such as sulfur and phosphorus adversely affect toughness. Aluminum can be used as an effective deoxidizer and grain refiner, but too much aluminum adversely affects toughness. To reduce the amount of aluminum needed for deoxidation, manganese, silicon, titanium, or zirconium can be substituted for aluminum. However, the alloy manganese and silicon can act as hardening agents if added in excess. Elements that are effective hardening agents can have an adverse effect on ductility and toughness. While nickel can increase the hardness of steel, it isn't nearly as effective as a hardening agent when compared to carbon, silicon, manganese, chrome, vanadium, or molybdenum. While it is not highly effective as a hardening agent, nickel does improve low-temperature toughness. When alloying elements in addition to carbon are added to the steel, it is considered a low-alloy steel or a high-alloy steel, depending on the amount used.

Temperature — Temperature is usually a design constraint that must be considered when selecting the base metal and filler metal. Steel that will be used at low temperatures is usually specified as fine grain, killed steel and often contains nickel to improve low-temperature toughness.

Processing — As already mentioned, the rolling process influences the grain size of the steel. During hot rolling, the grains of the steel are primarily elongated parallel to the direction of rolling. When the rolling temperature is high enough, the highly strained (elongated) grains will subdivide (recrystallize) to become unstrained grains. However, with each successive pass through the next stand of rolls, the grains are again strained, and recrystallization happens. With each pass through the rolls, the grains become refined (made smaller) and tougher. Welding can promote grain coarsening if high heat input is used and if cooling is retarded due to high interpass temperature. Low heat input promotes fast cooling and small grain size but can promote high hardness and low toughness if the cooling rate from austenitizing temperature is too high. So, preheat, heat input, and interpass temperatures are used to help control the cooling rate of the weld and HAZ. How can one improve the probability of producing welds with acceptable toughness?

1) Select a base metal that has demonstrated adequate toughness at the lowest anticipated service temperature. Notch toughness testing at a specified temperature can be performed at a nominal cost by the mill if the requirement is included in the purchase order. The purchase order should require the mill to provide certified material test reports indicating the specified toughness tests were performed along with the results of the tests.

2) Select a filler metal required to pass CVN testing at the test temperature (or lower). You heard it here: Not all filler metals are created equal. Check the filler metal specification to verify the filler metal classification is required to pass CVN testing and at what test temperature. Again, the purchase order provided to the filler metal supplier/manufacturer must specify the requirements for CVN testing on a lot-by-lot basis (review AWS A5.01, *Welding and Brazing Consumables—Procurement of Filler Metals and Fluxes*, for purchasing recommendations). Require the manufacturer to provide certified material test reports (not a typical certificate of conformity) for the filler metal. The filler metal documentation must include a copy of the procedure qualification record (PQR) listing the welding parameters used by the manufacturer while welding the test coupon. Specify an electrode classification that meets H4 low-hydrogen requirements. Diffusible hydrogen is not your friend. Be selective and choose a filler metal the manufacturer has shown to meet the project's needs. The manufacturer, specification, and classification are considered essential variables by many fabrication standards when notch toughness is a requirement. The following is an example of how to specify the filler metal on the WPS or PQR:

Manufacturer and brand name: ESAB Tubrod 15.00, Specification: AWS A5.20, Classification: E71T-5M H4.

3) Replicate the welding parameters the filler metal manufacturer used when the manufacturer qualified the filler metal. Pay attention to the preheat/interpass temperature, the maximum interpass temperature, and the heat input.

4) Monitor the welding of the test coupon. Record the welding parameters for each weld bead and closely control the preheat, heat input, and maximum interpass temperature. Allow sufficient time for excess heat to dissipate if the interpass temperature approaches the maximum interpass temperature listed by the WPS.

5) Welds deposited with gas shielded gas metal arc welding (GMAW) and gas shielded flux cored arc welding (FCAW-G) typically exhibit tougher welds compared to self-shielded flux cored electrodes. Whether gas shielded GMAW or FCAW-G is used, reduce or eliminate carbon dioxide in the shielding gas. The welding arc disassociates CO_2 into carbon and oxygen. Deoxidizers that interact with oxygen to prevent porosity in the weld will introduce oxides into the weld. Oxide inclusions tend to reduce toughness.

6) Ensure the test materials are properly cleaned for welding. Remove all traces of hydrocarbons using a solvent that evaporates completely and leaves no residue. Diffusible hydrogen in the weld or HAZ is never your friend.

7) Remove all mill scale, oxides, notches, etc. Remove all slag and oxides between weld beads. The welder will not burn out any residual slag or oxide left between weld beads.

8) If necessary, improve the weld bead profile before depositing the next weld bead. If a grinding disk is used, follow it with a rotary file to remove any embedded grinding grit before depositing the next weld bead.

9) Maintain the minimum preheat/interpass temperature and make sure the maximum interpass temperature is not exceeded. If the manufacturer lists a maximum heat input limitation, don't exceeded that maximum. Likewise, monitor the maximum interpass temperature. If needed, allow sufficient time for heat to dissipate when the interpass temperature approaches the maximum listed by the WPS.

10) If postweld heat treatment (PWHT) is required, make sure the PWHT procedure is followed.

11) Pay close attention to the location where the test specimens are extracted from the test assembly and how they are prepared. Verify that the laboratory used a broach to make the V-notch.

There is no magic formula to ensure a test assembly will meet the CVN requirements, but there are factors the fabricator must consider to increase the probability of meeting CVN requirements. Both the designer specifying the base metal and the person providing direction via the preliminary WPS have to understand the particularities of the welded steel. The selection of the filler metal is an important consideration. The alloying elements influence the properties of the completed weld. If toughness is required, pick a filler metal classification that requires the manufacturer to include CVN testing to qualify the filler metal. IT

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The Atlas of Welding Procedure Specifications Seminar

This seminar, offered via Zoom from April 7 to 11, is designed for individuals who need to develop welding procedures for steel construction, machinery, pressure piping, pressure vessels, and shipboard equipment in compliance with AWS standards or ASME Section IX. It will teach advanced techniques for creating WPSs that provide welders with the necessary information to meet code requirements. Topics will include handling AISI steels or other steels not covered by AWS or ASME standards, determining preheat requirements, setting interpass temperature limits, selecting filler metals for steels not listed in ASME Section IX or AWS standards, and using statistical analysis to interpret large PQR data sets, among other topics.

For more information, contact Al Moore of NAVSEA Solutions at *amoore999@comcast.net*.


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