



INSPECTION TRENDS

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THE MAGAZINE FOR MATERIALS INSPECTION AND TESTING PERSONNEL



Understanding Weld Cracking

Weld Repair of High Energy Steam Pipe

School Profiles

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R. Pascal



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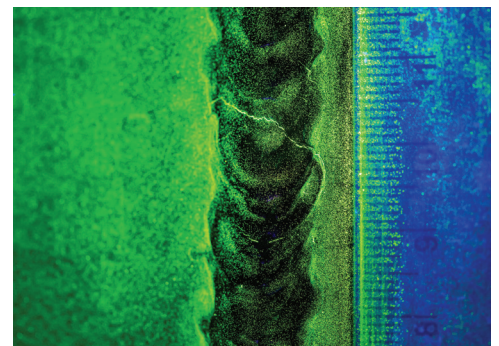
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COVER PHOTO:

Butt joint weld crack. (Credit: Shutterstock.)



PUBLISHER: Annette Alonso
aalonso@aws.org

EDITOR: Carlos Guzman
cguzman@aws.org

[EDITORIAL]

MANAGING EDITOR: Kristin Campbell
kcampbell@aws.org

SENIOR EDITOR: Cindy Weihl
cweihl@aws.org

ASSOCIATE EDITOR: Roline Pascal
rpascal@aws.org

ASSOCIATE EDITOR: Alexandra Quiñones
aquinones@aws.org

ASSOCIATE EDITOR: Brent Wiggins
bwiggins@aws.org

[DESIGN & PRODUCTION]

MANAGING EDITOR, DIGITAL & DESIGN:
Carlos Guzman
cguzman@aws.org

PRODUCTION MANAGER: Zaida Chavez
zaida@aws.org

ASSISTANT PRODUCTION MANAGER:
Brenda Flores
bflores@aws.org

[ADVERTISING]

MEDIA SALES EXECUTIVES:

Lea Owen
lea@aws.org

Scott Beller
sbeller@aws.org

SUBSCRIPTIONS REPRESENTATIVE:

Giovanni Valdes
gvaldes@aws.org

AMERICAN WELDING SOCIETY

8669 NW 36 St., #130, Miami, FL 33166-6672
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AWS DIVERSITY, EQUITY, AND INCLUSION STATEMENT

AWS values diversity, advocates equitable and inclusive practices, and engages its members and stakeholders in establishing a culture in the welding community that welcomes, learns from, and celebrates differences among people. AWS recognizes that a commitment to diversity, equity, and inclusion is essential to achieving excellence for the Association, its members, and employees.

Why Pursue a SCWI Credential?


Achieving AWS's Certified Welding Inspector (CWI) credential is quite an accomplishment. It is the culmination of years of experience, hours of studying, and intense examination. Successfully achieving that goal is worthy of a moment of praise and respite.

Attaining the CWI credential, though, is very much a beginning. For many, it opens the door into the large world of

quality control, supervising work, performing inspections, conducting audits, and verifying materials and processes. Additionally, working in this field inevitably means exposure to the application of any number of nondestructive examination (NDE) methods and other certifications (American Petroleum Institute, the International Code Council, etc.). Achieving the CWI credential is a great accomplishment, one that can put you on a course that will require you to continue to learn and grow professionally.

Over time, and after gaining considerable experience, you may begin to wonder what benefit adding Senior before the CWI acronym may offer you professionally. The answer to that question is not a universal one; the specific benefits of a Senior Certified Welding Inspector (SCWI) credential are specific to you and your professional situation.

At first glance, it may not seem as though there are clear cut benefits to pursuing this credential. It is rare to see job listings advertised exclusively for SCWIs. Depending on your employment situation, there may not be an immediate monetary gain in the form of a pay raise. CWIs exist who have extensive experience and are leaders in the industry but have not pursued an SCWI credential. After all, it is the responsibility of the employer to determine if an employee is capable of performing their assigned duties; no certification is a substitute for that evaluation.

So, isn't a CWI credential enough? Why pursue an SCWI credential? Earning the CWI credential is a notable achievement, but it is a beginning, one that promotes growth over time. If your position has grown from performing inspections to supervising inspectors and NDE technicians, from verifying conformance to developing and maintaining quality management systems, and from supervising the application of welding procedures to developing and writing procedure specifications, or if that is where you want your career to take you, then pursuing the SCWI credential may be advantageous. The SCWI credential is intended to, by means of testing and certification, identify one as an expert and supervisor in their field. If that sounds like the path you want to take, consider working toward adding Senior to your CWI credential. 

CALEB FECKER (cfecker@tip-cons.com) is an AWS SCWI and ASNT NDT Level III at Testing & Inspection Professional Consulting in Wappingers Falls, N.Y.



CALEB FECKER



AWS Hosts CWI Seminars

AWS held a CWI nine-year recertification seminar and a Certified Welding Inspector (CWI) seminar at AWS World Headquarters in Miami, Fla.

Jim Greer taught the AWS CWI nine-year recertification Jan. 14–19. Greer is a Certified Welding Educator (CWE), a Senior Certified Welding Inspector (SCWI), and the president of Techno-Weld Consultants.

Attendees of the nine-year recertification seminar included Adrian Suarez Diaz, Chandler Renken, Daniel A. Prado Pinzon,

Jared C. Prange, Jarrad E. Brayford, Jason J. Iacono, Joey Eshwar Ramdath, Lucien A. Brown, Nicholas Leckemby, and Nicholas T. Williams.

Rick Munroe led the AWS CWI seminar March 10–15. Munroe is an SCWI, a CWE, the owner of National Welding Lab & Inspection, and an instructor at Asnuntuck Community College.

Attendees of the CWI seminar included Edward Costello, John E. Auten, Kenneth D. Erickson, Robert Steinocher, Ryan F. Healy, Jake Fulgham, and Christian G. Horodynski.



The attendees of the CWI nine-year recertification seminar in the lobby of AWS Headquarters.



The participants of the CWI seminar pose outside of AWS Headquarters.

AWS Workshop to Produce CWI Certification Items

AWS will hold an item-writing workshop for AWS Certified Welding Inspectors (CWIs), Senior Certified Welding Inspectors, and Certified Welding Educators to produce quality questions (also called items) for the CWI Part A fundamentals exam.

The workshop will be held at AWS Headquarters in Miami, Fla., from Aug. 27 to 29. Participation includes the following:

- Opportunities to network with other welding professionals
- A paid hotel stay at a nearby establishment
- Breakfast and lunch each day of the workshop
- An invitation to the group dinner on the first evening

Following successful completion of the workshop, attendees will receive credits toward one renewal or recertification of any AWS certification, hours (in place of professional development hours) toward any recertification or renewal, and recognition in *Inspection Trends*.

Those who are interested can email their current résumé to cwiitemwriter@aws.org by May 30 for consideration. As spots are limited, we cannot guarantee selection; however, there will be several opportunities to participate in the future.

Those who teach or train individuals who plan to take any of the AWS certifications are not eligible to participate.

Penn College Offers Pathways for Aspiring NDE Inspectors

Pennsylvania College of Technology (Penn College or PCT), Williamsport, Pa., offers an associate degree and competency credentials in nondestructive examination (NDE).

“When we started this program, we had numerous companies come and say, ‘We will hire everyone who graduates from this program. We’re just desperate for trained NDT inspectors,’” recalled Bradley M. Webb, dean of engineering technologies.

While the college has offered some NDE classes since the mid-1980s, Penn College began the NDE associate degree major in fall 2022. The initiative was part of a three-year, \$599,816 National Science Foundation grant devoted to advanced technology education in fields that drive the economy.

The college purchased industry-standard equipment to enhance practical experience for students in a variety of NDE processes: radiographic, ultrasonic, phased array ultrasonic, magnetic particle, liquid penetrant, and visual inspection.

“Our degree is unique in that we’re giving students hours of training. They know how to use the equipment. They know how to inspect parts and accept and reject parts,” said Michael J. Nau, a welding instructor and former Level II radiographic NDE

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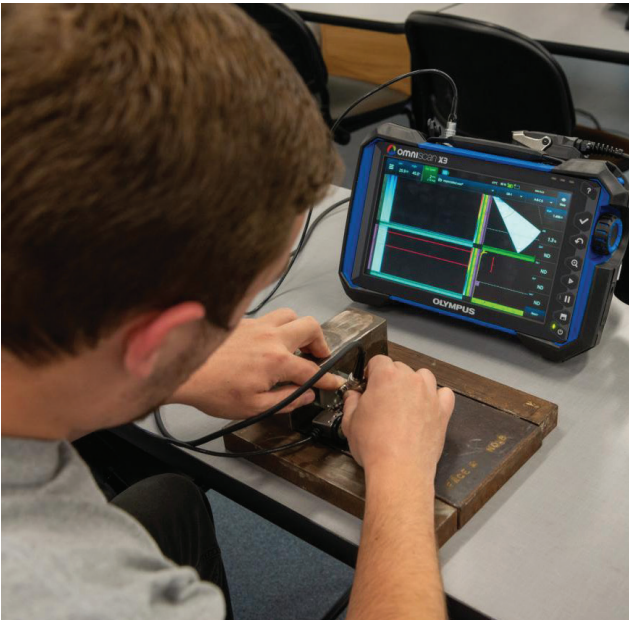
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A Pennsylvania College of Technology student engages in nondestructive examination (NDE) by using the phased array ultrasonic method. Penn College offers an associate degree and competency credentials to fill the demand for NDE inspectors.

inspector. Nau and James N. Colton II, assistant professor of welding, developed the NDE curriculum.

The NDE degree is intertwined with Penn College's welding program. NDE students learn welding basics in the college's 55,000-sq-ft lab before using their NDE skills to test the work produced by welding majors.

Graduates of the NDE associate degree earn essential classroom hours toward American Society of Nondestructive Testing certification in both radiographic and ultrasonic testing, the two most common NDE procedures. The college also offers a one-semester competency credential for either method. ASNT certification is achieved following on-the-job training.

"Depending on whether you want to work out in the field traveling for an inspection company or whether you want to work in-house somewhere, there are two different avenues you can take," Nau said.

Williamsport-based Lycoming Engines, a manufacturer of piston engines for aviation fleets, employs several in-house NDE inspectors. Over 30% of the company's workforce consists of Penn College graduates, a fact Shannon Massey, senior vice president of Lycoming Engines, credits to the company's diverse technical needs aligning with the school's commitment to applied technology education.



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“We were beyond ecstatic when PCT added the NDT associate degree. That provides an avenue not only for our workforce but across industries that are looking for this,” Massey said. “Right now, if I had an individual asking, ‘What’s a degree path that I know I’m not going to have to worry about having offers when I graduate?’ NDT is absolutely one of those degree programs that you want to look into.” – *Courtesy of Pennsylvania College of Technology*

Mark Your Calendar: ASNT Upcoming Key Events

The American Society of Nondestructive Testing (ASNT), Columbus, Ohio, organizes events to promote nondestructive examination (NDE) knowledge, collaboration, and education. Attendees can learn, network, showcase achievements, and contribute to the NDE community. Each conference also includes a trade show with exhibiting companies that offer NDE products and services.

■ **32nd ASNT Research Symposium: Beyond Boundaries, June 24–28 in Pittsburgh, Pa.** ASNT’s Research Symposium is a forum for sharing advancements in NDE. Connect with the NDE community and learn about new research through keynotes and featured speakers, preconference tutorials, the student poster competition, and numerous networking opportunities. On Monday, June 24, a day of tutorials will feature sessions that delve into fundamental topics in NDE, each with extended durations. Early bird registration, with a savings of \$200, ends on June 3. The event takes place at the David L. Lawrence Convention Center.

■ **ASNT 2024 Engage, October 21–24 in Las Vegas, Nev.** This year’s conference invites professionals from across the industry to connect. The theme “Engage” reflects the organization’s commitment to fostering meaningful interactions, sharing knowledge, and pushing the boundaries of NDE. ASNT 2024 will be hosted at Caesars Forum, Harrah’s, and The Linq. The event will feature more than 100 technical sessions, 210 exhibitors, and 2200 attendees.

Flyability Makes UT Probe Payload for Drone in Partnership with Cygnus

Flyability, a confined-space drones builder based in Paudex, Switzerland, has developed a new ultrasonic thickness measurement (UTM) payload for its flagship drone, the Elios 3. This payload was produced in partnership with Cygnus Instruments, an ultrasonic testing (UT) technology provider headquartered in Dorset, United Kingdom, to create a product that supports certified UT inspectors.

The new live A-scan UT payload is designed for spot thickness measurements of steel in ship hulls and inside tanks and between pipe racks, among many other applications. With UT critical to many inspection processes, this new payload presents a safer means of accessing thickness measurement locations (TMLs). The drone can enter confined spaces or

easily reach TML points at height, completing wall thickness gauging or corrosion surveys quickly and safely.

“Since our first projects with our oil and gas, maritime, and chemical industry customers, the ability to perform UTM in addition to visual inspections has been one of the most requested features,” Flyability CEO and Co-founder Patrick Thévoz said. “The complexity of this challenge involved four years of product development and research that was contingent on the Elios 3’s unique design. Now we can offer a reliable, safe, and effective UTM alternative for places unreachable with scaffolding, crawlers, or cherry pickers.”



The Elios 3 UT payload remotely captures A-scans at height and in hard-to-reach spaces.

The payload empowers operations under ISO 16809, *Non-destructive testing – Ultrasonic thickness measurement*, for thickness gauging.

This payload is the third unit for the modular Elios 3 and broadens the variety of industries served by Elios drones for mapping, surveying, and nondestructive examination needs.

Precision Aerospace Group Expands Portfolio with Aerofab NDT

Precision Aerospace Group (PAG), Aventura, Fla., a provider of products and value-added services to the aerospace, defense, and space industries, has acquired Aerofab NDT, a Kent, Washington-based company that engineers bespoke nondestructive examination tools to safeguard the integrity of aerospace components.

Aerofab NDT brings to PAG more than 50 years of expertise and a global customer base. It also comes with a comprehensive catalog of reference standards, eddy current probes, and ultrasonic transducers.

“This acquisition represents a significant milestone in our evolution, propelling us closer to expanding operations into fast-growing segments of the market,” said Maynard Hellman, Precision Aerospace Group chair. “Aerofab NDT’s expertise and reputation align seamlessly with our vision, and we look forward to leveraging this partnership for strong growth outcomes.” 

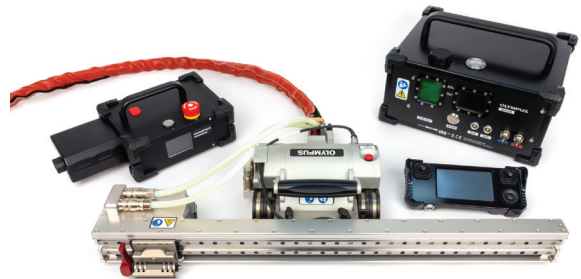


Evident Introduces Six Products for the NDE Industry

The next-generation Vanta™ handheld XRF analyzers — **Vanta Max** and **Vanta Core** — deliver improved elemental analysis and material identification using smart and cloud-connected technology. These updated portable XRF analyzers feature improved ergonomics, a refreshed interface, and enhanced connectivity for greater comfort and productivity. The Vanta Max model, replacing the M series, offers the product line's highest analytical capabilities for robust applications, including mining exploration, mineral analysis, soil testing, and environmental analysis. The Vanta Core model, replacing the C series, combines value with speed, low limits of detection, and a wide elemental range, enabling fast alloy identification. Both models are available with optional XRF accessories, including the redesigned field stand, soil foot, and holster.



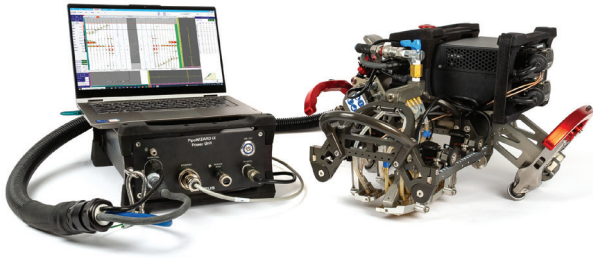
The **MapROVER™** and **SteerROVER™** scanners offer new capabilities that ease weld and corrosion inspections of hard-to-reach areas and high-temperature surfaces of pipes, large tanks, and pressure vessels. The scanners' shared handheld remote controller has improved touch-screen clarity and magnetic mounting fixtures that enable inspectors to keep their hands free. The new RECON camera kit improves the remote operation and validation capabilities of the steerable SteerROVER scanner. Inspectors can navigate the scanner more easily at a distance and keep an eye on the probe positioning and weld alignment to avoid the need to rescan. The onboard RECON Studio software on the camera kit tablet facilitates inspection analysis and reporting and offers comprehensive recording capabilities. The addition of an electronic cooling system with liquid-filled cooling plates on the MapROVER High-Temp (HT) raster arm and scanner provides fast, efficient corrosion mapping on surfaces up to 350°C (662°F).



The new **IPLEX™ TX II** videoscope enables better imaging in small spaces. It combines the versatility of a 2.2-mm (0.086-in.) flexible scope with an ultra-thin 1.8-mm (0.070-in.) rigid scope in a single package, allowing users to choose the best setup for their remote visual inspection application. The rigid insertion tube also has an air injection system that can be used to blow droplets of water or other liquids out of the way to obtain clear images. The videoscope's 120-deg field of view and high-pixel complementary metal oxide semiconductor (CMOS) sensor provide high image quality over a wide area. Bright LED illumination and image adjustments — like halation reduction — improve image quality. Captured images are displayed on a tablet, so inspectors do not have to physically bend down to look through the scope when they are working. The redesigned flexible insertion tube has a new articulation mechanism that eliminates common failure points, while metal braiding provides additional crushing and wear protection. In addition, the CMOS imaging sensor on the rigid scope tip enables the system to continue working if the tube is slightly damaged.



The **PipeWIZARD™ iX** automated ultrasonic testing (AUT) system has been upgraded to enhance pipeline weld joint assessments. The AUT system's redesign includes updated data acquisition technology that increases the efficiency and reliability of phased array (PA) inspections of circumferential pipeline welds. The new system features a lighter, easy-swivel umbilical, an optimized clamping mechanism, and a more-compact scanner with an integrated



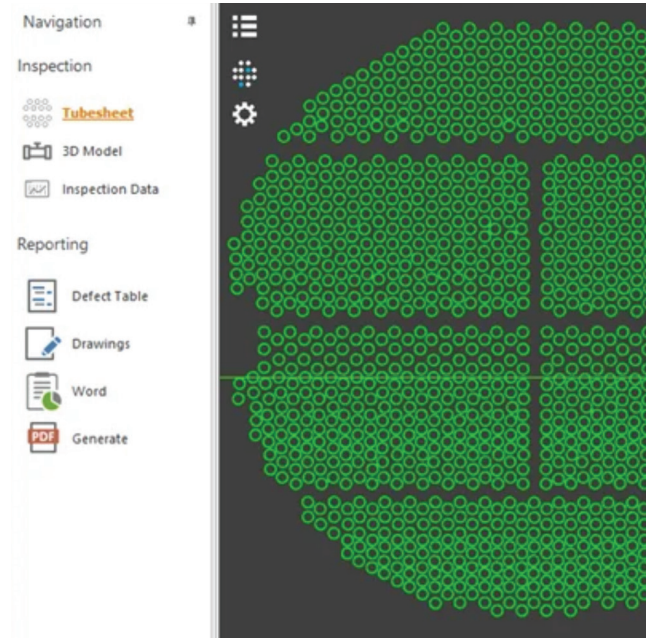
data acquisition instrument. The system offers additional umbilical length options, quick-latching connectors, and configurable probe modules, capable of holding up to 12 probes. The new QuickScan IX PA 64:256 data acquisition instrument features more powerful electronics and more input channels to support the complex firing patterns required for advanced ultrasonic techniques, such as the total focusing method (TFM).

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Reporting Software Elevates Heat Exchanger Tubing Inspections

The TubePro™ 6 advanced tubing inspection reporting software marks significant advancements compared to previous versions. The overall software speed has been improved through code optimization, making essential operations — from project loading to PDF generation — up to 40% faster. This optimization particularly benefits large tubesheet maps with over 2000 tubes, enhancing the efficiency of the entire reporting process. The addition of the new grid mode feature in tubesheet view allows users to interactively create and edit tubesheets. This feature not only speeds up the tubesheet creation process but also ensures precise tube alignment. Leveraging the newly implemented shortcuts in this version can also significantly help for quicker creation and modification of tube maps. The new version includes improved photo detection algorithms, which enable faster and more-accurate alignment of tubes to the closest pattern. The automatic tube alignment feature can further simplify the setup process and saves time for creating tube maps. Additional upgrades include improved defect table management, dynamic tube numbering display, advanced tube selection tools, enhanced 2D map and legend editor tools, and a more-intuitive interface for configuring the software's connection to Eddyfi Magnifi software. The upgraded reporting software is accompanied by an eLearning course through the Eddyfi Academy. The course covers various workflows within the software.

Eddyfi Technologies
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Internal Base Crawler Fits in Small Tubes



The TERAX internal base crawler operates inside pipes, making it ideal for internal applications. Its flexible design allows the crawler to fit into tubes as small as 8 in., ensuring accessibility in narrow and confined spaces. The crawler has robust rubber tracks that provide excellent grip on the pipe walls and allow it to propel forward quickly. This traction enables smooth movement and prevents slippage. The handheld controller offers steering joysticks and crawler control to command the crawler's movements and operations. It also provides a live video feed with the optional RECON camera system, allowing operators to monitor and assess their progress inside the pipe in real time.

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Q I need some direction on preheat. I've been tasked with a repair job on a 12-in. diameter bar fabricated from high-strength, low-alloy steel. The chemistry of the steel is the same as that of an AISI 4340 alloy steel. If the steel was a regular everyday steel used for a building or bridge, I could look it up in AWS D1.1, *Structural Welding Code – Steel*. This thing I have to weld is a creature of a different color. It contains chrome, nickel, molybdenum, and a good amount of carbon. How do I find the preheat requirements to ensure the repair doesn't crack?

A I have responded to several questions on preheat here in this column, but I don't recollect one being as specific as this one. I'll offer you the approach I use.

The chemistry of the AISI 4340 alloy steel is roughly 0.4% carbon, 0.78% manganese, 1.8% nickel, 0.8% chromium, and 0.3% molybdenum. The equations and guidelines in AWS D1.1/ D1.1M, *Structural Welding Code – Steel*, will not help you with this alloy.

The trick is to use sufficient preheat to reduce the cooling rate to prevent the austenite from decaying into martensite. With the combination of martensite, high residual stresses will push delayed cold cracking once the weld cools.

I use isothermal diagrams to tell me the temperature at which martensite starts to form. To complicate matters, time also comes into play, and isothermal diagrams give us that information.

Returning to your problem, how much preheat is needed to prevent the formation of martensite in the weld or

the heat-affected zone when welding AISI 4340? I use the isothermal diagram found in *Atlas of Time-Temperature Diagrams for Irons and Steels* from the American Society of Materials (ASM). AISI 4340 steel will form martensite rather easily if austenite is cooled below 600°F in less than a minute. In contrast, if the temperature is maintained above 600°F, austenite will decompose into ferrite and carbide. After about one hour at 600°F, all the austenite will have decomposed into ferrite and carbide. Thus, there is no retained austenite to decompose into martensite.

Considering the bar you are welding is 12 in. in diameter, it will take longer than an hour to weld. So, if you use a preheat and maintain the interpass temperature at 600°F or a little higher, you effectively prevent the decay of austenite into martensite. Without martensite, there is little danger of delayed cold cracking. Problem solved!

ASM is to the metallurgist what the AWS is to the welding engineer, inspec-

tor, and welder. AWS publishes welding standards to help us design welds, and ASM publishes references the metallurgist can use to predict how metals will respond to various heat treatments. The ASM references the *Atlas of Time-Temperature Diagrams for Iron and Steels*. It is my "Bible" when AWS structural welding codes do not list welding steels. The book includes pages of isothermal diagrams that provide hours of entertainment.

A short description of how to use an isothermal diagram is probably in order. Figure 1 depicts an isothermal diagram for a hypothetical alloy I'll call Al-alloy (so I don't get whacked with copyright infringement), which is very similar to the alloy known as unobtainium.

The isothermal diagram in Fig. 1 shows how austenite decomposes into various microstructures when the metal is cooled from the austenitizing temperature and held at a specified temperature for a long time. The left side of the diagram shows the tempera-

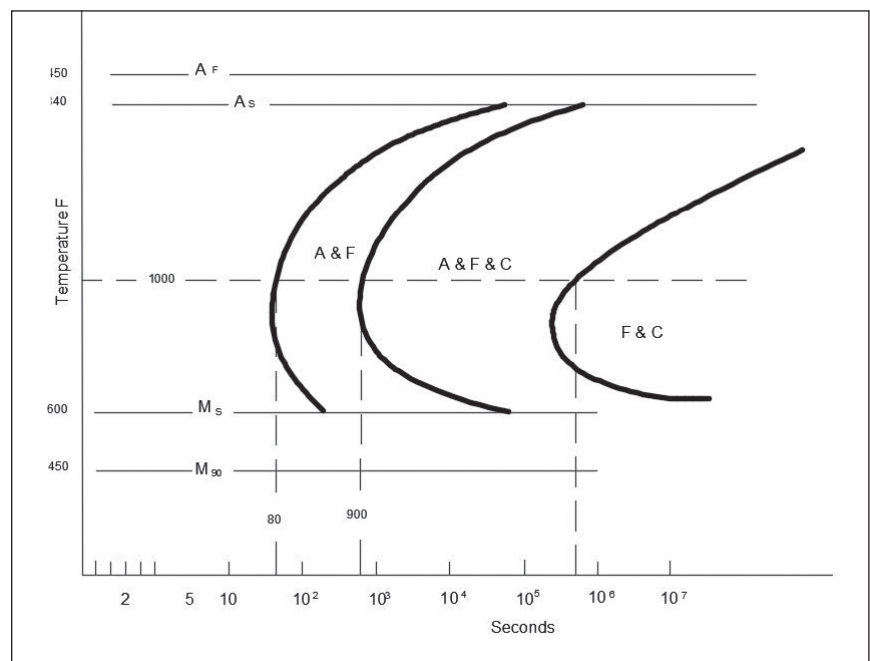


Fig. 1 — This is an isothermal diagram for Al-alloy, which is very similar to unobtainium, a fictitious base metal used to illustrate how the isothermal diagrams available from ASM can determine preheat.

ture, and the bottom axis shows time in seconds. The lower temperature of transformation for carbon steel is about 1335°F, which correlates closely with the horizontal line labeled A_s toward the top of the diagram. That is the temperature at which the steel will start to transform into austenite (face-centered cubic). However, the steel isn't completely transformed to austenite until it has reached a temperature of about 1450°F (remember, this is an imaginary alloy of steel: Al-alloy). Above 1450°F, the crystalline structure is face-centered cubic. It is austenitized. All the alloying constituents are in solution. Now, the alloy is cooled to a specified temperature and held at that temperature. This is usually accomplished by immersing a sample of the steel in a molten metal bath to maintain the temperature constant.

Using Fig. 1, draw a horizontal line at the temperature of 1000°F. Moving along the line from the left side of the graph (1000°F) toward the right, initially nothing happens. After about 80 seconds, the austenite will decay into austenite and ferrite, as indicated by the region to the right of the first curved line. Now, draw a vertical line at 900 seconds. The second vertical line intersects the second curved line, indicating the microstructure consists of retained austenite and ferrite. As you move further to the right, the retained austenite decays into ferrite and carbides (pearlite). If the horizontal line (1000°F) is followed further to the right, it will roughly intersect the third curved line, where a vertical line is drawn just shy of 10^6 seconds. The decay of austenite is complete, and just shy of 10^6 seconds has passed. The decomposition results in pearlite. One could now allow the Al-alloy to cool to room temperature without forming martensite because there is no retained austenite.

If we cool the sample quickly from the austenitizing temperature ($\approx 1450^\circ\text{F}$) down to 550°F in ten seconds, the Al-alloy will decompose into martensite. This gives you a good idea of what would

happen if you attempted to weld without preheat. The rapid cooling bypasses the left curve shown in Fig. 1 and drops into the region identified as M_s (martensite start), and austenite starts to decay into martensite. If the sample is cooled to 450°F, roughly 50% has decomposed into martensite. As the sample is cooled further, the retained austenite will decay to increase the percentage of martensite. When the sample is cooled sufficiently, about 90% of the sample will be martensite. Without cryo-quenching, the transformation to martensite is complete at 90%.

That's a lot to digest — nearly a semester's worth of metallurgy in just a few paragraphs.

Now for the fun stuff. I use the isothermal diagrams to identify the temperature at which the austenite begins to decay into martensite. That temperature is key because no martensite will form if I use a preheat temperature above the M_s temperature. It's magic! All I have to do is maintain an interpass temperature above M_s and there is no chance of forming martensite. Thus, there is little probability there will be a problem with delayed cold cracking. If the preheat is insufficient, there is the potential to form martensite. To complicate matters, at temperatures below 450°F, the nascent hydrogen can't easily escape (effuse) into the environment, and given sufficient time (I can hear it now), CRACK!

Are there other considerations? Certainly there are.

Like what? The use of a low hydrogen welding process, storing the low hydrogen shielded metal arc electrodes at a minimum of 250°F to ensure they are free of moisture, and ensuring the surfaces to be welded are clean, dry, and free of any hydrocarbons; in short, what we call low hydrogen welding practices.

Some people will say, "Al, you don't need to preheat above the M_s temperature." I won't argue the point. I'm sure they can preheat to a lower tempera-

ture and obtain crack-free welds, but as the preheat temperature is reduced, the probability of delayed cold cracking increases due to the increased potential to form Martensite. So, my response is, "Do you feel lucky?"

Most of the repair work I do is on one-of-a-kind machines. The lead time to obtain a replacement part may be one to two years. In the meantime, the machine isn't running, and the customer can lose upwards of one to two million dollars daily. My customer doesn't have the time to qualify for a welding procedure specification to prove that a lower preheat temperature will work. We have one shot at making the repair; the goal is to get the machine back into operation as soon as possible.

My approach is fairly conservative. The cost of the extra preheat is a drop in the bucket in comparison to the cost of a failed weld and the resulting lost revenue. Many of my repairs on alloy steels follow various heat treatments that might include in-process stress relief, stress relief, normalizing, and even quenching and tempering. Other than die steels, annealing isn't something I have to contend with.

I hope this gives you a rational means of determining the preheat for the low alloy and alloy steels you may encounter. **IT**

ALBERT J. MOORE JR. (*amoore999@comcast.net*) is owner of NAVSEA Solutions/Marion Testing & Inspection, Burlington, Conn. He is an AWS Senior Certified Welding Inspector and an ASNT NDT Level III. He is also retired from the AWS Qualification & Certification Committee on Methods of Inspection and the Inspection of Welds Committees.

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Weld Repair of High Energy Steam Piping

Crotch cracking in P91 tee fittings is analyzed

In recent years, the power industry has experienced several significant failures in High Energy Steam Piping (HEP) systems from cracking in girth welds and the “crotch area” of tee sections made of P91 creep strength-enhanced ferritic (CSEF) chrome-moly alloy. The concern has prompted organizations, such as the Electrical Power Research Industry (EPRI), to issue industry safety bulletins to promote close monitoring of these components. Industry experts estimate there

are thousands of tees like these currently in operation worldwide. Increased awareness and implementation of advanced inspection and nondestructive examination (NDE) programs have significantly improved safety and reduced the risk of failure and costly unplanned or forced plant outages.

As a result, energy owners, their operators, and service providers have gained tremendous knowledge in understanding the cause of failures, the most effective assess-



Fig. 1 — The through-wall thickness at the weld toes was 40 mm and below the minimum values. (Photo credit: Combustion Engineering Solutions [CES-ATC].)



Fig. 2 — A through-wall crack in the crotch position on one side and a partial crack on the opposite side of the tee, originating from the inside diameter. There were cracks at the toe of both run and branch girth welds originating from the outside diameter. (Photo credit: Combustion Engineering Solutions [CES-ATC].)

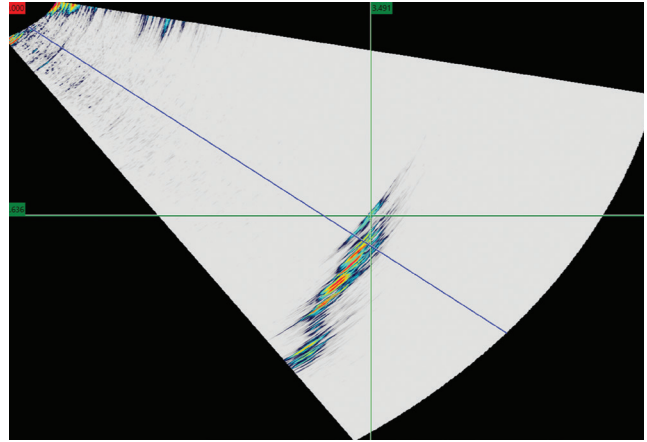
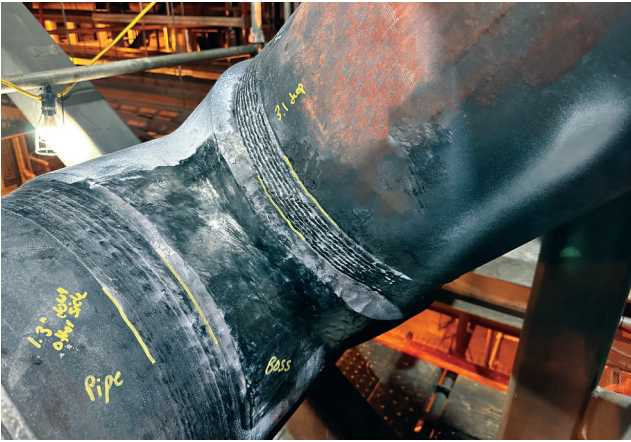


Fig. 3 — Example of an inspection performed by Applied Inspection Systems where a significant crack was detected in the tee crotch. (Photo credit: Applied Inspection Systems Inc.)

ment techniques, and corrective actions in complex P91 and P92 materials. Even though the tees are designed and fabricated as per American Society of Mechanical Engineers (ASME) B16.9, *Factory-Made Wrought Butt Welding Fittings*, failures have become all too common. The failures are generally the result of extensive creep damage from exposure to high-stress loads in this component.

Case Studies

A metallurgical analysis was completed in one failure, and the results confirmed a possible design flaw. Chemical composition was of concern but not the main culprit. Minimum wall thickness measurements were taken around the tee and compared to values in B16.9, which is 44 mm. In Fig. 1, the through-wall thickness at the weld toes was 40 mm and below the minimum values. The tee in Fig. 2 had a through-wall crack in the crotch position on one side and a partial crack on the opposite side of the tee, originating from the inside diameter (ID). There were cracks at the toe of both run and branch girth welds originating from the outside diameter (OD).

Initially, the original equipment manufacturers (OEMs) were responsible for the design and manufacturing for efficiency and reliability, as each had its own proprietary design and manufacturing processes. Unfortunately, these never made it into the ASME *Boiler and Pressure Vessel Code* rules. These issues with tees are a prime example of OEMs and suppliers' knowledge and expertise that worked well with the code even though it was not mandated. One industry expert states, "Fabrication of formed tees is a complex blacksmithing operation, and variations in geometry and thickness are expected and must be accounted for in the manufacturing operation." One OEM followed the proper steps in fabricating formed tees and other components in the HEP system. Extensive destructive testing was conducted on full-sized tees to verify and confirm stress calculations for different designs and sizes. Then, an extensive set of rules for fabrication was created

and followed during the manufacturing process, including quality control checks along the way.

Completing an in-service NDE inspection can be quite challenging due to the complex geometry, surface conditions, and environment. Having representative mockups or field-removed samples significantly increases any component's probability of detection. It is vitally important to have as much information about the component being inspected as you can, including material specs, welding processes, heat treatment information, and hardness readings. Figure 3 shows an example of an inspection performed by Applied Inspection Systems where a significant crack was detected in the tee crotch.

Repair Alternatives

There are presently three suitable repair alternatives that most have adopted. Each owner must determine which might be the best route for their individual situation.

One method would be to locate the crack using various NDE methods and then excavate down to remove as much of the crack as possible without breaking into the ID. If the ID is breached, a purge would have to be completed, thus complicating the repair process and scheduling delays.

For method 2, the idea is to weld an overlay pad over the crotch areas. This will increase the through-wall thickness and reduce stress, but the crotch cracking remains. This method is only meant to buy time to order replacement tees, as the lead time for new replacements is quite long. Selecting the correct weld filler rod is vitally important. In any case, the fact that we're dealing with CSEF steel implies the field weld repair process becomes more challenging and sophisticated to ensure the material properties are maintained for the service they will be subjected to. Engagement of knowledgeable material partners, planners, project managers, welders, and heat treaters is the key to maintaining high levels of quality, longevity, and safety. Given the complexity of the geometry, things as simple as maintaining the correct preheat and postweld heat treatment (PWHT) temperatures throughout are



Fig. 4 — This crack was found using phased array ultrasonic testing (PAUT). Once plotted, a repair plan was developed and the welders excavated the crack to just before breaking the system open. Preheat was applied and the weld repair began until flush with the contour of the tee. (Photo credit: Combustion Engineering Solutions [CES-ATC].)

crucial to achieving the proper microstructure. As Gary Lewis of Lewis Reliability Resources has suggested in previous *Welding Journal* articles, heat treatment is an essential variable in this type of weld repair, and “choosing the appropriate heating device, control methodology, and execution plan are critical for material processing and optimize assets, logistics, and production to control project costs, and shorten schedules.” (See the article Heat Treatment: An Essential Variable in Energy Plant Reliability in the March 2019 *Welding Journal*.)

Finally, a third, relatively new, alternative weld method is prescribed in ASME and AWS codes and standards that has been implemented successfully. This method was created to preclude the need for PWHT, where conventional solutions were impractical due to structural constraints, resource availability, or other factors driving the decision process. In 2015, EPRI and their utility members, along with technical experts from materials labs and leadership from the construction code groups at the National Board Inspection Code and ASME, began the process of developing this technique. The method has been recognized inside the industry as a welcomed approach to weld repair and new procedures identified as Weld Method 6 and Supplement 8. Figure 4 shows the process of tee crotch repairs from the initial detection to the final weld repair.

In Closing

One valuable lesson learned to ensure a successful repair is that once welding is complete and the weld repaired tee is back to normal room temperature, a pre-PWHT volumetric inspection must be completed to ensure weld cleanliness. Once this is achieved, complete the PWHT as per procedures and process, and then conduct the final PAUT inspection. An effective condition assessment program should include wall thickness measurements, chemical analysis, and hardness testing, along with a couple of NDE methods, including magnetic particle testing and PAUT. **IT**

JEREMY RING (jeremy.ring@appliedinspection.com) is director of business development, ASNT NDT Level II (MT, PT, UT, and VT) at Applied Inspection Systems, Advanced Technology Center, Huntersville, N.C.

TERRY HAIGLER (terry.haigler@appliedinspection.com) is director of business development, ASNT NDT Level III (MT, PT, UT, and VT) at Applied Inspection Systems, Advanced Technology Center, Huntersville, N.C.



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Understanding Weld Cracking

A discussion of causes and remedies is presented

Cracks are fracture-type discontinuities. They can be readily identified by their sharp tips and their high ratio of length and width to the displacement of the opening. Because of their tendency to propagate under stress, cracks are considered the most severe form of discontinuity. Cracks are generally the primary cause of catastrophic failure in structures and components. Welders, welding engineers, and designers must, therefore, strive to avoid this type of discontinuity.

Cracks occur in weld metals and base metals when localized stresses exceed the ultimate strength of the metal. Cracking is often associated with stress amplification near discontinuities in welds and base metals or near mechanical notches associated with the weldment design. Hydrogen embrittlement may contribute to cold crack formation in steel. Plastic deformation at the crack edges is very limited.

Cracks can be classified as either hot or cold types. Hot cracks develop at elevated temperatures. They

commonly form during the solidification of the weld metal. Cold cracks develop after the solidification of a fusion weld as a result of residual stresses. Cold cracks in steel are sometimes referred to as *delayed cracks*. They are often associated with hydrogen embrittlement. Hot cracks propagate between the grains (grain boundary or intergranular), while cold cracks propagate both between the grains and through the grains (transgranular).

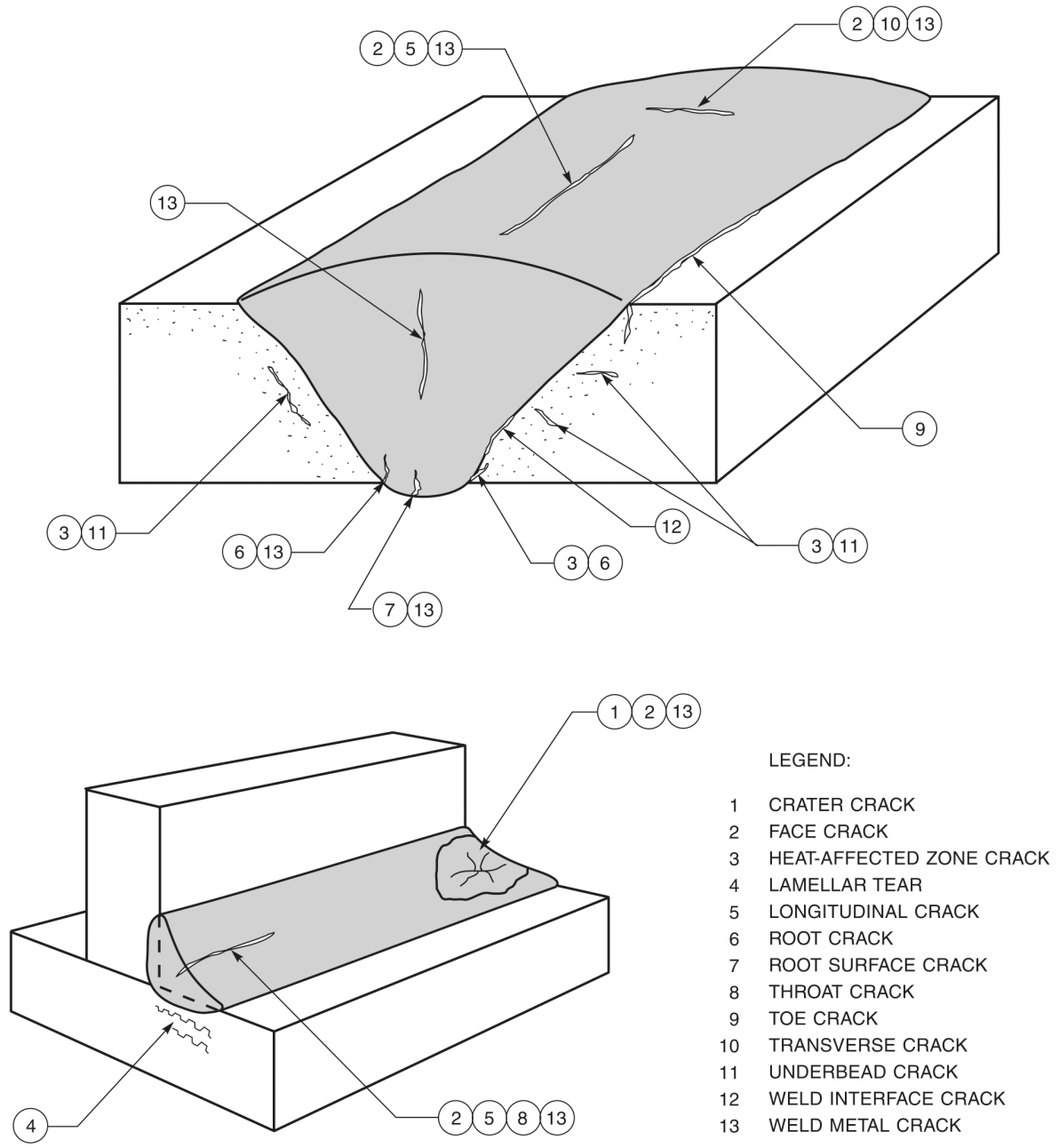
Cracks may be longitudinal or transverse with respect to the weld axis. Longitudinal cracks in the weld metal and the HAZ occur parallel to the axis of the weld. Transverse cracks are found perpendicular to the weld axis.

Cracking in any form is an unacceptable discontinuity, as it is detrimental to performance. Because cracks, by nature, are sharp at their tips or ends, they act as stress concentrators. The stress-concentration effect generated by cracks is greater than that produced by most other discontinuities. Therefore, regardless of their size, cracks are not normally permitted in weldments governed by

Excerpted from the Welding Handbook, Tenth Edition, Volume 1, Welding Science and Technology, Chapter 12 — Weld Quality. Published with edits.

most fabrication codes. They must be removed regardless of their location, and the excavation must be filled with sound weld metal if the excavation depth exceeds the minimum design thickness for the weldment.

Figure 1 illustrates the common types of cracks and presents the crack terminology established by the American Welding Society (AWS). These crack types are described below. A discussion of causes and remedies is presented following these descriptions.



Source: Adapted from American Welding Society (AWS) Committee on Definitions, *Standard Welding Terms and Definitions, Including Terms for Adhesive Bonding, Brazing, Soldering, Thermal Cutting, and Thermal Spraying*, AWS A3.0M/A3.0, Miami: American Welding Society.

Fig. 1 – Crack Types

Crack Types

Crater Crack

Crater cracks are usually shallow hot cracks formed by improper termination of a welding arc. Whenever the welding operation is interrupted incorrectly, these cracks may form in the crater. These cracks are often star-shaped and progress only to the edge of the crater. They are sometimes referred to colloquially as *star cracks*. This discontinuity is found most frequently in metals with high coefficients of thermal expansion, such as austenitic stainless steel. Crater cracks may be the starting point for longitudinal weld cracks, particularly when they occur in a crater formed at the end of a single-pass weld. A crater crack is shown in Figure 2.

The occurrence of crater cracks can be minimized or prevented by filling craters to a slightly convex shape prior to breaking the welding arc. The use of a welding current delay device when terminating a weld bead can also be effective, especially in mechanized or automated welding operations.

Face Crack

The term face crack refers to weld metal cracking. A face crack is a longitudinal crack on the exterior surface of the weld. This discontinuity may result from excessive concavity, insufficient reinforcement, or excessive welding speed. It may also be caused by shrinkage due to rapid cooling. Face cracks can be prevented by strictly adhering to the welding procedure. When they do occur, they should be ground out and rewelded.

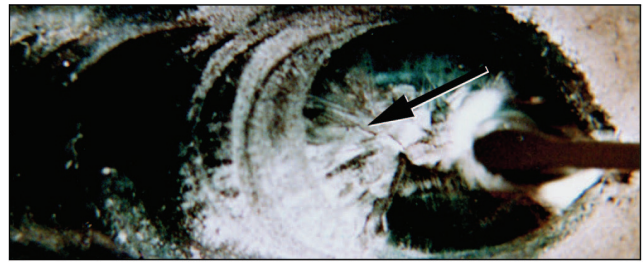
HAZ or Underbead Crack

HAZ or underbead cracks are generally cold cracks that form in the HAZ of steel weldments. They are usually short and discontinuous but can extend to form a continuous crack. Underbead cracking usually occurs when three elements are present: 1) hydrogen in solid solution; 2) a microstructure of low ductility, such as martensite; and 3) high residual or applied stress.

These cracks are found at regular intervals under the weld metal in the HAZ of the base metal. They rarely extend to the surface and generally follow the contour of the weld bead. The cracks may be either longitudinal or transverse, depending on the microstructure and the orientation of the residual stress. They cannot be detected by visual inspection and may be difficult to detect by ultrasonic and radiographic examinations.

Longitudinal Crack

Longitudinal cracks are almost always found within the weld metal and are usually confined to the center of the weld. The axis of the crack is parallel to the length of the weld, as shown in Figure 3. They may occur in



Source: American Welding Society (AWS) Committee on Methods of Inspection, *Guide for the Visual Examination of Welds*, AWS B1.11M/B1.11, Miami: American Welding Society.

Fig. 2 — Crater Crack



Source: American Welding Society (AWS) Committee on Methods of Inspection, *Guide for the Visual Examination of Welds*, AWS B1.11M/B1.11, Miami: American Welding Society.

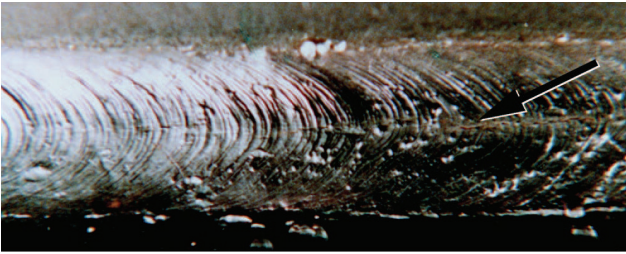
Fig. 3 — Longitudinal Crack

the middle of the weld or at the end of the weld (typical in fillet welds). In the latter case, the cracks may be an extension of another crack that initiated in the root bead and continued to propagate through the entire thickness of the weld.

One cause of longitudinal cracking is a high degree of restraint in the joint, which can initiate a crack around a discontinuity such as porosity or trapped slag in the weld. Another typical cause of longitudinal cracking is shrinkage stress in heavy sections or in joints between heavy and thin joint members. This may occur in high-speed welding such as is common in submerged arc welding, gas metal arc welding, and flux cored arc welding and in welds fabricated with automated equipment. Longitudinal cracks in small welds between heavy sections are often the result of rapid cooling rates and high restraint.

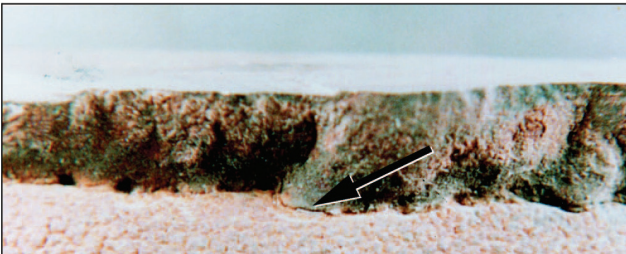
Root Crack

Root cracks run longitudinally along the weld root or in the weld surface. They can be either hot or cold cracks. These discontinuities may be either procedure-related or metallurgical in nature due to the characteristics of the material being welded. They can result from incomplete penetration or pretreatment, excessive travel speed, or too large a gap (spacing). Root cracks can also occur because of surface contamination or the incorrect use of a consumable insert. The specified welding procedure should be carefully followed to prevent their occurrence.



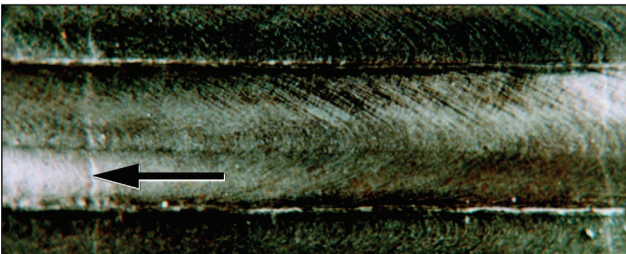
Source: American Welding Society (AWS) Committee on Methods of Inspection, *Guide for the Visual Examination of Welds*, AWS B1.11M/B1.11, Miami: American Welding Society.

Fig. 4 – Throat Crack



Source: American Welding Society (AWS) Committee on Methods of Inspection, *Guide for the Visual Examination of Welds*, AWS B1.11M/B1.11, Miami: American Welding Society.

Fig. 5 – Toe Crack



Source: American Welding Society (AWS) Committee on Methods of Inspection, *Guide for the Visual Examination of Welds*, AWS B1.11M/B1.11, Miami: American Welding Society.

Fig. 6 – Transverse Crack

Root Surface Crack

Root surface cracks are fracture-type discontinuities that are located on the exposed surface of the weld opposite the side from which welding was performed. These discontinuities can be procedure-related or metallurgical in nature. They can be prevented primarily by adhering strictly to the welding procedure.

Throat Crack

Throat cracks are cracks that run longitudinally in the face of the weld and extend toward the root of the weld. They are generally, but not always, hot cracks. A typical throat crack is presented in Figure 4. As throat cracks are a

form of longitudinal cracking, the reader is encouraged to refer to the section titled “Longitudinal Crack” (presented above).

Toe Crack

Toe cracks are generally cold cracks that initiate approximately parallel to the base material surface and then propagate from the toe of the weld, where residual stresses are higher. These cracks are generally the result of thermal shrinkage strains acting on a weld HAZ that has been embrittled. Toe cracks sometimes occur when the base metal cannot accommodate the shrinkage strains that are imposed by welding. A typical toe crack is shown in Figure 5. Toe cracks also initiate in fillet weld joints subjected to fatigue loading, such as occurs in small-diameter piping socket joints. Fatigue loading on these welds may cause toe cracks that propagate through the pipe from the weld toe, where the stresses are concentrated. Likewise, toe cracks in fillet weld joints may occur due to welding through coatings, such as hot-dip galvanized surfaces, or highly restrained weldments.

Transverse Crack

A discontinuity of the weld metal, transverse cracks run nearly perpendicular to the axis of the weld. They may be limited in size and completely within the weld metal, or they may propagate from the weld metal into the adjacent HAZ and the base metal. Transverse cracks are generally the result of longitudinal shrinkage strains acting on weld metal of low ductility. Transverse cracks in steel weld metals are typically related to hydrogen embrittlement. This type of crack, pictured in Figure 6, is common in joints that have a high degree of restraint.

Weld Metal Crack

The generic term weld metal crack is used to refer to cracks that occur in the weld metal.

Causes of Cracking and Remedies

Cracking in welded joints results from localized stresses that exceed the ultimate strength of the metal. When cracks occur during or as a result of welding, they do not normally exhibit evidence of deformation. Weld metal or base metal that has considerable ductility under uniaxial stress may fail without appreciable deformation when subjected to biaxial or triaxial stresses. Shrinkage occurs in all welds, and if a joint or any portion of it (such as the HAZ) cannot accommodate the shrinkage stresses by plastic deformation, then high stresses develop. These stresses can and do cause cracking.

An unfused area at the root of a weld may result in cracks without appreciable deformation if this area is subjected to tensile or bending stresses. When welding

two plates together, the root of the weld is subjected to tensile stress as successive layers are deposited. Incomplete fusion in the root promotes cracking. The chemical compositions of the base metal and the weld metal affect crack susceptibility. After a welded joint has cooled, cracking is more likely to occur if the weld metal or HAZ is either hard or brittle. A ductile metal, by localized yielding, may withstand stress concentrations that might cause a hard or brittle metal to fail. Cracking in the weld metal, the HAZ, and the base metal are discussed in further detail below.

Weld Metal Cracking

Transverse and longitudinal cracks as well as crater cracks occur in the weld metal in welds produced by fusion welding. The ability of the weld metal to remain intact under a stress system imposed during a welding operation is a function of the composition and structure of the weld metal. In multiple-layer welds, cracking is most likely to occur in the first layer (root bead) of the weld metal. Unless such cracks are repaired, they may propagate through subsequent layers as the weld is completed. Resistance to cracking in the weld metal can be improved with the implementation of one or more of the following procedures:

1. Modifying electrode manipulation or electrical conditions to improve the weld face contour or the composition of the weld metal;

2. Selecting an alternate filler metal to develop a more-ductile weld metal;
3. Increasing the thickness of each weld pass by decreasing the welding speed and providing more weld metal to resist the stresses;
4. Decreasing depth-to-width ratio of the weld bead;
5. Using preheat to reduce thermal stresses;
6. Using a low-hydrogen welding procedure;
7. Sequencing welds to balance shrinkage stresses; and
8. Avoiding rapid cooling conditions.

HAZ Cracking

Cracks in the HAZ may be longitudinal or transverse in nature. They are typically associated with hardenable base metals. High hardness and low ductility in the HAZ result from the metallurgical response to the weld thermal cycles. These two conditions are among the principal factors that contribute to crack susceptibility. In ferritic steels, as the carbon content and cooling rates increase, the maximum attainable hardness increases while the ductility decreases. The rate of cooling depends upon a number of physical factors, including the following:

1. Peak temperature produced in the HAZ;
2. Initial temperature of the base metal (preheat);
3. Thickness and thermal conductivity of the base metal;
4. Heat input per unit time at a given section of the weld; and
5. Ambient temperature.

Causes	Remedies
Weld-Metal Cracking	
Highly rigid joint	Preheat; relieve residual stresses mechanically; minimize shrinkage stresses using backstep or block welding sequence
Excessive dilution	Change welding current and travel speed; weld with covered electrode negative; butter the joint faces prior to welding
Defective electrodes	Change to new electrode; bake electrodes to remove moisture
Poor fitup	Reduce root opening; build up the edges with weld metal
Small weld bead	Increase electrode size; raise welding current; reduce travel speed
High-sulfur base metal	Use filler metal low in sulfur
Angular distortion	Change to balanced welding on both sides of joint
Crater cracking	Fill the crater before extinguishing the arc; use a welding current decay device when terminating the weld bead
Heat-Affected-Zone (HAZ) and Base Metal Cracking	
Hydrogen in welding atmosphere	Use a low-hydrogen welding process; preheat and hold for 2 hours after welding or postweld heat treat immediately
Hot cracking	Use low heat input; deposit thin layers; change base metal
Underbead cracking	Preheat; reduce cooling rate and stress
Low ductility	Use preheat; anneal the base metal
High residual stresses	Redesign the weldment; change welding sequence; apply intermediate stress-relief heat treatment
High hardenability	Preheat; increase heat input; heat treat without cooling to room temperature

Fig. 7 – Cracking – Common Causes and Remedies

The hardness of the HAZ is related to the hardenability of the base metal, which is dependent, in turn, on the chemical composition of the base metal. Carbon has the strongest effect on the hardenability of steel. In addition, it increases the hardness of the transformation products. Nickel, manganese, chromium, and molybdenum also contribute to the hardenability of steel. However, unlike carbon, these elements only moderately increase the hardness of the base metal.


High-alloy steels include the austenitic, ferritic, and martensitic stainless steels. Although the martensitic stainless steels behave similarly to medium-carbon and low-alloy steels, they are more susceptible to cracking. Austenitic and ferritic stainless steels do not undergo a phase transformation that hardens the HAZ. The ductility of the HAZ in ferritic stainless steels may be adversely affected by welding.

The metallurgical characteristics of the base metal affect the crack susceptibility of the HAZ. Small changes in the chemical composition of the base metal and the filler metal (hydrogen content) as well as added joint restraint can appreciably increase cracking. Significant differences are encountered in crack susceptibility among several heats of the same grade of low-alloy steel.

the base metal is caused by soluble hydrogen. Known by a variety of terms, including *underbead cracking*, *cold cracking*, and *delayed cracking*, hydrogen-induced cracking typically occurs at temperatures below 200°F (93°C) immediately upon cooling or after a period of several hours. The time delay depends on the type of steel, the magnitude of the welding stresses, and the hydrogen content of the weld and HAZs. In any case, it is caused by diffusible hydrogen trapped in the weld metal or the HAZ. The weld metal may crack, but this seldom occurs when the yield strength is below 90 kips per square inch (ksi) (620 megapascal [MPa]).

The diffusion of hydrogen into the HAZ from the weld metal during welding contributes to cracking in the base metal. The microstructures of the weld metal, the HAZ, and the base metal are also contributing factors.

Hydrogen-induced cracking can be prevented by using a low-hydrogen welding process. A combination of welding and thermal treatments that promotes the escape of hydrogen by diffusion may also produce a microstructure that is more resistant to hydrogen-induced cracking. Another preventive measure involves the use of welding procedures that result in low-welding stresses.

The causes and remedies of cracking in the weld metal, the base metal, and the HAZ are summarized in Figure 7. 

Base Metal Cracking

When welding many varieties of steels, the primary problem encountered with respect to the cracking of



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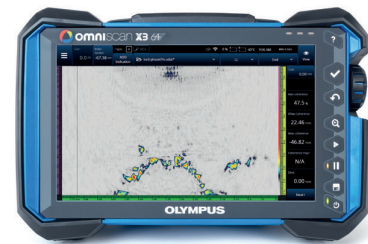
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Welding student Trevor Rothfuss (left) performs a calibration test using the phased testing process on an IIW type 2 calibration block while fellow welding student Brandon Dempsy reviews images on the GE CT machine.



INSPECTION + TESTING

AT WASHTENAW
COMMUNITY COLLEGE

Nondestructive examination has shown to be an important part of the college's welding and fabrication programs

Established in 1966 and located in one of the most educated cities in the country, Washtenaw Community College (WCC) in Ann Arbor is considered to be the number one community college in Michigan. It boasts some of the largest advanced programs that prepare students for high-demand, high-wage jobs in advanced manufacturing, welding, automotive technologies, and other STEM-related professions.

Welding and Fabrication Programs

The college's welding and fabrication department features highly sought-after programs, including Welding and Fabrication Advanced Applications, Welding Technology, Welding and Fabrication Principles, and more.

Welding and Fabrication Advanced Applications is a high-demand and high-skill advanced certificate program that combines welding fundamentals with more-complex welding, cutting, and fabrication techniques and applications aimed to further develop students' skills and core competencies. In this program, students weld using processes and positions common in the industry, perform destructive and nondestructive examinations (NDEs), identify weld failures and perform root cause analysis, execute repair techniques, perform advanced fabrication techniques, and execute automated welding and cutting programming and operations.

Welding Technology offers specialized welding and fabrication instruction through theoretical, practical, and technical learning objectives and strategies. The core curriculum specializes in welding and fabrication and delves into the expanses of welding technology as a whole. Students are first introduced to welding, cutting, and fabrication safety and theory and fundamentals. Then they transition to more-advanced welding and fabrication processes and applications, such as weld quality, inspection testing and repair techniques, and automated welding and cutting systems and operations.

The Welding and Fabrication Principles certificate program introduces students to safe welding and cutting practices and principles, including proper technique and position, weld quality requirements, destructive and NDE methods, print reading and interpretation of welding symbols, and basic metal fabrication. This certificate serves as a fundamental pathway into the Welding and Fabrication Advanced Applications certificate and Welding Technology degree.

Inspection and Testing

NDE has shown to be a vital component of safety protocols and quality assurance in a wide variety of industries. More welding programs are opening classes that are solely dedicated to welding inspection and quality testing, ensuring that NDE is an essential part of the curriculum.

At WCC's Welding and Fabrication Advanced Applications program, students are required to complete an inspection and testing course that highlights destructive and NDE methods. In this course, students are introduced to the most-common types of weld inspection and testing methods.

"Students start the course by learning about structural code AWS D1.1 [*Structural Welding Code — Steel*]. Specifically, VT [visual inspection] requirements for both qualification and inspection," said WCC Instructor Alex Pazkowski, welding and fabrication department. "After that, we introduce destructive methods, such as macro etch, bend testing, and fillet weld breaks. As the semester progresses, we introduce NDE methods."

The nondestructive methods focus on dye penetrant testing, magnetic particle testing, radiographic testing, and both mono-element angle beam and phased array ultrasonic testing (PAUT). The course also teaches students about different weld discontinuities and defects.

"Students learn how to look at the welds they perform by using all of the inspection methods. We intentionally design the welds so the students will fail. This gives the students an understanding of what causes failures and how to correct them," said Pazkowski. "We show the students how to perform a failure analysis on their welds by using different modalities of inspection."

Welding code acceptance criteria are also interpreted and applied to testing methods.

"The students also learn about code and how it relates to what they will see in industry. It's important to note that we aren't training inspectors; we're training welders. Giving welders the ability to analyze their welds makes them better at troubleshooting problems once they enter the industry," said Pazkowski.

Inspection and Testing Equipment

Pazkowski relies on indispensable NDE equipment to prepare students for real-world, hands-on training. Within the lab, there is a room solely dedicated to the inspection class.



For the NDE equipment, students use the General Electric phoenix v|tome|x m 240 computerized tomography machine.

“This allows us to take quick digital pictures of the students’ welds,” said Pazkowski.

For PAUT, students use the Olympus OmniScan MX2 phased array flaw detector.

“They are incredible machines. Despite the fact that UT [ultrasonic testing] is complicated, Olympus has designed an interface that is extremely user-friendly. With minimal guidance, I’m able to teach the students enough to analyze their own welds without hours of lecture on the theoretical aspect of the process,” said Pazkowski.

Professionals Leading Students

The welding faculty delivers comprehensive preparation and experiences for students to tackle just about anything the industry might demand. That is why Pazkowski joined the program in 2010.

“I came to the college with the intent to compete in the SkillsUSA competitions. In 2013, I was able to represent the USA at the WorldSkills Competition, where I placed second. I mention that because my involvement in the competition is what afforded me the outlet to develop the mechanical skills needed to teach people how to weld,” said Pazkowski.

From 2020 to 2023, he served as cochair of the department.


To help students become the well-rounded graduates that employers seek, Pazkowski teams up with fellow full-time instructors Bradley Clink, Ashley Jones, Glenn Kay II,

and Amanda Scheffler as well as full-time lab technicians Nathan Oliver, Joe Ortiz, and Jessica King, all of whom are WCC welding and fabrication alumni. All the instructors have a variety of experiences contributing to the program’s depth.

“We all care about the program because we’re all products of its success. We all work to make it better, and the role of the chair is just one of the many jobs we all do to keep the program healthy. It’s a privilege to call this program home. I’m just happy to help,” he said.

Conclusion

The importance of NDE cannot be overstated, as it contributes to safety and quality control. As welding programs and schools grow, courses dedicated to weld inspection and testing are seen as a necessity.

“Inspection isn’t something welders normally learn. Obviously, welding instructors are there to teach people how to weld. What comes with that education is a basic understanding of cause and effect. For example, if I turn the gas off, the result will be cluster porosity,” said Pazkowski. “At a very basic level, the average welding students understand that there are discontinuities and defects that are considered acceptable or unacceptable. Introducing students to welding code and allowing students to test their own welds gives depth to their education. It teaches them the rules of the game and makes them better employees after they leave.” 

ROLINE PASCAL (rpascal@aws.org) is associate editor of *Inspection Trends*.

NDE SCHOOL PROFILES

Attention Schools in Training and Testing for Materials Evaluation, Weld Inspection, and Quality Assurance:

Included in this section are welding schools across the country that have taken this advertising opportunity to promote their resources, both to industry in need of welders and to those searching for a solid career path to employment and growth. Reach more than 64,000 readers, many of whose livelihoods depend on quality assurance, materials testing, or weld inspection, with your school profile.

The **National Center for Welding Education and Training** (dba Weld-Ed) is a partnership of community colleges, universities, business and industry, and the American Welding Society. It is funded by the National Science Foundation. The Center's primary mission is to increase the quantity and quality of welding and materials joining technicians to meet industry demand through curriculum reform and educator professional development. Additional information is available at weld-ed.org. Participating schools display the Weld-Ed logo below next to their names.



All-State Career School Essington, PA

Are you interested in gaining the skills needed to enter the rewarding field of welding? If so, choose All-State Career School in Essington, Pa. Our welding instructors take pride in providing our students with essential education and training to create a well-rounded welding professional — one who is skillful with today's welding processes. The welding curriculum at All-State Career School is structured to provide focus on the design, production, performance, and maintenance of welding materials. Learn how you can enroll at All-State today and train to be able to earn your certificate in welding.

Essington Trades Campus
50 W. Powhattan Ave.
Essington, PA 19029
(610) 521-1818
allstatecareer.edu

All-State Career School Pittsburgh, PA

Did you know that welders are capable of gaining employment in a variety of industries, including car racing and manufacturing? At All-State Career School's welding program you will be provided with a foundation in industrial welding techniques, crafting skills, and welding mathematics to prepare you for a rewarding welding career. Fulfill your dream of becoming specialized in welding, cutting, soldering, or brazing with training from All-State Career School.

Pittsburgh Trades Campus
1200 Lebanon Rd., Suite 101
West Mifflin, PA 15122
(412) 823-1818
allstatecareer.edu

Amarillo College

Amarillo College (AC) is putting students on the fast track to good-paying careers in welding. AC's six-month welding option starts with courses in machine shop math, technical communication, shop practices, and blueprint reading — all of which lead to an advanced certificate in welding. AC also offers an advanced certificate spread over a longer period of time, but either way it's a credential that qualifies professional welders for employment in a great variety of industries.

Amarillo College
Ernie Sheets, Instructor
edsheets22@actx.edu
(806) 335-4221
actx.edu



Asheville-Buncombe Technical Community College

A-B Tech offers a welding associate's degree and diploma as well as a certificate in basic welding. The Welding Technology curriculum provides students with a sound understanding of the science, technology, and applications essential for successful employment in the welding and metal industry. Instruction includes consumable and nonconsumable electrode welding and cutting processes. Successful graduates of the Welding Technology curriculum may be employed as entry-level technicians in welding and metalworking industries. Career opportunities also exist in construction, manufacturing, fabrication, sales, quality control, supervision, and welding-related self-employment. For more information, visit abtech.edu/welding.

340 Victoria Rd.
Asheville, NC 28801 / (828) 398-7684
Michael Keller, Welding Tech. Chair
georgemkeller@abtech.edu
abtech.edu



Cal-Trade Welding School of Modesto

Cal-Trade Welding School of Modesto has been operating since 1975. Using the industry employers as a guide, we teach SMAW, GMAW, GTAW, FCAW, and pipeline welding. Welding technique training is primary and students are given one-on-one instruction. In the 18-week Combination Welding course, students have the opportunity to earn multiple certifications. Welding theory, mathematics for welders, and blue print reading are also offered. Lifetime job placement assistance is available to students after graduation.

424 Kansas Ave.
Modesto, CA 95351
(209) 523-0753
Fax: (209) 523-8826
caltradeweldingschool.com



Columbus State Community College

Columbus State Community College, located in Columbus, Ohio, offers individuals an opportunity to learn welding and complete a Welding Associate degree or an Intermediate Welder certificate. The certificate provides the necessary credentials for entering the workforce as an intermediate-level welder. Our Skilled Trades program proudly participates as a Level II SENSE school, teaching SMAW, GMAW, FCAW, GTAW, PAC, and oxyfuel processes. Certificate studies can be completed in one year. Financial aid and veteran's benefits are available.

Scott Laslo, Program Coordinator
(614) 287-2653
slaslo1@csc.edu
550 E. Spring St.
Columbus, OH 43215
csc.edu



Austin Community College

The Welding Technology program at Austin Community College offers varied certificates and AAS degrees to prepare students for a range of welding and inspection careers. Areas of specialty include welding inspection, ultrasonic testing, structural welding, and multiple process welding, as well as orbital tube welding, metallurgy, and pipe welding. Our Architectural and Ornamental Metals program includes fabrication, blacksmithing, power hammer, and metal sculpture. Classes totaling over 600 seats are offered at two campuses.

1020 Grove Boulevard
Austin, TX 78741
4400 College Park Dr.
Round Rock, TX 78665
(512) 223-6220
austincc.edu/welding



Central Wyoming College

Industry driven, affordable, hands-on! Central Wyoming College (CWC), located in the beautiful Wind River Valley, is an AWS Educational Institution with curriculum that aligns with AWS's SENSE program. CWC is also an Accredited Test Facility with the AWS. Students are trained to weld according to AWS prequalified welding procedures as well as the American Petroleum Institute's 1104 Pipeline Code. There is a large emphasis on blueprint reading, welding symbols, metallurgy, and weld inspection. Training includes Shielded Metal Arc Welding, Gas Tungsten Arc Welding, Gas Metal Arc Welding, Flux Core Arc Welding, and Oxyacetylene Welding. Students have a choice of earning a credential, a certificate, or an associate of applied science degree. Our welding lab has the most up-to-date welding equipment and a state-of-the-art air moving system.

Darryl Steeds, CWI
dsteeds@cw.edu | (307) 855-2138
Admissions (800) 855-0193
cw.edu



Cuesta College Welding Technology

Cuesta College is highly regarded for its excellent education programs and exceptional faculty and staff. The Welding Technology program offers a well-rounded curriculum that has a strong history of teaching diverse populations ranging from beginners to students preparing to work in industry. Candidates are provided the opportunity to obtain a Certificate of Achievement, two Certificates of Specialization, and an associate degree in Welding Technology as they reach the ultimate goal of becoming a certified welder. Our three CWI instructors qualify our students in structural steel and pipe welding to AWS D1.1, ASME Section IX, and API 1104 standards. Additionally, six part-time instructors add their vast industry experience teaching additional elective courses that set our students apart upon graduation.

Mike Fontes - mfontes@cuesta.edu
San Luis Obispo, CA 93403
(805) 592-9547
cuesta.edu



Fortis College Birmingham, AL

Small class sizes, experienced instructors, and lots of opportunities to develop your hands-on skills are only part of what makes Fortis special. Our comprehensive welding program is designed to prepare you with the knowledge and real-world skills you need to pursue entry-level employment as a welder. Call today to learn how to get started training for a career in welding at Fortis.

100 London Pkwy., Ste. 150
Birmingham, AL 35211
(205) 940-7800
fortis.edu



Fortis College Cincinnati, OH

Enjoy using your hands and finding practical solutions to complex problems? If so, a career in welding could be for you! The first step is to gain the essential training to be successful in the field. At Fortis, we have the training, guidance, and resources to help you succeed. Our Welding Technology program offers instruction in fundamental math applications, introduction to oxyfuel cutting, and experience in various welding processes to make you skillful in this skilled trade with a future. Give Fortis a call today to learn more and to schedule a campus visit.

11499 Chester Rd., Ste. 200
Cincinnati, OH 45246
(513) 771-2795
fortis.edu



Fortis College Houston South, TX

Train to become a welding technician at Fortis College — Houston South. The ideal blend of art and science, welding is integral to many industries, including construction, manufacturing, and aerospace. At Fortis College, you will learn from experienced professionals as they guide you through a comprehensive curriculum. Our small class sizes and skilled faculty are committed to helping you gain the knowledge and hands-on skills you need to achieve your goals.

1201 West Oaks Mall
Houston, TX 77082
(713) 266-6594
fortis.edu



Fortis College Smyrna, GA

Kick-start your welding career with a Fortis College education. In our Welding Technology program, you can get the training and hands-on expertise needed to enter the growing welding industry in various careers, including industrial welders, check welders, welding apprentices, and more. Our courses offer instruction on the intricacies of welding and all its phases, including the use of destructive and nondestructive testing, to ensure our students have a thorough understanding of quality welding. Contact us today to learn more about our program and schedule a campus visit.

2140 South Cobb Dr.
Smyrna, GA 30080
(770) 980-0002
fortis.edu



Fortis College Cuyahoga Falls, OH

Fortis College Cuyahoga Falls, formerly known as National Institute of Technology, was founded in Cuyahoga Falls, Ohio, in 1966. The Welding Technician program teaches students the principles of welding technology. In the program, students are introduced to basic air carbon arc, oxyfuel, and plasma arc cutting processes. The fundamental concepts of shielded metal arc welding and gas metal arc welding as well as flux core arc welding are taught. Pipe welding and gas tungsten arc welding applications are also included in the curriculum.

2545 Bailey Rd.
Cuyahoga Falls, OH 44221
(330) 923-9959
fortis.edu



Fullerton College

Welders are in demand across a wide spectrum of skilled trades and professions. According to the Bureau of Labor Statistics, Southern California ranks in the top three metro areas (Los Angeles, Long Beach, Anaheim) with one the highest employment levels, at the highest annual median wages in the U.S., for welders. The welding program here at Fullerton College is centrally located to this area and feeds directly into these high demand labor markets. All our full-time faculty are AWS Certified Welding Inspectors. We offer a Manufacturing Technology Associate degree with an emphasis in welding, a Welding Technology certificate, and a wide range of welding certifications to AWS codes and standards, all of which are designed to prepare students to apply a variety of welding processes across industry sectors. Our short-term certificate can be completed in as little as two semesters!

321 E. Chapman Ave.
Fullerton, CA 92832
(714) 992-7190
cte@fullcoll.edu | ce.fullcoll.edu



Georgia Trade School

At Georgia Trade School disruption is part of our magnetic culture. For 12 years we have changed what a postsecondary education looks like in one of the most cosmopolitan markets in the United States. Seven times our boutique welding school has been named a Cobb Chamber Top 25 Small Business of the Year in a county with over 46,000 businesses. With over 1600 graduates across 20 states in energy, construction, manufacturing, shipbuilding, film, and television our efforts to “Rebuild America” have led to critical acclaim and commercial viability. This transformative program changes lives and is a pathway to middle class security.

Ryan Blythe
rblythe@georgiatradeschool.com
4231 Southside Dr.
Acworth, GA 30101
(770) 590-9353
georgiatradeschool.com



GEORGIA TRADE SCHOOL
REBUILDING AMERICA

Hobart Institute of Welding Technology

Hobart Institute of Welding Technology (HIWT) offers a wide range of welding skill and technical training classes and certifications. The catalog includes the skill training programs, over 25 individual courses, corporate training, and a listing of the AWS-certified testing services provided. Corporate training may be done at our facility or yours. The HIWT bookstore offers a complete training curriculum that includes DVDs, instructor guides, and student workbooks along with other welding-education-related items.

400 Trade Square E.
Troy, OH 45363
(937) 332-9500
Fax: (937) 332-9550
welding.org



HOBART INSTITUTE
OF WELDING TECHNOLOGY

Modern Welding School

Modern Welding School is an ACCSC School of Excellence award recipient. Students receive training in OAW, SMAW, pipe, GTAW, and GMAW/FCAW. The school's full-time program is 900 hours and the evening part-time program is 665 hours. Job placement assistance is available for students of the career programs. Training is also available to companies looking for specialized welding training, welding certification testing, or consulting for their personnel.

Schenectady, NY 12304
(800) 396-6810
(518) 374-1216
Andrew Daubert
adaubert@modernwelding.com
learn2weld@modernwelding.com
modernwelding.com



Hill College

Hill College's welding program offers comprehensive training in a high-demand job market and is available on both Hillsboro and Cleburne campuses. Choose from several program options, including a certificate in basic welding up to an Associate of Applied Science in Welding Technology. Hill College is equipped with state-of-the-art technology to help you get a jump start on your career. With hands-on curriculum, you are given an experience that exceeds what a classroom can teach.

Hill County Campus
Hillsboro, TX 76645
Cleburne Technical Center
Cleburne, TX 76031
Joe Price
JPrice@hillcollege.edu
(254) 659-7984
hillcollege.edu



Lakeshore Technical College

Located between Milwaukee and Green Bay, Wisconsin, Lakeshore Technical College is a nationally recognized college where you can become workforce-ready in weeks. Experienced faculty, high-tech labs and classrooms, affordability, and graduate placement rates position Lakeshore among the best. Our state-of-the-art KOHLER Center for Manufacturing Excellence serves as the only AWS Accredited Test Facility in the area. Learn about flexible start dates and programs ranging from basics to robotic welding at gotoltc.edu today.

1290 North Ave.
Cleveland, WI 53015
(888) GO TO LTC
gotoltc.edu



Monroe County Community College

MCCC's Welding Technology Education includes training in SMAW, GMAW, FCAW, and GTAW of ferrous and nonferrous materials. Our state-of-the-art, hands-on training facility emphasizes mechanical and manual thermal cutting processes and techniques. American Welding Society (AWS) SENSE certification may also be attained through our ten-week QC-10 (entry level) and QC-11 (advanced level) offerings. MCCC proudly offers multiple certificate pathways, including a Basic Welding Certificate, Advanced Welding Certificate, and a Nondestructive Testing Certificate program in addition to the Associate of Applied Science Degree in Welding Technology that will transfer to both Ferris State University and Wayne State University. Apprenticeship training is available to companies with registered apprenticeship programs.

Steve Hasselbach-CWI, (734) 384-4118
shasselbach@monroeccc.edu
Jennifer St. Charles, (734) 384-4112
jstcharles@monroeccc.edu

MONROE COUNTY
COMMUNITY COLLEGE

enriching lives

Odessa College

Nationally recognized as one of the leading colleges in the country, Odessa College has an award-winning Welding Technology program that provides educational training for tomorrow's welding technicians. The four specialized lab areas are equipped with 75 welding stations for instruction on SMAW, GMAW, FCAW, GTAW, SAW, and robotic welding procedures. Learn the cutting process in oxyfuel, plasma, and CAC-A in both manual and mechanized methods. The modern classrooms utilize Smartwall technology with Lincoln Electric virtual welding training systems to enhance the learning experience. Students have the opportunity to earn a one-year certificate or a two-year AAS degree in Welding Technology. The program is an AWS Educational Institution Member and an active NC3 member with several trained instructors. Our AWS Student Chapter is active on the OC campus and in our community.

Syed Muhammad Naqvi – CWI/CWE
 snaqvi@odessa.edu
 (432) 335-6306
 odessa.edu



PIT Instruction & Training LLC Pit Weld U

Located in Mooresville, N.C., Pit Weld U, an Accredited Testing Facility, offers seven industry-specific welding, fabrication, and print-reading classes. The certificate-based program allows students to be selective in the courses they take, providing a faster, cost-effective path into the industry segment of their choice. Tuition includes AWS certification testing and an OSHA-10 certification in general safety, providing graduates with a foundation to a successful career. Veterans may use available GI Funds to attend, and all students may apply for scholarships available courtesy of industry partners.

156 Byers Creek Rd.
 Mooresville, NC 28117
 (704) 799-3869
 visitPIT.com



United Technical Inc.

Train, test, and certify as an AWS Certified Welding Inspector at our facility in southeast Michigan. The ability to train all common NDT methods (RT, UT, PT, MT, VT, etc.) makes United Technical your answer for any welding inspection need. Our classes emphasize hands-on training, so students spend most of their time actually performing inspections. With years of experience focused on corporate training, we know what it takes to create a successful welding inspection professional. Our in-house CWIs and CWEs enable United Technical to support manufacturing companies of any size.

1081 E. North Territorial Rd.
 Whitmore Lake, MI 48189
 (248) 667-9185
 Robert Dines
 info@unitedtech1.com
 unitedtech1.com



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Orange County Inspections Inc.

Email for more info and pricing:
 renewmycert@gmail.com

Schoolcraft College

Located in one of the largest manufacturing areas of the USA, Schoolcraft College offers certificates and associate degrees in an AWS Accredited Test Facility. The college provides state-of-the-art welding and fabrication equipment in an innovative, dynamic, and productive environment. Small class sizes give students easy access to knowledgeable, industry-trained experts and CWI instructors who strive to educate students for real-life, on-the-job scenarios. Schoolcraft College offers classes in all major welding processes as well as specialized classes in blueprint reading, inspection, metallurgy, OSHA 30, CAD, robotics, mechatronics, and CNC manufacturing. Schoolcraft College also offers courses for AWS certifications in aerospace, ASME, D1.1, B2.1, and several other codes and standards to enrolled students as well as local skilled tradesmen and tradeswomen.

Coley McLean
 cmclean@schoolcraft.edu
 Livonia, MI 48150
 (734) 462-7020 • schoolcraft.edu



Utah State University – Eastern

Utah State University – Eastern (USUE) offers both a one-year Certificate of Completion (CC) and a two-year Associate of Applied Science (AAS) in Welding Technology. Rather than focus solely on entry-level welding skill, the program at USUE is designed to help students reach their full potential in all aspects of the welding industry. Students from across the United States enjoy small class sizes, welding process-specific instruction, expert faculty, and affordable tuition. Contact Austin Welch for further details.

USU – Eastern
 451 E. 400 N.
 Price, UT 84501
 (435) 613-5413
 austin.welch@usu.edu



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 (248) 571-0120
brazingschool@wallcolmonoy.com
wallcolmonoy.com/brazingschool



WALLCOLMONOY

Waubonsee Community College

The Welding Technology program at Waubonsee Community College offers students options of two certificates as well as an Associate in Applied Science degree. Class sizes are small to ensure students get focused and individualized attention. Waubonsee's welding program includes classes in each of the basic processes, including OFW, TB, OFC-A, PAC, SMAW, GMAW, FCAW, and GTAW. Additionally, the curriculum includes two courses specifically devoted to pipe welding with GTAW and SMAW in all positions.

Rt. 47 @ Waubonsee Dr.
Sugar Grove, IL 60554
 (630) 466-7900, ext. 2263
btwe@waubonsee.edu
waubonsee.edu



WAUBONSEE
 COMMUNITY COLLEGE

Where futures take shape

Welding School of Nevada

Welding School of Nevada offers a comprehensive ten-week certificate-based course running five days a week and providing students a minimum 180 hours of hands-on training with an emphasis on being qualified per the AWS D1.1. There's also a focus on SMAW, FCAW, GTAW, and GMAW. Job placement is a priority, and the school works closely with local contractors to facilitate employment opportunities for graduates. Contractors are invited to the school before graduation to meet potential employees, ensuring a smooth transition into the workforce.

Greg Gilbert, School Director
 (609) 316-7018
 141 Industrial Park Rd. #306
 Henderson, NV 89015
weldingschoolofnevada.com



Washtenaw Community College

Discover the many opportunities offered at Washtenaw Community College (WCC) through the Welding and Fabrication program. With an impressive lab hosting 60-plus multiprocess workstations, WCC has a comprehensive curriculum supported by faculty with over 50 years of combined field and CWI experience. Students explore destructive and non-destructive testing methods, code interpretation, and manual and automated welding and cutting processes. Join us at WCC, where theory and practical learning come together to shape the next generation of welders!

Alex Pazkowski
Bradley Clink
 Ann Arbor, MI
 (734) 973-3628



Welder Training & Testing Institute

Welder Training & Testing Institute (WTTI) maintains a freestanding campus in Pennsylvania, housing a weld lab equipped with 65 workstations. Training is provided in all major welding processes. Classrooms are fully equipped to support lessons in theory, blueprint reading, and fitting. Specialized on-site training is available to industry. WTTI also offers CWI and NDT training and certification as well as welder certification through our AWS Accredited Test Facility and ISO 17025 Accredited Laboratory.

729 E. Highland St.
Allentown, PA 18109
 (800) 223-WTTI
info@wtti.edu



Wilson Community College

Established in 1958, Wilson Community College is one of the system's oldest institutions. The college offers associate degrees, diplomas, and certificates. The Welding Technology curriculum provides students with an understanding of the science, technology, and applications essential for successful employment in the industry. Instruction includes electrode welding and cutting processes, blueprint reading, metallurgy, welding inspection, and destructive and nondestructive testing to provide the student with industry-standard skills. Enrollment is approximately 17 to 25 students.

Travis Flewelling,
Dean of Industrial Technologies
tflewelling@wilsoncc.edu
 (252) 246-1210
 902 Herring Ave., Wilson, NC 27893
 (252) 291-1195 | wilsoncc.edu





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