Inspection Trends

THE MAGAZINE FOR MATERIALS INSPECTION AND TESTING PERSONNEL

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AWS

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Inspection Trends

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

Editor's Note

By Mary Ruth Johnsen

Dear Readers,

Who knew there was so much to say about Welding Procedure Specifications? Not me. When Al Moore proposed writing a four-article series on WPSs, I'll admit I was somewhat skeptical about whether there was really enough information to fill four articles and if the topic would hold your attention throughout a whole year's worth of *Inspection Trends*. I had some reservations even though the topic always comes up as an area the *IT* audience wants more information about in the reader surveys we've conducted. I should know I need to always listen to you, our readers, because from all reports you have been very interested in the detailed articles Moore has written on Welding Procedure Specifications.

I certainly know a lot more about the subject than I did a year ago. Moore has brought us step by step through the process of preparing WPSs. First he defined the types of WPSs, then he explained what essential and nonessential variables are, how to qualify a WPS by testing, and in this issue how to write a WPS that will help your company and its welders meet your customer's needs.

In this issue's article, Moore makes a statement that I believe sums up what we all need to do to make our writing clear and understandable whether we're preparing a WPS, inspection report, or an article in *Inspection Trends*. In the article, Moore's actually referring to a numbering system for WPSs, but I think it applies to all writing: "Keep in mind that a system that has a *rational basis* is easier to remember and use." (The emphasis here is mine.)

We're covering a wide area in this issue. The articles range from nitty-gritty topics such as writing WPSs and using fillet weld gauges to advanced NDE methods such as ultrasonic phased array inspections and acoustic pulse reflectometry. If you consider Ken Erickson's reflections on what the future holds for CWIs on page 18 in "The Answer Is . . .", I believe you'll agree that in the future, CWIs will need to be knowledgeable about and hold certifications for several NDE technologies. Many of you are already well-prepared for what the future will bring because you already hold multiple certifications.

I believe we're starting off this new year of *Inspection Trends* with a lot of valuable information. I hope you can put it to good use.

If you wish to submit an article, or have any questions or comments, please contact me at (800) 443-9353, ext. 238, or *mjohnsen@aws.org*.

I also want to wish you all a happy, healthy, and productive new year. — *Mary Ruth Johnsen*.

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Ultrasonic Phased Array Testing Played Part in Rescuing Chilean Miners

A company in Edmonton, Alb., Canada, played a role in the rescue of the 33 miners who were trapped in the San Jose copper and gold mine in Chile. All 33 of the miners were rescued in October 2010 after spending 69 days trapped in the mine.

Metalogic Inspection Services used its Metaphase ultrasonic phased array testing equipment to inspect the welds on the metal pipe that was inserted into the shaft that was used to reach the miners. The capsule that was used to carry the workers up to the surface was inserted into the pipe.

“We actually preinspect the weld,” said Quintin Bower, Metalogic’s corporate business development manager, according to a report from the Canadian Broadcasting Center. “So as they are manufacturing the pipe and putting it into the ground, we will do a full circumferential scan of the weld. They push it down deeper, and they put another joint in and so forth until they got the complete weld inside the shaft that they drilled.”

Bower said the company gathered staff and resources from Edmonton, Brazil, and Thailand to help with the operation.

ASQ Manufacturing Outlook Survey Shows Growth

The second annual ASQ Manufacturing Outlook Survey shows the majority of manufacturers are optimistic about an economic uptick in 2011 at their organizations — a slightly brighter outlook than for 2010. The survey was conducted by the American Society for Quality, Milwaukee, Wis.

The survey results showed 68% of respondents employed in the manufacturing sector predict their organizations will experience revenue growth. A year ago, 64.7% of respondents said revenue would grow in 2010.

The two areas from the survey that showed the most promise were in the areas of payroll and operational budgets. Only 18% expect a pay freeze at their organizations in 2011 compared to 44.8% in 2010, and 18% predict mandatory budget cuts this year as compared to 35.2% in 2010.

Of the other options surveyed, respondents anticipate the following:

- Expectations of a salary/merit increase (48%).
- Organizations will continue to create processes to reduce costs (47%). That’s down from 61.3% in 2010.
- Maintaining current staff levels at their organizations (42%).
- Hiring of additional staff (42%).
- No mandatory furlough days (73%). In 2010, 72% indicated they did not have to take furlough days.

The survey questioned whether staff reductions or other cutbacks implemented in 2010 negatively impacted the quality of the products/services delivered. Thirty-three percent of respondents believed the quality of their products and/or services was negatively impacted, and 32% believed quality did not suffer.

Respondents were also asked what one tip they would give to manufacturers to ensure revenue growth in 2011. The top four tips, which are similar to those listed in the 2010 outlook, are as follows:

- Continue to take part in continuous improvement practices, and increase use of quality processes;
- Increase customer satisfaction;
- Implement more lean processes;
- Reduce costs/eliminate waste.

“Though it appears the manufacturing sector is still facing some challenges on the road to full economic recovery, the incremental gains shown in this survey are very promising,” said ASQ Chair Peter Andres. “However, organizations still need to focus on and increase customer satisfaction, and implement continuous improvement practices to remain competitive.”

TÜV SÜD America Offering NDE Personnel Approval Services

TÜV SÜD America, Inc., Peabody, Mass., a global inspection and certification services organization, now offers NDE personnel approval services in accordance with the Pressure Equipment Directive (PED) (97/23/EC).

The company will act as a recognized third-party organization (RTPO) according to Article 13 of the PED through TÜV SÜD Industrie Service GmbH, ensuring that personnel who inspect welds on pressure equipment in Categories III and IV meet all the outlined requirements and have passed all theoretical and practical exams. Services include testing by U.S.-based personnel of the applicants through Level IIIs in the respective discipline using procedures described in CEN TR 15589. Currently, the company is the only Notified Body in North America additionally authorized as an RTPO.

E&E Mfg. Earns A2LA Accreditation

E&E Manufacturing recently earned accreditation by the American Association for Laboratory Accreditation (A2LA). The accreditation covers both ferrous and nonferrous metals and is to the ISO/IEC 17025:2005 standards.

“In addition to the testing we’ve offered for years, this accreditation also includes several new testing services that will enable us to better serve both existing and new customers alike," said President Wes Smith.

The certification entitles E&E to perform a wide range of tests including hardness, microstructure, case depth, microetching, macroetching, surface condition, and weld procedure qualification, as well as nondestructive tests such as magnetic particle and liquid dye penetrant.

E&E Manufacturing was established in 1962 as a producer of stampings for the auto industry. Today it has nearly 500,000 sq ft of production capability at plants in Plymouth, Mich., and Athens, Tenn. It still serves the auto industry as well as other industrial markets and the military.

Imperium Selects VP of Global Sales, NDT Products

Imperium, Inc., Beltsville, Md., a developer and manufacturer of ultrasound imaging cameras for nondestructive examination, has hired Bruce Stetler as vice president global sales, NDT products.

Stetler has been in the NDE industry for more than 27 years, most recently as midwest regional sales manager and west coast regional sales manager for Olympus. He has been a member of AWS for more than ten years and a member of ASNT for 25 years.

UV Light Source Offers Hands-Free Operation

The Spectroline® EK-3000 EagleEye™ UV-A/white light LED inspection kit features a palm-sized, cool-running inspection lamp. The lamp features two ultrahigh-intensity UV-A (365 nm) LEDs that are useful for NDE and mining inspection, plus a three-LED white light assembly for general illumination. An adjustable strap allows the lamp to be worn on a hard hat or directly on the head for hands-free operation. A lamp mount/sprayer attachment permits the lamp and a spray can to be mounted together for single-handed fluorescent yoke inspection. The lamp produces a nominal steady-state UV-A intensity of 5500 $\mu W/cm^2$ at 15 in. A built-in fan keeps the lamp cool to maintain optimum UV-A intensity during prolonged inspections. It includes a rechargeable lithium-ion battery that provides up to 45 min of continuous inspection between charges. Also included is a lanyard, two replacement splash guards with integral particulate filters, three batteries, a battery charging cradle, UV-absorbing spectacles, and carrying case.

Spectronics Corp.
www.spectroline.com
(800) 274-8888

Phased Array Instrument Provides Fast Data Recording

The Veo 16:64 phased array instrument is useful for pipeline weld inspection, corrosion mapping, and aerospace and composite testing. The instrument offers fast data recording, a simple-to-use interface, and rugged housing. Its display features full 3-D views of the user's test setup including probes, wedges, the weld, and

geometry, with phased array beams. It provides quick A-scan recording and reporting functionality and two separate conventional channels provide simultaneous phased array and time-of-flight diffraction scanning to speed up inspection and ensure correct data referencing for improved defect characterization.

Sonatest
www.sonatest.com
(210) 697-0335

Portable Pipe Inspection Camera Fits in Tight Spaces

The Pilit-Mini™ inspection camera fits in pipes ¾ in. and larger. It runs on battery or AC power, offers a 30-m fiberglass/stainless steel reinforced push rod with watertight connectors, and features a robust design that withstands the harsh conditions found with pipe inspection. It is lightweight, portable, and fits into tight spaces. The push rod is highly flexible, allowing it to easily pass around bends. It offers a wireless LCD screen that presents crisp color images.

Advanced Inspection Technologies
www.aitproducts.com
(321) 610-8977

Articulating Video Borescopes Feature Stand-Alone Image Processing

The company's VJ-Advanced® Series articulating video borescope features on-board (stand-alone) image processing and battery-powered, portable operation. It features a high-resolution 3.5-in. TFT LCD screen with a removable sun visor and 2× digital zoom function. It has a waterproof, 0.272-in. insertion tube and features braided stainless steel sheathing for resistance to oil, fuel, and 3.5% concentrated saltwater. The camera tip displays the temperature with lapse-time recording and temperature alarm display. It features a thumb-activated 360-deg joystick, weighs 20 oz, and includes four high-intensity LEDs with adjustable brightness control.

Titan Tool Supply, Inc.
www.titantoolsupply.com
(716) 873-9907

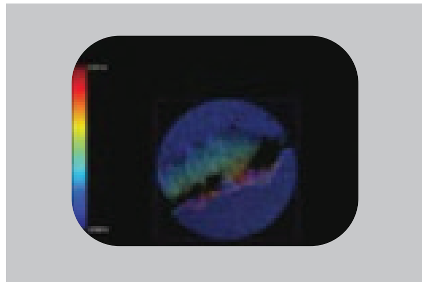
Alloy Sorter Quickly Identifies Metals

The TE-3000 thermoelectric alloy sorter takes 1 s per test to identify

materials such as steels, nickel, aluminum, titanium alloys, stainless steels, superalloys, specialty steels, tool steels, low-alloy steels, and common steels. Other applications include the detection of platings and plasma coatings, in-line and part testing, and scrap sorting. The instrument includes interchangeable probe tips for improved test metal contact, carry case, international voltage regulator, and data logging system.

Koslow Scientific Co.
www.koslow.com
(800) 556-7569

3-D Phase Measurement Technology Paired with Video Borescope



The company has paired its XLG3 video borescope with 3-D phase measurement technology to increase accuracy and productivity in aerospace and rotating equipment applications. The 3-D measurement eliminates the need to change the probe tip to capture the measurement, which streamlines the inspection process. The 3-D phase measurement offers Profile Views, a cross-section view of a portion of the surface. With Profile View, the inspector can rotate and zoom to get a more accurate view of the defect.

GE Sensing & Inspection Technologies
www.geinspectiontechnologies.com
(800) 833-9438

System Displays and Records Real-Time Video during Pipe Inspections

The ClipStream™ captures up to 16 GB (approximately 12 h) of AVI video and JPEG still images to a micro SD card. Recorded footage can be viewed directly on the system's 3.6-in. color LCD or transferred to a computer or smart phone by ejecting the card or tethering via USB. It clamps in seconds to the pole of the company's QuickView® zoom survey camera and displays and records real-time video during pipe and manhole inspections. In wireless mode, ClipStream™ transmits video to any monitor on the same frequency, which means several people can view the same video from different locations. When tuned to different frequencies, multiple units can be used in the same area without interference. The system accepts NTSC or PAL video input via a BNC connector, and outputs analog video via a phone jack. It runs on four AA batteries, or connects to mains power using an optional AC adapter.

Envirosight LLC
www.envirosight.com
(866) 936-8476

Official Interpretation:

Aluminum Brazing

Subject: Temperature Uniformity Requirements
Code Edition: AWS C3.7M/C3.7:2005
Code Provision: Page 4, Subclause 5.3.2 (Temperature Uniformity Requirements)

Inquiry: Do salt baths for brazing aluminum having a solidus of less than 1120°F have to meet a ±5°F, SAE/AMS 2750, Pyrometry, Class 1 temperature uniformity requirement?

Response: *Yes.*

By Albert J. Moore Jr.

Feature

Tips for Using Fillet Weld Gauges

The following advice will help you consistently size fillet welds properly

Other than the measuring tape, the fillet weld gauge is the most used measuring device in the welding inspector's kit. That is understandable considering the majority of the welds deposited are fillet welds. Yet many people measure the size of the fillet weld incorrectly.

The principle of the fillet gauge is pretty simple. The fillet weld has a cross section that is essentially a triangle. If the two members being joined are at right angles to each other, the cross section of the fillet weld resembles an isosceles right triangle — Fig. 1. One basic assumption is that the fillet weld is fused to the joint root, but not necessarily beyond. With those two assumptions in place, i.e., the cross section of the fillet weld is an isosceles right triangle and it has fusion to the root, we can establish a relationship between the length of the fillet weld legs and the theoretical throat. We need to know the dimension of the throat because it is the "weak link"; that is, it represents the shortest failure path through the cross section of the weld. With the two conditions noted in place, we can define the size of the fillet weld as the largest inscribed isosceles right triangle.

Inspectors usually use a leaf-type fillet weld gauge to measure the size of fillet welds. The gauges come as a set of individual gauges that are used to size fillet welds. I did not say "measure" fillet welds because the leaf-type gauge only indicates whether the weld is less than, larger than, or the same size as the gauge.

The inspector checks the size of the actual weld by using one or more gauges to compare the size of the weld to the size of the individual gauges. The gauges typically come in 1⁄16-in. increments for weld sizes ½ in. and smaller, and in ⅛-in. increments for sizes of ⅝ in. and larger.

The basic leaf-type gauge has two ends, one for sizing the weld leg and the other for checking the throat dimension. Well, that's not exactly accurate. The gauge does not directly measure or size the throat. Instead, it sizes the throat for the equivalent leg size for an isosceles right triangle.

As shown in Fig. 2, the gauge has two ends. The left end is used to size the fillet weld leg; the right end is used to size the weld throat.

If we were to check an ideal fillet weld, one that is a perfect isosceles right triangle that matched the size of the gauge, both the weld legs would be exactly ½ in. The throat of the fillet weld would measure exactly 0.354 in. (0.707×0.5). Rather than imprinting 0.354 on the right end of the gauge, the manufacturers imprint it with ½ because the fillet throat is the proper size for a fillet weld with ½-in. legs. That saves the inspector the time needed to calculate the required throat dimension for each leg dimension.

Figures 3 and 4 show that the fillet weld legs are exactly ½-in. each. Figure 5 depicts how to measure the vertical fillet leg. As indicated by the figure, the gauge has to be turned to verify the horizontal fillet leg is the proper size. After all, the two legs may not be the same size by design or as dictated by the welder's skill, so both the horizontal and vertical legs must be checked.

Checking the perfect fillet weld is

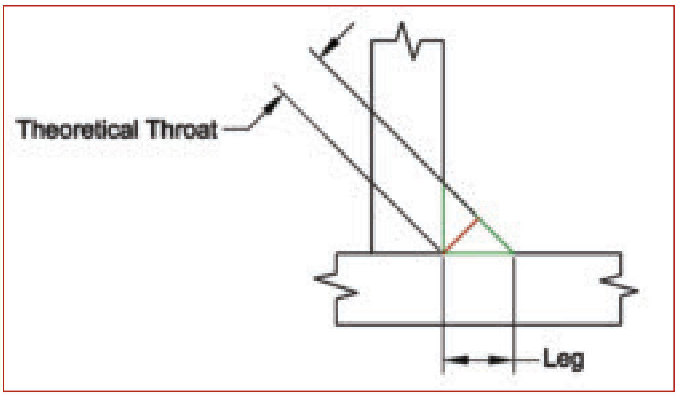


Fig. 1 — A typical fillet weld, such as the one shown here, has a cross section that resembles an isosceles right triangle.

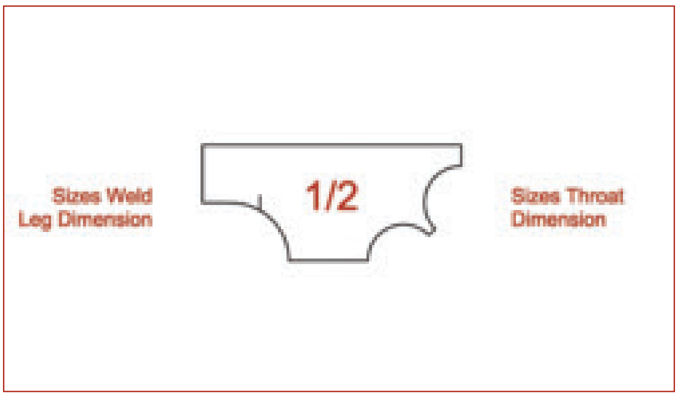


Fig. 2 — Example of a gauge used to size ½-in. fillet welds.

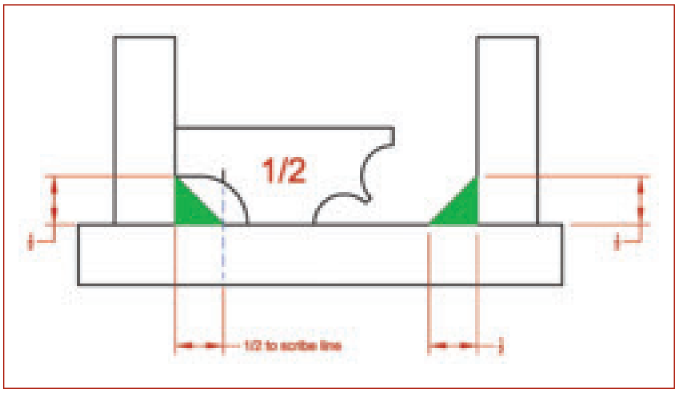


Fig. 3 — A ½-in. gauge is used to verify the leg size of a ½-in. fillet weld.

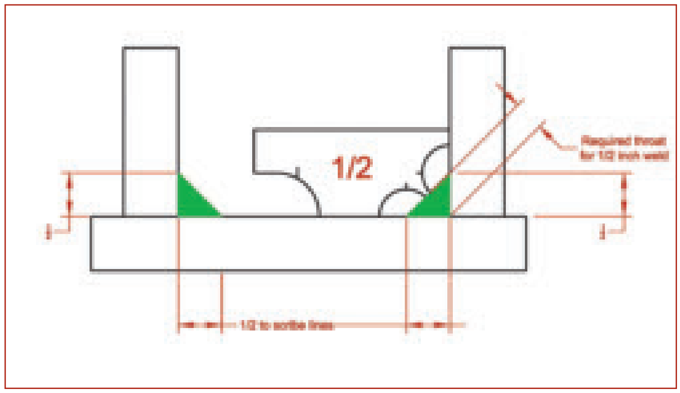


Fig. 4 — The ½-in. gauge used to verify the throat is properly sized for a ½-in. fillet weld.

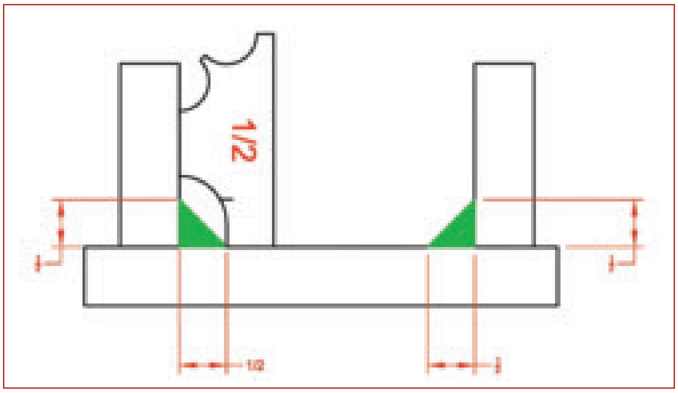


Fig. 5 — Verifying the horizontal leg meets the size requirement.

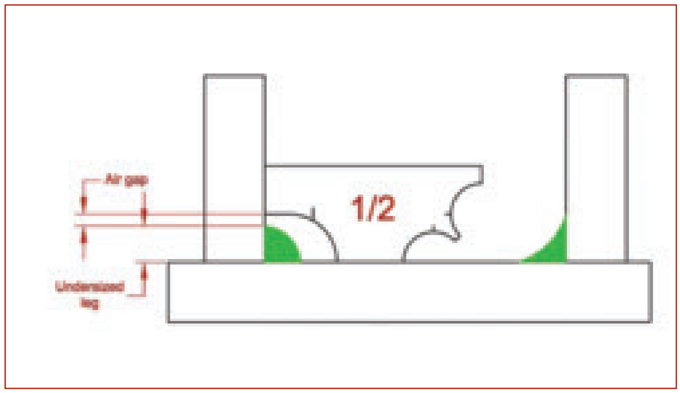


Fig. 6 — Undersized convex fillet weld. The vertical leg is too small.

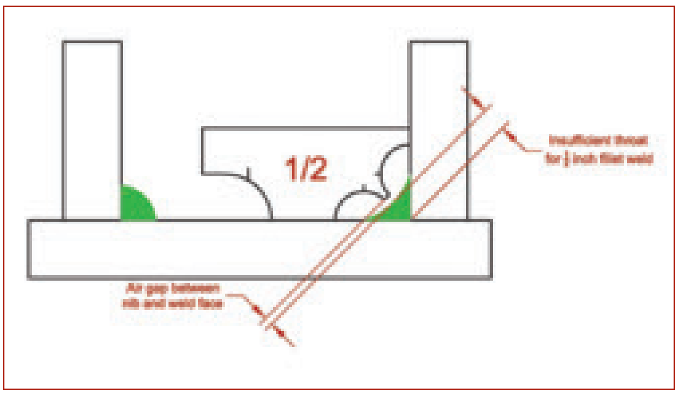


Fig. 7 — Fillet weld gauge sizing a concave fillet weld that has insufficient throat to meet the size requirements of a fillet weld with ½-in. legs.

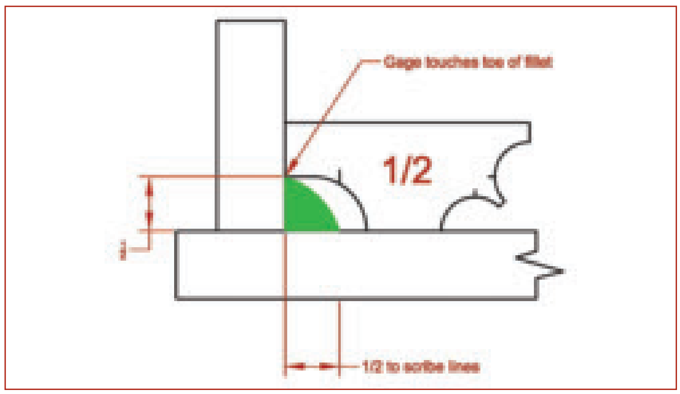


Fig. 8 — Convex fillet weld size is the same as the fillet weld gauge.

easy, but things get a little more complicated when dealing with fillet welds that are convex, concave, or a combination of both. The fillet weld gauge can be used for both convex and concave fillet welds. The first step is to determine the profile of the fillet weld face. The inspector can do that by lightly rubbing an index finger along the face of the weld. The tactile feel of the fingertip should be able to determine whether the weld face bulges out and is convex or the face of the weld sinks in and is concave. This is done so the inspector knows which end of the gauge to use. As you can see from Fig. 3, the left end of the gauge is used to size the leg dimension of a weld. As shown in Fig. 4, the right end of the gauge is used to size the throat of fillet welds.

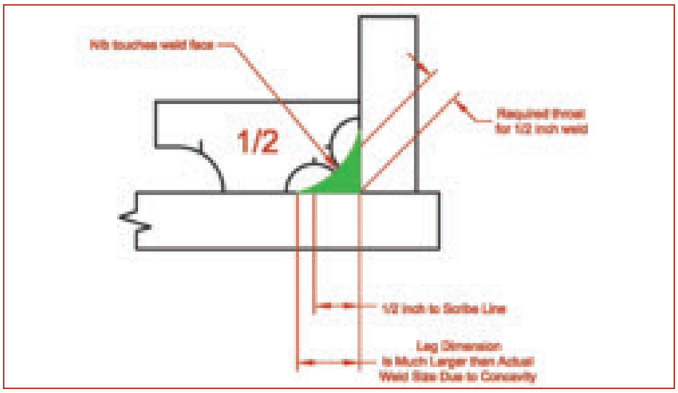


Fig. 9 — Concave fillet weld size is the same as the fillet weld gauge.

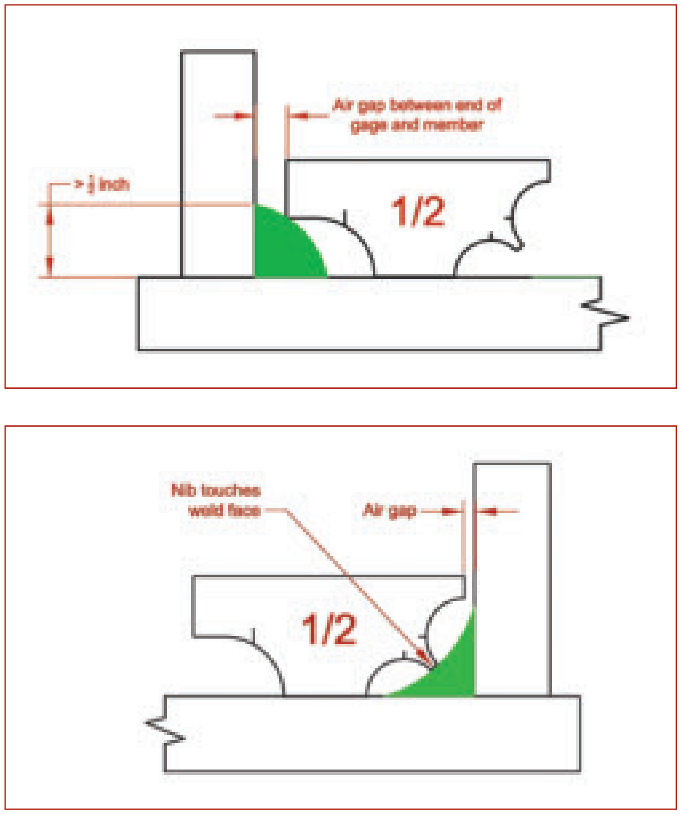


Fig. 10 — The convex (top) and concave fillet welds are larger than the size indicated by the fillet weld gauge.

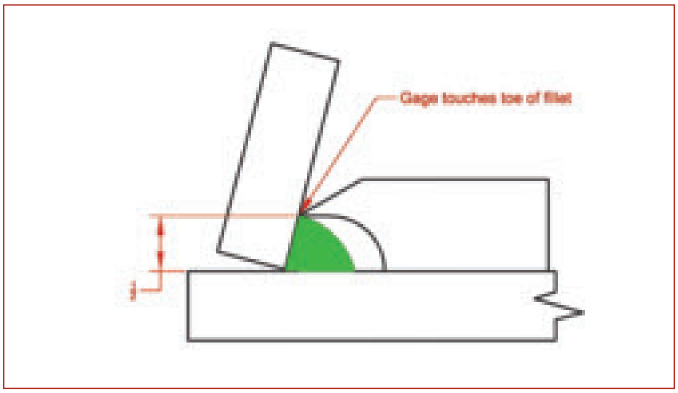


Fig. 11 — Modified fillet weld gauge used for measuring the leg of the fillet weld in a skewed joint.

To reiterate, fillet weld gauges do not measure fillet welds. The gauges are used to determine whether the weld is smaller than, larger than, or the exact size of the gauge being used. The set of leaves of the fillet weld gauges are a collection of "go/no-go" gauges. The inspector sizes the fillet weld by comparing the size of the weld to the size of several gauges until the inspector finds a gauge where the weld is slightly larger than the gauge.

Most welding standards include a statement to the effect the required weld size is as specified by the welding symbol. Dig a little deeper into the welding standard, and there may be provisions permitting a weld to be slightly smaller by some fraction or percentage of the specified weld size. The inspector's task is to determine what the smallest permitted weld size is and then verify all the fillet welds are at least as big as the smallest weld size permitted. Let us say the welding symbol specifies the weld size as 9⁄16 in. The welding standard allows the weld to under run the specified weld size by 1⁄16 in. The smallest weld permitted would be the specified size minus the allowable under run or 9⁄16 – 1⁄16 = ½ in. The inspector would select the ½-in. fillet weld gauge and check the weld legs (if the weld is convex) or the weld throat (if the fillet weld is concave). The welds would then be declared undersized if the welds were less than ½ in. or they would be accepted if they were ½ in. or larger.

The following figures depict the conditions the inspector might find during an inspection. Figure 6 depicts an undersized convex fillet weld, and Fig. 7 shows a concave fillet weld that is undersized under the defined constraints.

Figures 8 and 9 depict fillet gauges sizing welds that meet the minimum size requirement. Both the convex and concave fillet welds are acceptable if both legs of the convex fillet weld are found to be the proper size or in the latter case, the throat is the proper size.

Figure 10 shows a convex weld and a concave weld that are larger than the ½-in. fillet weld gauge used to check the weld sizes.

Let me now interject my personal philosophy on how to verify the size of a fillet weld when using the leaf-type fillet gauge. In the example provided, we determined the smallest acceptable weld size is ½ in. based on the stipulations of the welding standard. We also noted that the gauges are available in 1⁄16-in. increments up to ½ in. I do not interpolate the weld size when I use these fillet weld gauges. To put it another way, the weld is either smaller than the weld gauge, the same size as the weld gauge, or the weld is larger than the size of the gauge being used. I do not round the "measured" weld size up to ½ in. if the weld appears to be more than 15⁄32 in., i.e., 1⁄32 in. less than the ½-in. fillet size. The amount of under run permitted has already been taken into consideration.

When reporting the size of a fillet weld, I do not report the average size for the continuous fillet weld. If the size varies from ⅜ to ¼ in., I do not report it as 5/16 in. It is reported as ¼ in. and the length is discounted if it is less than ¼ in. due to the presence of an unfilled crater, etc. As an inspector, I report my findings and simply state the weld does not comply with the size specified by the welding symbol. When working under the auspices of AWS D1.1, *Structural Welding Code — Steel*, it is the Engineer's prerogative to accept undersized welds if it is determined they are suitable for the intended service. Other welding standards may have different provisions, such as no under run (same as undersized) is permitted, in which case the weld has to be at least as big as what is specified on the drawing.

There is one rather large fly in the ointment. The fillet weld gauges in this article work fine when the members are at right angles to each other, but what happens with welded joints that are skewed at an angle other than 90 deg? The gauge does not fit into the corner. There are gauges available from at least one vendor that are a slightly modified fillet gauge. This modified gauge is depicted in Fig. 11.

You can also make that type of gauge yourself. I usually make gauges like that shown in Fig. 11 out of heavy banding straps that I salvage from the scrap bin. The modified gauge is fine for measuring the leg dimension of a convex fillet weld, but it is not appropriate for a concave fillet weld. I'll leave it up to you to design your own gauge for that situation.

ALBERT J. MOORE JR. (AMoore999@comcast.net) *is vice president, Marion Testing & Inspection, Canton, Conn. He is an AWS Senior Certified Welding Inspector, an ASNT ACCP NDT Level III, and a member of the AWS Certification Committee and the Committee on Methods of Inspection of Welds.*

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2. Paid In-County Subscriptions Stated on Form 3541	None	None
3. Sales through Dealers and Carriers, Street Vendors, Counter Sales, and Other Non-USPS Paid Distribution	None	None
4. Other Classes Mailed through the USPS	None	None
C. Total Paid/Requested Circulation	22,243	22,433
D. Free Distribution by Mail (Samples, Complimentary and Other Free)		
1. Outside-County as Stated on Form 3541	81	79
2. In-County as Stated on Form 3541	None	None
3. Other Classes Mailed through the USPS	None	None
4. Free Distribution Outside the Mail (Carriers or Other Means)	None	None
E. Total Free Distribution	81	79
F. Total Distribution	22,324	22,512
G. Copies Not Distributed	526	588
H. Total	22,850	23,100
I. Percent Paid and/or Requested Circulation	99.6%	99.6%

16. Statement of Ownership will be printed in the Winter January 2011 issue of this publication.
   I certify that the statements made by above are correct and complete:
   Andrew Cullison, Publisher

The Answer Is

By K. Erickson and C. Mankenberg

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Q: When conducting welding from both sides on square groove butt sheet-to-sheet welder performance qualification testing in accordance with AWS D1.3, *Structural Welding Code — Sheet Steel*, what type of testing would be required?

A: The standard indicates to perform bend testing on two test samples for each assembly (Table 4.4 and subnote "a"). Although not specifically rquired by the code, since the joint is being welded from both sides, it would be good practice to perform two bend tests that would incorporate one bend from each side of the weld in the bend radius area.

Q: What is your perception of the welding industry and the employment forecast as a CWI for the next ten years?

A: (From Ken Erickson) I will provide the *IT* "The Answer Is" readers with my short version thoughts and feelings looking forward into the next decade.

First and foremost, I strongly believe that the welding industry and CWIs will be in higher demand years from now than they are today, which in turn will result in more employment opportunities and higher pay packages. As current CWIs age and retire they will not be replenished as plentifully in the job market to meet the growing demand. Like so many other industries, employers will search out and look for CWIs with knowledge and experience in specific fields and/or applications. Inspectors, in turn, will become more specialized and thus will be somewhat limited when venturing out to a new industry or welding field. CWIs should focus on obtaining a broad range of training and experience that can encompass numerous employment objectives and opportunities. Employers and project specifications will demand and mandate that both welders and inspectors be currently certified and must provide any certifications upon employment. Inspectors should add to their certification and experience résumés, whenever possible, as this will lead to greater financial gains and employment independence.

With the energy industries exploring both solar and wind power, you can anticipate that new standards and possibly new welding inspection credentials may be developed that will incorporate manufacturing and erection phases in regard to this expanding industry. In addition, nuclear power may once again be looked at to meet the increased energy demands and both welders and CWIs will play a large part in meeting these construction demands on longer-term projects. It would also be highly advisable for CWIs to add some other NDE certifications to their résumés such as liquid penetrant, magnetic particle, and/or ultrasonic inspection to further entice potential employers. These types of projects will encompass all forms of nondestructive examinations.

Industrial safety as related to welding, inspection, and overall construction will also become more demanding and individuals will need to also have and maintain current OSHA and other applicable training and certifications of completion prior to being considered for employment.

Inspectors will be required to be computer literate and able to generate and provide accurate and detailed reports encompassing digital photography and video to satisfy new requirements for project customers and clients located worldwide. More emphasis will be placed on individuals to develop and implement proven programs and procedures involving the need for inspectors beyond just from a welding standpoint.

The technology we are all experiencing today will have a significant impact on tomorrow's CWIs. National standards incorporating welding and inspection will continue to grow, expand, and become more detailed. There will be more demand for CWIs to be an integral part of this growth to satisfy the future needs of all industries.

Reader Comments on Q&A Related to Covered Electrodes

Ken Erickson was right on in his answer regarding covered electrodes (The Answer Is, page 42, *IT* Fall 2010). As CWIs, we may see covered electrodes being pulled from a rod oven, but we have no clue as to their history. I'm a big fan of the #10 can. My favorite line in the answer: "The welder should be provided every opportunity to complete a satisfactory weldment and the filler metal is a large part of this process."

Paul W. Cameron
CWI and Senior Welding Engineer
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Dodge Center, Minn.

Inspection Trends *encourages question and answer submissions. Please mail to the editor* (mjohnsen@aws.org).

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By Michael Moles

Phased Array Inspection of Small-Diameter Pipe Welds

New scanner technology combined with focused arrays produced better defect length estimates

Traditionally, small-diameter pipes have either not been inspected, or been inspected using radiography. However, radiography has significant limitations: safety and licensing issues, disruption to work schedules, chemical wastes, film storage, and poor detection of planar defects. Some codes permit manual ultrasonic testing, but that method suffers from a lack of recorded data and is highly dependent on the operator's skills.

In recent years, automated ultrasonic testing (AUT) has become commercially viable with the arrival of portable ultrasonic systems (Ref. 1), and now potentially offers both auditable and reliable results for small pipes (Ref. 2). However, the AUT solutions were generally lacking a reliable and low-profile delivery mechanism, and also had significant beam spread in small pipe diameters. Both these problems have been addressed with a new small-diameter pipe inspection system.

While little AUT is currently performed on small-diameter pipes, there are potentially many applications: boilers, process piping and product piping in refineries, shipbuilding, pharmaceuticals, nuclear power plants, etc.

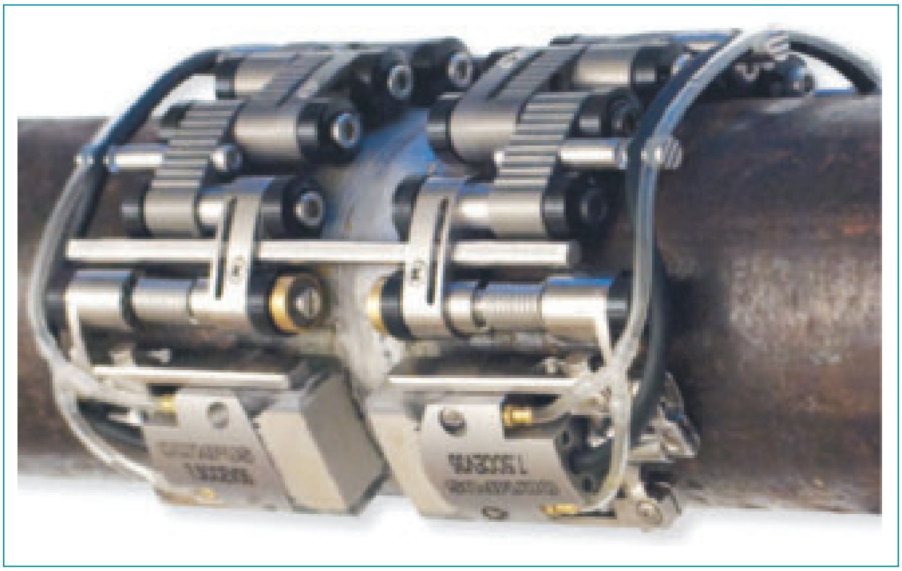


Fig. 1 — The COBRA scanner.

Codes

The arrival of ASME Code Cases 179 (Ref. 3) and 181 (Ref. 4) has permitted AUT of small-diameter pipe girth welds. ASME B31.1 CC 179 is a workmanship-based Code Case. ASME B31.3 does permit manual ultrasonic inspection of pipe welds, but that has the limitations listed previously (slow, operator dependent, no auditable results). As it is fracture mechanics based, B31.3 Code Case 181 needs accurate defect sizing and dimensioning. This is a difficult requirement for small-diameter pipe as the ultrasound beam naturally spreads (defocuses) on entry in the horizontal direction. This leads to defect oversizing, and hence higher repair rates. Phased arrays can focus the beam in an active plane, i.e., the vertical direction in the pipe, which theoretically permits better vertical sizing. However, it is questionable whether the vertical sizing accuracy is adequate for thin walls, but that is another issue not addressed in this article.

In summary, there are codes in place, both workmanship or fracture mechanics based, that permit AUT on small pipes, but hardware that can perform an adequate job has been deficient until recently.

Fig. 2 — Two-sided scan being performed on small-diameter vertical pipe.

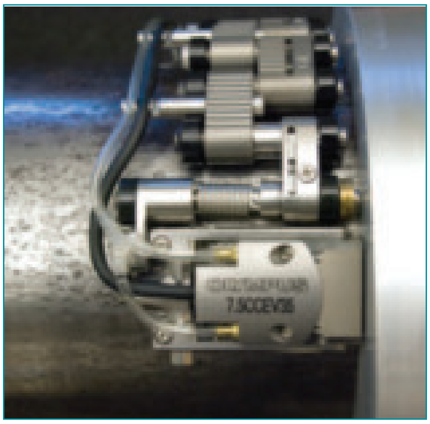
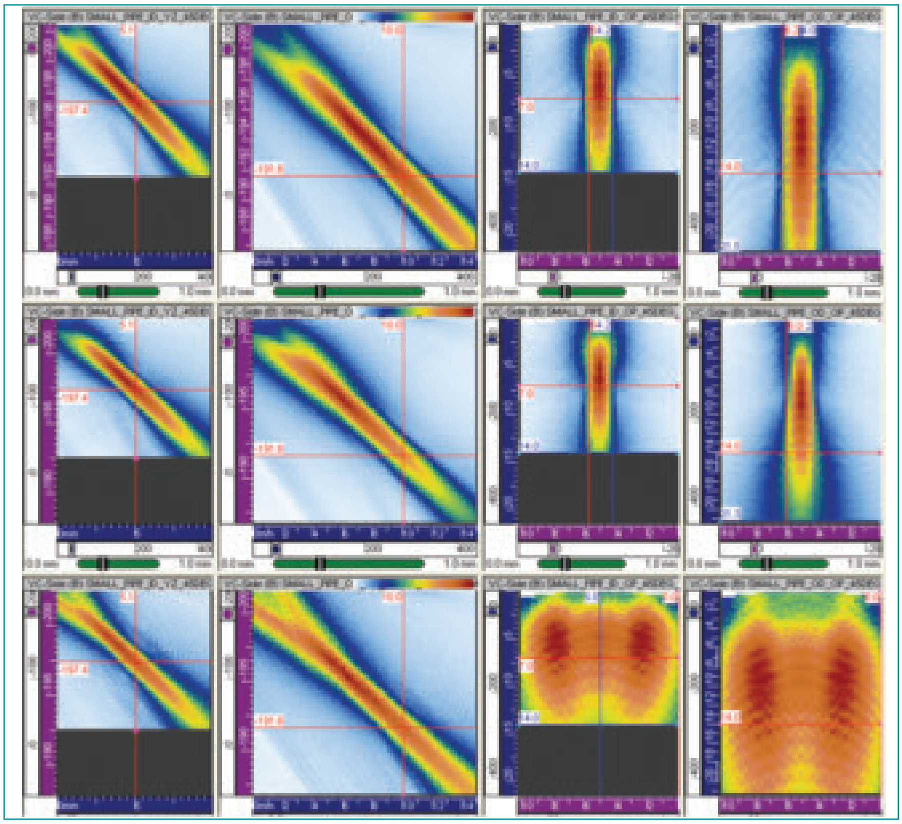


Fig. 3 — The scanner inspecting pipe-to-component weld in single-sided access.



16 x 8 matrix. Focal depth 5 mm. Field displayed in beam incidence plane.	16 x 8 matrix. Focal depth 10 mm. Field displayed in beam incidence plane.	16 x 8 matrix. Focal depth 5 mm. Field displayed in beam plane.	16 x 8 matrix. Focal depth 5 mm. Field displayed in beam plane.
16-element linear probe with radius of curvature of passive axis 22 mm. Focal depth 5 mm. Field displayed in beam incidence plane.	16-element linear probe with radius of curvature of passive axis 22 mm. Focal depth 10 mm. Field displayed in beam incidence plane.	16-element linear probe with radius of curvature of passive axis 22 mm. Focal depth 5 mm. Field displayed in beam plane.	16-element linear probe with radius of curvature of passive axis 22 mm. Focal depth 10 mm. Field displayed in beam plane.
16-element flat linear probe 5L16-Al. Focal depth 5 mm. Field displayed in beam incidence plane.	16-element flat linear probe 5L16-Al. Focal depth 10 mm. Field displayed in beam incidence plane.	16-element flat linear probe 5L16-Al. Focal depth 5 mm. Field displayed in beam plane.	16-element flat linear probe 5L16-Al. Focal depth 10 mm. Field displayed in beam plane.

Fig. 4 — Modeled beam profiles of matrix array (top), curved array (middle), and flat array (bottom) under various parameters (from Ref. 5).

Mechanical Scanner

Many small pipes are closely packed together, so a low-profile scanner is essential. In conjunction with an outside supplier, Olympus NDT has developed COBRA, a portable, one-axis scanner that fulfills the essential requirements — Fig. 1.

The scanner is semiautomated, i.e., it is hand pushed around the weld. Hand propelling saves costs, is technically easier, and is convenient for small-diameter welds. The scanner itself can be adapted to a range of sizes, which can be matched to the pipe diameter. As it is spring loaded, it can inspect both carbon steel and non-magnetic materials (e.g., stainless steels) with no changes. Experience has shown that the scanner provides good coupling for 360 deg around the pipe, which is essential.

This scanner can inspect pipe diameters from 21 to 115 mm (0.84 to 4.5 in.) OD. Clearance, including the low-profile array, is 12 mm, which permits it to inspect most small-diameter welds in most configurations. It is waterproof, rust-free, and CE compliant. As can be seen in Fig. 2, it is portable, lightweight, and it is easy to change the arrays and wedges. The encoder has a resolution of 32 steps/mm, which is plenty for AUT of welds. For welds with one-sided access only (e.g., flanges or pipes to component), the scanner can be re-configured for single access — Fig. 3.

The scanner is designed to operate in conjunction with encoded portable phased array equipment, primarily the company's OmniScan MX. In addition, there are various accessories to complete the package, such as links to establish a full range of ring sizes, water pump, and carrying case.

Focused Arrays

Early field results showed that lateral (or horizontal) oversizing could become a major problem as repairs may become significant. This was

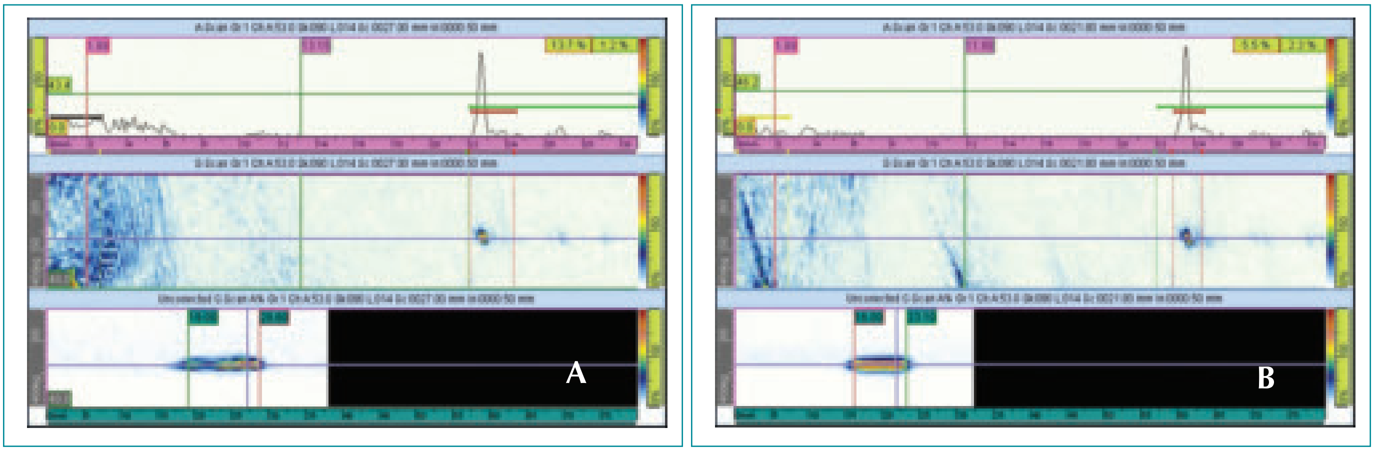


Fig. 5 — Detection of the 6.9-mm-long notch using the flat and curved probes (single skip) on 70-mm pipe. A — Flat probe. The measured notch length is 9.6 mm. B — curved probe. The measured notch length is 7.1 mm.

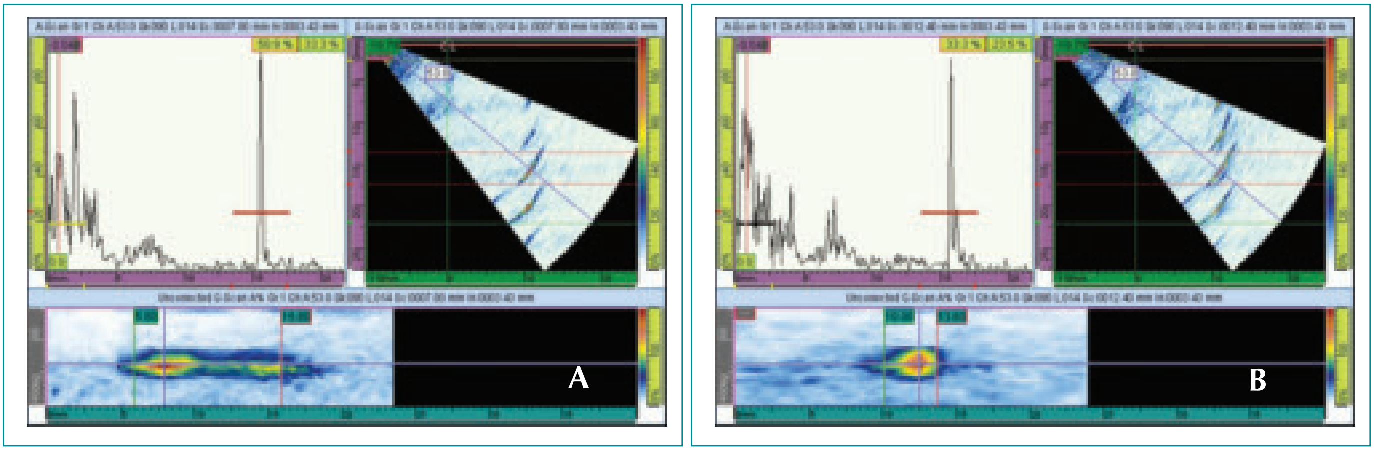


Fig. 6 — Detection of the OD end of the 1-mm through hole with the flat and curved probes (double skip) on 38-mm pipe. A — Flat probe. The measured size is 10 mm. B — focused probe. The measured size is 3.6 mm.

particularly important for smaller-diameter pipes, as beam spread was more significant.

Initially, an R&D project was defined to evaluate the possible solutions to beam spread with phased array units: matrix (2-D) arrays, mechanically curved arrays, or any combinations. Both matrix and curved arrays offer practical solutions for focusing in both axial and circumferential directions. Modeling was performed using PASS to determine the relative merits (Ref. 5). Modeling showed that only two curvatures were required to cover essentially all small pipe diameters, independent of wall thickness. The larger radius curved array was manufactured and tested on known reflectors, and compared with a standard flat (unfocused) array on pipes of 70 and 38 mm diameter. The summary results follow, and are compared with flat arrays.

Figure 4 shows the modeled results, with beam profiles displayed in both beam axis and cross section. Comparing the images in the third (last) row with either the first or second row, it was immediately clear that the flat, unfocused beam had significantly worse beam spread than either the matrix array or the curved array. Wall thickness had been demonstrated as relatively unimportant since multiple skips were required for thinner walls, so beam paths tended to be quite constant. (Note that PASS cannot simulate the field with a beam skip, so the OD field is calculated by ignoring the pipe ID reflection and by just considering total metal path.)

There was no obvious advantage in using the matrix probe over a linear array probe with an optimized radius of curvature. Matrix arrays would be more expensive and complex to implement. Curved arrays can be implemented with no extra hardware or software, unlike matrix arrays. Subsequent modeling with a 10-MHz linear array confirmed these results for 25-, 30-, 50-, and 75-mm diameters.

In summary, the modeling showed that one probe with 40-mm radius of curvature is suitable for pipe with an OD greater than 25 mm, and one probe with 30-mm radius of curvature for pipe OD less than 25 mm. Two curved arrays effectively covered all pipe diameters.

Experimental Confirmation of Modeling Results

Selected for testing were two pipes in sizes 2.75 in. (70 mm) and 1.5 in. (38 mm). Two wedges were contoured to match the pipe diameters, as per standard practice. Appropriate notches and holes were used as reflectors. The

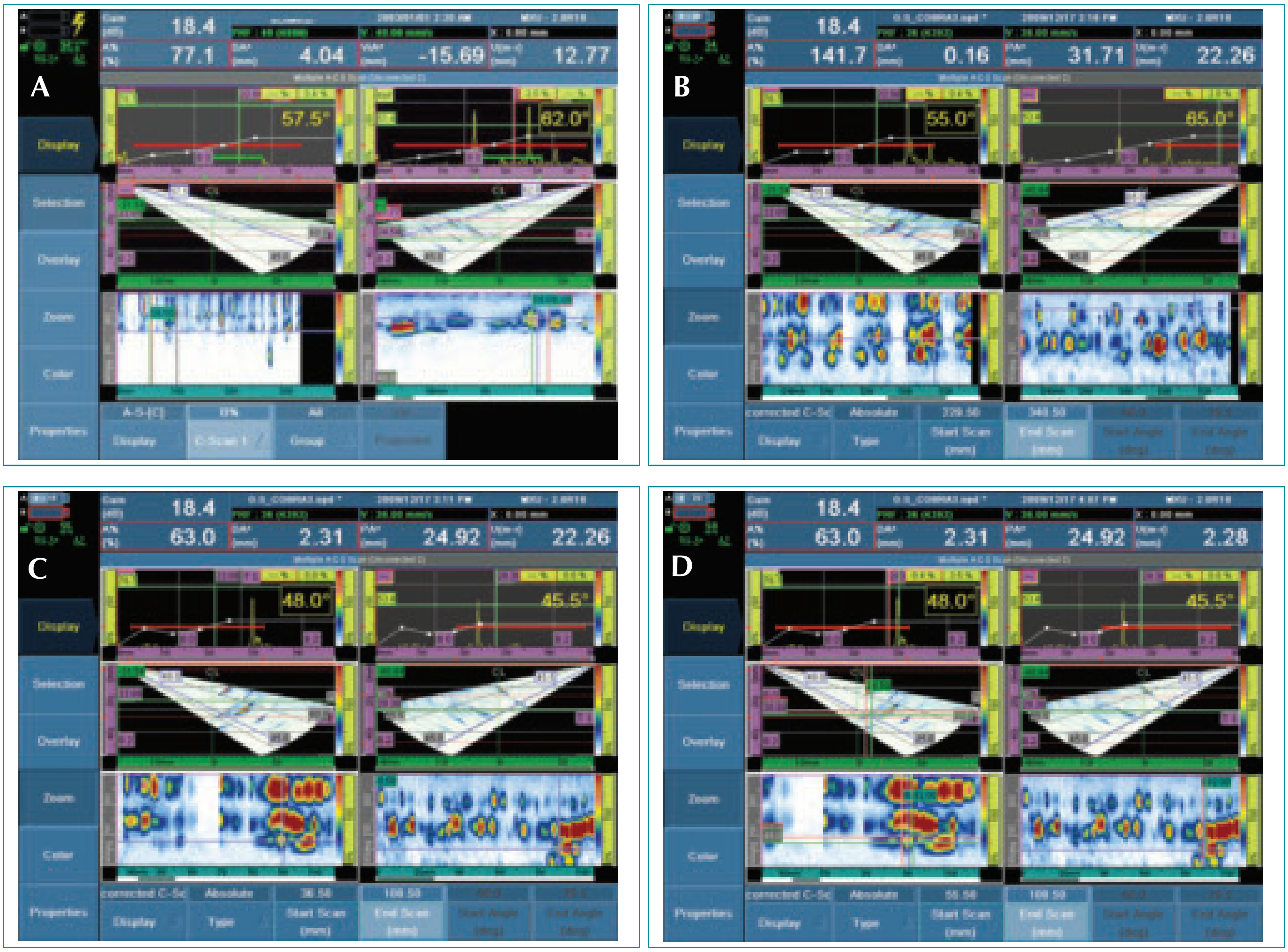


Fig. 7A–D — A weld 115 mm in diameter and 12.7 mm thick scanned using a variety of setup parameters.

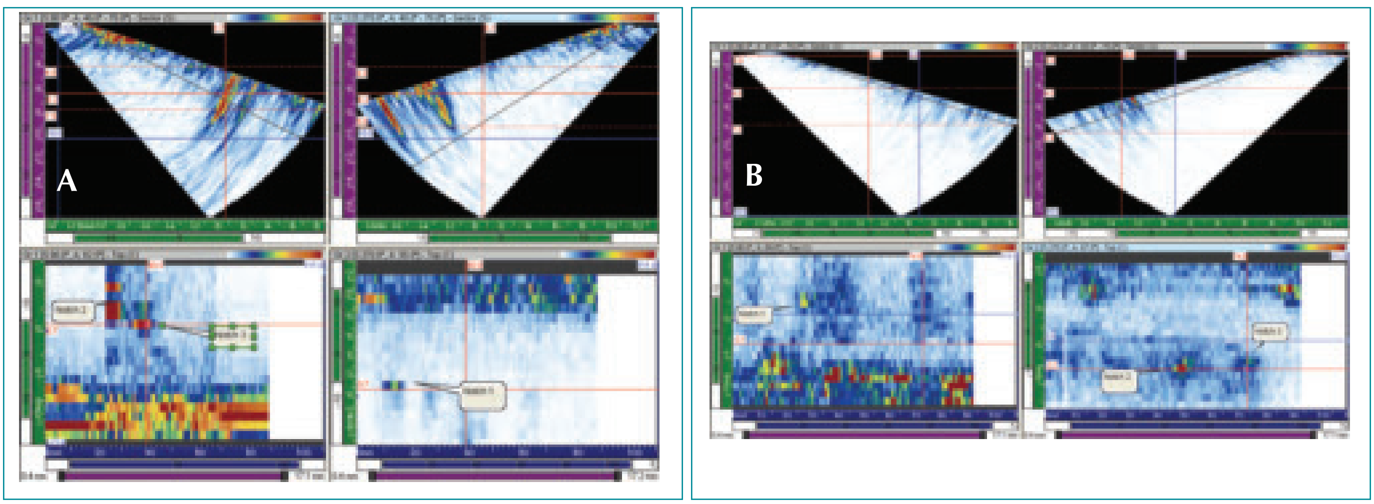


Fig. 8 — Scans of 25-mm-diameter, 3-mm wall thickness pipe showing notches. A — Carbon steel pipe; B — stainless steel pipe.

notches and holes were scanned with an OmniScan MX using typical phased array inspection procedures based on S-scans. The same setup was used for the two probes except the gain was necessarily reduced for the curved probe. The 6-dB drop criterion was used for sizing.

Figures 5 and 6 show sample scan results from the 70- and 38-mm pipes, comparing flat and focused arrays.

All the calibration reflectors in the two tubes showed consistent results: smaller-diameter tubes gave more severe defocusing (beam spread) than larger diameters, and focused arrays gave much better lateral sizing results than flat arrays.

Rather than have multiple curved arrays, a manufacturing compromise was made. The modeling was performed on 5- and 10-MHz arrays; in practice, we chose a 16-element, 7.5 MHz array. The two curvatures selected as optimum were 30 mm for diameters less than 25 mm, and 40 mm for diameters above that. A compromise radius of 35 mm was chosen. Along with a 60-deg natural angle wedge for high angles, this became the standard for the new scanner (Ref. 6).

Scan Results

Figure 7 shows a typical scan of a weld from both sides using the new system. The pipe was 115 mm in diameter and approximately 12.7 mm thick. The ultrasonic parameters were slightly varied to illustrate possibilities.

As with all the company's phased array inspections, considerable detail can be viewed in the tables in Fig. 7, e.g., defect depth, amplitude, and position. In addition, cursors can be used to box in a defect for measurements (Ref. 1). The angle of maximum amplitude can be determined using the cursor, and displayed as an A-scan for those who prefer such views. Overall, there is the usual choice of views available: A-, B-, S-, and C-scans. These more than fulfill code requirements.

In contrast, Fig. 8 shows very small, thin pipes: 25-mm (1-in.) diameter and 3-mm wall. The pipe in Fig. 8A is carbon steel; a stainless steel pipe is shown in Fig. 8B. Note that the carbon steel notches show better than the stainless steel, but this is primarily due to the problems with ultrasonic inspection of austenitic steels.

Conclusions

1. A novel, semiautomated small-diameter pipe scanner has been produced with two major features: Low profile for clearance, and focused arrays to minimize lateral beam spread (and hence overcalls).

2. The scanner has a number of useful features. It is adaptable from 21- to 115-mm diameters; offers one-side access scanning; and works on both carbon and stainless steel.

3. The experimental results confirm that using the scanner and focused arrays produce significantly better defect length estimates. IT

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6. For wedge and probe details, see *www.olympusndt.com/en/probes/*; for COBRA, see *www.olympus-ims.com/en/scanners/cobra/*.

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Official Interpretations:

D17.1, *Specification for Fusion Welding for Aerospace Applications*

Subject: Qualified Thickness Range
Code Edition: D17.1:2001
Code Provision: Paragraph 4.3.3.1
AWS Log: D17.1-01-I04

Inquiry: Paragraph 4.3.3.1 (1) defines the qualified thickness range based on a test weld thickness of t. It also defines that 2 test welds qualify welds with intermediate thickness.

It is, however, unclear on the qualification range when 2 unequal thicknesses are used in a fillet test weld. This can be interpreted in several different ways. Take the following for example:

a.) 0.67t of thinner member to 4t of the thicker member
b.) 0.67t to 4t of the thinner member
c.) Range of thinner member to thicker member thicknesses

Proposed reply: Define qualified thickness range if unequal thickness members are used in fillet weld tests for welder qualifications.

Response: *The answer is 0.67t to 4t of the thinner member.*

Subject: Special Application Qualification Range
Code Edition: D17.1:2001
Code Provision: Paragraphs 4.3.7.5, 4.3.3.1
AWS Log: D17.1-01-I05

Inquiry: When the "Special Application" provision of paragraph. 4.3.7.5 is invoked, can the provisions of paragraph 4.3.3.1 "Qualified Thickness Range" (0.67T – 4T) be applied?

Response 1: *No.*

By Noam Amir

Inspecting Tubing with Sound

An acoustic-based technology offers an option for 100% inspection of heat exchangers and other tube applications

Most manufacturing facilities today contain thousands of tubes and pipes as the backbone of their fabrication processes. The tubes and pipes extract, generate, and deliver the required energy content that enables the facilities to be productive, efficient, and profitable. Of these, heat exchangers are one of the most common workhorses in many industries. It is, therefore, imperative that these perform at their utmost capacity, which requires regular, comprehensive inspection and maintenance. Traditionally, a process known as sampling has been used for heat exchanger tube inspection. This involves testing a percentage of tubes (typically 8–10%) as a gauge of the entire system. Sampling, however, brings a significant amount of risk when making major decisions regarding the integrity of these critical systems.

The conventional nondestructive examination (NDE) methods that have historically been used for heat exchanger inspection can be invasive, slow, and cumbersome. Additionally, these methods are limited by tube configuration, size, and material, making it difficult for full inspections to be carried out. As a result, it isn't surprising that the practice of sampling has become the typical equipment owner's inspection alternative. As new

Fig. 1 — The Dolphin™ system from AcousticEye performs quick, nondestructive inspections of tubes and pipes. The system inspects tubes made of any material and in any configuration.

Fig. 2 — The acoustic pulse reflectometry system in use. It can detect such discontinuities as holes, pits, wall loss, and bulges.

technologies enter the market that enable 100% inspection of tubes easier and faster than previously possible, organizations can begin to put an end to sampling to ensure the safety and efficiency of their critical systems.

Acoustic Pulse Reflectometry

An acoustic-based technology is enabling companies to accurately and rapidly perform comprehensive inspections, drastically reducing the chance of catastrophic failures. Acoustic pulse reflectometry (APR), the technology found in the AcousticEye Dolphin™ tube inspection system (Fig. 1), offers speed, accuracy, and objective testing results.

Acoustic pulse reflectometry inspects pipes and tubes from the inside and is independent of tube material or configuration. It is noninvasive and the report generated is objective and independent of a highly trained professional; therefore, the entire inspection procedure can be up to ten times faster than other methods.

The core technology of APR encompasses an acoustic pulse traveling down the air enclosed in the tube — Fig. 2. As long as the pulse does not encounter any changes in the tube cross section, the pulse continues to propagate, with some attenuation due mainly to friction between the molecules of air and the tube wall. If, however, any discontinuity is encountered, reflected waves are created, which propagate back up the tube. The more abrupt the changes in the cross section, the stronger these reflections are. Software records and analyzes the reflections to determine what kind of discontinuity caused them. Discontinuities diagnosed include holes, pits, general wall loss, and bulges. By identifying these types of faults before problems arise, organizations can prevent costly failures down the road.

Real-World Applications

Acoustic pulse reflectometry is being successfully used in the inspection of heat exchangers. Essentially, heat exchangers are devices used to transfer heat from one fluid to another. Most commonly, heat exchangers are constructed of hundreds to thousands of tubes in parallel, encased in a metal shell. In general, heat exchangers are found in a large variety of industries such as power plants; refineries; paper mills; heating, ventilation, and air-conditioning; food and beverage; chemicals; and many more. Operating around the clock over long periods, heat exchangers are subject to eventual degradation or failure through many mechanisms: erosion, corrosion, abrasion (caused by support plates rubbing against the tubes), thermal shock, sedimentation, fouling, etc. Plant operators are aware of these inevitable issues and aim to inspect their heat exchangers periodically, both to ensure their efficiency and to prevent catastrophic failures, which can be very costly. Acoustic pulse reflectometry is helping plant operators to easily and quickly perform these important inspections, minimizing downtime for their facilities.

Acoustic pulse reflectometry is also a valuable tool in the assessment of internal cleanliness of heat exchanger tubes. Tubes are routinely cleaned during plant turnaround periods to remove any deposits hampering their functionality; however, the traditional technologies used for this are slow. In an APR inspection, tubes that were not properly cleaned will demonstrate multiple reflections from the constriction caused by such deposits, providing a rapid and cost-effective means for assessment of tube cleanliness as the inspection is carried out.

Additionally, APR has been applied to inspection of reactors in chemical plants. Reactors are similar to heat exchangers, though they operate at elevated temperature and pressure levels, causing failures in the form of both bulges and collapse of tubes. Both types of faults present a great challenge to traditional testing methods, but with the noninvasive nature of APR, complete testing of these systems is possible.

A Look at Traditional NDE Inspection Methods

While other NDE methods have been around for ages, they do not deliver the ideal inspection. The ideal should be fast, accurate, and easy to use. This has led to the accepted process of sampling.

The most well-known inspection method for heat exchangers is eddy current testing (ET). In this method, a probe is physically pushed through each tube and pulled back. The probe contains one or more coils, whose electrical impedance is affected by the surrounding tube. Eddy current testing is relatively accurate, with the ability to inspect 30–60 tubes per hour, but it is heavily dependent on tube wall material, which is a twofold limitation: It cannot be used to inspect ferromagnetic materials at all, and requires a "calibration standard" for any tube it can be used on.

Additionally, ET depends heavily on the subjective interpretation of the technician. A study conducted by MTI and EPRI, for example, showed that a skilled technician detected 87% of the faults in a heat exchanger mockup, whereas another technician detected only 50% of the faults on the same tubes.

Another well-known NDE method is based on ultrasound. Ultrasound is a form of reflectometry: Sending a wave through a medium, and recording any reflections from discontinuities in the medium. Adapting this method to tube inspection is quite involved: Once more, a probe is invasively inserted down the tube. The probe creates an ultrasonic beam parallel to the tube axis, which hits a spinning 45-deg mirror. As the probe moves down the tube, it scans the tube wall in a spiral. This method is known as an internal rotating inspection system (IRIS). The IRIS method, although accurate, does have drawbacks. The need for good resolution dictates a narrow beam, which in turn entails a very slow pull rate if the spiral scan of the tube is to provide full coverage. Filling the tubes with water, without air bubbles, is messy and time consuming. An internal rotating inspection system also requires cleaning the tubes down to the metal, which is time consuming and costly, and must take place before inspection begins. Finally, the accuracy of IRIS reduces with the thickness of the tube walls, and it cannot be used below a thickness of 0.9 mm.

Benefits of APR

Following are some of the main benefits of APR, along with a comparison to other NDE methods.

- **It is not material dependent.** Tube material does not affect APR. It works equally well on metal (ferromagnetic or not), graphite, composite, and plastic. This is in contrast to eddy current, which cannot work on ferromagnetic tubes.

- **It does not require calibration standards.** With APR, reflections are detected by subtracting each measurement from a baseline that represents a faultless tube, so there is no need to calibrate on known faults. Eddy current testing requires a calibration standard, which is a sample tube with carefully manufactured defects, for every type of material, diameter, and wall thickness.

- **It provides straightforward analysis.** It offers a straightforward method for detecting and sizing faults of tubes, comparing the peak reflections to sets of predetermined thresholds. Software is available to easily perform this comparison, and can scan through the measurements from hundreds of tubes in seconds, automating data analysis. Eddy current readings must be analyzed by a highly trained technician, a lengthier and more subjective process.

- **It enables full inspection of all types of tubes.** Acoustic waves propagate easily through U-bends, coils, and spirals, which are often overlooked in testing or usage due to their historical difficulty to inspect with invasive methods. By enabling reliable and easy testing of these different tubes, APR is helping companies to opt for more energy-efficient tubes in their systems.

Summary

Today's emphasis on preserving the environment brings the importance of well-maintained tubes, integrity testing, and inspection to a new meaning. Industry should closely examine its energy consumption, efficiency, and increased need to quickly and efficiently maintain, inspect, and refurbish facilities. Acoustic pulse reflectometry technology is enabling both small and large enterprises to increase efficiency, safety, and inspection speed. By eliminating sampling, unnecessary and costly downtime of mission-critical equipment can be avoided. With APR, it is not necessary to judge the integrity of 100% of the tubes based on a choice selection of tested tubes. Instead, 100% of the tubes can be tested quickly and at less cost. ■

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Ultrasonic Phased Arrays Quickly Detect Corrosion

The technology can be used on most common geometries, such as pipes, vessels, and tank bottoms suspected of having corrosion problems

Industrial plants require safe and reliable operations, but corrosion is a major problem for the owners of industrial equipment, installations, and plants, due to the presence of corrosive chemicals and harsh operating and environmental conditions. For industries throughout the world, corrosion costs billions of dollars. Mitigation costs include corrosion prevention and detection, as well as repairing the results of corrosion.

Corrosion requires reliable methods for efficient detection. If undetected for a long time, corrosion can cause leaks and component failures, which reduce the performance and reliability of important equipment. In extreme cases, corrosion can lead to unexpected disruptions that are often costly in terms of lost production, the expense of repairs, lost or contaminated products, environmental damage, and potential harm to humans. In many facilities, key equipment may have been in service for decades and have the potential to be compromised even by relatively slow corrosion mechanisms.

What Is Corrosion?

Corrosion in welds occurs despite the proper material having been selected, industry standards followed, and welds deposited that possess complete joint penetration and have the proper shape and contour. Corrosion occurs as a result of the material's exposure to harsh conditions, and this may be external, internal, or both.

Corrosion is a chemical or electrochemical reaction between a material, usually a metal, and its environment, which produces a deterioration of the material and its properties. Corrosion can be widespread and relatively uniform or localized, in the form of pitting and cracking.

Fig. 1 — The latest phased array equipment, such as the Phasor CV/DM from GE Sensing & Inspection Technologies, uses multiple ultrasonic elements and electronic time delays. Advantages include repeatability, speed of inspection, and capability for inspecting complex geometries. Shown is the screen shot of the reference block.

Considerable efforts are expended to reduce the extent of corrosion by techniques such as inhibitors, coatings, metallurgy selection, and cathodic protection. However, these methods are typically slow, and fail to completely prevent corrosion.

It is, therefore, essential to continuously monitor critical equipment to prevent catastrophic failure and to maintain excellent on-stream factors.

How Can We Detect Corrosion?

Usually, corrosion detection is performed with a thickness gauge or a portable flaw detector. The residual thickness is checked by spot measurements or a couple of coarse scans. If only general corrosion is present, this method works fine. However, this technique has a high chance of missing localized pitting corrosion, even when large surface samples are scanned.

Ultrasonic Phased Array

Ultrasonic phased array technology has become an established method for advanced nondestructive examination (NDE) applications. Phased array technology reveals defects hidden inside a structure or weld by testing the structural integrity. This newer ultrasonic testing technique is based on generating and receiving ultrasounds, but instead of a single transducer and beam, phased array equipment uses multiple ultrasonic elements and electronic time delays to create beams with constructive and destructive interference patterns — Fig. 1.

Phased array is an advanced pulse-echo technique that utilizes multiple miniaturized transducers and time delays to shape the ultrasonic beam to a desired angle and focus. The versatility of the system permits simultaneous views of different presentations, such as sectoral views as

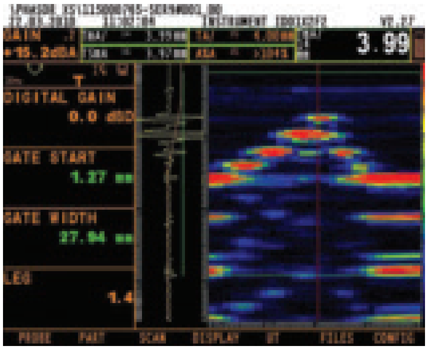


Fig. 2 — Corrosion pattern as displayed by the Phasor CV/DM. Phased array technology can display simultaneous views of different presentations, such as sectoral views, as well as A-scan, B-scan, and C-scan representations.

Fig. 3 — An example of a dual array corrosion probe.

well as A-scan, B-scan, and C-scan representations — Fig. 2.

In comparison to manual pulse-echo techniques, the advantages of phased array testing are its excellent repeatability, increased inspection speed, more accurate results, and the ability to inspect complex geometries and to visualize indications in welds and/or base materials using B, C, D, and S-scans (with all A-scans included). Moreover, phased array allows the digital storage of all data, location, and system settings, and is very much safer to operate within a working environment when compared with NDE methods that use X-rays and gamma-rays for detecting imperfections.

This technique is ideal for use in combination with tank floor testing. The tank floor is first tested with magnetic flux leakage (MFL) equipment. Traditionally, when an indication is found by MFL, the area of the indication is checked with a thickness gauge or portable flaw detector. The chances of missing a pinhole indication are very high using that equipment, but when a phased-array probe is used (Fig. 3), the indication becomes very clear. The time taken to inspect the area is also much shorter using the phased-array probe, since it can inspect 44 mm at a time.

Phased array can also be used for the detection of laminations caused by hydrogen-induced cracking. Typically, this is done using a traditional ultrasonic probe, which is time consuming. Using the phased-array probe saves a lot of time, because it can quickly determine whether there are any indications present or not.

The probe can be used on all vessels or pipes that are suspected of having corrosion problems.

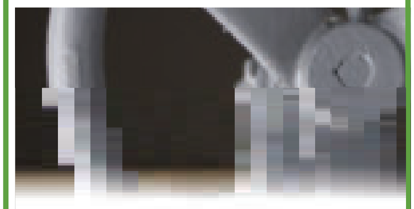
Phased Array by SGS Industrial Services

SGS Industrial Services, part of the SGS Group, is a global service provider for technical verification, inspection, testing, and conformity assessment. SGS Industrial Services performs conventional and advanced NDE inspections throughout the world and is continuously developing its services and applications. The company operates in more than 30 countries worldwide.

Applications include fabrication, pipe manufacturing, pipelines, plant construction, chemicals, petrochemical plants, shipyards, the offshore industry, and conventional and nuclear power plants.

When conducting phased array inspections, the company's experienced and qualified NDE experts not only provide the phased array inspection test results, but also a detailed interpretation of the data obtained and technical consultancy to advise the next steps to be carried out.

Based on information provided by SGS Industrial Services, www.sgs.com/industrial.



By Albert J. Moore Jr.

Writing the Welding Procedure Specification

Here's help in writing useful WPSs that will ensure welders meet the customer's requirements

This is the fourth and final article in a series aimed at helping you understand the concept of Welding Procedure Specifications (WPSs). This article aims to help you write an actual WPS.

Before getting into a lot of detail about what a Welding Procedure Specification (WPS) must contain, I believe it is useful to define what the purpose of the WPS is. The WPS is a formal written instruction that provides the welder with the directions necessary to deposit welds in a consistent manner that meets the project specifications. To use the same analogy as in the previous three articles, the WPS is a recipe a welder can follow to make a weld much like a cook follows a recipe to make brownies.

This article shows you how to write a WPS that the welder can use and will ensure the customer's requirements are met. While the approach works for both prequalified WPSs and those qualified by testing, we will develop a WPS that is qualified by testing and review some essential variables typically required by a welding standard. However, keep in mind that no two welding standards are the same. Each welding standard has unique requirements that have to be reviewed to ensure the WPS complies with all the requirements. While our approach is applicable for writing a WPS for any standard, never forget that a WPS written to meet ASME Section IX (and the applicable construction code) is different from a WPS written to meet AWS D1.5 or NAVSEA S9074-AR-GIB-010/278.

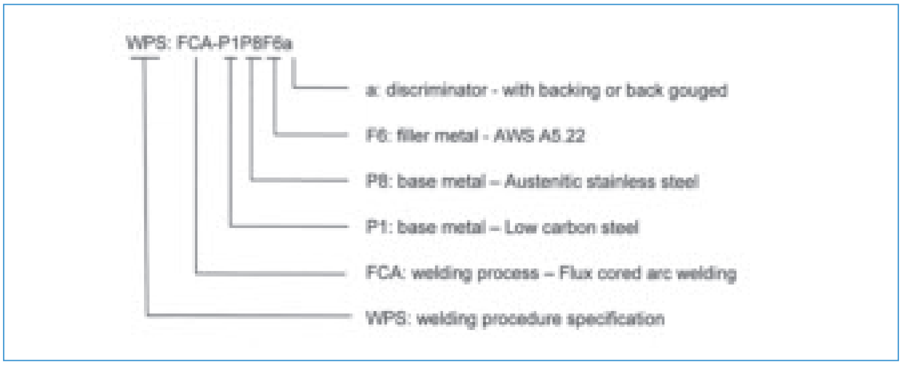


Fig. 1 — An example of a numbering system for Welding Procedure Specifications.

What the WPS Needs to Include

Identification

Each welding document must have a unique identification. Welding standards do not define the system of identification. It is left to the manufacturer to devise a system suitable for its needs. A simple numbering system is fine when there are a limited number of WPSs. However, as the number of WPSs increases, too simple of a numbering system becomes clumsy to use. I prefer an identification system that provides the user with some basic information about the WPS. Remember that it is not a good idea to use the same system for both the Procedure Qualification Record (PQR) and the WPS. I use an alpha numeric system that lists the welding process, base metals, filler metal, and, finally, a single letter discriminator to differentiate between two similar WPSs. Figure 1 is an example of this system.

There is nothing sacred about this system. Use what works for you, but keep in mind that a system with a rational basis is easier to remember and use.

Supporting PQRs

Welding procedures that are qualified by testing must list the supporting PQR(s). A WPS qualified by testing must be supported by one or more PQRs. An example in which more than one PQR is used to support a single WPS is when the welding positions used in production must be qualified by testing. Once all the required PQRs are approved, they can be combined into one WPS.

Welding Process

The WPS has to list the welding process and, when applicable, any variation such as transfer mode, whether pulsing is used, and whether the process is manual, semiautomatic, mechanized, automatic, or robotic.

ANNEX A-1
Carbon Steel Specifications/Preheat

Preheat Requirements

Specification	Grade	Thickness	Minimum Preheat	Comments
ASME SA36			32°F	Plate & shapes
ASME SA53	Type F, S, E, Grades A and B		(If ambient temperature is below 32°F,	Pipe welded and seamless
ASME SA105		⅛ to ¾ in.	base metal shall be	Flanges and fittings
ASME SA106	Grade A and B		preheated and maintained	Pipe, seamless
ASTM A108	1015 CW, 1018 CW, 1020 CW		at a min. temperature of 70°F.)	Bar
ASME SA134	SA283 Grades A, B, C, D	>¾ in. to 1½ in.	50°F	Pipe, welded
	SA285 Grades A, B, C			
ASME SA139	Grades A, B, C, D, E	>1½ in. to 2½ in.	150°F	Pipe, welded
ASME SA178	Grades A and C			Tube, ERW
ASME SA179		Over 2½ in.	225°F	Tube, seamless
ASME SA181	Class 60			Flanges and fittings
ASME SA192				Tube, seamless
ASME SA234	WPB			Fittings
ASME SA266	Class 1			Forgings
ASME SA283	A, B, C, D			Plate
ASME SA285	A, B, C			Plate
ASME SA333	1, 6, 10			Pipe, seamless and welded
ASME SA334	1, 6			Tube, welded
ASME SA352	LCA and LCB			Castings
ASME SA372	A			Forgings
ASTM A381	Grade Y35, Y42 Y48, Y46, Y50			Pipe, welded
ASME SA420	WPL6			Fittings

Fig. 2 — Annex A-1 is an example of one page from an annex, and shows how an annex can be used to list the base metals and preheat requirements.

Base Metals

The WPS must list the base metals to be joined. Whether to list the base metal specification; the P, M, or S number; or the base metal chemistry is a decision the manufacturer has to make in conjunction with the applicable welding standard.

Welding standards group the base metals together that have similar weldability. AWS D1.1 divides the carbon steel and high-strength low-alloy steels into Groups, ASME Section IX groups them by P numbers, NAVSEA uses S numbers, and AWS B2.1 uses M numbers. Base metals included in a specific grouping typically have similar chemistry and weldability. Unless impact toughness is a requirement of the applicable welding standard, all the base metals within a group can be welded with the same WPS. The WPS usually lists the group to indicate all the base metals within the group can be welded.

There is one major problem with this practice. The problem is that the grouping (P #, M #, S #, etc.) is not typically stenciled on the raw material. There is no easy way for the welder (or the inspector) to know whether the WPS is applicable to the piece of raw stock in the inventory based on the material specification marked on the metal.

What information is typically stenciled on the raw material and what information is not? Usually the size and material specification and grade or alloy are marked on the raw stock. For example, the welder might pick up a length of stainless pipe that is marked "ASTM A312 Type 316" along the length, but P8 is not listed anywhere. A structural wide flange beam might be marked ASTM A992, but you will not find Group II listed anywhere on the beam.

What to do? How can the welder correlate the information listed on the WPS to the information marked on the raw material? One approach is to list the grouping, i.e., P# or M #, etc., on the WPS and reference an annex that contains all the applicable base metals in the same group listed by the WPS. There are other alternatives such as listing all the applicable material specifications and grades or alloys in the WPS, but that would turn the WPS into a 20-page document. Another solution is to provide the welders with their own copy of the welding standard, but to say that solution would be costly is an understatement. Including an annex with the WPS is a viable solution — Fig. 2. The annex only lists those material specifications used by the manufacturer.

Table 1 — Example of the Welding Parameters Recorded in a PQR

Procedure Qualification Data
GF-F6P1-A
19-Oct-2010

Welding Parameters

Side	Pass	Layer	Class	Diameter	Volts	Amps	WFS	Seconds	Travel	Heat Input	Deposit Thk.	PH/IPT
A	1	Root	E7OS-2	⅛	12	160		672	4.0	28800	3/16	81
A	2	2	E7OS-3	⅛	11	175		687	2.4	48090	¼	108
A	3	3	E71T-1MJH4	0.045	26.5	200	299	302	5.8	55080	⅜	84
A	4	3	E71T-1MJH4	0.045	27	235	350	188	8.8	43377	⅜	145
A	5	3	E71T-1MJH4	0.045	27	235	350	198	9.0	42158	⅜	153
A	6	4	E71T-1MJH4	0.045	27	235	350	193	9.0	42140	½	220
A	7	4	E71T-1MJH4	0.045	27	230	350	208	8.8	42170	½	185
A	8	4	E71T-1MJH4	0.045	27	230	350	188	9.7	38607	½	204
A	9	4	E71T-1MJH4	0.045	27	238	350	246	7.6	50993	½	220
A	10	5	E71T-1MJH4	0.045	27	230	350	181	10.6	35125	¾	243
A	11	5	E71T-1MJH4	0.045	27	230	350	212	9.1	41141	¾	275
A	12	5	E71T-1MJH4	0.045	27	234	350	227	8.5	44818	¾	258
A	13	5	E71T-1MJH4	0.045	27	239	350	236	8.1	47591	¾	289
A	14	Cover	E71T-1MJH4	0.045	26	199	305	314	6.3	49251	⅞	208
A	15	Cover	E71T-1MJH4	0.045	26	200	305	274	7.2	43176	⅞	251
A	16	Cover	E71T-1MJH4	0.045	26.6	200	305	310	6.4	49976	⅞	272
A	17	Cover	E71T-1MJH4	0.045	26	205	305	260	7.6	41994	⅞	84
A	18	Cover	E71T-1MJH4	0.045	26	199	305	284	7.0	44528	⅞	110

The annex also serves another useful purpose. I find it the perfect location to list preheat and interpass requirements.

Filler Metal

If a filler metal is required, it must be listed in the WPS. Filler metals are grouped in a similar manner as base metals. Filler metals are grouped by F numbers by AWS and ASME; NAVSEA welding standards group the filler metals by A numbers.

F numbers can be used for a couple of purposes. The F number is considered to be an essential variable for welder performance qualification and when qualifying the WPS.

The F number is listed on the WPS, and the WPS is valid for all the electrodes contained within the F number group. That does not mean the welder can substitute one filler metal for any other filler metal within the same group; it simply means the WPS does not have to be requalified if the manufacturer decides to change from one filler metal to another within the same F number group.

In addition to the filler metal F number, the specification and the classification are listed. Listing the specification and classification narrows the selection of filler metals the welder can use. An example might be useful to illustrate how the system works. Let's look at the F number group F6 (there is no F6 in D1.1, so you can stop looking). F6 contains all ferrous filler metals not included in groups F1 through F5. F6 includes filler metals for GMAW, FCAW, GTAW, OFW, and SAW. It includes filler metals for carbon steels, and high-strength low-alloy, high-alloy, and heat-treatable low-alloy steels. It's a trash heap of ferrous filler metals. You will find F6 filler metals listed in both ASME Section IX and AWS B2.1. It wasn't always this way. Before the introduction of Standard Welding Procedure Specifications and the influence of ASME, F numbers were more specific. It used to be that in B2.1 the F numbers were also used to group filler metals, the alloy constituents, and the welding process. You might encounter an F10 filler metal when reviewing a WPS written in the 1970s or early 1980s. It was after 1984 that AWS B2.1 adopted the ASME F number groupings.

A weld is a composition or alloy of the base metals being joined and the filler metal used. If you change the composition of either member being welded, there is a high probability the alloy composition of the completed weld can be changed even though the F number has not changed. A system of A numbers that applies only to ferrous metals was devised to address that problem. The A number reflects the chemistry of the completed weld. The WPS is only qualified for a weld with a specific A number when working with either ASME Section IX or AWS B2.1. A numbers are included in AWS D1.1 and D1.5 because those welding codes only apply to carbon- and low-alloy steels where the mechanical properties of the weld are not as likely to be affected by dilution if matching filler metals are used.

The WPS also lists the appropriate filler metal diameters the welder is to use.

Should a consumable insert be required, it is usually included along with the filler metal. Other things that might be included are the flux for SAW and any supplementary fluxes, filler metals, or powders used.

Shielding Gas

Gas tungsten arc, gas metal arc, and flux cored arc welding typically require a shielding gas to protect the molten weld pool from atmospheric gases. The gas may be an inert gas such

Table 2 — Descriptive Statistics. Analysis of the Welding Data Recorded in the PQR

Data Analysis
Procedure Qualification
GF-F6P1-A
19-Oct-2010

	Volts	Amps	WFS	Seconds	Travel	HI	PH/IPT
Mean	26.7	221.2	332.8	238.8	8.1	44507.9	200.1
Median	27.0	230.0	350.0	231.5	8.3	43276.2	214.0
Standard Deviation	0.4	16.8	23.0	46.6	1.3	5006.5	67.3
Range	1.0	40.0	51.0	133.0	4.8	19954.3	205.0
Minimum	26.0	199.0	299.0	181.0	5.8	35125.3	84.0
Maximum	27.0	239.0	350.0	314.0	10.6	55079.7	289.0

as argon or helium, a reactive gas such as carbon dioxide, or a combination of gases that may have minor additions of oxygen or hydrogen. The gas or gas mix to be used is influenced by the welding process, the base metals being joined, and, possibly, the welding position.

AWS first published A5.32, *Specification for Welding Shielding Gases*, in 1997. Shielding gases meeting the requirements of A5.32 are pure enough for all welding applications except for the gases used for laser beam welding.

In addition to listing the shielding gas, the WPS needs to list the appropriate flow rates. The flow rate is a function of the shielding gas and the diameter of the gas nozzle used. Different shielding gases have different densities, which necessitates using the proper flow meter and flow rate to provide adequate shielding of the molten weld pool. The shielding gas is usually an essential variable. The WPS will have to be requalified if the manufacturer decides to change to a different shielding gas or mixture of shielding gases.

Trailing gases and purge gases are also listed when they are required. The need to use a purge gas and the type of purge gas required is not left to the discretion of the welder.

While on the subject of purge gases, it is my recommendation that a method of determining when the purge is satisfactory should be included in the WPS. Different base metals can tolerate different levels of contamination. Reactive base metals are intolerant of moisture, oxygen, or nitrogen when compared to austenitic stainless steel. Success or failure when welding reactive and refractory base metals can depend on the completeness of the purging operation. Specific instructions for detailed information about purging can be provided to the welder through use of another annex. The WPS can simply list that purging is required and reference the appropriate annex for more detailed information.

Welding Parameters

The WPS has to provide the information the welder needs to set the welding parameters. The information the welder needs includes the type of welding machine suitable for the welding process to be used, current type, polarity, arc voltage, amperage (wire feed speed), electrode extension (if applicable), tungsten type and end preparation (if applicable), travel speed, etc. The parameters listed in the WPS are those that are appropriate for the welding process being used.

The WPS is based on the information gathered while welding the successful PQR. If the PQR was properly documented, it will list the welding parameters the welder used while welding the test coupon. The parameters listed in the PQR serve as the starting point for the WPS. The welding parameters used to weld the test coupon are "good" because the test weldments passed all the required tests. The welding parameters used when the test weldments were welded are likely to vary somewhat from bead to bead. An example of the welding parameters recorded in the PQR are listed in Table 1.

Recording the welding parameters in a MicroSoft Excel™ spreadsheet makes it easy to determine the minimum, maximum, and ranges for each parameter used to weld the test coupon. The descriptive statistical tool provided by MicroSoft Excel™ can be used to analyze the data. The presentation is shown in Table 2.

Some welding standards such as AWS D1.1, D1.5, B2.1, etc. allow the ranges listed on the WPS to be "opened up" by certain amounts, usually expressed as percentages of the values recorded on the PQR. In such a case, I would typically use the median value shown in Table 2 as my data point.

It is acceptable to use the parameter ranges listed by the manufacturer if the welding standard used does not impose limits on those ranges, i.e., voltage, wire feed speed (WFS), amperages, etc. The ranges listed by the WPS should be reasonable. The average welder should be able to deposit an acceptable weld using the high and low values of the ranges listed in the WPS.

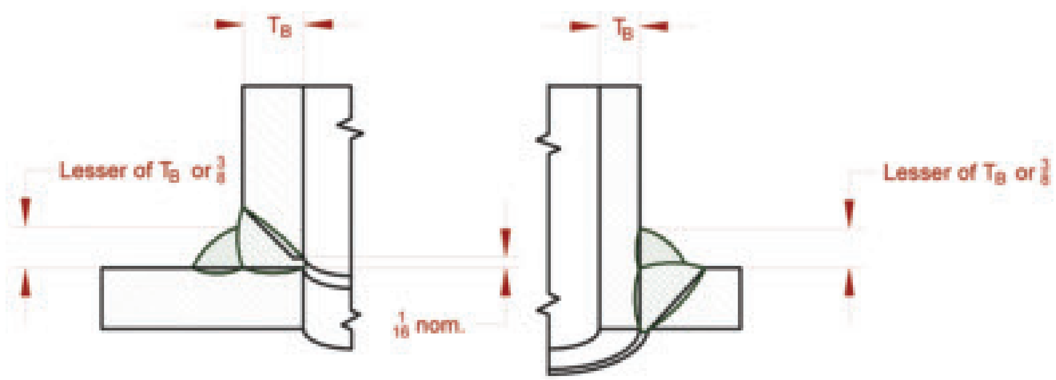
There are three important welding parameters to note when welding with either FCAW or GMAW. They are important because they are "constants" that the welder sets. The parameters are arc voltage, wire feed speed, and electrode extension (EE). In general, once the wire feed speed is dialed into the wire feeder, it does not change whether the welder is actually welding or holding the gun in the air. Amperage will vary as the welder increases or decreases the electrode extension. Welders can use the electrode extension to their advantage to increase the amperage by shortening the EE slightly or decrease the amperage by

Annex B-2

Welding symbols shall be interpreted in accordance with AWS A2.4-2007, *Symbols for Welding, Brazing, and Nondestructive Testing*. The following shall be considered default values when interpreting welding symbols.

1. Intermittent Fillet Welds: The following requirements apply to intermittent fillet welds;
   a. Intermittent fillet welds shall begin and terminate at the ends of the joint. The end welds shall be no less than two-times the specified segment length.
   b. Length: The length specified by the welding symbol shall be the minimum acceptable length of each weld segment. The minimum segment length shall be 1½ in.
   c. Size: The weld size specified by the welding symbol shall be the minimum acceptable weld size of each weld segment.
   d. Spacing: The maximum unwelded length between adjacent weld segments shall be no greater than the specified pitch minus the length of the weld segment.

The sketches that follow are Standard Details. Other joint details may be utilized provided a welding symbol or sketch provides all the applicable information.



Typical Branch Connection consisting of a coupling or half-coupling welded to the run pipe. The diameter of the coupling shall not exceed the smaller of NPS 2 or ¼ the diameter of the run pipe. As a minimum the coupling shall have a rating of Class 2000.

Fig. 3 — Annex B-2 is an example of one page from an annex showing the joint details.

increasing the EE by a small amount. Some FCAW electrodes require a short EE of ½ to ¾ in. and other electrodes require 1½ to 3 in. to operate properly. It is also important to recognize the need to control EE when welding with GMAW. Short circuiting transfer requires a shorter EE than either the globular or the spray transfer modes.

The type of tungsten electrode required when welding with the GTAW process should be included in the WPS. The end preparation should be noted as well. The base metal to be welded and the type of current (direct or alternating current) used can influence the choice of electrode. The current type used largely dictates the end preparation. If direct current electrode negative is used, the tungsten is typically tapered to a blunted point. If alternating current or direct current electrode positive is used, the end of the tungsten has a balled end.

Welding with pulsing characteristics presents a host of new concerns. Each manufacturer has developed specific waveforms utilizing various values for the frequency, upslope, downslope, duration, peak, and background currents, and in some cases even the characteristics of the power supply varies from constant current to constant potential while the "arc is on." To state it as simply as possible, it is nearly impossible to qualify a pulse welding procedure for GMAW using a welding machine and program developed by one manufacturer with a machine manufactured by a different company.

ASME requires the "power" to be recorded as a "work around" of the complexities introduced by the pulsing mode of welding. It is a move in the right direction, but simply matching the "power" of one pulsing machine to another is not going to produce the same results. The only way to compare the output of one machine model to another is to use an oscilloscope. The bottom line is that if you intend to write a WPS for pulsing, use the same model of welding machine for

Welding Procedure Specification

WPS: GTA/FCA-P1F6

WPS:		GTA/FCA-P1F6		Rev.:		O		Date: 28-Nov-10	
Supporting PQR:		GF-P1F6-A		Rev.:		—		Date: 19-Oct-10	
Process:	GTAW	MA	X	SA	—	ME	—	AU	—
Process:	FCAW	MA	—	SA	X	ME	—	AU	—

Base Metal

Base Metal: Alloy/Grade:	Low-carbon, medium-carbon, and high-strength low-alloy steels. Refer to Annex A-1.		Low-carbon, medium-carbon, and high-strength low-alloy steels.
P No.:	1		1
Product Form:	Shapes, plate, pipe, & fittings	Welded to	Shapes, plate, pipe, & fittings
Thickness:	1⁄16 through 2 in.		1⁄16 through 2 in.
Diameter:	All diameters		All diameters
Group No.:	1		1

Joint Details

Fillet welds, partial joint penetration groove welds, and complete joint penetration groove welds as depicted in Annex B-2

Filler Metal

Process:	GTAW	FCAW
Weld Layer:	Root and 2nd layer	Intermediate and cover
Specification:	ASME A5.18	ASME A5.20
Classification:	E70S-2	E71T-1MJH4 (ESAB Dual Shield II 70T-12H4)
F Number:	6	6
Diameter:	1⁄8 in.	0.045 in.
Product Form:	Rod	Spooled wire
A No.:	1	1
Maximum Deposited Thickness:	1⁄2 in.	1½ in.
Consumable Insert:	None	None
Classification:	NA	NA
Supplementary Flux:	None	None

Fig. 4 — A sample WPS that was qualified by testing. (The WPS continues on pages 35 and 36.)

production as was used to qualify the welding procedure. The name of the manufacturer, model number, and the pulsing program are also important information that should be recorded on the PQR by the test witness and needs to be listed on the WPS used for production.

Travel speed is listed in units of inches per minute or millimeters per second. It is the distance divided by the time it takes to weld from point A to point B along the length of the joint. Whether the welder utilizes a stringer bead or a weave bead can influence the mechanical properties of the completed weld. In general, when welding carbon steels, the use of a weave bead technique results in higher heat input, slower cooling rates, coarse grains, higher ductility, slightly lower tensile and yield strengths, and lower toughness in comparison to a weld made using stringer beads. Provided we restrict the conversation to low and mild carbon steels, both weave and stringer beads will meet the minimum ultimate tensile strength and yield strength requirements of the applicable welding standard if a matching filler metal is used. However, if the base metals being welded are aluminum alloys, quenched and tempered steels, austenitic stainless steels, etc., changes in heat input can have a dramatic influence on the mechanical properties.

The interrelationship between arc voltage, WFS, and amperage can make it difficult to present the information to the welder in a meaningful way. A graphic presentation is easier for the welder to use than simply listing the voltage, WFS, and amperage as ranges without correlation. The WPS that follows illustrates one way to present the welding parameters for a semi-automatic welding process such as FCAW.

Welding Procedure Specification (continued)

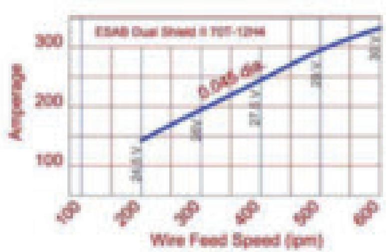
Shielding Gas

WPS: GTA/FCA-P1F6

Process:	GTAW	FCAW
Layer:	All	All
Shielding Gas:	SG-A	SG-AC-25%
Specification:	AWS A5.32	AWS A5.32
Flow Rate:	15 to 35 ft³/h	45 ft³/h
Nozzle Diameter:	#4 through #10 (¼ through ⅝ in.) w/ gas lens	½ in.
Root Purge:	None	None
Purge Gas:	None	NA
Specification:	NA	NA
Flow Rate:	NA	NA
Trailing Gas:	None	NA
Trailing Gas Type:	None	NA
Specification:	NA	NA
Flow Rate:	NA	NA

Electrical Characteristics

Process:	GTAW		FCAW
Layer:	Root		Intermediate and cover
CV or CC:	CC		CV
Current/Polarity:	DCEN		DCEP
Voltage:	11–12		Refer to chart
Amps:	160–175		Refer to chart
Tungsten:	EWTh-2	Gun:	Profax 400A
Diameter:	⅛ in.	Cooling:	Gas cooled
Electrode Extension:	½ cup dia.		½ to ¾ in.
Pulsing:	No		No



Preheat/Interpass Temp./PWHT

Preheat Temp.:	Annex A-1	Max. Interpass Temp.:	500°F
PWHT:	Required	Max. Temp.:	1150°F
Time @ Temp.:	1-hour plus 1-hour per in.	Max Cooling Rate:	100°F/hour to 500°F then air cool

Preheat and Postweld Heat Treatment

Preheat is utilized when welding carbon steels and high-strength low-alloy steels to control the cooling rates and the microstructure of the completed weld. Sufficient preheat reduces the cooling rate of the weld, heat-affected zone (HAZ), and adjacent base metal to minimize or prevent the formation of hard brittle martensite. Preheat requirements are dependent on the carbon equivalency, base metal thickness, and level of joint restraint. The preheat requirements can be presented as a table in the WPS or the WPS can reference an annex where the preheat requirements can be addressed in more detail.

Not all base metals respond to heat treatment in the same manner. Aluminum and austenitic stainless steels do not typically need to be preheated for purposes other than to remove any surface moisture. What works for one base metal does not necessarily work for all base metals.

Postweld heat treatment (PWHT) is usually employed to reduce the residual stresses to a tolerable level. It can also be used to reduce the level of diffusible hydrogen in the weld and HAZ when welding steels sensitive to the detrimental effects of hydrogen. The PWHT that works for one family of base metals may not work with a different family of base metals. The level of detail required is specific to the type of heat treatment required. The WPS can provide the details required or it can refer the reader to a separate procedure that describes the PWHT requirements. The WPS must indicate whether PWHT is required or not. Entries such as "NA" or "NR" are not appropriate. The PQR must support the WPS. If the production weld is subject to PWHT, the supporting PQR must be subjected to the same PWHT. If the production weld is used in the "as-

Welding Procedure Specification (continued)

Technique

		WPS: GTA/FCA-P1F6
Process:	GTAW	FCAW
Layer:	Root and second layer when CJP from one side without backing is specified.	Intermediate and cover layers for all fillet welds, PJP, and CJP welds made with backing.
Position:	All	All
Progression:	Vertical Uphill	Vertical Uphill
Travel Speed:	2–5 in./min	4–12 in./min
Stringer/Weave:	Either, split layer required when previous layer exceeds ⅜ in. in width.	Either, split layer required when previous layer exceeds ⅝ in. in width.
Single/Multiple Electrode:	Single	Single
Electrode Spacing:	NA	NA
Single/Multiple Pass per Side	Either	Either
Peening:	None	None
Chamber:	None	None
Method of Cleaning:	Refer to Annex B	Refer to Annex B
Method of Back Gouge:	Refer to Annex B	Refer to Annex B
Heat Input Limitations:	60 kJ/in.	60 kJ/in.

Other:

FCAW electrodes shall be stored in the manufacturer's sealed container until needed. Once opened, the spool of electrode shall be used within an 8-hour period, electrode not used shall be discarded or any electrode not exposed for the full 8-hours may be returned to a vented electrode holding oven set to 250° F minimum.

This example of a WPS is for illustrative purposes only. It is not intended to meet the specific requirements of any welding standard and is not intended for production welding.

ASME SA285	A, B, C	Plate
ASME SA333	1, 6, 10	Pipe, seamless and welded
ASME SA334	1, 6	Tube, welded
ASME SA352	LCA and LCB	Castings
ASME SA372	A	Forgings

welded" condition, the PQR must be tested in the as-welded condition.

Technique

There are several welding variables that are listed under the heading "technique." Whether weave beads or stringer beads are used can be presented here. Any limitations on the width of the weave bead can be listed under this heading.

This is a good time to note that welding standards published by ASME[1], AWS, and even the military do not place limits on the width of a weld bead deposited with the SMAW process. Any such restriction on the width of a weave bead is imposed by the manufacturer and not the code. When notch toughness is required, the width of the bead is controlled to limit the heat input by controlling the travel speed.

Other information listed under the heading of "technique" include travel speed, whether single-pass or multipass welds are used, the need for and method of backgouging, cleaning, and welding positions. Technique is a catch-all category for any information not listed elsewhere in the WPS.

Joint Details

A WPS can address the requirements applicable to a single joint detail or many joint details. A WPS can easily accommodate the details for one or two joints, but a general WPS that covers many different joints can easily grow in size to the point where it weighs more than the components being welded. Once again, the annex comes to the rescue. A separate annex can list all the appropriate joint details, fit-up requirements, and tolerances applicable to the work — Fig. 3. The WPS can refer the reader to the appropriate annex used to show the details of each joint. When an annex is used, each joint detail should be assigned a unique identifier. There are a couple of systems in place already. Two that come to mind are the joint designations found in AWS D1.X and MIL-STD-22D. There is no need to reinvent a system when it is easier to adopt something that already exists.

Acceptance Criteria

Welding standards typically do not include a requirement for the WPS to list the applicable visual acceptance criteria for the weld. However, the WPS and the drawings are the two primary documents the welder works with. What better vehicle is available to define what visual acceptance criteria is appropriate for a particular job?

1. ASME does have a restriction on the bead width when a repair is made and PWHT is not used.

The WPS can be the vehicle used to link the welding requirements and the visual acceptance criteria. It can reference a specific annex where the visual acceptance criteria are listed.

I hear your wheels turning already: It is not required by the code, the welder should already know the acceptance criteria, every weld should be a perfect weld, etc., so why should it be included in the WPS? Well, welcome to the real world. The visual acceptance criteria can change from one job to another. Welders should be made aware of any special requirements and of the visual acceptance criteria that apply to each job.

Welders are responsible for the work they produce. They should be responsible for examining the completed weld before it is passed on to quality control for the final inspection. If the welders are to be an integral part of the quality control process, they must know what visual acceptance criteria are applicable. The annex listing the applicable acceptance criteria and special requirements is a means of providing welders with the information they need to do the job properly.

Format

The WPS and the PQR are not required to be presented in any particular format. ASME, AWS, API, etc., provide sample forms that can be used as templates for typical PQRs or WPSs, but their use is not mandatory. You may decide to develop a format that allows you to increase the size of the font so the welder can read it in dim light or the sample forms may not provide ample space for additional information you believe will be useful to the welder.

An Example of a WPS

The example shown in Fig. 4 is a WPS that uses two different welding processes. The WPS is qualified by testing, i.e., it is supported by a single PQR where the test plate was welded using the two processes listed in by the WPS. The welding parameters recorded on the PQR are listed in Table 1. The format I use is similar to one you may have seen before, but I have tweaked it to suit my needs. I believe the guidelines I have presented here will help prepare you to write your own WPSs.

ALBERT J. MOORE JR. (AMoore999@comcast.net) *is vice president, Marion Testing & Inspection, Canton, Conn. He is an AWS Senior Certified Welding Inspector and an ASNT ACCP NDT Level III. He is also a member of the AWS Certification Committee and the Committee on Methods of Inspection of Welds.*

Mark Your Calendar

ASNT 20th Annual Research Symposium and Spring Conference. March 21–25, Hyatt Regency San Francisco, San Francisco, Calif. Contact American Society for Nondestructive Testing, (800) 222-2768 or *www.asnt.org*.

Houstex. April 18–20, George R. Brown Convention Center, Houston, Tex. Contact Society of Manufacturing Engineers, *www.houstexonline.com*.

AWS Weldmex. May 11–13, Cintermex, Monterrey, Mexico. Held in conjunction with FABTECH Mexico and Metalform Mexico. Contact American Welding Society (800/305) 443-9353 or *www.awsweldmex.com*.

International Symposium on Nondestructive Testing of Materials and Structures. May 15–18, Suleyman Demirel Cultural Center, Maslak Campus of Istanbul Technical University (ITU), Istanbul, Turkey. Hosted by Istanbul Technical University. Contact Symposium Secretariat at 90.212.285.3756, or *www.ndtms.itu.edu.tr*.

ASNT Fall Conf. and Quality Testing Show. Oct. 24–28, Palm Springs Convention Center, Palm Springs, Calif. Contact American Society for Nondestructive Testing, (800) 222-2768 or *www.asnt.org*.

FABTECH. Nov. 13–16, McCormick Place, Chicago, Ill. Contact American Welding Society, (800/305) 443-9353, ext. 264; or visit *www.fabtechexpo.com* or *www.aws.org*.

Educational Opportunities

NDE Classes. Moraine Valley Community College, Palos Hills, Ill., conducts publicly offered and customized NDE classes in PT, MT, UT, RT, Radiation Safety, and Eddy Current to ANSI/ASNT-CP-189, ATA-105, and NAS 410 standards, as well as API 510 exam prep and weld inspection. For more information, contact (708) 974-5735; *wdcs@morainevalley.edu*; *morainevalley.edu/NDE*.

Welding Certification Prep Course. Prepares candidates for the AWS Certified Welding Inspector (CWI) seminar and examination. Contact Lincoln Electric's Welding School at (216) 383-8325 or visit *www.lincolnelectric.com*.

AWS CWI Seminar and Exam. The seminar is taught by an AWS instructor and covers how to reference AWS codes, examine welds, and prepare for the CWI exam on that following Saturday (proctored by AWS). Contact Lincoln Electric's Welding School at (216) 383-8325, or visit *www.lincolnelectric.com*.

CAN WE TALK?

The *Inspection Trends* staff encourages an exchange of ideas with you, our readers. If you'd like to ask a question, share an idea or voice an opinion, you can call, write, e-mail or fax. Staff e-mail addresses are listed below, along with a guide to help you interact with the right person.

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Positive Material Identification Seminars. Topics covered will include basics of X-ray fluorescence (XRF) analysis, APRI RP 578, and recommended PMI procedures. For more information or to register, contact Thermo Fisher Scientific, Inc., at *www.niton.com/News-and-Events*.

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Nondestructive Examination Courses. A course schedule is available from Hellier, 277 W. Main St., Ste. 2, Niantic, CT 06357, (860) 739-8950, FAX (860) 739-6732.

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Preparatory and Visual Weld Inspection Courses. One- and two-week courses presented in Pascagoula, Miss., Houston, Tex., and Houma and Sulphur, La. Contact Real Educational Services, Inc., (800) 489-2890; *info@realeducational.com*.

Boiler and Pressure Vessel Inspectors Training Courses and Seminars. For complete course listings and schedules, call (614) 888-8320, or visit *www.nationalboard.org*.

CWI/CWE Course and Exam. A ten-day program presented in Troy, Ohio. Contact Hobart Institute of Welding Technology (800) 332-9448; *www.welding.org; hiwt@welding.org*.

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CWI/CWE Prep Course and Exam and NDT Inspector Training Courses. An AWS Accredited Testing Facility. Courses held year-round in Allentown, Pa., and at customers' facilities. Contact: Welder Training & Testing Institute (WTTI). Call (800) 223-9884, *info@wtti.edu*, or visit *www.wtti.edu*.

Welding Inspection, Welding Supervisor, Welding Health and Safety, INTEG, and Welding for Sales Reps Courses. Contact the Canadian Welding Bureau for schedule at (800) 844-6790, or visit *www.cwbgroup.org.*

Official Interpretations:

D1.3, *Structural Welding Code — Sheet Steel*

Subject: Exposed Moisture
Code Edition: D1.3/D1.3M:2008
Code Provision: Subclause 5.1(2)
AWS Log: D1.3-08-I08b

Inquiry: May tack welding be performed when base metals are exposed to moisture (e.g., snow, rain, etc.)?

Response: *No, see Subclause 5.2.*

Subject: Rust and Moisture
Code Edition: D1.3/D1.3M:2008
Code Provision: Subclause 5.2
AWS Log: D1.3-08-I09b

Inquiry: The second sentence in Subclause 5.2 reads: "Surfaces to be welded and surfaces adjacent to a weld shall also be free from loose or thick scale, slag, rust, moisture, grease, or other foreign material that would prevent proper welding or produce objectionable fumes."

When applying this sentence specifically to rust and moisture, may we perform production welding (i.e., arc spot welding to structural steel) in the presence of rust and moisture so long as there isn't enough rust and moisture to prevent proper welding?

Response: *No, see Subclause 5.2.*

D1.5, *Bridge Welding Code*

Subject: Yield Strength and Filler Metal Qualification
Code Edition: D1.5M/D1.5:2008
Code Provision: Tables 4.1 and 4.2
AWS Log: D1.5-08-I06

Inquiry: For WPS Qualification, must Yield Strength (0.2% offset) be used to comply with the requirements for Yield Strength in the D1.5 code?

Response: *No. Yield Strengths established by the all weld metal tension test have multiple allowable methods for determining Yield Strength per ASTM A370 or AWS B4.0 (Subclause 5.18.4).*

Seminars, Code Clinics, and Examinations

Application deadlines are six weeks before the scheduled seminar or exam. Late applications will be assessed a $250 Fast Track fee.

Certified Welding Inspector (CWI)

Location	Seminar Dates	Exam Date
Long Beach, CA	Feb. 6–11	Feb. 12
Miami, FL	Exam only	Feb. 17
Corpus Christi, TX	Exam only	Feb. 19
Milwaukee, WI	Feb. 27–March 4	March 5
Atlanta, GA	Feb. 27–March 4	March 5
San Diego, CA	Feb. 27–March 4	March 5
Miami, FL	Feb. 27–March 4	March 5
Houston, TX	March 6–11	March 12
Norfolk, VA	March 6–11	March 12
Perrysburg, OH	Exam only	March 12
Indianapolis, IN	March 13–18	March 19
Portland, OR	March 13–18	March 19
Mobile, AL	Exam only	March 19
Rochester, NY	Exam only	March 19
Boston, MA	March 20–25	March 26
Phoenix, AZ	March 20–25	March 26
Anchorage, AK	March 20–25	March 26
Chicago, IL	March 20–25	March 26
York, PA	Exam only	March 26
Miami, FL	March 27–April 1	April 2
Dallas, TX	April 3–8	April 9
Springfield, MO	April 3–8	April 9
Portland, ME	April 3–8	April 9
Las Vegas, NV	April 3–8	April 9
Knoxville, TN	Exam only	April 16
Corpus Christi, TX	Exam only	April 23
St. Louis, MO	Exam only	April 23
Baton Rouge, LA	May 1–6	May 7
San Francisco, CA	May 1–6	May 7
Waco, TX	Exam only	May 7
Nashville, TN	May 8–13	May 14
Jacksonville, FL	May 8–13	May 14
Baltimore, MD	May 8–13	May 14
Detroit, MI	May 15–20	May 21
Miami, FL	May 15–20	May 21
Albuquerque, NM	May 15–20	May 21
Long Beach, CA	Exam only	May 28
Spokane, WA	June 5–10	June 11
Oklahoma City, OK	June 5–10	June 11
Birmingham, AL	June 5–10	June 11
Hartford, CT	June 12–17	June 18
Pittsburgh, PA	June 12–17	June 18
Beaumont, TX	June 12–17	June 18
Miami, FL	June 12–17	June 18
Corpus Christi, TX	Exam only	June 25

Certified Welding Supervisor (CWS)

Location	Seminar Dates	Exam Date
New Orleans, LA	April 4–8	April 9
Minneapolis, MN	July 18–22	July 23
Miami, FL	Sept. 12–16	Sept. 17

CWS exams are also given at all CWI exam sites.

9–Year Recertification Seminar for CWI/SCWI

For current CWIs and SCWIs needing to meet education requirements without taking the exam. The exam can be taken at any site listed under Certified Welding Inspector.

Location	Seminar Dates	Exam Date
Denver, CO	Feb. 7–12	No exam
Dallas, TX	March 14–19	No exam
Miami, FL	April 11–16	No exam
Sacramento, CA	May 9–14	No exam
Pittsburgh, PA	June 6–10	No exam
San Diego, CA	July 11–16	No exam
Miami, FL	July 17–23	No exam

Certified Radiographic Interpreter (CRI)

Location	Seminar Dates	Exam Date
Miami, FL	Feb. 7–11	Feb. 12
Seattle, WA	March 7–11	March 12
Houston, TX	April 4–8	April 9
Las Vegas, NV	May 16–20	May 21
Miami, FL	June 6–10	June 11
Dallas, TX	July 18–22	July 23

The CRI certification can be a stand-alone credential or can exempt you from your next 9-Year Recertification.

Certified Welding Sales Representative (CWSR)

Location	Seminar Dates	Exam Date
Miami, FL	Feb. 23–25	Feb. 25
Houston, TX	March 23–25	March 25
Miami, FL	May 4–6	May 6
Atlanta, GA	June 8–10	June 10
Miami, FL	Aug. 24–26	Aug. 26

CWSR exams will also be given at CWI exam sites.

Certified Welding Educator (CWE)

Seminar and exam are given at all sites listed under Certified Welding Inspector. Seminar attendees will not attend the Code Clinic portion of the seminar (usually first two days).

Senior Certified Welding Inspector (SCWI)

Exam can be taken at any site listed under Certified Welding Inspector. No preparatory seminar is offered.

Certified Robotic Arc Welding (CRAW)

Week of	Location	Contact
Feb. 7	ABB, Inc., Auburn Hills, MI	(248) 391–8421
Feb. 14	Genesis–Systems, Davenport, IA	(563) 445–5688
Feb. 28	Lincoln Electric Co., Cleveland, OH	(216) 383–8542
March 7	Wolf Robotics, Ft. Collins, CO	(970) 225–7736
April 25	Wolf Robotics, Ft. Collins, CO	(970) 225–7736
May 2	ABB, Inc., Auburn Hills, MI	(248) 391–8421
May 23	Genesis–Systems , Davenport, IA	(563) 445–5688
Aug. 1	Wolf Robotics, Ft. Collins, CO	(970) 225–7736
Aug. 1	ABB, Inc., Auburn Hills, MI	(248) 391–8421

International CWI Courses and Exams

Please visit *www.aws.org/certification/inter_contact.html*

Errata B2.1/B2.1M:2009

Specification for Welding Procedure and Performance Qualification

Base Metal[b]	Millimeters		
	TS[a]	A	C
M-23 (as welded) M-35 except B148 and B271 All base metals welded with F-23 consumables	<3 3	(16-1/2)TS 50	(18-1/2)TS+1-1/2 57
M-11 M-23 (annealed) M-25 M-35, B148, and B271	<10 10	(6-2/3)TS 67	(8-2/3)TS+3 90
M-24 (annealed) M-27, M61, and M-62	≤10	8TS	10TS+3
M-52 and M-53	≤10	10TS	12TS+3
M-54	≤10	14TS	16TS+3
All other M-Number metals	<10 10	4TS 40	6TS+3 63

The following errata have been identified and will be incorporated into the next reprinting of this document.

Pages 62 and 63, Figures B.5A and B.5B — Metric values in both figures have been corrected to reflect proper conversion, as shown at left.

Base Metal[b]	Millimeters	
	TS[a]	A
M-23 (as welded) M-35 except B148 and B271 All base metals welded with F-23 consumables	<3 3	(16-1/2)TS 50
M-11 M-23 (annealed) M-25 M-35, B148, and B271	<10 10	(6-2/3)TS 67
M-24 (annealed) M-27, M61, and M-62	≤10	8TS
M-52 and M-53	≤10	10TS
M-54	≤10	14TS
All other M-Number metals	<10 10	4TS 40

Page 64, Figure B.5C — Metric values in figure corrected to reflect proper conversion as shown at left.

Errata D17.1:2001

Specification for Fusion Welding for Aerospace Applications

The following errata have been identified and will be incorporated into the next reprinting of this document.

Page iii. Personnel. Add M. Webber Raytheon Co. after J. Waugh Lockheed Martin Aeronautics
Page 9. Table 4.3, Revise Footnote (1) to read: A grove weld does not qualify for fillet welds in base metal £ 0.063 in. in thickness.
Page 71. Under B3. Procedure revised to read as follows: Managing Director of Technical Services
Page 7. Clauses 4.3.7.6 and 4.3.7.7 should be subordinate to Clause 4.3.7.5 and revised as follows:

4.3.7.5 Special Applications. When none of the test welds described above are applicable to a given production weld, a special welder or welding operator qualification limited to the specific application may be achieved with a test weld consisting of the given production weld or a test weld representative of the given production weld.

(1) Qualification Limitations. The qualification is limited to the welding conditions of the test weld with regard to welding process, base metal composition, base metal thickness, welding position, base metal form, type of weld, and the other welding conditions of 4.3.6.

(2) Acceptance Criteria. The required inspection, examination, and acceptance criteria shall be consistent with 4.3.8 or with production part criteria.

Official Interpretations:

D1.1, *Structural Welding Code — Steel*

Subject: Ceramic Backing and Welder Qualification
Code Edition: D1.1:2006
Code Provision: Clause 4
AWS Log: D1.1-06-I10b

Inquiry 1: If the WPS clearly states that the ceramic backing to be used will be removed, with back gouging to follow and a back weld, then could this WPS then be deemed as prequalified?

Response 1: *Yes, provided all conditions for a prequalified weld are met. Backing other than steel is not a prequalified substitute where steel backing is required.*

Inquiry 2: Regarding welder qualifications, if a welder is qualified in FCAW-S process using a E70 series electrode (example E71T-11), is he/she qualified to use other E70 (FCAW) series electrodes (example E71T-8)?

Response 2: *Yes.*

Inquiry 3: Is that same welder also qualified to use FCAW-G (example E71T-1)?

Response 3: *Yes.*

Subject: Single-V-Groove Butt Joints and Groove Type Qualification
Code Edition: D1.1:2006
Code Provision: Table 4.5 Variable Nos. 31& 32 and Subclause 4.9
AWS Log: D1.1-06-I11b

Inquiry 1: Does a WPS qualified using a single-V-groove CJP butt joint qualify for all other joints in conformance with 3.12 or 3.13 regardless of joint design, except for square groove joints as listed in essential variable 32, even if they require CVN testing?

Response 1: *Yes.*

Inquiry 2: Does the requirement of Section 4.9.1.1 supersede the essential variable 31 and require the WPS be qualified with the same groove configuration to be used in construction as written in the code?

Response 2: *Yes, for nontubular connections qualified by test.*

Inquiry 3: Is it acceptable to allow previously qualified Single-V-Groove CJP butt joints to qualify single-bevel CJP T & Corner joints?

Response 3: Yes, except for CJP groove welds for nontubular connections (see 4.9.1.1).

Subject: Sample Forms and Required Information
Code Edition: D1.1:2006
Code Provision: Clauses 3, 4, Annex N
AWS Log: D1.1-06-I12b

Inquiry 1: What is the minimum required information required by the code for WPS, PQR & Welder Qualification Test Records?

Response 1: *Minimum WPS requirements are listed in Clauses 3.6, 4.6, and 7.6. Minimum information required for welders, welding operators, or tack welders are listed in Clause 4.22. Additional information may be needed to fully document the requirements of the specific application. The Contractor is responsible for the content and style of the WPS/PQR and Welder Qualification form. Annex N forms are a guide only and convey no code-mandated use.*

Inquiry 2: Is it acceptable to list base metals, joint designs and fit-up tolerances by making reference to code groupings and joint designs?

Response 2: *Yes.*

Subject: Other than Steel Backing and Prequalified Joints
Code Edition: D1.1:2008
Code Provision: Subclauses 2.17, 5.10
AWS Log: D1.1-08-I02

Inquiry: Can the use of backing “other than” steel be considered prequalified where back-gouging and welding is performed on the second side?

Response: *Yes, provided all conditions for a prequalified weld are met. Backing other than steel is not a prequalified substitute where steel backing is required.*

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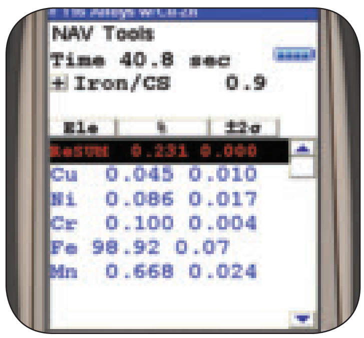

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