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WELDING *Journal*

September 2009



- **Advancements in Shipbuilding**
- **Understanding Weld Cracking**
- **Bonus: The American Welder**

PUBLISHED BY THE AMERICAN WELDING SOCIETY TO ADVANCE THE SCIENCE, TECHNOLOGY, AND APPLICATION OF WELDING AND ALLIED JOINING AND CUTTING PROCESSES, INCLUDING BRAZING, SOLDERING, AND THERMAL SPRAYING

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PRESS TIME

NEWS

ESAB Alters Manufacturing Operations

ESAB Welding & Cutting Products is restructuring its Florence, S.C., manufacturing operations. According to the company, the goal of this plan is to focus its efforts on best practices in manufacturing to highlight its expertise and quality while encouraging growth.

Among the changes anticipated to be in place by the end of 2009 are as follows: The manufacture of gantry cutting machines, arc equipment, and plasma power supplies will be moved to other global factories; the company's North American headquarters in Florence, S.C., will remain the global center for the plasma cutting technology business, and it will continue to manufacture and sell steel industry products, gas apparatus equipment, and consumables; mechanized cutting machine technology in North America will continue to be marketed and supported with a service and aftermarket organization based in Florence; and the facility will continue to provide centralized services for North America.

"We are continuing to be cautious about the economic outlook and are therefore moving forward with reengineering efforts to optimize our manufacturing base and focus our product offerings to truly support our customers," said Brendan Colgan, president and chief executive officer.

All other facilities in North America and all locations in Canada and Mexico, along with all North American service and distribution centers, are unaffected by these changes.

Canadian Government Initiates Shipbuilding Consultation

The Government of Canada's Shipbuilding Consultation took place recently in Gatineau, Q.C. The information received there will be used to outline the government's objectives for a long-term shipbuilding procurement strategy.

Also, the government is committed to building and maintaining a federal fleet of ships for maritime security and services. Fleet renewal plans could see the government invest in excess of \$40 billion to build more than 50 large vessels over the next 30 years.

"I would like to thank the Canadian shipbuilding industry for their attendance at this consultation and for their invaluable contribution to this important initiative," said Peter MacKay, minister of national defence and minister for the Atlantic Gateway. "Our combined efforts will help ensure the Canadian Navy gets the fleet of vessels it needs, while high-value jobs are created and sustained in shipyards across Canada."

Edison Welding Institute and Recognition Robotics Join Forces for Welder Training Systems

Edison Welding Institute (EWI), Columbus, Ohio, and Recognition Robotics, Inc., Sheffield Lake, Ohio, have agreed to collaborate on the development and commercialization of interactive welder training systems. The new technology monitors torch positions and arc data while welding, providing in-helmet feedback to assist the welder with learning proper techniques more quickly. In addition, the EWI training system incorporates a proprietary single-camera optical tracking technology developed by Recognition Robotics to measure torch motions in 3-D during welding.

GE Sensing & Inspection Technologies Awarded Contract with U.S. Navy

GE Sensing & Inspection Technologies, Billerica, Mass., recently announced a contract with the U.S. Navy to provide remote visual inspection equipment, operator training, and data management software to the U.S. Navy's Naval Sea Systems Command inspection teams supporting the Atlantic and Pacific fleets. The company will supply XL G3 VideoProbes® outfitted with menu-driven inspection software. Onsite training will be provided about the tool's features and functionalities as it relates to specific Naval inspection applications.

The U.S. Navy will deploy the equipment to large Naval bases within the continental United States as well as overseas. Plus, it will be used to inspect steam-generation and rotating power and propulsion components on all nonnuclear-powered ships.

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American Welding Society

550 NW LeJeune Rd., Miami, FL 33126

(305) 443-9353 or (800) 443-9353

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EDITORIAL

My Springboard to a New Career in Welding

I'm not sure how it happened, but I've been in the welding business my entire career. It started when I went to work for a friend who was running a welding job shop. I was a freshman in college, and it seemed like a good summer job. Knowing I was technically adept but new to welding, my friend put me under the wing of a guy who had been around the block a few times, a professional welder who looked at welding as a solid profession that he was able to very nicely support his family on. He taught me a lot about welding, but more importantly, he helped me understand that there is very little that isn't touched by welding in some way.

For me, this summer job, which actually ended up lasting for three summers, was my springboard into making the welding field my career. I'm sure there are a lot of stories like mine out there. I started out many years ago as a welder and here I sit today as chair of WEMCO, the Welding Equipment Manufacturers Committee of AWS. My point is that a career in welding can take an individual in any number of directions. I haven't thanked that old friend of mine, but I plan to. If it weren't for him I'm not sure where my career would have taken me.

I probably don't have to tell you that welding as a profession is an outstanding choice. It's a career that is exciting and as full of challenges as any other trade. The major benefit for people who choose welding as a career today is that there is a greater need than ever for qualified welders. WEMCO's Image of Welding Committee is supporting the American Welding Society in helping find those future welders. Thankfully, we're optimistic about the prospects. The promotion of welding to young and old alike is all over television. Shows like *American Chopper*, *Monster Garage*, *Build It Bigger*, and others show welding and cutting as integral to the projects being worked on. Those television programs are an excellent way to showcase the importance of welding in the fabrication process.

The groundwork those shows lay is a great start, but there's much more work to be done if we want to create a pipeline of qualified welders. You've likely heard it before, but it's worth repeating: The average age of a welder is 55 years old. What's more, the influx of younger welders is not keeping up with the demand. As an industry it's critical that we have an ongoing supply of qualified professional welders. They form the backbone of U.S. industry and are a critical component for keeping U.S. industry viable.

Maybe even more important is the timing of selecting welding as a career. We are on the front end of an effort to rebuild the infrastructure of America. The American Recovery and Reinvestment Act will provide funding for years to come. Many of those projects will require skilled welding professionals making this difficult time for the economy the absolute best time to be a welder.

We're fortunate to work in an industry where people, companies, and organizations are banding together to promote careers in welding. WEMCO is working with the Gases and Welding Distributors Association (GAWDA) to get this message out. GAWDA's members realize the importance of sustaining and growing the pool of welding talent. GAWDA's commitment and its extensive reach, along with the strength of the message from the AWS and WEMCO will be a solid one-two punch in spreading the word that welding is an outstanding career choice.

I'm proud to be a part of WEMCO, an organization that is fully committed to supporting this important effort. The benefits of WEMCO extend well past its support of the Image of Welding. If you are a manufacturer of welding equipment and you're looking for an organization that can help you improve the performance of your business and also help you play a part in sustaining the vitality of our industry, then consider becoming a member of WEMCO. You won't regret it.



Jeff Deckrow
Chair, WEMCO



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NEWS OF THE INDUSTRY

Maritime Science Center to Train Ship Welders in Alabama



Alabama Industrial Development Training Director Ed Castile (shown behind the lectern) spoke about the Maritime Science Center at its recent launch. Also present at the event was Alabama Governor Bob Riley. Academy students will learn to construct ships.

The new Maritime Science Center in Mobile, Ala., was launched on June 29. Its mission is to provide a technically trained, highly skilled, and educated workforce for maritime-related technologies. Also, the center will promote the growth and expansion of companies through maritime science education.

Alabama Governor Bob Riley and Alabama Industrial Development Training (AIDT) Director Ed Castile were on hand for the ceremony. The \$9.4 million center, funded by taxpayer dollars, is set for completion in April 2010 and expanded training will start that May.

"This Maritime Science Center will give people the chance to learn new trades or crafts or a chance to advance their trades or crafts with no-cost, free training to them and shipbuilding companies in the area," said Tony Hopper, the project coordinator and training instructor. "The state of Alabama is trying to help with training for these companies at no cost to the people who received training."

It is expected at least 700 people a year will be trained at the Maritime Science Center for work in the shipbuilding industry. This amount should prove to be important — aging baby boomers are employed by shipbuilding companies along the

Gulf Coast and in the U.S., and a younger work force needs to be educated in this field.

"With about 16 shipbuilding companies in south Alabama, the state can help all shipyards in the area by doing the training at one location and training all students under the same courses," Hopper said.

AIDT will use the center to provide multipurpose training and education to assist a host of maritime/shipbuilding companies in the Mobile area and throughout Alabama. The facility will assist expansion projects such as Atlantic Marine, Austal, Bender, and C&G Boats. Additionally, it will be used by the Alabama Community College System for various maritime programs and individual companies needing specific training or contract projects.

According to Hopper, there will be starter programs in almost all crafts, then an intermediate program will take place during a student's the second year, followed by an advance pro-



The above diagram lists the services and results this Maritime Science Center is designed to provide.

gram for each craft to begin their third year. Shielded metal, gas metal, flux cored, gas tungsten, and submerged arc welding will be taught. Other processes to be added include brazing.

"The amount of time in each course will change with the level you are in by how your present job adds to your skills on a daily basis," Hopper explained.

The 60,000-sq-ft facility will include the following: welding shops and labs meeting Occupational Safety and Health Administration specifications; Miller Electric Mfg. Co. and The Lincoln Electric Co. equipment; high bay shops; classrooms; and offices. Freddie Lynn with Goodwyn, Mills and Cawood, Inc., is the center's principal architect.

For more information on AIDT and the maritime training this organization provides, visit www.aidt.edu. — Kristin Campbell, associate editor.



This drawing shows what the Maritime Science Center will look like. Its principal architect is Freddie Lynn. Construction should be completed next April, and expanded training will begin in May.

Energy Solutions Group Provides Free Instruction to Relieve Welder Shortage



As part of his training at Energy Solutions Group, David Sanders performs gas tungsten arc welding on 6-in. pipe.

For the U.S. power industry to survive, a new generation of welders and craftsmen must be trained with the skills to build new, technically sophisticated power plants as well as maintain the existing ones. Energy Solutions Group (ESG), Chattanooga, Tenn., took this into account by opening an advanced skills welding school that offers free welding instruction.

Al Lovins, director of welding, oversees the school's daily operation while Hal Perry serves as the managing instructor. Steve McBryar and John Skinner are senior instructors, and Patrick Jackson is the toolroom attendant. Airgas, The Lincoln Electric Co., and Redi-Arc provided discounts on welding machine rentals and contributed electrodes and training materials.

Students are trained to weld critical pressure parts in all positions; learn the major processes including gas tungsten, shielded metal, flux cored, and gas metal arc welding; and given extensive training with automated orbital equipment. The goal is for them to pass the ASME Boiler and Pressure Vessel Code: Section IX — Welding and Brazing Qualifications test. The class takes place four days a week for ten hours a day, and on average, it takes six months to complete.

Prospective students are accepted through a referral process and screened to ensure they have the physical, moral, and intellectual attributes to succeed in the industry and properly represent the company. Requirements include excellent eyesight, good mechanical aptitude, no history of drug or substance abuse, a valid driver's license and Social Security card, capability of passing a criminal background check, financial support during the full term of the training period, a strong work ethic, punctuality, and willingness to travel for extended periods of time.

Currently, there's waiting list of students wanting to enter ESG's program. Anyone wishing to have their name added to this list may contact Lovins at alovins@atc-tn.com.

Individuals who complete this class will work for the company either at its fabrication facility in Chattanooga, Tenn., which is now under construction, or at one of the many power or petrochemical plants across the United States.

"When the opportunity to become a welder came along, it was though someone had handed me the keys to the kingdom," Lovins said. "To now be able to give young people that same opportunity to learn a skill that is in high demand, will remain in high demand for his entire working life, and helps this country maintain what is left of its manufacturing base is tremendously satisfying."

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Northrop Grumman Authenticates Keel for Amphibious Assault Ship *America* (LHA 6)



Northrop Grumman Corp. held a keel authentication ceremony in July for *America* (LHA 6), the Navy's newest class of large-deck amphibious assault ships, at the company's Pascagoula, Miss., facility. Lynne Pace, the ship's sponsor and wife of retired U.S. Marine Corps Gen. Peter Pace, former chairman of the Joint Chiefs of

Staff, and Irwin F. Edenzon (left front), sector vice president and general manager, Northrop Grumman Shipbuilding - Gulf Coast, thank Northrop Grumman Shipbuilding Welder James Sumlin Jr., a 37-year employee, for welding Mrs. Pace's initials onto the keel plate. *America* will be 844 ft long and 106 ft wide; it will accommodate 1204 crew and 1871 troops. Also observing the event (from left) were U.S. Navy Cmdr. MacGregor McClellan, chaplain; U.S. Navy Capt. Robert Howell, executive officer and director of contracts, Supervisor of Shipbuilding, Gulf Coast; and U.S. Navy Capt. Jeff Riedel, program manager, Amphibious Warfare Programs, PEO Ships. (Photo courtesy of Northrop Grumman Corp.)

U.S. Department of Transportation Awards \$17.1 Million in Shipyard Grants

The U.S. Department of Transportation's Maritime Administration recently announced \$17.1 million in grants to 14 small shipyards in 10 states. As part of the Assistance to Small Shipyards program, the purpose of these grants is to make capital and infrastructure improvements facilitating the efficiency, competitive operations, and quality in ship construction and repair.

Following is a list of some recipients along with the amounts awarded: Total Marine Services, Jefferson, Inc., Harvey, La., \$640,264 for a 100-ton crawler crane and welding equipment; Basic Marine, Inc., Escanaba, Mich., \$1,376,187 for a cutting table, press brake, and welding machines; Zidell Corp., Portland, Ore., \$454,042 for a plasma cutting machine, welding equipment, and vacuum plate lifter; and William E. Munson Co., Inc., Edmonds, Wash., \$150,585 for welding machines, shear, and press.



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Tulsa Welding School to Provide Students with AWS Memberships



Tulsa Welding School, with campuses in Tulsa, Okla., and Jacksonville, Fla., will provide all of its students and applicants with memberships in the American Welding Society (AWS). As shown above, a student practices shielded metal arc welding. "A crucial part of career preparation, for welding as in any other profession, is to participate in the worldwide community that is devoted to advancing that profession," said Dawn Bravo of Tulsa Welding School. AWS student memberships will enable the school's students to participate in the Society's local Section activities in any of more than 200 localities worldwide. As members, the students will receive subscriptions to the Welding Journal and discounts on numerous educational and certification programs, as well as savings on hundreds of AWS publications.

Weld Joint Facing Tools Made under Navy Metalworking Center Sent to Shipyards



The prototype weld joint facing tools were tested in June at the shipyards where DDG 1000 is manufactured. This image shows the tool automatically shaving weld reinforcement on exterior hull panels on a DDG 51. (Photo courtesy of General Dynamics Bath Iron Works.)

Under a Navy Metalworking Center (NMC) project, two prototype (preproduction) weld joint facing tools were developed



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and delivered to Bath Iron Works (BIW) and Northrop Grumman Shipbuilding-Gulf Coast (NGSB-GC). They will reduce or eliminate the need for manual grinding of certain weld reinforcements on the DDG 1000 class of ships.

The butt joint welding of exterior ship panels produces a weld protrusion exceeding DDG 1000 fairness requirements. Approximately 23,000 ft of weld reinforcement would have required manual hand grinding to bring the weld flush with the hull. Cost savings from using the weld joint facing technology for removal of these welds on DDG 1000 is estimated at \$750,000 per hull.

Plus, the preproduction tools remove the weld automatically at a minimum rate of 20 ft/h. A modified version of the tool is presently being considered for backgouging and welding.

The NMC project team consists of BIW, NGSB-GC, General Dynamics Electric Boat, Naval Surface Warfare Center-Carde-rock Division, DDG 1000 Program Office (PMS 500), and Push-Corp, Inc. NMC developed and validated the weld joint facing tool concept, and PushCorp, Inc., designed and manufactured the preproduction tools.

Industry Notes

- This year represents the 40th anniversary for **TRUMPF Inc.**, Farmington, Conn., in the United States. The company is a subsidiary of TRUMPF Group, Germany, a leader in the development and production of machine tools and laser technology.

- **Airgas, Inc.**, reaffirmed its commitment to Operation Homefront, a charity supporting America's troops, with a recent donation of \$100,000 presented at its store in San Antonio, Tex.
- An estimated \$7500 worth of pipe, much of it 42 in. in diameter, has been donated by **Rockies Express Pipeline** for future welding classes at Midwest Technical Institute, Springfield, Ill.
- **The Lincoln Electric Co. (Asia Pacific) Pte., Ltd.**, acquired 100% control of Jinzhou Jin Tai Welding and Metal Co., Ltd., a welding wire business in Jinzhou, China.
- The Photovoltaic Laboratory of **Newport Corp.'s** Technology and Applications Center, Irvine, Calif., has been accredited to the highest international standard for calibration labs by the American Association of Laboratory Accreditation.
- **Coastal Welding Supply, Inc.**, Beaumont, Tex., opened its sixth store in Silsbee, Tex. The company's capabilities include welding, industrial gases, and distribution systems.
- **Sermatech International Holdings Corp.**, a supplier of protective coatings and processes used on industrial and aviation gas turbines, has been acquired by **Praxair Surface Technologies, Inc.**, Indianapolis, Ind., from Arsenal Capital Partners.
- **Elliott-Matsuura Canada Inc.**, Oakville, Ont., has been selected as **Jet Edge, Inc.'s** exclusive waterjet systems distributor for Canada.

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INTERNATIONAL

UPDATE

Gulco Provides Overhead Welding Equipment for Scottish Bridge Project



Welders observe overhead welding in the 4G position with Gulco KAT oscillator combination equipment for a bridge for the M74 motorway in Scotland.



Partial joint penetration welds in butt joints for the bridge were completed in one run for passes one and two.

ing travel times and reducing traffic congestion, improving road safety by reducing the number of accidents, and playing a key role in the transport plan for Scotland's delivery of the Commonwealth Games in Glasgow in 2014.

Initially, Cleveland Bridge approached Gulco to automate welding of short welds in the workshop to eliminate the need to turn large beams in order to save time as well as avoid the risk of twisting and bending of the beams. Once that proved successful, the process is to be repeated on site where a large quantity of overheads welds need to be performed on joints many meters in length.

The partial joint penetration welds were made in butt joints at depths from 15 to 20 mm on 50- to 85-mm-thick plates. The first and second passes were made in one run with split weaves to suit the particular joint made afterward. The equipment and consumables used were Gulco Kat oscillator combination running on a rigid track, 1.2-mm-diameter, gas shielded, rutile flux cored wire, and 80% argon, 20% CO₂ gas. Parameters were set as follows: Travel speed, 22 cm/min; arc voltage, 24; amperage, 210; torch angle, 5–10 deg pull; oscillation, none for the root, 4 mm thereafter; and side dwells, none.

Team to Aid in Offshore Gas Project Near Trinidad

Carillion Caribbean Ltd. will provide approximately 60 workers who will assist in the hookup of equipment, piping, electrical, and instrumentation for well protector platforms for the BHP Billiton Petroleum – Angostura Gas Project. The Angostura Block is lo-

Cleveland Bridge worked with Gulco International (UK) Ltd. to mechanize the overhead welding for a bridge that is part of the M74 Motorway in Scotland. The M74 project is a partnership between Transport Scotland, Glasgow City Council, South Lanarkshire Council, and Renfrewshire Council. The project is part of a massive infrastructure investment in Scotland's transport system, which includes a new rail link to Glasgow airport, a rail link between Airdrie and Bathgate, and improvements to the central Scotland motorway network. Project goals include helping to grow Scotland's economy by improving transportation, providing new jobs, improv-



Members of the engineering and fabrication offshore maintenance team from Carillion Caribbean Ltd. will participate in work for the BHP Angostura Gas Project near Trinidad. Shown from left are Jetender Gosine, technical clerk; Artram Toolsiram, quality control/quality assurance inspector; Ashmeed Ian Khan, construction superintendent; Hashim Russell Ali, construction manager; Ricky Ramlogan, health, safety, and environmental representative; Christian Jones, schedule planner; and Anderson Bajnath, materials logistic coordinator.

cated off the northeast coast of Trinidad. Carillion is subcontracted through Dynamic Industries, Inc. (DII), Lafayette, La.

The DII project team is led by Joseph Tortomase Jr., project sponsor, and Craig Collins, senior project manager. Carillion, with assistance from DII, will provide labor and equipment. The project is expected to commence in January and to last for approximately 300 days.

Adept Robotics Center Inaugurated in India

Adept Technology, Inc., Pleasanton, Calif., a provider of intelligent vision-guided robotics and robotics services, recently announced PSG College of Technology in Coimbatore, India, would open a new robotics center. The inauguration took place in August at the National Seminar on Robotics and Intelligent Automation in Manufacturing and Services event hosted by PSG.

The Adept Robotics Center features an Adept Cobra™ s600 SCARA robot with integrated vision guidance for high-speed handling or precision assembly applications. Plans call for the eventual addition of more robots and software.

For more information about the school, contact Dr. P. Radhakrishnan at prk@psgtech.edu.

ArcelorMittal Purchases European Laser Welded Blank Operations

ArcelorMittal, a steel company with operations in more than 60 countries, recently completed the acquisition of all the issued and outstanding shares of Noble European Holdings B.V. (Noble BV), a Dutch privatized limited liability company engaged in laser welded blanks manufacturing primarily in Europe.

In May, ArcelorMittal signed a definitive purchase agreement with Noble BV's parent company Noble International, Ltd., which has filed for reorganization under the U.S. bankruptcy laws.

Noble BV has tailored blanks operations in Belgium, France, Germany, Spain, United Kingdom, Slovakia, and Australia, and has joint ventures in Mexico, China, and India. It employs 481 full-time workers and had revenues of more than \$487 million in 2008.

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Q&A

Q: Our company recently prototyped parts on existing tooling and we were able to successfully produce the required spot welds. However, the tooling integrator has informed me that our AC transformer is now undersized thermally and needs to be upgraded. How is it possible that we can generate the required weld current to produce satisfactory welds but our transformer is considered thermally undersized?

A: This is a common question within the industry, and depending on who you talk with, they may indicate that you are inquiring about a subject that is as much art as it is science. The truth is that you are actually dealing with the engineering aspects of transformer sizing. A discussion on the proper application of the fundamental techniques associated with this unique process will touch on most aspects of resistance welding. A few of the specific areas to focus on to answer this question are the electrical duty cycle of the transformer, the impedance of the secondary electrical circuit, and the weld schedule.

To begin with, every component in an electrical circuit has an electrical rating associated with it. This rating may be characterized based on voltage, current, kVA, temperature, or some other measurable parameter, and can be referenced to an applicable code or standard for that component. The determination of the component's electrical rating may even involve some form of calculation. Regardless of how it is determined, this electrical rating strongly affects equipment safety and component longevity.

The thermal rating of a resistance spot welding transformer is measured in kilovolt amperes (kVA), and is based on several important but controllable characteristics. These include process characteristics such as secondary voltage, secondary weld current, weld time, number of welds per job, and the jobs per hour. Additionally, the physical characteristics of the tooling are required to complete the analysis so that secondary impedance of the tooling can be calculated — Fig. 1. The determination of secondary impedance is potentially an area where the expertise of the individual performing the calculations comes into play. While there are meters available that can directly measure the total impedance of a secondary circuit, they are not widely used. Additionally, many electrical circuits are in the conceptual stage (i.e., they exist on paper only) and a direct measurement is not possible. Instead, it is common practice to utilize various tables,

BY DONALD F. MAATZ JR.

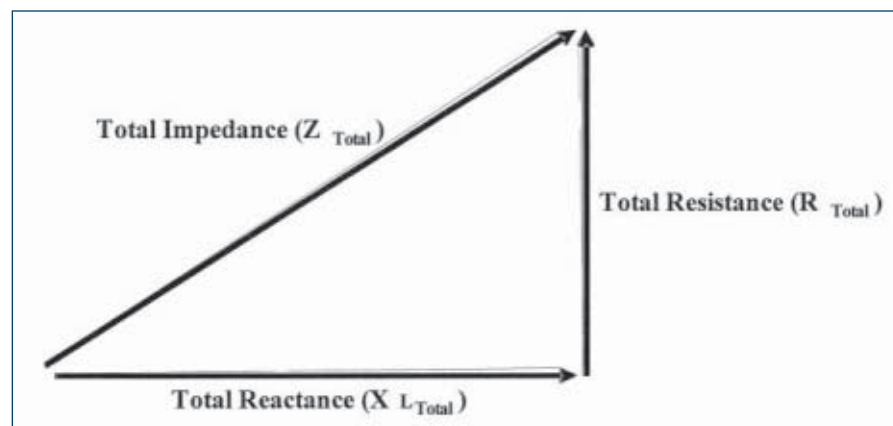


Fig. 1 — Total impedance as determined by its component parts, resistance, and reactance.

charts, and graphs that permit for the determination of the secondary resistive and reactive loads based on various assumptions. The true practitioners of this science have elevated the determination of total impedance to a very high or almost mythical level, thus the perception that the process is a bit of a “black art.”

Once the process and physical characteristics have been determined, they are used to calculate the electrical duty cycle with further calculations determining the thermal load on the transformer. Once these calculations have been completed, it is really a matter of comparing the calculated results to the label-plate data of the component in question — in this case the transformer.

The following examples should help illustrate the concepts discussed previously. They detail the results of four different weld schedules and the subsequent effects of changing secondary weld current and time on the transformer's thermal load. The resistance and reactance tooling data are from an actual example. The calculations are based on equations taken from the *Resistance Welding Manual*, revised 4th Edition, Section 19. Please note that select answers are rounded.

Condition	Weld Current	Weld Time
1	13.0 kA	21 cycles
2	13.5 kA	24 cycles
3	13.0 kA	27 cycles
4	14.0 kA	21 cycles

The only change from Condition 1 to Condition 2 is an increase of three cycles of weld time and 500 A of secondary current. A change of this type may be in response to an increase in coating weight or substrate gauge. The change outlined in Condition 3 is to reduce the weld current

back to the original level in weld condition but adding even more time in an effort to maintain the effective heat of the weld. Condition 4 takes the opposite approach and reduces the weld time to the original value of 21 cycles but adds additional current to again help maintain the effective heat of the weld. On the surface these may seem like relatively small changes (< 4% for current and < 13% for weld time based on Condition 2). However, when examined under the potentially harsh light of thermal capability, the changes suddenly become significant.

Overview

Transformer (These values will be unique for every transformer.)

Dual-secondary 84 kVA with a secondary series bar

Internal resistance = 128 $\mu\Omega$

Internal reactance = 101 $\mu\Omega$

Open-Circuit Voltage_{transformer} = 12.1 V

Welding Gun

Resistance = 96 $\mu\Omega$

Reactance = 294 $\mu\Omega$

Workpiece plus other resistive loads

Resistance = 135 $\mu\Omega$

Total Resistance (R_{Total}) is the sum of all resistance = 359 $\mu\Omega$

Total Reactance (X_{LTotal}) is the sum of all reactance = 395 $\mu\Omega$

Total Impedance (Z_{Total}) = $\sqrt{(R_{Total}^2 + X_{LTotal}^2)} = 534 \mu\Omega$

Welding Condition

19 Welds per job on each schedule

66 Parts per hour

Welds per minute = $(19 \times 66/60) = 21$

(This value should never be rounded down and must account for the worst possible minute of production. As an example, it may be possible, based on the example given, for the tooling to make 19 welds on

a part, transfer parts, and begin welding on another part within 1 min thus increasing the number of welds per minute.)

Condition 1

Duty Cycle = (Weld Time_{average} × Welds per minute × 100%)/(60 s/min × frequency)

Duty Cycle = (21 × 21 × 100%)/(60 × 60) = 12.3%

$V = I \times Z$ (Ohm's Law)

$V = 13.0 \text{ kA} \times 534 \mu\Omega = 6.9 \text{ V}$ (Value must be < Open-Circuit Voltage_{Transformer} or required secondary current is not obtainable.)

$kVA_{\text{Demand}} = (\text{Average Current} \times \text{Open-Circuit Voltage}_{\text{Transformer}})/1000$

$kVA_{\text{Demand}} = (13,000 \times 12.1)/1000 = 157 \text{ kVA}$

$kVA_{\text{Rating@50\% Duty Cycle}} = (kVA_{\text{Demand}} \times \sqrt{\text{Duty Cycle}})/7.07$

$kVA_{\text{Rating@50\% Duty Cycle}} = (157 \times \sqrt{12.3})/7.07 = 78 \text{ kVA}$

Condition 2

If we follow the same process as outlined in Condition 1, we obtain a value for $kVA_{\text{Rating@50\% Duty Cycle}} = 87 \text{ kVA}$.

Condition 3

If we follow the same process as outlined in Condition 1, we obtain a value for $kVA_{\text{Rating@50\% Duty Cycle}} = 88 \text{ kVA}$.

Condition 4

If we follow the same process as outlined in Condition 1, we obtain a value for $kVA_{\text{Rating@50\% Duty Cycle}} = 84 \text{ kVA}$. (See boxed item top of next column.)

Result

The transformer used in this example has a thermal rating of 84 kVA and is properly sized for Condition 1, undersized for the applications detailed in Conditions 2 and 3, and right at the limit with Condition 4. If the tooling is operated as outlined in Conditions 2 and 3, the transformer may fail prematurely. As stated earlier, the parameters from Condition 4 place the transformer right at its thermal limit. While operating under these circumstances is technically not over the limit, the utilization of the tooling at this level would most likely elicit a frown from the transformer manufacturer's electrical engineers.

An important point to consider is that a transformer is actually a source of voltage. As such, based on the limits of Ohm's law, the transformer will produce secondary current to the limit of the physics as-

Condition	Weld Current	Weld Time	kVA Demand	kVA Margin
1	13.0 kA	21 cycles	78 kVA	6 kVA
2	13.5 kA	24 cycles	87 kVA	-3 kVA
3	13.0 kA	27 cycles	88 kVA	-4 kVA
4	14.0 kA	21 cycles	84 kVA	0 kVA

sociated with its application. This means that it can be easy to operate the transformer or any other part of the electrical system in a manner that exceeds its thermal capabilities. The net effect is that it is possible, although very undesirable from both a safety and cost aspect, to utilize any electrical component as a very big fuse.

So to answer your question: Yes, it is possible for your tooling to operate at a new elevated secondary current level and be undersized thermally since, as has been shown, even a subtle change in a weld schedule is enough to push an electrical component like a transformer beyond its thermal limits. Another way to look at this problem is to think of the designed rev/min limit for your car's engine. While it is possible to operate near, or even in excess, of the red line once in a while, one does so knowing that the next time just might be the last. ♦

Acknowledgment

The author would like to thank the

RWMA (Resistance Welding Manufacturing Alliance) for the use of information from its publication *Resistance Welding Manual*, revised 4th Edition, to answer this question. This resource is available at www.rwma.org in the publication section.

Donald F. Maatz Jr. is laboratory manager, RoMan Engineering Services. He is a member of the AWS Detroit Section Executive Committee, serves on the D8 and D8D Automotive Welding committees, is vice chairman of the Certified Resistance Welding Technician Working Group and of the RWMA Technical Committee, and is a graduate of The Ohio State University with a BS in Welding Engineering. This article would not have been possible were it not for the assistance from members of the RoMan team. Send your comments/questions to Maatz at dmaatz@romaneng.com, or to Don Maatz, c/o Welding Journal, 550 NW LeJeune Rd., Miami, FL 33126.

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STAINLESS

Q&A

Q: We are building telescoping booms of 12-in.-square carbon steel tubing with Nitronic 60® stainless steel bars fillet welded to the carbon steel tubing. The choice of Nitronic 60 is for galling resistance as these bars are to slide over another steel surface. We have been trying manual GTAW with ER309L filler metal but encountered a lot of centerline cracking in the welds. Is there a better filler metal for this combination?

A: Nitronic 60® stainless steel is known by the generic UNS Number S21800. It was originally developed by Armco Steel Co. some 30 or more years ago. It has been widely applied for galling resistance. Table 1 lists the chemical composition as given in the ASTM A276 specification for stainless steel bars. The noteworthy points about this alloy are the high manganese, high nitrogen, and especially the high silicon as compared to more common stainless steels like 304L.

From a welding point of view, the component of most concern is the nominally 4% Si. Stainless steel weld metal that solidifies as primary austenite (i.e., austenite is the first phase to solidify from the liquid) is generally susceptible to solidification cracking, and high silicon aggravates this tendency. The rather normal choice of ER309L for filler metal for this joint is predicated on the idea that, with normal dilution, a stainless steel to carbon steel joint will solidify as primary ferrite (i.e., ferrite is the first phase to freeze). With primary ferrite solidification, the tendency to solidification cracking virtually vanishes.

Normal dilution means about 30 to 35%, which is what would be expected with SMAW, GMAW, or FCAW. With these processes, there is a relationship between arc current and filler metal deposition rate, which usually maintains dilution in the expected range. The problem with manual GTAW in a stainless steel to carbon steel joint is that there is absolutely no relationship between arc current and filler metal deposition rate. The welder adds filler metal on what he perceives as an as-needed basis. As a result, literally any dilution from 0 to 100% is possible. Large excursions from normal dilution are rather the norm in manual GTAW because welders almost invariably melt more base metal than necessary.

Many years ago, Harry Espy of Armco Steel published an excellent paper discussing the welding of nitrogen-strengthened stainless steels. In it, he noted that these base metals, including S21800, and their filler metals, are designed to produce

BY DAMIAN J. KOTECKI

Table 1 — Chemical Composition of S21800 Stainless Steel (wt.-%)

C	Mn	Si	Cr	Ni	N
0.10 max	7.00 to 9.00	3.50 to 4.50	16.00 to 18.00	8.00 to 9.00	0.08 to 0.18

a small amount of ferrite in the otherwise austenitic autogenous fusion zone. Today, we realize that this small amount of ferrite is evidence of solidification as primary ferrite which accounts for the high resistance to solidification cracking.

Excessive dilution of stainless steel compositions like S21800 and ER309L with carbon steel can convert the solidification mode of the fusion zone from primary ferrite to primary austenite. This is so because carbon steel contains virtually no ferrite-promoting elements like chromium, but a considerable amount of an austenite-promoting element — carbon. Normally, we can use a constitution diagram like the WRC-1992 Diagram to illustrate this and the effect of dilution on the solidification mode of dissimilar metal joints. However, the WRC-1992 Diagram does not make realistic predictions for Nitronic 60, as noted in the November 2002 Stainless Q&A column. The 1982 paper of Harry Espy includes a proposed constitution diagram, based on the old Schaeffler Diagram, applicable to this steel. But even Espy did not propose to apply that diagram to dissimilar metal joints.

If, as Espy indicated, the S21800 produces about 7 FN in an autogenous GTAW fusion zone, and if the ER309L produces a normal 10 FN or so, then dilution of 40% or more (20% from the carbon steel and 20% from the Nitronic 60) by GTAW into the ER309L filler metal could be expected to result in primary austenite solidification. In such high dilution, since the S21800 contains about 4% Si, the diluted fusion zone would be expected to contain 1% or more silicon. This combination of primary austenite solidification and high silicon, I believe, is the source of your solidification cracking.

Substitution of a higher-ferrite filler metal, such as ER312, for the ER309L filler metal can maintain primary ferrite solidification even with considerably more dilution than 40%. However, ER312 filler metal is not as readily available as ER309L, and ER312 is more costly. Another approach could be to mechanize the GTAW with ER309L filler metal so that

continuous wire feed would prevent excessive dilution and wide dilution excursions. However, I suggest that a better approach would be to abandon GTAW for this application. Use of SMAW, GMAW or FCAW with 309L filler metal properly designed for 10 or more FN would eliminate large excursions in dilution from this application, and should eliminate the solidification cracking.

In general, I am not enthusiastic about using manual GTAW for dissimilar metal joints involving stainless steel filler metal, such as ER309L, in which a small amount of ferrite is expected, or in which solidification in the primary ferrite mode is expected. This concern applies to many more situations than just your joint of S21800 to carbon steel. It is very difficult with manual GTAW to maintain a consistent level of dilution. As a result, wide excursions in dilution from the normally expected 30 to 35% are likely. With high dilution comes the very real possibility that primary austenite solidification will occur in some portions of the weld, and centerline cracking can be the result. SMA, GMA, and FCA are all better choices for the welding process for these situations.

DAMIAN J. KOTECKI is president, Damian Kotecki Welding Consultants, Inc. He is a past president of the American Welding Society, currently treasurer and a past vice president of the International Institute of Welding, and a member of the AWS A5D Subcommittee on Stainless Steel Filler Metals, and the AWS D1K Subcommittee on Stainless Steel Structural Welding. He is a member and past chair of the Welding Research Council Subcommittee on Welding Stainless Steels and Nickel-Base Alloys. E-mail your questions to Dr. Kotecki at damian@damiankotecki.com, or send to Damian Kotecki, c/o Welding Journal, 550 NW LeJeune Rd., Miami, FL 33126.

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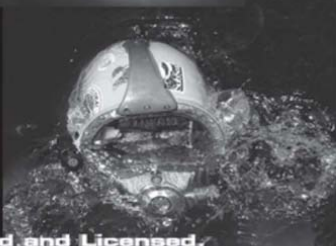


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Fig. 1 — LPD 21 New York under construction at NGSB Avondale will be delivered to the U.S. Navy this year.

Orbital Welding of Titanium Pipe for U.S. Navy Ships

The greatest footage of titanium piping ever in a Navy surface ship is now being installed in the San Antonio class of LPD ships

BY BARBARA K. HENON

When Northrop Grumman Shipbuilding (NGSB) was awarded a contract by the U.S. Navy to design and construct the first of an anticipated 12 ships under the Navy's LPD 17 program in December 1996, it specified titanium piping to be installed using both orbital and manual gas tungsten arc welding (GTAW) technology. The use of titanium and orbital welding is consis-

tent with the mission and the advanced design features of the ship. The LPD 17 (Landing Platform Dock) San Antonio Class is the latest class of amphibious force ships for the U. S. Navy. The LPD 17 ships have a crew of 361 sailors and a mission to transport Marines and their equipment and supplies by air cushion or conventional landing craft and expeditionary fighting ve-

hicles (EFVs), augmented by helicopters and tiltrotor aircraft such as the MV-22 Osprey. The initial plan was for Northrop Grumman Avondale Facilities in New Orleans, La., to build 12 LPD 17 ships. Currently, the first four ships have been delivered to the Navy, with the fifth ship, *New York* LPD 21 (Fig. 1) scheduled for delivery in 2009. The sixth through

BARBARA K. HENON is with Arc Machines, Inc., Pacoima, Calif.

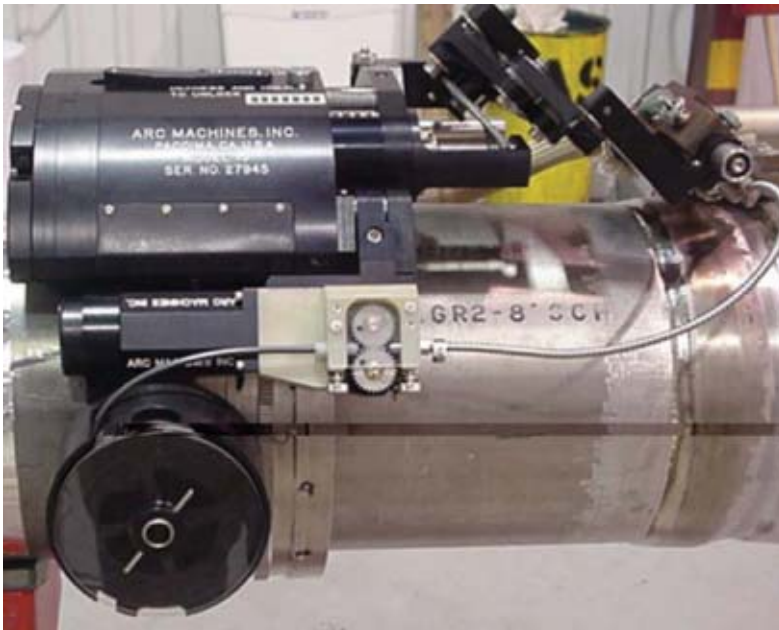


Fig. 2 —The orbital weld head designed for titanium pipe welding.

ninth ships, LPD 22–LPD 25, are presently in various stages of construction across NGSB's Gulf Coast facilities. A Navy advance procurement contract was recently awarded to NGSB for the purchase of long lead time materials for a ninth ship, LPD 26. These ships will replace 40 existing ships. Several of the LPD 17 ships have now been completed with more than 70,000 ft of titanium piping assemblies installed in LPD 17 through LPD 22 or 12,000 ft of titanium per ship (Ref. 1). Although the titanium piping represents only a fraction of the piping on the ship, this is the largest amount of titanium piping ever installed in any U.S. naval surface ship.

Selection of Titanium Pipe

Titanium CP Grade 2 was selected by the design team to replace copper-nickel (CuNi) seawater systems, such as ballast and fire main piping, since titanium is virtually corrosion-free in seawater. The service life of CuNi is severely limited by its corrosion in seawater. Thus, while titanium has an initial higher cost, the savings realized by lower maintenance costs are much greater than the higher initial cost of material and fabrication. Also, since the titanium piping will exceed the service life of the ships, the life-cycle cost is considerably less. Titanium is a low-density element and has the added advantage of a significant weight savings when compared to CuNi. This is important since the piping extends over the length of the ship and the use of titanium will result in a lighter, more stable, faster, and more maneuverable ship that will make it more effective in its designated role.

Titanium Pipe Fabrication Plan

Although titanium offers many advantages and is readily weldable by the GTA process, it is a reactive metal that will absorb oxygen, nitrogen, and hydrogen when heated above 500°F. Of foremost concern is preventing the loss of ductility that results if atmospheric oxidation occurs during welding.

NGSB Avondale began to work with the Navy (NAVSEA) to develop a pipe fabrication plan to address the unique properties of titanium several years before the start of construction of the first LPD 17 ship in June 2000. Patrick Hoyt, chief welding engineer at Avondale, came to NGSB in 1997 and along with Robert Duhe, pipe shop supervisor, organized the titanium program. Hoyt was familiar with orbital welding when he arrived, and he introduced orbital welding technology to the shipyard. Welding procedures were developed both for manual GTA welding, which was used on pipe sizes from 2 to 12 in. Schedule 10, and orbital GTA welding, which was used on pipe sizes from 6 to 12 in.

Avondale's titanium pipe procedures including its fabrication plan, test procedures, quality assurance, and welder training were officially approved by NAVSEA to give them the required U.S. Navy certification. To be certified as titanium welders, the welders had to pass extensive testing, which included classroom work, assignments, and on-the-job training. Orbital welding operators were selected from the pool of qualified manual welders for additional training. A total of 25 manual

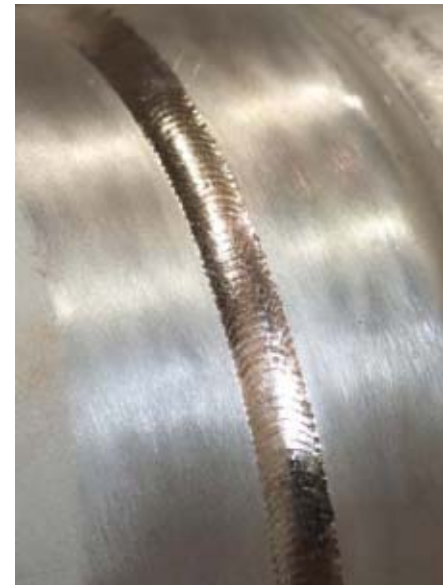


Fig. 3 —A completed orbital weld on a titanium pipe. Note the shiny appearance of the weld bead.

welders were qualified to weld titanium and at the peak of operations, there were a total of nine orbital systems in operation.

Developmental Work

The fabrication document for titanium welding at NGSB Avondale is NAVSEA Technical Publication 278, which covers building and installation of Class P2 piping systems with low temperature and pressure requirements. Bend and tensile testing of the joints were done to meet the requirements of NAVSEA Technical Publication 248, which is similar to Section IX of the ASME *Boiler and Pressure Vessel Code*. The first production weld was done in 1999.

After production started, NGSB Avondale, Edison Welding Institute (EWI), Navy Joining Center (NJC), and NAVSEA continued to refine the welding procedures to minimize the cost drivers. Extensive research was done on the requirements for interpass temperature, shield gas dewpoint, and base metal cleaning methods. Improvements included raising the interpass temperature from 250° to 600°F and raising the required dewpoint from –60° to –40°F. They also tested and approved a nondestructive hardness tester. These changes were monitored and approved by the Navy as it was clearly demonstrated that the changes could be accomplished without detriment to weld quality. Significant reductions in time per weld were achieved by these developments.

Orbital Welding

With orbital welding the torch moves



Fig. 4 — A welding operator viewing the progress of an orbital weld on titanium pipe.

automatically in a circumferential path around a stationary weld joint. Orbital GTAW can be done with or without the addition of wire, but most pipe welding is done with wire. The orbital welding systems used (Fig. 2) were Model 227 orbital welding power supplies and Model 15 full-function pipe weld heads manufactured by Arc Machines, Inc., Pacoima, Calif.

The power supply is microprocessor-based and stores weld programs for the various pipe sizes. The power supply controls weld parameters, which include primary and background amperage (maximum 225 A pulsed), torch travel speed (in./min), pulse times, and wire feed speed. The weld head mounts on a guide ring or track that is clamped onto the pipe and the head moves around the pipe to make the weld. In addition to the basic wire feed functions, it can also be programmed to oscillate or weave across the weld joint and to electronically control the length of the arc (automatic voltage control [AVC]). A special extension of the weld head was provided to position the torch at a 45-deg angle to the pipe for the fillet welds — Fig. 2. The direction of the AVC is in the same plane as the torch.

Welding Details

The joint configuration is a P80 lap joint with the pipe end expanded into the flange forming a bell shape. Although the joint could readily be done in a single pass, the welding specification Tech Pub 278 requires two passes with the second pass completely covering the first pass. The first pass is a stringer with no oscillation while the second pass is done with oscillation. The lap joint is simpler and easier to achieve than a square butt joint as it does not require complete joint penetration. A large gas cup is used to protect the tungsten electrode and weld pool from oxidation and an auxiliary shielding device or trailing shield, which covers a significant portion of the joint, is attached to the

torch block and moves with the torch. This maintains the inert gas cover until the metal has cooled below the oxidation temperature.

Color Tells the Story

Color is the criterion used to determine whether a titanium weld is acceptable or whether ductility has been affected. A color chart consisting of acceptable and unacceptable

sample welds is posted on the wall of the titanium shop. The color changes as the thickness of the oxide film increases. Straw color is acceptable, while blue color is not. The worst case is terminal oxidation characterized by a dull grey flaky surface. However, the use of a trailing shield can make an oxidized weld appear acceptable. Brushing a discolored weld may give the weld a silver appearance that may look passable, but which would have lost ductility. A good titanium weld has very shiny and reflective surface (Fig. 3), while a brushed weld has a duller appearance. The welds are inspected in the as-welded condition. Brushing is not allowed. To be on the safe side, NGSB Avondale uses a portable hardness tester as an additional assurance that the welds are ductile. The trailing shield made it impossible to view the weld and steer the torch from behind the torch, so the operators had to make the adjustment to control the weld from a position in front of the torch which is more difficult. The welder views the weld through the lens on the “heads up display” (Fig. 4) and makes cross joint adjustments to keep the torch centered on the joint. Minor adjustments in welding current, wire feed speed, and AVC are also possible.

Orbital Welding Advantages

Orbital welding permits continuous nonstop welding for 360 deg since it is unaffected by out-of-position welding. Travel speed is 3 to 4 in./min. After each pass the orbital welding operator jogs the weld head to reposition the torch and staggers the next pass. This generally allows for sufficient cool-down time to begin welding the second pass. However, if color appeared from heat buildup, welding would be stopped and another joint begun. Time can be saved by mounting multiple guide rings on joints to be welded and

jumping from weld to weld rather than trying to complete both passes consecutively on the same joint. Because a complete pass can be made without stopping, orbital welding proved to be advantageous on the larger pipe sizes. Avondale was able to improve productivity on manual welds by raising the interpass temperature specified in TP 278 from 150° to 600°F. This reduced the time for a 2-in. manual weld joint from 90 to 30 min. Interpass temperature is not a factor on the larger diameter pipe sizes on which the total arc time for a two-pass orbital weld on a 12-in. pipe is only 20 min, significantly faster than manual welding.

After welding 70,000 ft of titanium pipe, NGSB Avondale has achieved a reject rate of less than 0.15%. Hydro testing was done on individual systems and then on entire systems. No leaks were found. Welds undergo random hardness checks quarterly to ensure that weld ductility has not been compromised.

Unique Titanium Welding Shop

The special shop for welding titanium has been greatly expanded to triple the available space. It is air conditioned to control humidity with climate-controlled work areas. The shop can now accommodate more welders and additional orbital welding equipment. Electrified tools are used since oil from compressed air powered tools would contaminate titanium. The company is pioneering ways to make titanium work better in a shipyard by making the process simpler and more economical. The results with titanium piping reflects teamwork and dedication of all of those involved, and NGSB Avondale has been designated a Center of Excellence for Titanium. ♦

Reference

1. Hoyt, P. 2006. Titanium emerges as new seawater piping material for Navy vessels. *Welding Journal* 85(6): 62–65.

Acknowledgments

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Understanding Weld Cracking



Fig. 1 — Understanding the typical causes of both hot and cold weld cracking is the first step in preventing costly downtime and rework associated with this defect.

*Here's help for
determining the causes,
consequences,
and remedies for
cracks in welds*

BY JOE BUNDY

Whether the result of poor parts fitup, rapid cooling, or a variety of possible contaminants — from the atmosphere, base material, or filler metal — weld cracking carries with it significant consequences for any welding operation. Not only does this defect adversely affect the integrity of the finished weldment, but it also requires significant time and money to rectify — Fig. 1. In a best-case scenario, a welding operator must remove the weld crack by carbon arc gouging (or other means) and repair the weld, while in other instances the welded part must be completely rejected and scrapped.

In critical applications, companies can also incur significant costs for inspecting welds that may ultimately be rejected if a crack is present. Once reworked, these parts require a second round of testing that increases the company's cost for this portion of the operation. In the case of products that need to be postweld heat treated (PWHT), hours or even days must pass between the completion of the rework and a new evaluation, adding to a company's overall downtime and lost productivity. For companies that must meet

contract terms, such delays can result in fines for missed deadlines.

Fortunately, weld cracking doesn't have to be a complete enigma or a total drain on a company's productivity or profit. Understanding the basic types of weld cracks and their causes can go far toward preventing them in the first place.

Beat the Heat: Hot Cracking at a Glance

Hot weld cracking occurs at high temperatures — generally over 1000°F (538°C) — and the defect appears more or less immediately (though not always visibly) upon solidification of the weld. Hot cracking almost always appears in the longitudinal direction of the weld bead itself or directly adjacent to it. Hot cracking can also appear intermittently along the weld's length.

There are two main types of hot cracking, centerline and crater, with the first being further divided into either segregation or bead shape cracking.

As indicated, centerline cracking occurs through the center of the weld, and in the case of segregation cracking, is

the result of elements with low melting points being rejected to the center of the weld upon solidification — Fig. 2. Materials such as free-machining steels (due to their high sulfur and phosphorous content) are especially susceptible to segregation cracking as are materials with zinc plating, galvanized coatings, or those covered with paints or primers. Certain alloys found in filler metals may also be responsible for the problem. For example, boron, which is added to many filler metals to help refine grain structure, can, in excess, cause segregation cracking.

The second type of centerline cracking — bead shape cracking — occurs as the result of poor part fitup or a poor joint design. To compensate for these conditions, welding operators often create a wide weld bead with a thinner throat, which makes the finished weld weaker and puts undue stress on the centerline, in turn causing a crack. Welding at high voltages, especially with an electrode or welding wire that creates a particularly fluid weld pool, can also cause the resulting weld bead to be more concave. This again reduces the throat thickness and weld strength, making it more prone to bead shape cracking.

JOE BUNDY is engineering manager, Hobart Brothers Co., Troy, Ohio, www.hobartbrothers.com.

Similar results can occur from the presence of shallow craters as well.

Crater cracking occurs when the welding operator stops welding prior to finishing a pass on a weld joint, leaving a wide, thin depression at the end. It can also appear in areas that have been tack welded when the corresponding weld passes do not meet fully against the tacks. In both instances, using a backfill technique — backing up slightly to fill in the area at the end of the weld — can help prevent the problem by adding greater thickness to the crater.

For all the aforementioned reasons, careful filler metal and base material selection, as well as good parts fitup, proper joint design, and thorough welding techniques are all essential to avoid hot weld cracking.

Hydrogen Hazards: A Closer Look at Cold Cracking

Unlike hot cracking, cold weld cracking occurs at temperatures well below 600°F (316°C) and does not appear until hours, even days, after the weld cools. Also, most cold cracking begins in the base metal instead of the weldment itself and passes transversely into the weld as it progresses — Fig. 3. Cold cracking is often referred to as hydrogen-induced and/or heat-affected zone (HAZ) cracking.

Broadly speaking, cold cracking occurs in the HAZ as the result of residual stresses from the base material restraining the weld, along with the presence of diffusible hydrogen. Cold cracking is particularly prevalent in thick materials, as they tend to create areas of high restraint and can serve as a heat sink that leads to fast cooling rates. Such rapid cooling causes the microstructure in the HAZ to form a new crystalline microstructure called martensite. While very hard, martensite is also very brittle and lacks ductility. Martensite also provides a location for diffusible hydrogen to coalesce, which in turn creates residual stresses that build in the HAZ. Once these residual stresses reach a critical level, cold cracking occurs.

Hydrogen can be introduced to the weld via the filler metal, base material, or atmosphere. While hydrogen is quite soluble in molten or nearly molten weld metal, as the weld cools it will naturally begin to diffuse out of the area. As alluded to previously, any hydrogen that remains in the weld then gathers around the martensitic crystals or other imperfections in the HAZ, increasing pressure on the microstructure and causing a crack. This hydrogen diffusion can take hours or



Fig. 2 — The centerline crack shown on this fillet weld is the result of low melting point material segregation (segregation cracking).

days to occur, hence cold cracking's delayed appearance.

Materials prone to cold cracking include those with high carbon and/or high alloy levels and which are therefore also higher in strength. Such materials, especially thicker ones, are generally less ductile and tend to shrink after welding, which causes additional residual stresses that lead to cracking.

Techniques like backstepping can help prevent cold cracking. To perform this technique, the welding operator welds in one direction for a short length, returns to prior to the beginning of the last weld and repeats the weld pass, stopping at the start of the first weld. In essence, the heat of the subsequent weld pass serves as a type of stress relieving. The best defense against cold cracking, however, is proper pre- and postweld heat treatments, along with general practices that minimize the exposure to hydrogen sources (these are discussed in detail in the following section).

Preheating the base metal prior to welding slows down the cooling rate, allowing more time for hydrogen to diffuse from the weld, and it also forms a more ductile, less hard microstructure often referred to as pearlite. Pearlite forms at the expense of martensite and is much less susceptible to the damaging effects of hydrogen. Similarly, holding the finished weld at a given temperature for a period of time (via a process like induction heating) slows the cooling process, allowing hydrogen to diffuse more readily and limiting the chance of cold weld cracking.



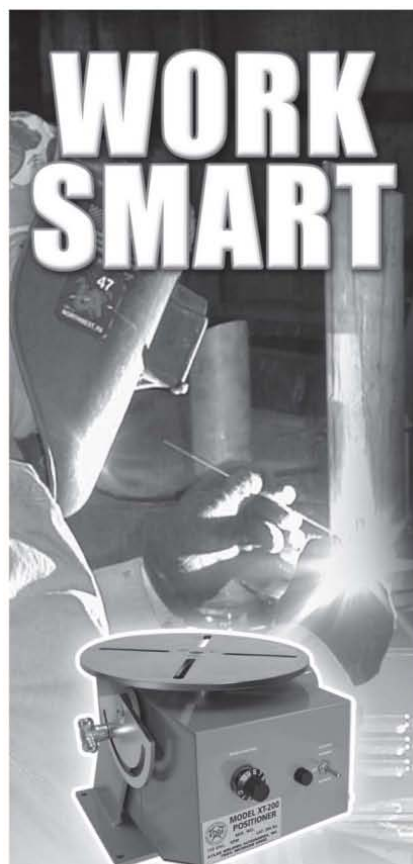
Fig. 3 — An example of a cold crack that has occurred in the toe of the weld (a toe crack). This type of crack initiated nearly parallel to the base metal surface and propagated from the toe of the weld where residual stresses are higher. (Photo from AWS B1.11, Guide for the Visual Examination of Welds.)

Postweld heat treatment reduces the propensity for cold cracking by both relieving residual stresses and driving the diffusible hydrogen from the weldment. Once released, hydrogen cannot naturally diffuse back into the weldment. Note that rapid heating and cooling rates during PWHT generate thermal gradients that can increase residual stresses and lead to cracking just before the full benefits of PWHT are realized.

Other Best Defenses: Selecting and Storing Filler Metals

In addition to the aforementioned techniques, proper filler metal selection and storage can also help prevent costly weld cracking, especially cold cracking.

In particular, using filler metals that



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feature a low-hydrogen designator, such as H4 or H8, are a good defense against cold cracking. These designators indicate that the product offers low diffusible hydrogen levels, or in these examples, less than 4 or 8 mg of hydrogen per 100 g weld metal.

Filler metals with a basic slag system can similarly mitigate the risk of cracking, as they have a high volume of hydrogen scavengers (fluoride, sodium, and calcium, for example) that are able to combine with hydrogen, removing it from the solidifying weld. Note: Despite having large amounts of hydrogen scavengers, products with a basic slag system typically cannot be used for out-of-position welding. They also tend to have more challenging operating characteristics than those with an acidic slag system.

Filler metals should be stored in a dry area and remain in the packaging in which they were received from the filler metal manufacturer until ready for use. Ideally, that packaging should be heat and/or vacuum sealed to block moisture from reaching the product. The storage area should also be similar in temperature to the environment in which the welding will take place; storing the filler metal in a cold area and moving it to a hot one can lead to condensation, increasing the chance of

hydrogen pickup in the weld. If a storage area of similar temperature is not available, allowing the filler metal to acclimate to the temperature of the welding environment before opening the package can help minimize the risk of condensation and subsequent chances of cracking.

Unfortunately, even the best filler metals and the most appropriate storage practices are not guaranteed defenses against cold cracking. Hydrogen can still be absorbed into the weld via the atmosphere, especially in high-humidity areas, or by contaminants on the base metal, particularly rust, mill scale, oils, lubricants, and primers. Defective gas lines or connections can also cause shielding gases to have a high dew point and, therefore, greater amounts of hydrogen. For all of these reasons, care must be taken throughout the welding process to avoid these additional hydrogen sources.

The bottom line: Weld cracking costs money, no matter what type it is. And it can mean the difference between a solid competitive edge and profit for a company or ongoing rework and low productivity. Fortunately, as with any part of the welding process, knowledge is the key to understanding the problem — and to solving it. ♦

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Barge Builder's Gantry Boosts Weld Quality

A host of problems was solved when this company-built-and-installed system of sliding workpiece lead connections was placed on a ten-head gantry welding machine

BY CHET BISHOP



This 5000-A capacity sliding workpiece lead connection system enables fast travel speeds, cuts down on rework, and saves labor.

To facilitate welding longitudinal stiffeners ("longs") on hulls and deck panels of ocean-going barges, the weld tech department at Gunderson, LLC, Portland, Ore., upgraded a gantry several years ago to carry ten welding machines and enable both sides of five longs to be welded simultaneously.

Excessive pick up, repair, and rework was needed though on the welds this gantry produced. The welding discontinuities stubbornly resisted being "exorcised"

by usual adjustment-type solutions, causing a lot of expensive headaches for operators and supervisors.

To keep porosity in the welds to a minimum, it was also necessary to remove the primer coating from the adjoining surfaces, which added a great deal of additional labor. The coating was supposed to be a weldable primer, yet it wasn't working out that way. No substandard welds ever left the plant, due to inspection by quality assurance personnel before leaving the work area and an American Bureau of Shipping surveyor before assembly on the barge, but the welds were costing much more to produce than they should.

Plus, the lightweight inverter welding machines used to limit the total weight on this gantry frequently failed and had to be repaired or refurbished.

Finding the Source of the Problems

When this gantry was first upgraded to ten welding heads from the original six, Gunderson's maintenance department warned that there might not be sufficient power to operate with the increased load. The transformer meters seemed to indicate more than enough power was being delivered, but the problems persisted.

It worked well when only one head was run, for example during a test. However, with all ten running, even when the machines were operating at maximum voltage, the weld quality was less than desirable. A tong meter was used to read the voltage during the welding process at the point of work as opposed to across the transformer studs, and it was discovered with all ten heads running, there was a 9-V drop from the transformers to the weld torches. The parameters were actually not

CHET BISHOP (Chet.Bishop@gbrx.com) is with the weld tech department at Gunderson, LLC, Portland, Ore.

achieved that the meters indicated...not even close.

Phil Formento with ESAB Welding and Cutting Products suggested a test be run with all ten heads in operation, but with an additional workpiece lead attached to each transformer that was clamped directly to the panel. The panels are frequently 60 ft long, so this necessitated ten 100-ft 4/0 leads for the experiment; quite a bit of additional weight. Five workers were temporarily stationed to pull the leads along behind the gantry, so as not to overload its drive motors, and then ran the test. All ten welds came out nearly flawless.

Searching for Solutions

The company was on the right track, but it needed to eliminate the parasitic mass of the festooned workpiece cables, while simultaneously giving superior conductivity to eliminate the voltage drop. The weld tech department was convinced that a sliding workpiece lead connection was the answer, but was unsure of how to build it, or whether such an item was already available on the market.

ESAB Welding Engineer Dave Hebble sent photos of a sliding workpiece lead connection made by Romar. This connection consisted of a thick copper plunger, spring loaded to slide under pressure along a flat-bar track, running the full length of the gantry work table. Hebble encouraged the company to make something similar, especially tailored to its own need.

Each Romar plunger was rated at 1000 A, and between 3500 and 4000 A were drawn, so it was determined five plungers were needed. Four might have sufficed, but five were used in case anything happened to one or more plunger assemblies.

The plungers were made with the steel outer case threaded from end to end on the outside. Two big nuts threaded onto the case from either end to entrap the mounting bracket between them at the desired distance from the connection bar. The means of attachment got changed along with a number of other details, most notably including a ball and socket joint in the "business end" to simultaneously allow easy replacement of an inexpensive "wear shoe" instead of a whole plunger, and to allow the end of the plunger to rock slightly, "floating" over any inconsistencies in the flat-bar track — Fig. 1. The wear shoes are not fastened to the plunger; they are held in place by the compression spring, which forces the plunger against the bar. Brass bushings were also included to reduce wear and/or possible galvanic displacement of metal by electrolysis because of dissimilar metals.

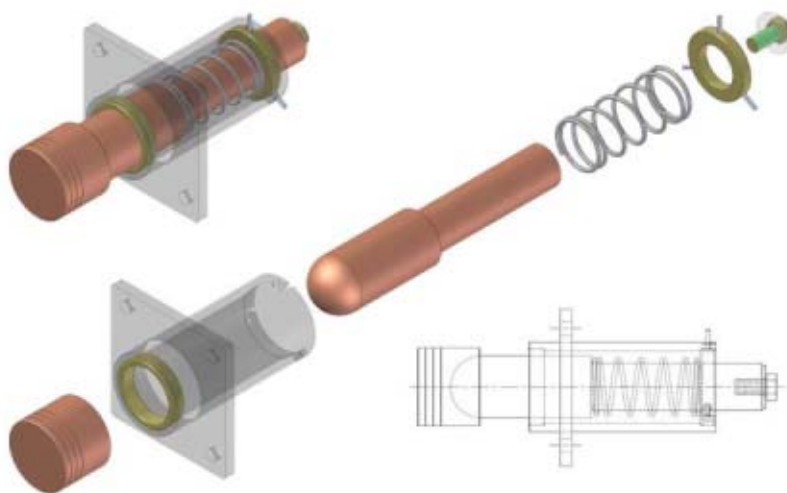


Fig. 1 — The plungers created as part of a new sliding workpiece lead connection (illustrated in this drawing) contain a different attachment means with ball and socket joints in the "business end." Another improvement is the quick-release ring in its back end.

The other major improvement was a quick-release ring in the back end of the case to allow easy installation and removal of the plunger or spring. If needed, a wear shoe can be changed out in seconds or a plunger in a matter of minutes, but neither has become necessary yet.

The plunger assemblies themselves were made in the company's machine shop — Fig. 2. These mechanical improvements were largely the ideas of two machinists, Greg Miller and Tom Halverson, who also devised the phenolic plastic insulating "sandwiches" in the mounting brackets (see lead photo) that prevent the

gantry frame from becoming part of the welding circuit in case of a catastrophic failure of the workpiece connection leads.

Installing the System

The flat bar was installed over a period of two or three days using a tightly stretched piano wire as a guide to get it as straight as possible and construction levels to keep the face as plumb as possible. Each butt joint weld between the individual bar lengths was finished flush and buffed as smooth as was practical to avoid any rough transitions between bar sections



Fig. 2 — Various components make up the complete plunger.



Fig. 3 — Between the individual bar lengths, each butt joint weld was buffed smooth.



Fig. 4 — The back side of this system features a new 4/0 workpiece lead for each inverter and routes them two to a plunger.

— Fig. 3. In addition, the entire 240-ft length of the flat-bar track was wiped with a cloth so workers could find and eliminate any snags, spatter, or other surface discontinuities that might catch a wear shoe and tear it off the end of the plunger.

The mounting bracket was installed, and each plunger case was bolted to the bracket. The only demanding thing was getting the bracket at a level that aimed the plungers correctly at the track. There was not much working room to spare, but it was imperative that the new workpiece connections not be a tripping hazard and also not be exposed to damage from accidental impacts, so the whole apparatus is under the side of the gantry frame.

The plungers were installed followed by the springs and quick-release rings. Then, the back of each plunger was pulled out to compress the springs, allowing the installation of wear shoes. A new 4/0 work-

piece lead for each inverter was added, attaching them to a previously existing bus bar, and routing them to the plungers where they were installed two to a plunger — Fig. 4. The festooned cables were allowed to remain in place, as a temporary safety net, until it was sure the new system was working as planned.

Testing Phases

The gantry operator began a new panel, and while all the welds seemed to be about as near perfect as was hoped, it was not known how much of that to attribute to the new system without removing the old.

A tong meter was used to check the current flow across the new system and the old. The new system had immediately taken up 90% of the current, leaving the old to carry 10%. The voltage drop had

been reduced from a 9-V drop to a 1.5- to 2-V drop, which was acceptable.

The new system was given a week to run parallel to the old system and settle in. All went well during that time, so the old system was disconnected and removed. The voltage drop decreased even further and stabilized at 1-V, an 89% overall decrease in voltage drop.

Facing New Challenges

Immediately, a 33% increase in travel speed was gained, so new welding procedure specifications (WPS) had to be produced. The American Welding Society's D1.1, *Structural Welding Code — Steel*, allows a 25% increase before requiring a new WPS.

What's more, further testing has already demonstrated the system will actually be able to travel even faster (possibly a 75% overall increase), but the company wants operators to have time to get used to the new parameters before further increasing the travel speed.

The practice of removing the weldable primer was eliminated — it really is a weldable primer, after all, and now is working as it should. Of course, this saves labor.

At least 75–80% of the rework at that station has already been eliminated. The rework that still occurs there is due to other issues not problems with the gantry itself.

Finally, since the day the system was installed, Gunderson has not had to replace, repair, or refurbish a single welding machine on the ten-head gantry. They are all running well within their duty cycles and holding up without a problem.

The Bottom Line

The new system, including materials, parts, and labor, cost less than \$10,000. Much of that cost was the labor for installation, as there were a lot of snags encountered in installing a perfectly flat, straight bar along a 240-ft table that was anything but straight or flat; because it is made of Z bars. In fact, the flat bar did not turn out absolutely flat or straight, but the wear shoes swivel slowly and smoothly just as they are designed to do and glide over every variance without a hitch.

In terms of eliminated rework, saved labor (removing primer), and saved cost of repair on machines, the new sliding workpiece connection system paid for itself in the first few weeks of operation. The wear shoes showed no measurable wear after eight weeks of operation, and it is estimated they will last at least three to five years without replacement, but an extra set was made and set aside just in case.



Fig. 5 — Example of a gantry system shown with an angled application.

Since the system was installed, Gunderson has not had to replace, repair, or refurbish a single welding machine on the ten-head gantry.

The several hundred feet of 4/0 cop- per cable from the festoon can be put to good use elsewhere in the plant or even sold; whatever its destination, the cable is no longer a massive load for the gantry drive motors to drag up and down the bay. This saves wear and tear on machinery as well as eliminating inventory.

Less power is used, and a better qual- ity product at a cheaper price is produced as well. This system will pay for itself many times over every year it is in operation.

Additionally, the company uses other gantry welding machines of several types. All have the festooned workpiece leads and suffer a significant voltage drop. So far, similar systems have been installed on two more of these gantry welding systems, with similar results. The sliding systems are only applied to flux cored arc and sub- merged arc welding applications, but they would work in any system requiring a mov- able workpiece lead connection system.

An angled plunger system has been tried wherein the flat bar is welded directly to the angle track on which the gantry is traveling. One particular gantry system re- quired the angled application, and it works well but tends to collect debris, abrasive dust, and/or liquid drips such as primer, all of which could negatively af- fect overall conductivity — Fig. 5. Even- tually, a brush/scrapper system will be in- stalled to maintain a clean sliding surface ahead of the plungers in both directions.◆

Acknowledgments

The suggestions, support, and assis- tance received from ESAB, in particular Phil Formento and David Hebble, is ap- preciated. The author also expresses thanks to the innovative, thoughtful peo- ple in Gunderson's plant, particularly its machine shop and weld tech departments, without whom none of this would have happened.

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Repairing Cracks in Refinery Heat Exchangers

BY SANYASI RAO, DENNIS C. NIEMEYER, AND NABEEL S. AL-BANNAI

In-situ postweld heat treating requires considerable planning to develop a detailed procedure and determine the number of power sources required

During the planned testing and inspection of one of the Saudi Aramco refineries, fine radial cracks were observed around the circumference of the channel flange face of the effluent/feed heat exchangers of the hydrocracker unit. The hydrocracker plant in one of the Saudi Aramco refineries has 13 high-pressure effluent/feed heat exchangers. Ten of the 13 exchangers are stacked in pairs. These exchangers are the shell and tube type. Operating temperature varies from 500° to 800°F for the tube side and 300° to 700°F for the shell side. The operating pressure varies from 2150 to 2190 lb/in.² for the tube side and from 2230 to 2290 lb/in.² for the shell side. The shell side fluid is vacuum gas oil (VGO) for 11 exchangers and hydrogen for the remaining two. The tube side fluid is a mixture of VGO and hydrogen gas for all 13 exchangers. These heat exchangers are made of either 1.25%Cr-0.5%Mo or 2.25%Cr-1%Mo steel. The tubesheet, channel, and channel flanges are clad with 347 stainless steel. Wall thickness of the shell varies from 68 to 136 mm and the thickness of the channel flange at the rim varies from 175 to 225 mm. These flanges were supplied in the quenched and tempered condition.

The channel flange is clad at the gas-

ket face area with 309L stainless steel as a barrier layer followed by 347 stainless steel. A diaphragm plate (gasket) made of 321 stainless steel or chrome-moly steel is fillet welded on the stainless steel cladding. On top of the gasket, the channel cover is bolted to the channel flange. This arrangement is shown in Fig. 1. The purpose of the stainless steel cladding is to avoid welding of the diaphragm plate directly to the air-hardenable, low-alloy steel flanges as this would require post-weld heat treatment every time the diaphragm is removed and rewelded. Detail designing and fabrication of these exchangers is by Belleli, Italy.

New exchangers were received in 1997 with welded diaphragms installed by the manufacturer. In 1998, during precommissioning, some of the exchangers developed minor internal leaks. This necessitated removal of welded diaphragm gaskets. Due to the nonavailability of an automatic cutting machine, a manual grinding machine was used for the removal of the gaskets. Improper grinding resulted in numerous deep grinding grooves close to the gasket facings of some of the exchangers. Due to frequent shutdown and start-up cycles, these exchangers began developing leaks in the welded diaphragm areas. Frequent gasket removal caused the

outside of the diaphragm cladding to become irregular and subsequent installation required a larger fillet weld. This made subsequent removal more difficult. It was planned in 2005 to repair the above-described grooves during a 2007 shutdown.

Cracks on the Gasket Face

On removing the gasket, cracks were seen on the edges of the stainless steel clad gasket face. On machining, several cracks appeared on the machined surface. The cracks were in a radial direction and spread all around the circumference of the channel flange face. Some of the cracks were as long as 125 mm and extended deep into the stainless steel cladding. The cracks are shown in Fig. 2. Several tests were done but the cause of the cracks could not be ascertained conclusively. Chemical analyses were done on the chips taken at various depths and the results are shown in Table 1. Delta ferrite could not be calculated from the chemical analyses because the chips could not be analyzed for carbon and silicon. Delta ferrite on the cladding was not directly measured but the morphology of the cracks is not suggestive of solidification cracking due to low ferrite. Hence the possibility of these cracks resulting from low ferrite in the weld metal and being present since the exchangers were first manufactured is ruled out.

Several replicas were taken in the location of the cracks, and it was seen that the cracks were both transgranular and intergranular. The replica shown in Fig. 3 reveals the intergranular nature of cracking. The replica shown in Fig. 4 shows transgranular cracks with extensive

SANYASI RAO (sannyasi.rao@aramco.com), DENNIS C. NIEMEYER (dennis.niemeyer@aramco.com), and NABEEL S. AL-BANNAI (nabeel.bannai@aramco.com) are with Saudi Aramco, Dhahran, Saudi Arabia.

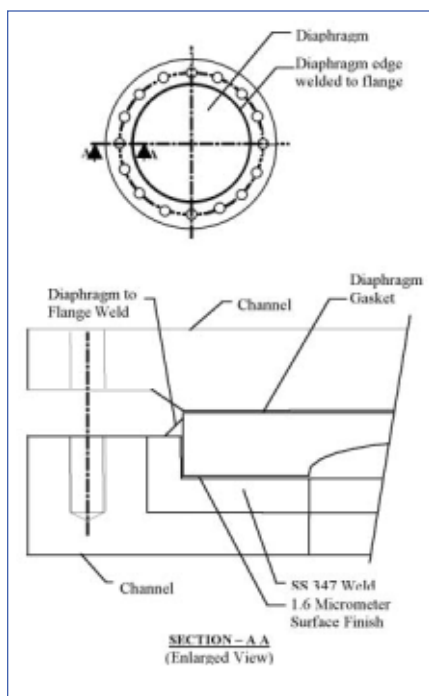


Fig. 1 — Channel flange design.

branching suggestive of environmental cracking. This crack morphology could be consistent with chloride stress corrosion cracking or caustic stress corrosion cracking. Although chloride concentration of the stream is low, concentration of chlorides is possible at the crevice between the gasket and flange. Similarly, caustic concentration can result from neutralization by soda ash washing that is done to prevent polythionic acid stress corrosion cracking. Crack surfaces were not analyzed to detect the presence of sodium and chloride ions. However, cracks were found predominantly underneath the stainless steel cladding that is not exposed to any environment.

Hard phases like martensite are known to form in the unmixed zone at the interface of low-alloy steel and austenitic stainless steel cladding. The presence of hard phases in addition to a difference in coefficient of thermal expansion between the low-alloy steel and austenitic stainless steel cladding could be the cause of cracks.

Weld Repair

Although a detailed fitness-for-service evaluation was not carried out, it was felt that the size, number, and distribution of cracks were too severe to leave the cracks unrepaired. Hence, it was decided to repair all the cracks. Several initial repair attempts were made that resulted in cracking both in the weld metal and heat-affected zone — Figs. 5, 6. The final repair sequence that was established follows.



Fig. 2 — Cracks on the stainless steel cladding on the flange face.

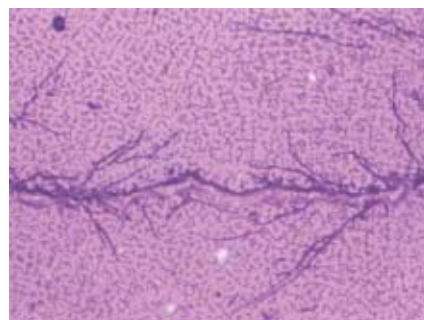


Fig. 4 — Replica showing branching cracks (200 ×).

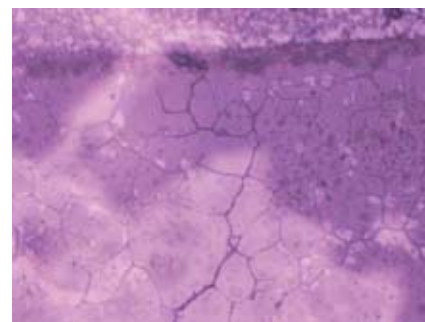


Fig. 3 — Replica showing intergranular mode of cracking (200 ×).



Fig. 5 — Crack in the weld during initial repair.



Fig. 6 — Crack in the heat-affected zone during initial repair.

Dehydrogenation

Because these heat exchangers had been in hydrogen service, the channel flanges of the exchangers were first dehydrogenated by soaking them at 350° to 400°C for about 4 h. This operation took several hours due to the heavy thickness of the equipment (rim of the flange varies from 175 to 225 mm thick).

Complete Removal of the Cracks and Original Cladding

After dehydrogenation, the entire weld cladding was removed by in-situ machining — Fig. 7. Complete removal of cracks was assured by dye penetrant test. It was found that if a weld was deposited over the original cracks, the cracking could propagate through the new cladding.

Welding Procedure

The welding process selected was shielded metal arc welding (SMAW). The initial welding process used was gas tungsten arc welding (GTAW), but the SMAW appeared to be less susceptible to cracking in this case and was more appropriate for cladding. The welding electrode recommended for all of the layers was ENi-CrFe-3. The preheat used was 200°C. No interruption in welding or preheat was permitted until the completion of the cladding. Postheating was recommended at 350°C for 2 h after completion of weld-

ing and during any interruption in welding. It was required to cover the flange with an insulating blanket after postheating. Postheating and covering with an insulating blanket after postheating was recommended to prevent hydrogen-induced cracking. The PWHT cycle was kept unchanged. However, it was mandated to carry out PWHT after completion of the barrier layer without allowing the job to cool below 200°C (preheat temperature). The rest of the layers were to be welded after completion of PWHT and without any preheating as welding was now to be done on the Inconel® barrier layer and not on the chrome-moly steel. Recommended PWHT temperature was 690°C, which is 30°C below the tempering temperature of the flange. This was essential to prevent any significant changes in mechanical properties. Dye penetrant testing was required after PWHT and before



Fig. 7 — In-situ machining.

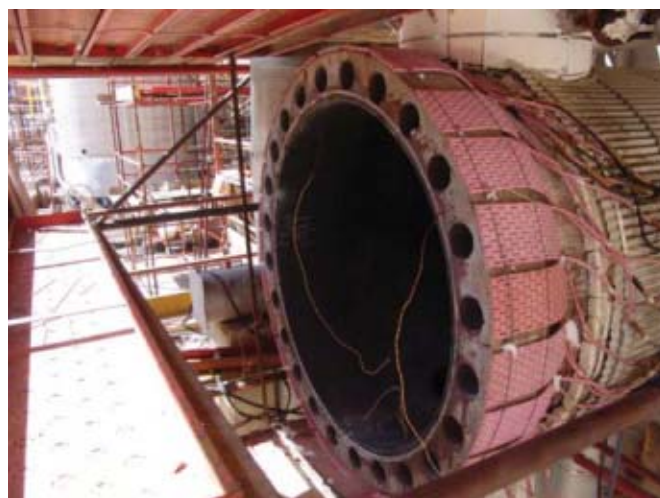


Fig. 8 — Heating arrangement for preheating and PWHT.

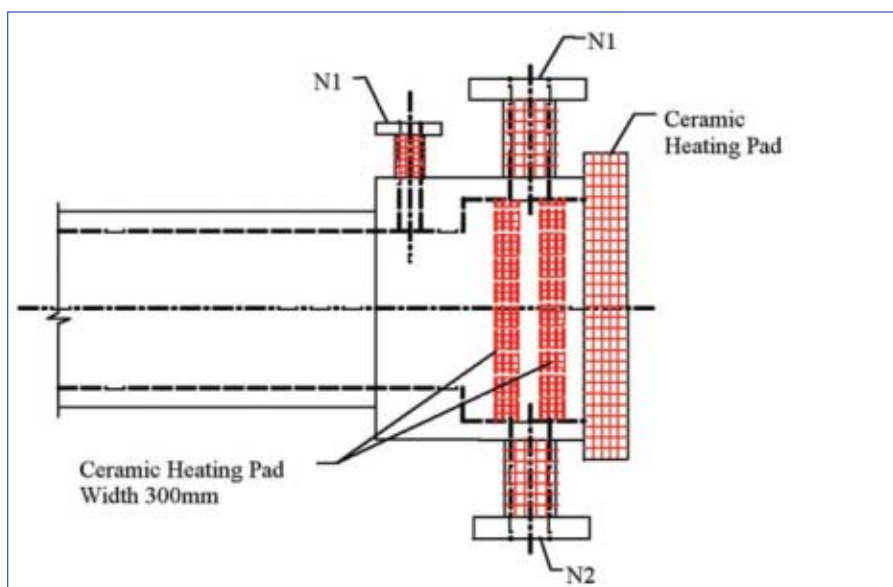


Fig. 9 — Modified heating arrangement for PWHT.

depositing further layers. This was to ensure that there were no cracks before proceeding with the second layer. Welding with this procedure did not result in any cracking on the weld or heat-affected zone.

The welders found it difficult not to weld on the chrome-moly steel when depositing the second layer of cladding. Since welding directly on the chrome-moly steel required re-postweld heat treating, the WPS was revised to complete welding all layers before carrying out PWHT. Moreover, all the layers were to be welded with the same preheat (200°C). This would ensure that any welding on chrome-moly steel at any stage would be with the required preheat and it would certainly undergo PWHT.

Welding as per the above procedure did not result in any cracking and the same

procedure was employed on all the exchangers.

Postweld Heat Treatment

The chrome-moly channel flanges had a thickness of 175 to 225 mm at the rim. Any welding on this thickness requires PWHT per the requirements of the ASME Boiler and Pressure Vessel Code, Section VIII Division 1. However, in-situ PWHT of heavy wall thickness is difficult and requires considerable planning. Although cracks were not anticipated, repair of grooves made by grinding required PWHT. Hence, the PWHT procedure was prepared well in advance. The PWHT procedure required heating only on the channel by placing heating elements around the rim of the flange as shown in

Fig. 8. For the five pairs of stacked exchangers, it was required that PWHT be carried out simultaneously in order to allow simultaneous expansion and contraction. Interconnecting pipe between the two exchangers was also prepared for heating. The temperature was to be monitored during PWHT and, if required, it was to be heated.

During the course of repair, it was realized that the PWHT procedure was not adequate to ensure structural integrity of the channel and associated piping. Although the primary aim of PWHT is to heat treat the flange face, confining the heating to the rim of the flange as shown in Fig. 8 and with the channel being constructed of a heavy wall thickness, the channel would experience a high magnitude of thermal stresses. Moreover, the two heavy nozzles on the channel, as can be seen in Fig. 8, would experience a temperature gradient across the nozzles, which would result in bending stresses on the nozzles and the connecting piping. This can lead to distortion and cracks. In order to overcome the problem, the following major changes were made to the PWHT procedure — Fig. 9:

1. Two more heating zones were added to the procedure. Two 300-mm-wide bands of heating elements that centered on the outer edges of the two nozzles were added. The temperature of these two bands was required to be maintained at about 75°C lower than the PWHT temperature.

2. Heating of the two nozzles by wrapping the heating element around them was added. The temperature of these two bands was also required to be about 75°C lower than the PWHT temperature.

Due to additional heating requirements, four to six power sources of 50/65 kVA each were required for the PWHT of one exchanger. Since the stacked exchangers were to be subjected to PWHT

simultaneously, 8 to 12 power sources were required at a time. Moreover, if preheating and welding of other exchangers was not to be held up while PWHT was being done for the completed exchangers, more power sources would be required.

The two nozzles on the channel were calculated to move 10-mm vertically and laterally back, also by 10 mm. The following further precautions were necessary to ensure structural integrity of the exchangers during in-situ PWHT:

1. Bolts for the front and middle saddles were loosened to allow movement of the exchangers due to thermal expansion.

2. Pipe anchors for channel outlet pipes, wherever present, were cut and removed.

3. Because hard refractory insulation on the channel outlet pipe was touching a concrete pillar, the insulation was removed to allow free movement of the pipe during PWHT.

4. One of the exchangers had a 12.5-mm-thick 321 stainless steel pass partition (PP) plate welded to the chrome-moly channel. It was calculated that due to the difference in the coefficient of thermal expansion between the chrome-moly channel and stainless steel PP plate, the PP plate would expand about 12 mm more than the channel. This would result in distortion of the PP plate. Hence, a 20-mm-wide slot was cut at the center along the width of the PP plate toward the fixed tubesheet. This was repaired by welding after completion of PWHT.

Conclusion

Any extensive in-situ repair of heavy wall thickness equipment made of air-hardenable steels is difficult and time consuming. A detailed welding procedure must be prepared for the repair. It must allow for a dehydrogenation treatment if applicable. In-situ PWHT requires considerable advanced planning with respect to development of a detailed procedure and number of power sources required. The PWHT procedure must be designed to avoid steep thermal gradients and allow for free movement of the equipment during heating and cooling. All existing restraints must be identified and eliminated to ensure structural integrity of the equipment. ♦

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Acknowledgments

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Tandem Wire Process Improves Ship Panel Production

High deposition rates and low heat input are among the benefits of using two separately controlled arcs

BY GERD TROMMER

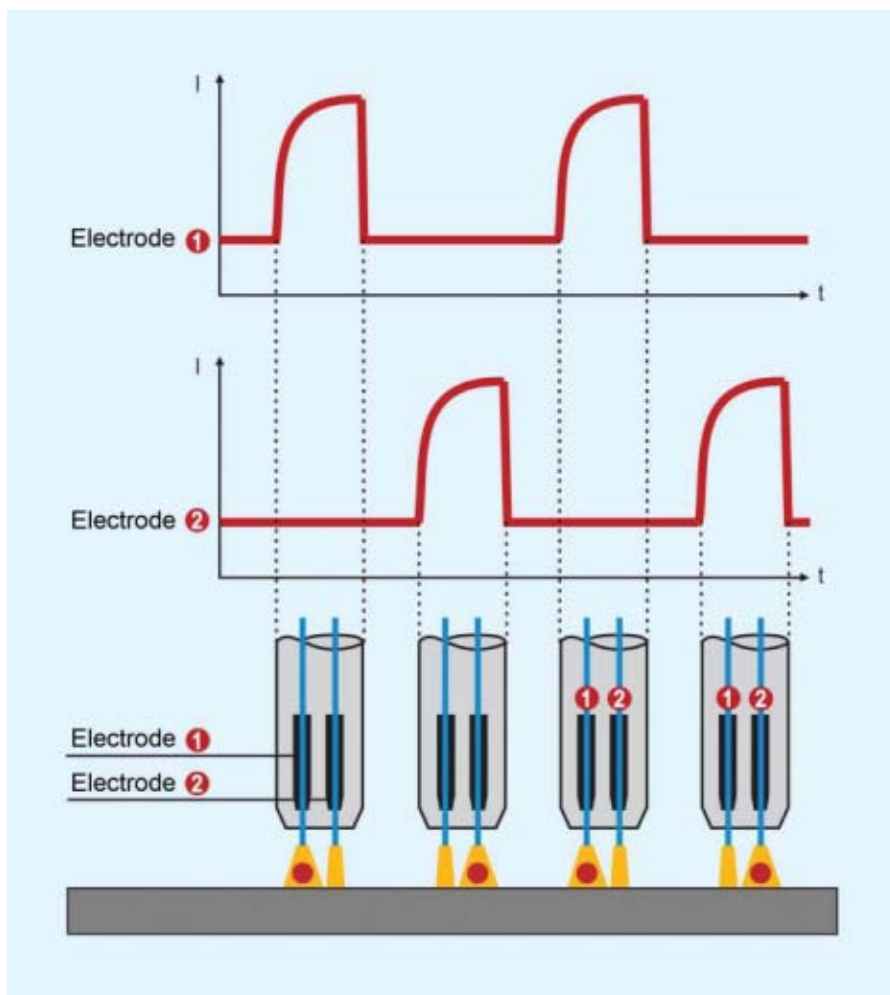


Fig. 1 — The pulsed arcs that are phase-delayed by 180 deg achieve excellent material transfer.

The motto for the Olympic games — swifter, higher, stronger — can also be applied in a broader sense to the needs of modern welding. Industrial use requires reliable, automated processes, as well as equipment that is readily available and easy to operate and maintain. This article provides examples of how these requirements can be met through tandem high-performance welding.

Arc welding with two simultaneously consumable wire electrodes characterizes one method for achieving high deposition rates and welding speeds. There are two welding types to distinguish between: twin-wire and tandem processes. In twin-wire welding, a joint contact tube controls both electrodes, both of which always have the same electrical potential. In contrast, in the tandem process, the electrodes are controlled separately and electrically isolated. This means they can have different electric potentials and can also work simultaneously, e.g., using two different process options. Fronius prefers the tandem process, a flexible, multifaceted method that can be used for a number of applications. It has proven to be successful in welding, cladding, and in special applications such as brazing or combined brazing and welding. Applications can mainly be found in the construction of

- Ships and boats
- Systems and machines
- Automobiles

GERD TROMMER (trommer.gerd@mukomm.de) is an editor in Gernsheim, Germany. Additional information is available from Fronius International GmbH at www.fronius.com.

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Digitization as the Basis for Better User Benefits

As is the case for most industrial manufacturing processes today, increased automation means improved quality, profitability, and safety. Digital technologies maintain the standard that has been achieved and give considerable support to further development. In gas metal arc welding (GMAW), digital technologies affect several areas: Drastically reduced weights and volumes, especially for power sources; flexible and optimizable control of welding parameters; and a multitude of welding programs that incorporate the technical welding knowledge of whole generations of welders as well as targeted research findings from development laboratories. Synergies from these factors also benefit tandem high-performance welding.

A TimeTwin Digital welding system from Fronius consists of two TransPuls Synergic 4000 or 5000 GMAW single systems. These are connected on the control plane by a rapid digital data interface. The system was designed for automated joining processes. The user can individually control performance of both arcs and other parameters, the most important of which are arc length and type. The equipment produces stable arcs paired with excellent droplet detachment, high deposition rates, high welding speeds, and low heat input. The start-up phase and end-crater filling are equally effective. The advantage of welding using two wires in a shared weld pool is that the second arc improves the circulation of the liquid weld pool, therefore reducing fusion errors and number of pores. By turning the welding gun, offset wire electrodes increase the ability to bridge root openings and enable wide discharge of the capping run without weaving. A further benefit comes to light in the welding of several layers. During this process, the equipment switches automatically between leading and trailing wire electrodes. The cycle times are also reduced because no end-of-joint realignment is needed before a change in direction. In addition, a compact gun provides easy access for complex welding tasks. Working with the saved programs means uniform characteristics and appearance can be achieved along the full length of the joint.

Pulsed or standard arcs are available. These combinations result in four arc variations, three of which are particularly useful in practice. They are as follows:

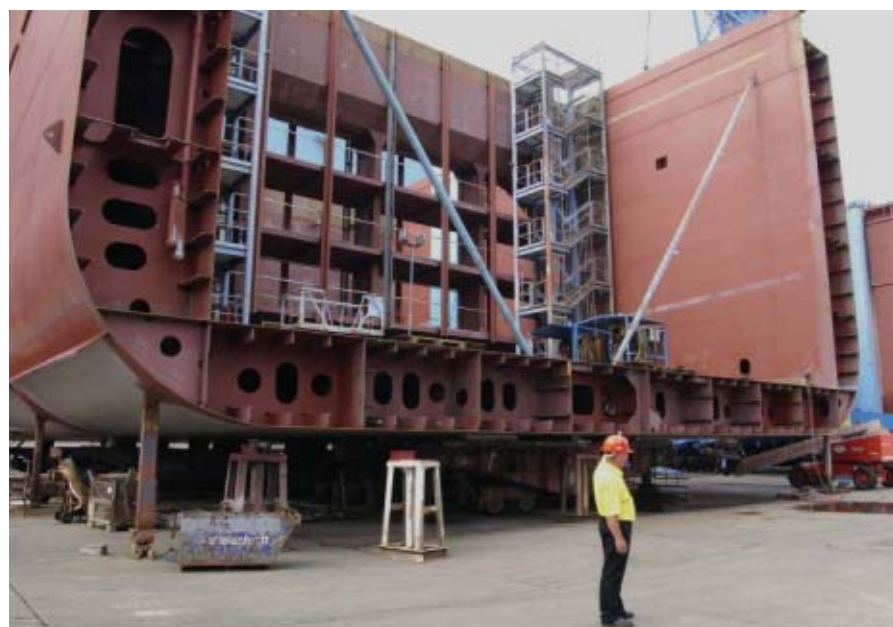


Fig. 2 — Klaus-Peter Frank, head welding engineer at Peene-Werft, is shown with a container ship module. Frank calls the panel production line the “backbone” of the shipyard.

Pulsed arcs for both electrodes: This is the most frequently used version. Material transfers are mostly phased-delayed by 180 deg. This means that when the base current is present on one electrode, the second is in the power pulse current phase and vice versa — Fig. 1.

Pulsed and standard arcs: The main focus here is on the maximum welding speed and ability to bridge root openings. When the leading electrode welds using the pulsed arc, the second electrode follows using the standard arc.

Standard and pulsed arcs: For deep penetration, the first electrode welds with a standard arc, the trailing electrode welds with a pulsed arc.

It is not so much the degree of innova-

tion or even the sophistication of the technology that is the deciding factor for the investor and user, but rather it is the ongoing convenience and level of safety that can be sustainably achieved in everyday use. The following three examples demonstrate how users have achieved this in practice.

Welding of Steel Panels for Container Ships

There are 288 skilled, qualified welders working at Peene-Werft GmbH in Wolgast, Germany. “The panel production line is the backbone of this shipping yard,” said Klaus-Peter Frank, head welding engineer. He explained that everything with an even surface is welded — Fig. 2. This applies to 90%



Fig. 3 — Automation is used to join both sides of the reinforcement plate to the floor area using the tandem wire welding system.



Fig. 4 — Two tandem systems — one on the right and one on the left — make the fillet weld joining the reinforcement plate and the floor area.

of all panels. The shipbuilders process different steel materials, mainly regular and high-strength shipbuilding steels. In 2007, the 70-m-long panel production line was completely replaced.

Panels are the prefabricated plates mainly used for the sections of container ships. They have a floor area of up to 12×12 m made of sheets between 5 and 20 mm thick. To reinforce them, metal strips are fused across the whole width of the floor area — Fig. 3. To weld both sides of the fillet welds between the floor area and the reinforcement plates, components pass through a portal containing a high-performance welding system. The system consists of two systems that simultaneously weld both the left-hand and right-hand welds on the reinforcement plate — Fig. 4.

“Until a few months ago, we were experiencing a production bottleneck due to the high demand for container ships,” explained Frank. This was because the previous single-wire welding system, with a maximum welding speed of 1.0 m/min, was simply no longer up to the job. Now, however, two tandem wire systems simultaneously fuse the fillet welds. They achieve 2 m/min for a dimension of 3 mm.

The main part of the fillet weld has an a-dimension of 3.5 to 4 mm; speeds range from 1.60 to 1.70 m/min. “In comparison to the previous solution, that is nearly a whole meter quicker. And with constantly better quality than before,” Frank said. He attributes this to the favorable ratio of welding current/voltage to welding speed. He cites the low levels of panel deformation and reduced distortion as examples of this. The energy input for the newer process per unit length is approximately 40% lower than with the single-wire process. Fracture test reports from an independent company certify a good root region and a finely crystalline joint.

Making Steel or Aluminum Yacht Panels

Another shipyard is a premium provider of yachts, marine ships, and special boats. Panels are an important component of these vessels. The company manufactures approximately 80% of the panels from steel and the remaining 20% from aluminum. It constructed one yacht exclusively using aluminum per the cus-

tomers’ specifications. The company has been using tandem wire technology since 1998. At that time, it was still analog equipment. After seven years of operation, replacement investment seemed appropriate. Those in charge at the company started researching and discussing the possibilities for improvement digital technology offered. The deciding factor was that they could modulate the two wires differently, meaning that they have considerably more technological flexibility. The increased continuous power also improves profitability.

The shipyard is now using three tandem wire systems to weld both steel and aluminum panels. It receives the aluminum plates in pieces no larger than 2.5×12 m, and which are 6 to 10 mm thick. The tandem wire system welds them to the base plates of the panel with a square groove weld in a butt joint using GMAW and 100% argon shielding gas. The edges of the sheets to be joined are simply chamfered; the root opening is approximately 3 mm wide. Two 1.2-mm AlMg4.5MnZr wires at a wire feed speed of 10 to 12 m/min weld the joints. Depending on the thickness of the sheet, the welding speed is between 45 and 85 cm/min. The company’s welding experts achieve the desired excess weld metal of between 1.0 and 1.5 mm through the arc setting and wire feed speed. All synergic lines for the welding processes originally came from Fronius and have been modified in collaboration with the shipyard.

After joining, a conveyor belt carries the base plates to where the HP reinforcement bars are welded. The bars span the whole width of the plates and are between 80 and 140 mm tall and up to 10 mm thick. For joint preparation, the oxides are ground down on the surface of the joint of the HP bars. Then, the other two tandem wire welding systems launch into action. They simultaneously weld both fillet welds at speeds of between 1.25 and 1.35 m/min. Their a-dimension is usually 3.5 mm. The remaining conditions are similar to those used for the square groove connection weld. After almost two years of permanent operation, the high expectations in the shipyard regarding the benefits of a digital process have been met.

Pipe Welding

Uhlig Rohrbogen GmbH is one of the leading European manufacturers of torch necks and branch connections for applications such as biomass power stations. Senior Manager Wolfgang Hoffmeister explained that in the past the company used gas tungsten arc welding (GTAW) for thin-walled components of up to 6 mm, and for sheets with a wall thickness of at least 8 mm, it welded the root passes us-



Fig. 5 — Welders at Uhlig Rohrbogen achieve a deposition rate that is up to 2.5 times faster when using the tandem wire system in comparison to single-wire welding.

ing GTAW and the fill and cap passes using single-wire GMAW. It has since replaced the laborious GTAW process and conventional GMAW method with a tandem process (Fig. 5), even for stainless steel and copper-nickel, Hoffmeister said.

The materials the company uses the process on includes structural steels in accordance with EN 10025, fine-grained

structural steels in accordance with DIN/EN 1002, high-temperature steels (EN 10028), high-temperature-resistant and rustproof steels, as well as ASTM/special materials. This wide range of materials demands efficient welding processes that are as cost-effective as possible. Until recently, Uhlig always used GTAW and GMAW for top-quality oper-

ations and root pass welding on critical materials. In an attempt to optimize its processes, Uhlig converted to the more efficient tandem procedure. Sheets of 6 mm are only welded with one layer. In the case of thick-walled components that have a wall thickness of at least 8 mm, welders first join the root pass using just one electrode, and then they pour in the remainder from both electrodes using the tandem mode. “In practice, we achieve an arc-on time that is in excess of two and a half times faster, which means we can also save time,” Hoffmeister said.

The engineers working for Uhlig have optimized the processes and constructed a special welding station. The tandem wire system travels between the two rotary disks on a machine carrier. This means one rotating disk can be set up for work, while welding is carried out on the other. The system can weld three torch necks at the same time. The necks each have a diameter of 500 to 1200 mm and a wall thickness of 6 to 20 mm, and are clamped and riveted to a disk. Using copper busbars as gas backing ensures that evenly shaped roots are produced and prevents considerable overhang. Hoffmeister said with the tandem procedure, “We can achieve good results without reverse welding on sealing runs and therefore save so much time.” ♦

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CONFERENCES

2009 FABTECH International & AWS Welding Show Conference Schedule Chicago, Ill.

New Developments in Thermal Spray Coatings, Processes, and Applications Conference November 16

This one-day event organized by the American Welding Society and the International Thermal Spray Association will introduce the process and its uses to new potential users with sessions focusing on actual applications and new developments in thermal spray technology. It will include a half-day tutorial on thermal spray fundamentals titled "What Is Thermal Spray" sponsored by the International Thermal Spray Association.

Weld Cracking: 'The Heat-Affected Zone' Conference November 16

One of production welding's greatest moments, the construction of the Liberty ships during World War II, was accompanied by a new problem. Weld cracking was observed on some of these ships, and the reason for the cracking was a mystery. The cause has since been determined, but as new metals and alloys have come into use the problem comes back in different forms to haunt the welding metallurgist. A crack costs money, takes time to re-

pair, and interrupts production. So where does one go for help? The experts will be at Weld Cracking VII. You will obtain answers to your current problems and will be better prepared to solve cracking problems in the future. You can also learn about the latest equipment including induction heating, a wireless heat-treat system, and portable X-ray diffraction equipment. The use of fracture mechanics will be explored. Descriptions will be given on the heat-affected zone and on the many types of cracks that accompany welding. Base materials covered will include various steels, the stainless steels, aluminum, and titanium.

Welding of Chrome-Moly Steels Conference November 17

The welding of chrome-moly steel goes back to the days when tubing was oxyacetylene welded to make up the fuselages of the early prealuminum airplanes. It all required outstanding precision on the part of the welder, and even though the methods have changed, the welding of 4130 steel still requires utmost precision. The welding of chrome-moly steels requires great skills on all parties involved, and not just the welding; heat treatment and nondestructive examination are essential to a successful weld. The 2½ Cr-1 Mo steels are popular materials for boilers and pressure vessels. More recently, the modified 9 Cr-1 Mo steel is widely specified in the electric utilities and is moving into the oil and gas industry. Conventional welding processes are all used effectively on 4130, 2½Cr-1 Mo, and modified 9 Cr-1 Mo steels. Newer processes such as hybrid welding have also become popular.

AWS/DVS Electron Beam Welding Conference November 16 and 17

This event will include a two-day technical program and a half-day tutorial. Join scientists, engineers, and technical personnel from around the globe who are involved in the research, development, and application of electron beam welding.

Welding the Corrosion-Resistant Alloys Conference November 18

Interest in welding corrosion-resistant alloys is extraordinarily high. The reasons include the entry of the duplex stainless steels and other high-performance grades. Another is the unstable prices in nickel, molybdenum, and titanium. When the price of nickel hit the roof, many fabricators switched from 316 to 201 stainless because of the latter grade's lower nickel content. Research is feverish throughout the world in the development of new and cheaper methods of producing titanium. Will a lower-cost titanium make the metal more popular? The overall activity is intense. Cladding and strip overlay processes have become more popular means of protecting parts exposed to heavy corrosion. Duplex stainless is now being welded for over-the-road tankage. Newer processes, like friction stir welding and thermal stir welding, will be discussed. Keep abreast of this exciting new world in welding where corrosion-resistant alloys have taken center stage.

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PWT is introducing its latest gas shielding product, the small curved trailing shield for welding pipe and tube. Like its patented Ultimate Shield® auxiliary/trailing shield cousins, the curved trailing shield is designed to interface with industry common manual or machine gas tungsten arc welding torches. The new curved trailing shield can be supplied in skirt sizes of one inch increments, and kits are available with all four skirts for users welding several different diameters.

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NOTE: A DIAMOND (♦) DENOTES AN AWS-SPONSORED EVENT.

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Essen Welding Fair (Schweissen & Schneiden). Sept. 14–19, Essen, Germany. Visit www.messe-essen.de.

25th ASM Heat Treating Society Conf. and Expo. Sept. 14–17, Indiana Convention Center and RCA Dome, Indianapolis, Ind. Visit www.asminternational.org.

Gear Mfg. Conf. at Gear Expo 2009. Sept. 15–17, Indiana Convention Center, Indianapolis, Ind. Visit www.sme.org/gears.

Asiamold — Guangzhou Int'l Trade Fair for Moldmaking and Tooling, Design and Application Development. Sept. 16–18, Poly World Trade Centre Expo, Guangzhou, P. R. China. Visit www.messefrankfurt.com.

♦ **GAWDA Annual Meeting.** Sept. 20–23, Grand Hyatt Hotel, San Antonio, Tex. Sponsored by Gases and Welding Distributors Assn. Visit www.gawda.org.

Lean to Green Mfg. Conf. Sept. 28–30, University of Austin, Austin, Tex. Visit www.sme.org/I2g.

Numerical Analysis of Weldability, 9th Int'l Seminar. Sept. 28–30, Graz-Seggau, Austria. Sponsored by Graz University of Technol-

ogy, Austria Institute for Materials Science and Welding, and IIW Commission IX Working Group Mathematical Modeling of Weld Phenomena. Visit <http://iws.tugraz.at>.

Aerospace Measurement, Inspection & Analysis. Sept. 29–Oct. 1, Baltimore Convention Center, Baltimore, Md. Visit www.sme.org/aero-defense.

SOUTH-TEC 2009. Oct. 6–8, Charlotte Convention Center, Charlotte, N.C. Visit www.sme.org/southtec.

♦ **Welding of Corrosion-Resistant Alloys Conf.** Oct. 6, 7, New Orleans, La. Contact American Welding Society, (800/305) 443-9353, ext. 229; or visit www.aws.org.

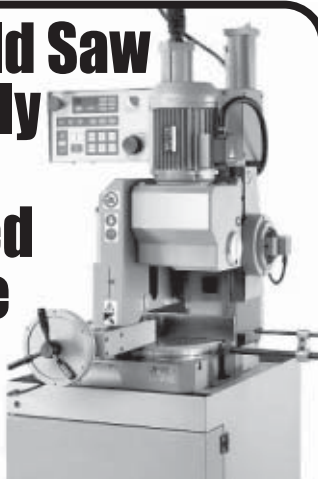
Power-Gen Asia and Renewable Energy World Asia Conf. and Expo. Oct. 7–9, IMPACT Exhibition & Convention Centre, Bangkok, Thailand. Visit www.powergenasia.com.

Lean Product Development Conf. Oct. 13–15, Motorola, Inc., Schaumburg, Ill. Visit www.sme.org/leanpd.

Canadian Manufacturing Technology Show. Oct. 19–22, Direct Energy Centre, Toronto, Ont., Canada. Visit www.cmts.ca.

The Aluminum Association Annual Meeting, "2010: Opportunities & Challenges." Oct. 19, 20, Hotel Palomar & Waterview Conf.

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Society of Naval Architects & Marine Engineers, SNAME 2009 Annual Meeting and Expo. Oct. 21–23, Providence Convention Center, Providence, R.I. Visit www.snameexpo.com.

MACTECH 9th Int'l Expo for Machine Tools, Industrial Tools, Welding and Cutting Equipment. Oct. 22–25, Cairo Fair Ground, Cairo, Egypt. Visit www.ifg-eg.com.

96th ASM Annual Meeting at Materials Science & Technology 2009. Oct. 25–29, Pittsburgh, Pa. Coorganized by ASM Int'l, ACerS, and AIST. Visit www.matscitech.org.

National Robot Safety Conf. XXI. Oct. 26–29, Hyatt Regency, Dearborn, Mich. Contact Robotic Industries Assn. at ria@informz.net or ria@robotics.org.

2009 Shanghai Int'l Science Journals Summit. Oct. 27, 28, Shanghai, P. R. China. Visit www.sjs-sh.org.cn.

ICALEO®, 28th Int'l Congress on Applications of Lasers & Electro-Optics. Nov. 2–5, Hilton in the Walt Disney World Resort®, Orlando, Fla. Visit conferences@laserinstitute.org; or visit www.icaleo.org.

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35th Int'l Symposium for Testing Failure Analysis (ISTFA). Nov. 15–19, San Jose, Calif. Visit www.asminternational.org.

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Micromanufacturing & Nanomanufacturing Conf. and Exhibits. April 14, 15, Hilton Phoenix East/Mesa, Mesa, Ariz. Visit www.sme.org/micro and www.sme.org/nanomanufacturing.

Montreal Manufacturing Technology Show. May 18–20, Place Bonaventure, Montreal, Que., Canada. Visit www.mmts.ca.

Rapid Conf. & Expo and 3D Imaging Conf. May 18–20, Disneyland Resort Anaheim, Anaheim, Calif. Visit www.sme.org/rapid.

EASTEC 2010. May 25–27, Eastern States Exposition, West Springfield, Mass. Visit www.easteconline.com.

◆ **LÖT 2010, 9th Int'l Conf. on Brazing, High-Temperature Brazing, and Diffusion Bonding.** June 15–17, Aachen, Germany. Sponsored by DVS (German Welding Society), cosponsored by AWS, ASM Int'l, and other societies. Visit www.dvs-ev.de/loet2010.

21st World Energy Congress. Sept. 12–16, 2010, Palais des Congrès, Montreal, Que., Canada. Visit <http://montreal2010.ca>.

EuroBLECH 2010, 21st Int'l Sheet Metal Working Technology

Exhibition. Oct. 26–30, 2010, Exhibition Grounds, Hanover, Germany. Visit www.euroblech.com.

◆ **FABTECH International & AWS Welding Show including METALFORM.** Nov. 2–4, 2010, Georgia World Congress Center, Atlanta, Ga. This show is the largest event in North America dedicated to showcasing the full spectrum of metal forming, fabricating, tube and pipe, welding equipment, and technology. Contact American Welding Society, (800/305) 443-9353, ext. 455; or visit www.aws.org.

Educational Opportunities

ASM Int'l Courses. Numerous classes on welding, corrosion, failure analysis, metallography, heat treating, etc., presented in Materials Park, Ohio, online, webinars, on-site, videos, and DVDs. Visit www.asminternational.org, search for “courses.”

Automotive Body in White Training for Skilled Trades and Engineers. Orion, Mich. A five-day course covers operations, troubleshooting, error recovery programs, and safety procedures for automotive lines and integrated cells. Contact Applied Mfg. Technologies, (248) 409-2000, www.appliedmfg.com.

Basic and Advanced Welding Courses. Cleveland, Ohio. Contact The Lincoln Electric Co. for schedules, www.lincolnelectric.com.

Basics of Valves and Actuators Seminars and Expo. Oct. 29, Sheraton Houston Brookhollow Hotel, Houston, Tex. Sponsored by Valve Manufacturers Assn. Visit <http://vma.yourmembership.com/?valvebasics>.

Boiler and Pressure Vessel Inspectors Training Courses and

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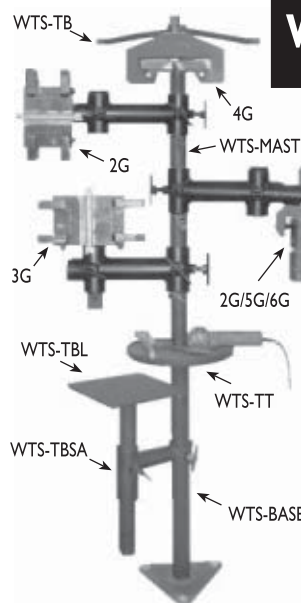


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Seminars. Columbus, Ohio. Call (614) 888-8320; visit www.nationalboard.org.

CWI/CWE Course and Exam. Troy, Ohio. This is a ten-day program. Contact Hobart Institute of Welding Technology, (800) 332-9448, www.welding.org/technical/schedule2008.html.

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, (800) 223-9884, info@wtti.edu; visit www.wtti.edu.

CWI Preparatory and Visual Weld Inspection Courses. Classes presented in Pascagoula, Miss., Houston, Tex., and Houma and Sulphur, La. Contact: Real Educational Services, Inc., (800) 489-2890, info@realeducational.com.

Environmental Online Webinars. Free, online, real-time seminars conducted by industry experts. For topics and schedule, visit www.augustmack.com/Web%20Seminars.htm.

EPRI NDE Training Seminars. EPRI offers NDE technical skills training in visual examination, ultrasonic examination, ASME Section XI, and UT operator training. Contact Sherryl Stogner, (704) 547-6174; sstogner@epri.com.

Essentials of Safety Seminars. Two- and four-day courses are held at numerous locations nationwide to address federal and California OSHA safety regulations. Contact American Safety Training, Inc., (800) 896-8867, www.trainosha.com.

Fabricators and Manufacturers Assn. and Tube and Pipe Assn. Courses. Call (815) 399-8775; visit www.fmanet.org.

Firefighter Hazard Awareness Online Course. A self-paced, ten-module certificate course taught online by fire service professionals. Fee is \$195. Contact Industrial Scientific Corp., (800) 338-3287; www.indsci.com.

Fundamentals of Brazing Seminar. Sept. 29–Oct. 1, Hyatt Regency Hotel, Philadelphia, Pa. Visit www.lucasmilhaupt.com; or call (800) 558-3856.

Gas Detection Made Easy Courses. Online and classroom courses for managing a gas monitoring program from gas detection to confined-space safety. Contact Industrial Scientific Corp., (800) 338-3287; www.indsci.com.

Hellier NDT Courses. Contact Hellier, 277 W. Main St., Ste. 2, Niantic, CT 06357; (860) 739-8950; FAX (860) 739-6732.

Inspection Courses on ultrasonic, eddy current, radiography, dye penetrant, magnetic particle, and visual at Levels 1–3. Meet SNT-TC-1A and NAS-410 requirements. Contact TEST NDT, LLC, (714) 255-1500, www.testndt.com.

Laser Safety Online Courses. Courses include Medical Laser Safety Officer, Laser Safety Training for Physicians, Industrial Laser Safety, and Laser Safety in Educational Institutions. Contact Laser Institute of America, (800) 345-3737, www.laserinstitute.org.

Lyncole XIT™ Grounding Course. Training to protect facilities and equipment from power surges. Oct. 15, 16, Las Vegas, Nev. Contact: www.lyncole.com; (800) 935-2610

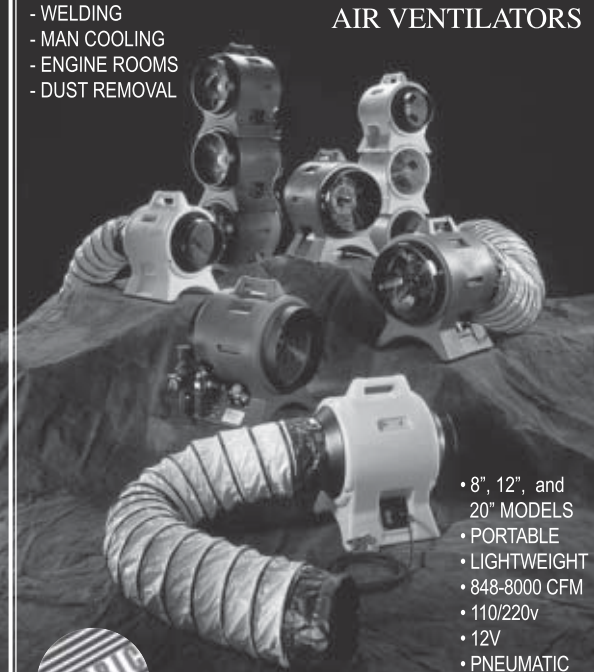
Machine Safeguarding Seminars. Contact Rockford Systems, Inc., (800) 922-7533, www.rockfordsystems.com.

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Machining and Grinding Courses. Contact TechSolve, www.TechSolve.org.

Medical Laser Safety Officer Course. Sept. 19, 20, San Francisco, Calif.; Nov. 14, 15, New Orleans, La. Visit www.laserinstitute.org.

Motorsports Welding School Advanced Materials Courses. Cleveland, Ohio. Sept. 14–18, Oct. 12–16, Dec. 7–11. Contact The Lincoln Electric Co., www.lincolnelectric.com.

Motorsports Welding School Basic Materials Courses. Cleveland, Ohio. Sept. 8–11, Sept. 21–25, Oct. 5–9, Nov. 9–13, Nov. 30–Dec. 4. Contact The Lincoln Electric Co., www.lincolnelectric.com.

NACE Int'l Training and Certification Courses. Contact National Assoc. of Corrosion Engineers, (281) 228-6223, www.nace.org.

NDE and CWI/CWE Courses and Exams. Allentown, Pa., and at customers' locations. Contact Welder Training and Testing Institute, (800) 223-9884, www.wtti.edu.

Pipe Welding. Cleveland, Ohio. Three-week-long courses beginning Sept. 14 and Oct. 26. Contact The Lincoln Electric Co., www.lincolnelectric.com.

Plastics Welding School. A two-day, hands-on course for certification to European DVS-approved plastics welding standards for hot gas and extrusion techniques. Contact Malcom Hot Air Systems, www.plasticweldingtools.com.

Protective Coatings Training and Certification Courses. At various locations and online. Contact The Society for Protective Coatings. Call (877) 281-7772, www.sspc.org.

Shielded Metal Arc Welding of 2-in. Pipe in the 6G Position — Uphill. Troy, Ohio. Contact Hobart Institute of Welding Technology, (800) 332-9448, www.welding.org.

Structural Welding: Design and Specification Seminars and AWS D1.1, Structural Welding Code — Steel. Contact Steel Structures Technology Center, www.steelstructures.com, (248) 893-0132.

Tool and Die Welding Courses. Troy, Ohio. Contact Hobart Institute of Welding Technology, (800) 332-9448, www.welding.org.

Unitek Miyachi Corp. Training Services. Offers personalized training services on resistance and laser beam welding and laser marking. Call (626) 303-5676; visit www.unitekmiyachi.com.

Victor Training Seminars. Programs for gas apparatus and service repair technicians, end users, and sales personnel. Visit www.victorequip.com.

Welding Courses. A wide range of specialized courses presented throughout the year. Contact The Lincoln Electric Co., visit www.lincolnelectric.com/knowledge/training/weldschool/courses.asp, or call (216) 486-1751.

Welding Introduction for Robot Operators and Programmers. This one-week course is presented in Troy, Ohio, or at customers' locations. Contact Hobart Institute of Welding Technology, (800) 332-9448, ext. 5603; www.welding.org.

Welding Skills Training Courses. Courses include weldability of ferrous and nonferrous metals, arc welding inspection and quality control, preparation for recertification of CWIs, and others. Contact: Hobart Institute of Welding Technology, (800) 332-9448, visit www.welding.org.

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About AWS Corporate Memberships:

The American Welding Society (AWS), understands that one size does not fit all. For that reason, we've created FOUR different levels of corporate membership, starting for as little as \$150 per year, allowing you to select a program that best fits with the way your company operates. With an 88-year history in the welding industry, and 50,000+ members worldwide, AWS Corporate Membership offers your company the ability to **INCREASE ITS EXPOSURE and IMPROVE ITS COMPETITIVE POSITION.**


American Welding Society

Contact Us:

CALL US FOR MORE INFORMATION, OR TO JOIN AT:
(800) 443-9353, EXT. 480, OR (305) 443-9353, EXT. 480.
OR VISIT US ON-LINE AT WWW.AWS.ORG/MEMBERSHIP.

AWS Certification Schedule

Certification 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
St. Louis, MO	Sept. 20-25	Sept. 26
Miami, FL	Sept. 20-25	Sept. 26
New Orleans, LA	Sept. 20-25	Sept. 26
Anchorage, AK	EXAM ONLY	Sept. 26
Tulsa, OK	Oct. 4-9	Oct. 10
Long Beach, CA	Oct. 4-9	Oct. 10
Newark, NJ	Oct. 4-9	Oct. 10
Miami, FL	EXAM ONLY	Oct. 15
Portland, OR	Oct. 18-23	Oct. 24
Roanoke, VA	Oct. 18-23	Oct. 24
Cleveland, OH	Oct. 18-23	Oct. 24
Atlanta, GA	Nov. 1-6	Nov. 7
Dallas, TX	Nov. 1-6	Nov. 7
Sacramento, CA	Nov. 1-6	Nov. 7
Spokane, WA	Nov. 1-6	Nov. 7
Corpus Christi, TX	EXAM ONLY	Nov. 21
St. Louis, MO	EXAM ONLY	Dec. 5
Syracuse, NY	Dec. 6-11	Dec. 12
Reno, NV	Dec. 6-11	Dec. 12
Miami, FL	Dec. 6-11	Dec. 12
Fresno, CA	Jan. 10-15, 2010	Jan. 16, 2010
Beaumont, TX	Jan. 10-15	Jan. 16
Corpus Christi, TX	EXAM ONLY	Jan. 23
Miami, FL	Jan. 24-29	Jan. 30
Albuquerque, NM	Jan. 31-Feb.5	Feb. 6
Pittsburgh, PA	Jan. 31-Feb.5	Feb. 6
Denver, CO	Jan. 31-Feb.5	Feb. 6
Seattle, WA	Jan. 31-Feb.5	Feb. 6
Miami, FL	EXAM ONLY	Feb. 25
Birmingham, AL	Feb. 21-26	Feb. 27
Long Beach, CA	Feb. 21-26	Feb. 27
Milwaukee, WI	Feb. 28-Mar. 5	Mar. 6
Atlanta, GA	Feb. 28-Mar. 5	Mar. 6
San Diego, CA	Feb. 28-Mar. 5	Mar. 6
Houston, TX	Mar. 7-12	Mar. 13
Norfolk, VA	Mar. 7-12	Mar. 13
Perrysburg, OH	EXAM ONLY	Mar. 13
Indianapolis, IN	Mar. 14-19	Mar. 20
Portland, OR	Mar. 14-19	Mar. 20
Miami, FL	EXAM ONLY	Mar. 18
Rochester, NY	EXAM ONLY	Mar. 20
Corpus Christi, TX	EXAM ONLY	Mar. 20
Boston, MA	Mar. 21-26	Mar. 27
Phoenix, AZ	Mar. 21-26	Mar. 27
Anchorage, AK	Mar. 21-26	Mar. 27
Chicago, IL	Mar. 21-26	Mar. 27
York, PA	EXAM ONLY	Mar. 27
Miami, FL	Mar. 28-Apr. 2	Apr. 3
Dallas, TX	Apr. 11-16	Apr. 17
Knoxville, TN	EXAM ONLY	Apr. 17
Springfield, MO	Apr. 18-23	Apr. 24
Mobile, AL	EXAM ONLY	Apr. 24
St. Louis, MO	EXAM ONLY	Apr. 24
Portland, ME	Apr. 25-30	May 1
Las Vegas, NV	Apr. 25-30	May 1
Waco, TX	EXAM ONLY	May 1
Baton Rouge, LA	May 2-7	May 8
San Francisco, CA	May 2-7	May 8

9-Year Recertification Seminar for CWI/SCWI

LOCATION	SEMINAR DATES	EXAM DATE
Dallas, TX	Oct. 5-10	NO EXAM
Miami, FL	Nov. 30-Dec. 5	NO EXAM
New Orleans, LA	Jan. 11-16, 2010	NO EXAM
Denver, CO	Feb. 22-27	NO EXAM
Dallas, TX	Mar. 14-19	NO EXAM
Miami, FL	Apr. 11-16	NO EXAM
Sacramento, CA	May 3-8	NO EXAM

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

Certified Welding Supervisor (CWS)

LOCATION	SEMINAR DATES	EXAM DATE
Tulsa, OK	Oct. 5-9	Oct. 10
Long Beach, CA	Nov. 30-Dec. 4	Dec. 5
Atlanta, GA	Jan. 25-29, 2010	Jan. 30, 2010
New Orleans, LA	Apr. 19-23	Apr. 24

CWS exams are also given at all CWI exam sites.

Certified Radiographic Interpreter (CRI)

LOCATION	SEMINAR DATES	EXAM DATE
Miami, FL	Oct. 19-23	Oct. 24
Miami, FL	Feb. 1-5, 2010	Feb. 6, 2010
Miami, FL	Mar. 8-12	Mar. 13
Miami, FL	Apr. 16-23	Apr. 25

Radiographic Interpreter 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	Oct. 21-23	Oct. 23
Chicago, IL	Nov. 16-18	Nov. 18
Miami, FL	Feb. 25-27, 2010	Feb. 27, 2010
Miami, FL	May 6-8	May 8

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 Welding Engineer – (CWEng)

Exam can be taken at any site listed under Certified Welding Inspector. No preparatory seminar is offered. Two exam days are necessary for this certification.

Certified Robotic Arc Welding (CRAW)

LOCATION	WEEK OF:	CONTACT
Wolf Robotics, Ft. Collins, CO	Sept. 21	(970) 225-7736
ABB, Inc., Auburn Hills, MI	Oct. 5	(248) 391-8421
Lincoln Electric, Cleveland, OH	Oct. 19	(216) 383-8542
ABB, Inc., Auburn Hills, MI	Nov. 2	(248) 391-8421
Wolf Robotics, Ft. Collins, CO	Nov. 2	(970) 225-7736
ABB, Inc., Auburn Hills, MI	Dec. 14	(248) 391-8421
Wolf Robotics, Ft. Collins, CO	Dec. 14	(970) 225-7736

International CWI Courses and Exams

AWS training and certification for CWI and other programs are offered in many countries. For international certification program schedules and contact information, please visit http://www.aws.org/certification/inter_contact.html



American Welding Society®

For information on any of our seminars and certification programs, visit our website at www.aws.org/certification or contact AWS at (800) 443-9353, Ext. 273 for Certification and Ext. 455 for Seminars. Please **apply early** to save Fast Track fees. **This schedule is subject to change without notice.** Please verify the dates with the Certification Dept. and confirm your course status before making final travel plans.

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For the latest conference information visit our website at www.aws.org/conferences or call 800-443-9353, ext. 455.

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WELD CRACKING

"THE HEAT AFFECTED ZONE"

CONFERENCE

SOCIETY NEWS

BY HOWARD M. WOODWARD

AWS Leaders Train at AWS HQ



The Leadership Symposium Class of 2009

The 11th annual Leadership Symposium was held July 12–15 at AWS headquarters in Miami, Fla. AWS Section members in leadership positions representing all 22 AWS Districts participated in the seminar. Attending the seminar were (District numbers in parenthesis): 1) **Philip Witteman** and **Eloise Crane**; 2) **Robert Waite**; 3) **Michael Sebergandio** and **Janelle Rishell**; 4) **Wayne Johnson** and **Gladys Johnson**; 5) **Robert Brewington**; 6) **Paul Swatland** and **Candy Swatland**; 7) **Michael Finney** and **Sheena Finney**; 8) **Dusti Jones** and **Dena**

Jones; 9) **Michael Skiles** and **Beverly Skiles**; 10) **Phillip Schmidt**; 11) **Jeff Seelye**, **Susan Seelye**, and **Donald Maatz Jr.**; 12) **Charles Frederick** and **Robert Bruss**; 13) **Eric Krauss**; 14) **Victor Shorkey**, **Tony Brosio**, **Feather Brosio**, and **Gailyn Cornell**; **Joel Ziegler**, **Tiffany Ziegler**, and **Todd Bridigum**; 16) **Jason Hill** and **Erin Hill**; 17) **Kirk Jordan** and **Jamie Pearson**; 18) **John Stoll**; 19) **Azwinder Sumal** and **Leela Sumal**; 20) **Dean Mitchell** and **Jana Mitchell**; 21) **Anthony Barraza**; and 22) **Matt Wysocki** and **Bruce Tanner**.

The symposium is conducted each year by Dr. **Ron Gilbert**, senior partner and principal management consultant for GEMS of Florida (Gilbert Education & Management Systems), www.gilbertems.com, and a professor of management in the Chapman Graduate School of Business at Florida International University, Miami, Fla. Working with Gilbert every year is **Lee Kvidahl**, an AWS past president, and manager of welding/manufacturing engineering at Northrop Grumman Ship Systems Ingalls Operations in Pascagoula, Miss.

Milwaukee Section Continues its Traditional Robotic Arc Welding Conference

Last May 11–13, **Karen Gilgenbach** and **Craig Wentzel** cochaired the AWS Milwaukee Section's National Robotic Arc Welding Conference and Exposition, featuring talks from experts in the field and tours of the Miller Electric Mfg. Co. and Caterpillar's Aurora, Ill., facility.

This year's theme was *Expanding the Use of Robots in Arc Welding beyond Traditional Applications*. Some of the non-traditional applications considered were using robots on short run jobs, one-off jobs, robots used in repair, laser hybrid welding, and making large weldments.

Don Vincent, executive vice president

— Robot continued on next page



Shown at the Milwaukee Section's National Robotic Arc Welding Conference are cochairmen Karen Gilgenbach and Craig Wentzel (front, center) with (from left) Jeff Noruk, John Hinrichs, Larry Gross, Bob Bruss, Gerald Blaski, and John Bultman.

— Robot continued from previous page

emeritus of Robotic Industries Assn., presented the keynote speech, *The Robotics Industry: Past and Future*.

The program highlighted the following presentations: *Welding automation for high-mix, low-volume production* — **Efi Lebel**, Smart TCP; *Adaptive welding increases your welding process robustness* — **Mike Garman**, Kawasaki Robotics; *Moving to modular welding fixturing is the key to success* — **Bob Ellig**, Bluco Corp.; *Laser hybrid welding* — **Ed Hansen**, ESAB Welding and Cutting Products; *Robotic*

arc welding case study success stories — **Doug Rhoda**, **Mike Davis**, and **Josh Cirbo** of Wolf Robotics; *Repair welding automation for steam turbine equipment* — **John Sassatelli**, GE Infrastructure; *Small maintenance for big success* — **Robert Bro-man** and **Lincoln Schildgen** of Helgesen Industries; *Robotics and tandem welding technology improve insourcing capability at Case New Holland* — **Doug Brooks** of Case New Holland and **Jim Berge** of Berge Robotics; *Using industrial robotic automation as a manufacturing competitive advantage* — **Andy Glaser**, Ellison Automation Technologies; *Cost, quality and*

speed in today's fast-paced lean power sports industry — **Jeff Steiner**, Plaris Industries; *Flexible and intelligent tooling for robotic automation* — **Mike Sharpe**, FANUC Robotics; and *Implementing Robotic welding in a job shop environment* — **Joe Lane**, D & S Manufacturing.

Cosponsors for the event were Fabricators and Manufacturers Assn. Int'l, Milwaukee Area Technical College, Caterpillar, Airgas, and the AWS D16 Committee on Robotic and Automatic Welding. Visit www.aws.org/sections/milwaukee, or write Karen Gilgenbach, karen.gilgenbach@airgas.com, for more information.

Member-Get-A-Member Campaign

Listed are the members participating in the 2009–2010 Member-Get-A-Member Campaign. See page 65 in this *Welding Journal* for campaign rules and prize list, or visit www.aws.org/mgm. These standings are as of July 21, 2009. If you have any questions regarding your member proposer points, call the AWS Membership Dept. (800/305) 443-9353, ext. 480.

Winner's Circle

Sponsored 20+ new members.

The superscript indicates the number of times, if more than once, Winner's Circle status was achieved since June 1, 1999.

J. Compton, San Fernando Valley⁷
E. Ezell, Mobile⁷
J. Merzthal, Peru²
G. Taylor, Pascagoula²
L. Taylor, Pascagoula²
S. Esders, Detroit
M. Haggard, Inland Empire
M. Karagoulis, Detroit
S. McGill, NE Tennessee
B. Mikeska, Houston
W. Shreve, Fox Valley

T. Weaver, Johnstown/Altoona
G. Woormer, Johnstown/Altoona
R. Wray, Nebraska

President's Roundtable

Sponsored 9–19 new members.

V. Craven, Pascagoula — 19
H. Thompson, New Orleans — 9

President's Club

Sponsored 3–8 new members.

R. Ellenbecker, Connecticut — 4
S. Keskar, India — 4
E. Ravelo, International — 4

President's Honor Roll

Sponsored 2 new members.

J. Barber, Connecticut
G. Burrión, South Florida

J. Compton, San Fernando Valley
R. Davis, Utah
G. Euliano, Northwestern Pennsylvania

Student Member Sponsors

J. Morash, Boston — 27
S. Burdge, Stark Central — 20
R. Evans, Siouxland — 20
E. Norman, Ozark — 20
G. Seese, Johnstown-Altoona — 16
A. Stute, Madison-Beloit — 15
R. Munns, Utah — 14
S. Kuntz, Pittsburgh — 10
W. Garrett, Olympic — 7
J. Fitzpatrick, Arizona — 4
S. MacKenzie, Northern Michigan — 4
N. Carlson, Idaho/Montana — 3

Distinguished Member and Student Chapter Member Awards Announced

Thomas P. Baldwin, Arrowhead Section, District 15, has attained the status of Distinguished Member for his participation in the Society's leadership, professional development activities, and membership recruitment. To qualify for distinguished member status, applicants must accrue 35 or more points from at least three of the following four categories: National AWS leadership, local AWS leadership, professional development, and AWS membership recruitment. If you believe you qualify for Distinguished Member status, call the AWS Membership Department at (800/305) 443-9353, ext. 260.

The following student members were

selected to receive the AWS Student Chapter Member Award by Section representatives at the District conferences.

Patrick Soddors, Nashville, District 8

Sheila Bender and **Ngoc Le**, Pascagoula, District 9

Shawn Mills, **Brandon Travassos**, and **Clint Taylor**, Baton Rouge, District 9

Jason Kaufman, Wyoming, District 20

Dusty Galloway, **Rory Compton**, and

Daniel Kahle, Sacramento, District 22

The AWS Board of Directors established the Student Chapter Member Award to recognize AWS Student Members whose Student Chapter activities have produced outstanding school, com-

munity, or industry achievements. This award also provides an opportunity for Student Chapter advisors, Section officers, and District directors to recognize outstanding students affiliated with AWS Student Chapters, as well as to enhance the image of welding within their communities.

To qualify for this certificate award, the individual must be an AWS Student Member affiliated with an AWS Student Chapter. The criteria and nomination form can be downloaded from the AWS Web page www.aws.org/sections/awards/student_chapter.pdf, or call the Membership Dept. at (800/305) 443-9353, ext. 260.

Nominations Sought for National Offices

AWS members who wish to nominate candidates for President, Vice President, and Director-at-Large on the AWS Board of Directors for the term starting Jan. 1, 2011, may 1) Send their nominations electronically by Oct. 5, 2009, to Gricelda Manalich at gricelda@aws.org, c/o Gene E. Lawson, chairman, National Nominating Committee, or 2) Present

their nominations in person at the open session of the National Nominating Committee meeting scheduled for 2:00 to 3:00 PM, Tuesday, November 17, 2009, at McCormick Place, Chicago, Ill., during the 2009 FABTECH International & AWS Welding Show.

Nominations must be accompanied by biographical material on each candi-

date, including a written statement by the candidate as to his or her willingness and ability to serve if nominated and elected, letters of support, plus a 5- × 7-inch head-and-shoulders color photograph. Note: Persons who present their nominations at the Show must provide 20 copies of the biographical materials and written statement.

Tech Topics

Errata B2.1-4-220:1999

AWS B2.1-4-220:1999, *Standard Welding Procedure Specification (WPS) for Gas Tungsten Arc Welding (Consumable Insert Root) of Chromium-Molybdenum Steel (M-4/P-4, Group 1 or 2), 1/8 through 1/2 in. Thick, As-Welded Condition, 1/8 through 3/4 in. Thick, PWHT Condition, IN515 and ER80S-B2, Primarily Pipe Applications*

The following errata have been identified and incorporated into the current reprint of this document.

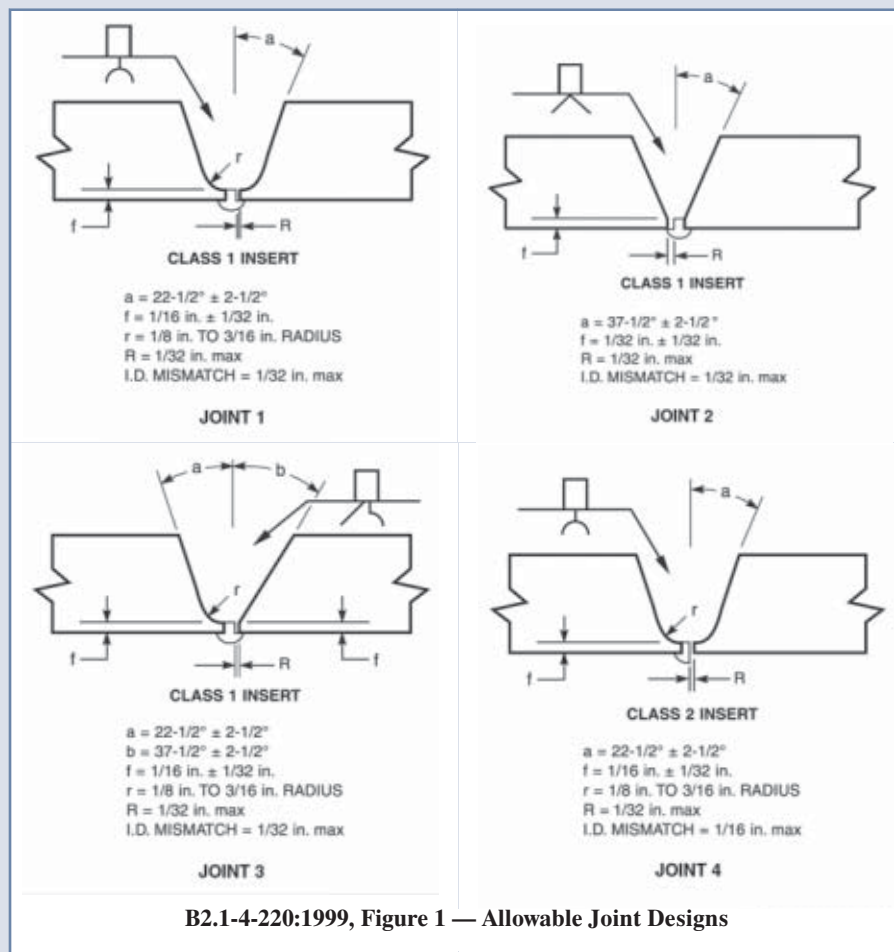
Pages 5, 6 — Figure 1, Joints 1–4 — Incorrect illustrations. Replace joint figures with the correct joint illustrations shown at right.

Errata D1.5:2008

AASHTO/AWS D1.5M/D1.5:2008, *Bridge Welding Code*

The following errata have been identified and incorporated into the current reprint of this document.

Page 241, Clause H2, first paragraph — Incorrect reference. Change reference from “Annex Table G.1” to “Annex Table H.1”.



B2.1-4-220:1999, Figure 1 — Allowable Joint Designs

Technical Committee Meetings

All AWS technical committee meetings are open to the public. Persons wishing to attend a meeting should call the staff secretary of the committee as listed below at (800/305) 443-9353.

Sept. 22–25, D1 Committee on Structural Welding and subcommittees. Philadelphia, Pa. Call S. Morales, ext. 313.

Oct. 6–8, B2 Committee on Procedure and Performance Qualification. Pittsburgh, Pa. Call S. Morales, ext. 313.

Oct. 14–16, A2 Committee and Subcommittees on Definitions and Symbols. Wheeling, W.Va. Call A. Alonso, ext. 299.

Oct. 22, C4 Committee on Oxyfuel Gas Welding and Cutting. Cleveland, Ohio. Call A. Alonso, ext. 299.

New Standards Projects

Development work has begun on the following revised standards. If you want to contribute to this work, contact the secretary listed. Participation on AWS technical committees is open to all persons.

A5.29/A5.29M:200X, *Specification for Low-Alloy Steel Electrodes for Flux Cored*

Arc Welding. This specification prescribes the requirements for classification of low-alloy steel electrodes for flux cored arc welding. Stakeholders: Welding Industry. R. Gupta, ext. 301.

D16.1M/D16.1:200X, *Specification for Robotic Arc Welding Safety*. This standard establishes safety requirements with respect to the design, manufacture, maintenance, and operation of arc welding robot systems and ancillary equipment. It also helps to identify and minimize hazards involved in maintaining, operating, integrating, and setting up of arc welding robot systems. Stakeholders: Robotic arc welding personnel. M. Rubin, ext. 215.

D16.4M/D16.4:200X, *Specification for the Qualification of Robotic Arc Welding Personnel*. This specification provides requirements for the qualification of robotic arc welding support personnel at three different levels — CRAW-L1, CRAW-O, and CRAW-T. The revisions in this edition align education and experience requirements more realistically with those in industry. Stakeholders: Robotic arc welding personnel. M. Rubin, ext. 215.

F1.1M:200X, *Method for Sampling Airborne Particles and Gases Generated by Welding and Allied Processes*. This document aids the reader in the proper technique for sampling welding fume and gases in the workplace. Stakeholders: Industrial hygienists, safety professionals. S. Hedrick, ext. 305.

Z49.1:200X, *Safety in Welding, Cutting, and Allied Processes*. This standard covers all aspects of safety and health in the welding environment, emphasizing oxygen gas and arc welding processes with some coverage given to resistance welding. It contains information on protection of personnel and the general area, ventilation, fire prevention and protection, and confined spaces. A significant section is devoted to precautionary information, showing examples, and an extensive bibliography is included. Stakeholders: Welders, supervisors of welders, educators. S. Hedrick, ext. 305.

New Standards Approved by ANSI

D1.7/D1.7M:2010, *Guide for Strengthening and Repairing Existing Structures Supplement*. Date 7/1/09.

D17.3/D17.3M:2009, *Specification for*

Friction Stir Welding of Aluminum Alloys for Aerospace Applications. Date 7/1/09.

Standards for Public Review

B5.5:200X, *Specification for the Qualification of Welding Educators.* Revised standard — \$25. 8/24/09.

C4.1-77 (R200X), *Criteria for Describing Oxygen-Cut Surfaces.* Reaffirmed standard — \$25. 8/31/09.

D10.14M/D10.14:200X, *Guide for Multipass Orbital Machine Pipe Groove Welding.* New standard — \$25. 8/17/09.

D10.17M:200X, *Guide for Welding Tubular Steel Vehicle Structures.* New standard — \$25. 8/17/09.

AWS was approved as an accredited standards-preparing organization by the

American National Standards Institute (ANSI) in 1979. AWS rules, as approved by ANSI, require that all standards be open to public review for comment during the approval process. The above standards were open for public review until the date shown. Contact R. O'Neill, (800/305) 443-9353, ext. 451, roneill@aws.org, for copies.

ISO Draft Standard for Public Review

ISO/DIS 6947.2, *Welds — Welding positions.* Copies of this standard are available for review and comment through your national standards body, which in the United States is ANSI, 25 W. 43rd St., Fourth Floor, New York, NY, 10036; (212) 642-4900. Send comments regarding ISO documents to your national stan-

dards body. In the United States, if you wish to participate in the development of international standards for welding, contact Andrew Davis, (305) 443-9353, ext. 466; adavis@aws.org.

Revised Standards Approved by ANSI

A3.0M/A3.0:2010, *Standard Welding Terms and Definitions.* Approved 7/1/09.

B1.10M/B1.10:2009, *Guide for the Nondestructive Examination of Welds.* Date 7/1/09.

B2.2/B2.2M:2010, *Specification for Brazing Procedure and Performance Qualification.* Date 7/7/09.

D18.2:2009, *Guide to Weld Discoloration Levels on Inside of Austenitic Stainless Steel [CHART].* Date 6/22/09.

Members Sought for AWS Technical Committees

Thermal Spraying

Volunteers are sought to participate on the C2 Committee on Thermal Spraying. Its documents include **C2.16**, *Guide for Thermal-Spray Operator Qualification*; **C2.18**, *Guide for the Protection of Steel with Thermal Sprayed Coatings of Aluminum and Zinc and their Alloys and Composites*; **C2.19**, *Machine Element Repair*; **C2.20**, *Thermal Sprayed Coating for Reinforced Concrete*; **C2.21**, *Specification for Thermal Spray Equipment Acceptance Inspection*; **C2.23**, *Specification for the Application of Thermal Spray Coatings (Metallizing) of Aluminum, Zinc, and Their Alloys and Composites for the Corrosion Protection of Steel*; **C2.25**, *Specification for Thermal Spray Feedstock — Solid and Composite Wire and Ceramic Rods.* Contact Reino

Starks, rstarks@aws.org, (800/305) 443-9353, ext. 304, for information, or visit www.aws.org/1UQ4 to submit your application online.

Welding Sales Representatives

AWS established a new certification program for welding sales representatives in 2009. Be part of the technical subcommittee responsible for setting the qualification requirements, **AWS B5.14**, *Specification for the Qualification of Welding Sales Representatives*, that this program is based on. For complete information about this committee's work, contact John Gayler, gayler@aws.org, (800/305) 443-9353, ext. 472; or submit a technical committee application online at www.aws.org/1UQ4.

Robotic and Automatic Welding

Volunteers are sought to participate on the D16 Committee on Robotic and Automatic Welding. Its documents include **D16.1**, *Specification for Robotic Arc Welding Safety*; **D16.2**, *Guide for Components of Robotic and Automatic Arc Welding Installations*; **D16.3**, *Risk Assessment Guide for Robotic Arc Welding*; and **D16.4**, *Specification for Qualification of Robotic Arc Welding Personnel.* Persons engaged in robotic welding operations and suppliers of equipment who want to contribute their expertise to the preparation of one or more of these documents are urged to contact Matt Rubin, mrubin@aws.org; (800/305) 443-9353, ext. 215, for information; or visit www.aws.org/1UQ4 to submit your member application online.

Name Your Candidate for the Prof. Masubuchi Award

November 2 is the deadline for submitting nominations for the 2010 Prof. Koichi Masubuchi Award, sponsored by the Dept. of Ocean Engineering at Massachusetts Institute of Technology. This award includes an honorarium of \$5000. It is presented each year to one person who has made significant contributions to the advancement of materials joining through his or her research and de-

velopment activities.

The candidate must be 40 years old or younger, may live anywhere in the world, and need not be an AWS member. The nomination package should be prepared by someone familiar with the research background of the candidate. It should include the candidate's résumé listing background, experience, publications, honors, and awards, plus at

least three letters of recommendation from fellow researchers.

This award was established to recognize Prof. Koichi Masubuchi for his numerous contributions to the advancement of the science and technology of welding, especially in the fields of fabricating marine and outer space structures. E-mail your nominations to Prof. John DuPont at jnd1@lehigh.edu.

Life Members Offered Perks at FABTECH International & AWS Welding Show

AWS Life Members are urged to take advantage of their complimentary free admission to the upcoming FABTECH International & AWS Welding Show, including MetalForm, plus free registration to the entire Professional Program (a \$325 value).

The event will take place Nov. 15–18, 2009, at McCormick Place in Chicago, Ill.

The free Professional Program registration entitles AWS Life Members to attend any of the technical sessions occurring during the three-day period.

The registration form is part of the *Advance Program* to be mailed to all members with the September issue of *Welding Journal*; or call the Membership Dept., (800) 443-9353, ext. 260, to have

the form mailed to you.

To obtain your free registration, be sure to mark "AWS Life Member: Free Registration" at the top of the form. Then fax both sides of the form to (305) 443-7559, Attn.: Ruben Lara, accounting director, or mail the form to AWS c/o Ruben Lara, 550 NW LeJeune Rd., Miami, FL 33126.

SECTION NEWS



Tom Ferri (standing, rear) is shown with vocational instructors during the Boston Section program in July.



Laurie Jones (left) is shown with Gary Hylan at the Boston Section golf outing.



Winners in the Boston Section June golf outing are (from left) John Matarese, Paul Kimbar, Fred Baglioni, and Tom Ferri.

District 1

Russ Norris, director
(207) 604-9262
russ.norris@airgas.com

BOSTON

JUNE 22

Activity: The Section held its 26th consecutive annual golf outing at Ridder Farms Country Club in East Bridgewater, Mass. The scramble-style golf tournament was won by **John Matarese, Paul Kimbar, Fred Baglioni, and Tom Ferri.** Laurie Jones served as golf outing committee chairman.

JULY 1

Activity: **Tom Ferri** presented the new AWS video on *Hot Bikes, Fast Cars, and Cool Careers* to the Massachusetts Association of Vocational Administrators annual Connecting for Success seminar. Attending this Boston Section program were metal fabrication and welding in-



Shown proctoring the Connecticut Section's CWI exam are (from left) Tom Ferri, Walter Chojnaki, and Kathie McGirr.

structors representing 25 Massachusetts Regional Vocational Schools. Following the presentation, Ferri demonstrated the features of the Thermal Arc Arcmaster AC/DC inverter and 95S 110-V welding machine. The program was held in Marlboro, Mass.

CONNECTICUT

JUNE 20

Activity: The Section hosted a CWI examination at Marriott Hotel at Bradley Int'l Airport in Hartford, Conn. Proctors for the event were **Walter Chojnaki, Tom Ferri, and Kathie McGirr.**



Reading Section Level 1 welding contestants are (from left) Nick Reber, Allen Burton, Cory Stuebner, and Luke Johnson.



Reading Section Level 2 welding contestants are (from left) Jonathan Spontak, Travis Davies, Jason Wallace, Nate Bauman, and Alex Ferrara.



Shown at the Reading Section welding program are contest chairman Francis Butkus (center) with Level 3 contestants Shane McEntarfer (left) and winner Austin Chavous.

District 2

Kenneth R. Stockton, director
(908) 412-7099
kenneth.stockton@pseg.com

District 3

Michael Wiswesser, director
(610) 820-9551
mike@welderinstitute.com

READING

APRIL 16

Activity: The Section met at Reading-Muhlenberg Career and Technology Center in Reading, Pa., for presentation of the student welding contest awards. **Francis Butkus** served as contest chairman. Top scorers in Levels 1, 2, and 3 were **Luke Johnson**, **Alex Ferrara**, and **Austin Chavous**, respectively. Others receiving certificates were **Drew Lehr**, **Jeremy Martin**, **Joseph Zavala**, **Shane McEntarfer**, **Joey Brennan**, **Jonathan Spontak**, **Travis Davies**, **Jason Wallace**, **Nate Bauman**, **Nick Reber**, **Cody Byrnes**, **Allen Burton**, **Jacob Padilla**, and **Cory Stuebner**. The welding instructors voted for the following contestants to receive the Most Outstanding Senior Award in Welding for 2009: **Austin Chavous**, **Allen Burton**, **Samuel Soto**, **Nate Bauman**, and **Derek Nissley**.

District 4

Roy C. Lanier, director
(252) 321-4285
rlanier@email.pittcc.edu

District 5

Steve Mattson, director
(904) 260-6040
steve.mattson@yahoo.com

District 6

Kenneth Phy, director
(315) 218-5297
kenneth.phy@gmail.com

District 7

Don Howard, director
(814) 269-2895
howard@ctc.com

PITTSBURGH

JULY 13

Activity: The Section held an executive board meeting at Rockefeller's Grille in McKees Rocks, Pa., to discuss plans for the upcoming season's activities. Attending were Chairman **Dave Daugherty**, **John Menhart**, **Jim Sekely**, **Carl Spaeder**, **Tom White**, **Carl Ott**, **Dave McQuaid**, and **Brad King**.

District 8

Joe Livesay, director
(931) 484-7502, ext. 143
joe.livesay@ttcc.edu

District 8 Conference

JUNE 3, 4

Activity: The District 8 conference was held in Mt. Juliet, Tenn. Attending were District 8 Director **Joe Livesay**, **Robbin Shull**, **Patrick Soddors**, **Rodney Patterson**, **Dusti Jones**, **Joe Smith**, **Bob O'Neal**, **Robert Roehl**, **Gary Gammill**, **William Hamilton**, **John Kahl**, **Dave Hamilton**, AWS past President **Tom Mustaleski**, **Bob Humphrey**, **Conrad Young**, **Julian Kerr**, **Richard White**, and **Linda Henderson**, AWS staff representative.

WEST TENNESSEE

JULY 7

Activity: The Section conducted a business meeting at Tennessee Technology Center in Jackson, Tenn., to vote on a Section bylaws amendment and install the incoming slate of officers.

District 9

George D. Fairbanks Jr., director
(225) 473-6362
fits@bellsouth.net



Shown at the Pittsburgh Section board meeting are (front row, from left) John Menhart, Jim Sekely, Carl Spaeder, and Tom White; (back row, from left) Carl Ott, Chair Dave Daugherty, Dave McQuaid, and Brad King.

District 10

Richard A. Harris, director
 (440) 338-5921
richaharris@windstream.net

District 11

Eftihios Siradakis, director
 (989) 894-4101
ft.siradakis@airgas.com

DETROIT

JULY 17

Activity: The Section hosted its annual golf outing at Sycamore Hills Golf Club and Banquet Center in Chesterfield Township, Mich. **Thomas Slawnyk** presented trophies to the first-place team members **Pat Gilmore**, **John Grugel**, **Mark Gutting**, and **Greg Chmielewski**. The event attracted 50 players and raised \$590 for the Section's scholarship fund.

District 12

Sean P. Moran, director
 (920) 954-3828
sean.moran@hobartbrothers.com

District 13

W. Richard Polanin, director
 (309) 694-5404
rpolanin@icc.edu

District 13 Conference

JUNE 5

Activity: **Rick Polanin**, District 13 director, conducted the conference at Grizzly Jack's Resort in Utica, Ill. **Andrew Davis**, managing director, Technical Services, participated as the AWS staff representative. Polanin, Davis, and **John Willard**, J.A.K. Section chair, presented **Hank Sima**, Chicago Section chair, the District Educator Award.



Shown at the District 8 conference are (front row, from left) Robbin Shull, Patrick Soddors, Rodney Patterson, Dusti Jones, Joe Smith, Bob O'Neal, Robert Roehl, Gary Gammill, and Linda Henderson; (back row, from left) William Hamilton, John Kahl, Dave Hamilton, Tom Mustaleski, Bob Humphrey, District 8 Director Joe Livesay, Conrad Young, Julian Kerr, and Richard White.



Shown at the Detroit Section golf outing are (from left) Pat Gilmore, John Grugel, Mark Gutting, Greg Chmielewski, and Thomas Slawnyk.



Shown at the District 13 conference are (from left) AWS staff representative Andrew Davis; Hank Sima, Chicago Section chair; Rick Polanin, District 13 director; and John Willard, J.A.K. Section chairman.



Shown at the Chicago Section meeting are (from left) Jim Greer, Marty Vondra, Chair Hank Sima, Cliff Ifitimie, and Eric Krauss.

CHICAGO

JUNE 30

Activity: The Section held a board meeting at Baily's Restaurant in Westmont, Ill., to plan for the upcoming season's events. **Jim Greer**, a past AWS president, was elected Section chairman for 2009–2010.

District 14

Tully C. Parker, director

(618) 667-7795

tparke@millervelds.com

District 15

Mace V. Harris, director

(612) 861-3870

macevh@aol.com

District 16

David Landon, director

(641) 621-7476

dlandon@vermeermfg.com

District 16 Conference

JUNE 13

Activity: The District 16 conference was held in Omaha, Neb., conducted by **David Landon**, District 16 director. Attending were **Mike Vincent**, **Dennis Wright**, and **Jason Miles** (Kansas City Section); **Rick Hanny**, **Eric Nordhues**, and **Karl Fogleman** (Nebraska Section); **Diane Steadham** (Kansas Section); **Marla and Bob Kephart** (Iowa Section); and **Monica Pfarr**, corporate director, Solutions Opportunities Squad, AWS Foundation.



Shown at the District 16 conference are (from left) Rick Hanny, Mike Vincent, Eric Nordhues, and Karl Fogleman.



District 16 attendees included (front row) Marla and Bob Kephart, District 16 Director David Landon, and Diane Steadham; (back row, from left) Mike Vincent, Dennis Wright, and Jason Miles.

KANSAS CITY & KANSAS

MAY 19

Activity: The Kansas City and Kansas Sections held a joint meeting to tour the Taylor Forge Engineered Systems plant in Paola, Kan. The company is a supplier of precision products to the pipeline, processing, refining, chemical, power, nuclear, aerospace, and defense industries.

District 17

J. Jones, director

(940) 368-3130

jjones@thermadyne.com

District 18

John Bray, director

(281) 997-7273

sales@affiliatedmachinery.com



Working the District 16 conference are (from left) Monica Pfarr, District 16 Director David Landon, Dennis Wright, and Jason Miles.



Kansas City and Kansas Section members are shown during their tour of Taylor Forge Engineered Systems in May.



District 19 Section officers are shown at the District 19 conference May 30.

District 19

Neil Shannon, director
(503) 419-4546
neilshnn@msn.com

District 19 Conference

MAY 30

Activity: **Neil Shannon**, District 19 director, conducted the meeting in Seattle, Wash. Attending were representatives from the Alaska, Alberta, British Columbia, Inland Empire, Olympic, Portland, Puget Sound, Spokane, and Willamette Valley Sections. The event featured a dinner cruise on Lake Washington.



Shown at the Olympic Section program are (from left) Ashe Weatherly, Sjon Delmore, and Trevor Buechner.

OLYMPIC

MAY 20

Activity: The Section hosted its social outing at Old Town Music Society Hall in Tacoma, Wash. Scholarship Chairman **Sjon Delmore** presented \$500 scholarships to **Trevor Buechner** of Bates Technical College, and **Ashe Weatherly** from Olympic College.



Shown at the Colorado Section meeting are (from left) Chairman James Corbin, speaker Mark Bell, and Dean Mitchell, vice chairman.

District 20

William A. Komlos, director
(801) 560-2353
bkoz@arctechllc.com



The Idaho/Montana Section and INLREA members are shown during the June 11 tour.



Eric Larsen (standing) spoke at the Idaho/Montana Section June 18 program. Shown are (from left) Corrie Nichol, David Pace, and Rodney Shurtliff.



Welding technology graduate Ingrid Edwards is shown with Jack Compton, chair, San Fernando Valley Section.

COLORADO

MAY 9

Speaker: **Mark Bell**, past District 20 director

Affiliation: P.E., welding consultant

Topic: Stainless steel failure analysis

Activity: **James Corbin** received an appreciation award for serving as Section chairman. The program was held at Warren Tech Career & Technical High School Welding Center in Lakewood, Colo.

IDAHO/MONTANA

JUNE 11

Speaker: **David Petti**, Fellow

Affiliation: Idaho National Laboratory

Topic: Status of nuclear reactor and nuclear fuels research nationally and internationally

Activity: The Section met with members of the Idaho National Laboratory Retired Employees Association (INLREA) for a joint outing to tour the Center for Advanced Energy Studies in Idaho Falls, Idaho. **Oren Hester**, deputy director, con-

ducted the tour of the laboratory and presented an overview of its current research programs. A special guest was **Jesse Webb**, a welding engineering student at Weber State University, who traveled from Ogden, Utah, to participate in the program.

JUNE 18

Speaker: **Eric Larsen**, lead engineer

Affiliation: Idaho National Laboratory

Topic: The Yucca Mountain waste package closure system

Activity: Larsen discussed the complexity of software integration for the 13-axis system. This event was part of the Idaho National Laboratory Brew with the Crew informal technical seminar series, held in Idaho Falls, Idaho.

District 21

Nanette Samanich, director

(702) 429-5017

Nan07@aol.com

SAN DIEGO

APRIL 7

Speaker: **Ricky Morgan**

Affiliation: Smith-Emery Co.

Topic: Northridge revisited, the post-seismic nondestructive testing

Activity: The Section met with members of the local chapter of ASNT for this program.

MAY 19

Activity: The Section members met at San Diego Community College to support local welding students and share information about the school's new welding program. **Brian Ellison**, vice president of instruction and student services continuing education, made a presentation then conducted a tour of the updated welding facility that features 90 welding booths.

SAN FERNANDO VALLEY

JULY

Activity: **Ingrid Edwards**, recipient of District 21 and San Fernando Valley Section scholarships, graduated from College of the Canyons with an associate of arts degree in welding technology. She studied with **Jack Compton**, professor of welding technology and Section chairman. Edwards plans to pursue a bachelor's degree in business administration then start a welding business.

District 22

Dale Flood, director

(916) 288-6100, ext. 172

flashflood@email.com

**NEW PRIZES.
NEW CAMPAIGN.
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MEMBERS TODAY!**

Win Great Prizes in the **2009-2010 AWS Member-Get-A-Member Campaign***

ABOUT: AWS is looking for individuals to become part of an exclusive group of AWS Members who get involved and win. Give back to your profession, strengthen AWS and win great limited-edition prizes by participating in the 2009-2010 Member-Get-A-Member Campaign. By recruiting new members to AWS, you're adding to the resources necessary to expand your benefits as an AWS Member. Year round, you'll have the opportunity to recruit new members and be eligible to win special contests and prizes. Referrals are our most successful member recruitment tool. Our Members know first-hand how useful AWS Membership is, and with your help, AWS will continue to be the leading organization in the materials joining industry.

To recruit new Members, use the application on the reverse, or visit www.aws.org/mgm

PRIZE CATEGORIES

President's Honor Roll: Recruit 1-2 new Individual Members and receive an AWS key chain.

President's Club: Recruit 3-8 new Individual Members and receive an AWS hat and an AWS key chain.

President's Roundtable: Recruit 9-19 new Individual Members and receive an AWS polo shirt, hat and an AWS key chain.

President's Guild: Recruit 20 or more new Individual Members and receive an AWS watch, an AWS polo shirt, a one-year free AWS Membership, the "Shelton Ritter Member Proposer Award" Certificate and membership in the Winner's Circle.

Winner's Circle: All members who recruit 20 or more new Individual Members will receive annual recognition in the *Welding Journal* and will be honored at FABTECH International & AWS Welding Show.

SPECIAL PRIZES

Participants will also be eligible to win prizes in specialized categories. Prizes will be awarded at the close of the campaign (June 2010).

Sponsor of the Year: The individual who sponsors the greatest number of new Individual Members during the campaign will receive a plaque, a trip to the 2010 FABTECH International & AWS Welding Show, and recognition at the AWS Awards Luncheon at the Show.

Student Sponsor Prize: AWS Members who sponsor two or more Student Members will receive an AWS key chain.

The AWS Member who sponsors the most Student Members will receive a free, one-year AWS Membership, an AWS polo shirt, hat and an AWS key chain.

International Sponsor Prize: Any member residing outside the United States, Canada and Mexico who sponsors the most new Individual Members will receive a complimentary AWS Membership renewal.

LUCK OF THE DRAW

For every new member you sponsor, your name is entered into a quarterly drawing. The more new members you sponsor, the greater your chances of winning. Prizes will be awarded in November 2009, as well as in February and June 2010.

Prizes Include:

- ★ Complimentary AWS Membership renewal
- ★ AWS t-shirt
- ★ AWS hat

SUPER SECTION CHALLENGE

The AWS Section in each District that achieves the highest net percentage increase in new Individual Members before the June 2010 deadline will receive special recognition in the *Welding Journal*.

The AWS Sections with the highest numerical increase and greatest net percentage increase in new Individual Members will each receive the Neitzel Membership Award.

*The 2009-2010 MGM Campaign runs from June 1, 2009 to May 31, 2010. Prizes are awarded at the close of the campaign.



American Welding Society

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☐ Mr. ☐ Ms. ☐ Mrs. ☐ Dr. Please print • Duplicate this page as needed

Last Name _____

First Name _____ M.I. _____

Title _____ Birthdate _____

Were you ever an AWS Member? ☐ YES ☐ NO If "YES," give year _____ and Member # _____

Primary Phone () _____ Secondary Phone () _____

FAX () _____ E-Mail _____

Did you learn of the Society through an AWS Member? ☐ Yes ☐ No

If "yes," Member's name: _____ Member's # (if known): _____

From time to time, AWS sends out informational emails about programs we offer, new Member benefits, savings opportunities and changes to our website. If you would prefer not to receive these emails, please check here ☐

ADDRESS

NOTE: This address will be used for all Society mail.

Company (if applicable) _____

Address _____

Address Con't. _____

City _____ State/Province _____ Zip/Postal Code _____ Country _____

PROFILE DATA

NOTE: This data will be used to develop programs and services to serve you better.

- ① Who pays your dues?: ☐ Company ☐ Self-paid ② Sex: ☐ Male ☐ Female
- ③ Education level: ☐ High school diploma ☐ Associate's ☐ Bachelor's ☐ Master's ☐ Doctoral

PAYMENT INFORMATION (Required)

ONE-YEAR AWS INDIVIDUAL MEMBERSHIP\$80
TWO-YEAR AWS INDIVIDUAL MEMBERSHIP†~~\$160~~ \$135



New Member? ☐ Yes ☐ No

If yes, add one-time initiation fee of \$12\$ _____

International Members add \$50 for optional hard copy of *Welding Journal* (note: digital delivery of *WJ* is standard)†††\$50 (Optional)

{ Domestic Members add \$25 for book selection (\$192 value), and save up to 87%††.....\$ _____ (Optional)

{ International Members add \$75 for book selection (note: \$50 is for international shipping) ††.....\$ _____ (Optional)
(Note: Book Selection applies to new Individual Members only – Book selections on upper-right corner)

TOTAL PAYMENT\$ _____

AWS STUDENT MEMBERSHIP †††

- ☐ Domestic (Canada & Mexico incl.)\$15
☐ International\$50

TOTAL PAYMENT\$ _____

NOTE: Dues include \$18.70 for *Welding Journal* subscription and \$4.00 for the AWS Foundation.

Payment can be made (in U.S. dollars) by check or money order (international or foreign), payable to the American Welding Society, or by charge card.

- ☐ Check ☐ Money Order ☐ Bill Me
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Source Code **WJ** _____ Date _____ Amount _____



American Welding Society

P.O. Box 440367
Miami, FL 33144-0367
Telephone (800) 443-9353
FAX (305) 443-5647
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Member Services Revised 12/12/08

†Two-year Individual Membership Special Offer: applies only to new AWS Individual Members. ††Discount Publication Offer: applies only to new AWS Individual Members. Select one of the six listed publications for an additional \$25; International Members add \$75 (\$25 for book selection and \$50 for international shipping); Multi-Year Discount: First year is \$80, each additional year is \$75. No limit on years (not available to Student Members). †††Student Member: Any individual who attends a recognized college, university, technical, vocational school or high school is eligible. Domestic Members are those students residing in North America (incl. Canada & Mexico). This membership includes the *Welding Journal* magazine. Student Memberships do not include a discounted publication. ††††International hard copy *Welding Journal* option: applies only to International AWS Welder Members (excludes Canada and Mexico). Digitized delivery of *WJ* is standard

BOOK/CD-ROM SELECTION

(Pay Only \$25... up to a \$192 value)

NOTE: Only New Individual Members are eligible for this selection. Be sure to add \$25 to your total payment.

ONLY ONE SELECTION PLEASE.

- ☐ *Jefferson's Welding Encyclopedia (CD-ROM only)*
- ☐ *Design and Planning Manual for Cost-Effective Welding*
- ☐ *Welding Metallurgy*
- ☐ *Welding Handbook (9th Ed., Vol. 3)*
- ☐ *Welding Handbook (9th Ed., Vol. 2)*
- ☐ *Welding Handbook (9th Ed., Vol. 1)*

For more book choices visit

www.aws.org/membership

Learn more about each publication at www.aws.org/membership

☐ New Member ☐ Renewal

A free local Section Membership is included with all AWS Memberships.

Section Affiliation Preference (if known):

Type of Business (Check ONE only)

- A ☐ Contract construction
- B ☐ Chemicals & allied products
- C ☐ Petroleum & coal industries
- D ☐ Primary metal industries
- E ☐ Fabricated metal products
- F ☐ Machinery except elect. (incl. gas welding)
- G ☐ Electrical equip., supplies, electrodes
- H ☐ Transportation equip. — air, aerospace
- I ☐ Transportation equip. — automotive
- J ☐ Transportation equip. — boats, ships
- K ☐ Transportation equip. — railroad
- L ☐ Utilities
- M ☐ Welding distributors & retail trade
- N ☐ Misc. repair services (incl. welding shops)
- O ☐ Educational Services (univ., libraries, schools)
- P ☐ Engineering & architectural services (incl. assns.)
- Q ☐ Misc. business services (incl. commercial labs)
- R ☐ Government (federal, state, local)
- S ☐ Other

Job Classification (Check ONE only)

- 01 ☐ President, owner, partner, officer
- 02 ☐ Manager, director, superintendent (or assistant)
- 03 ☐ Sales
- 04 ☐ Purchasing
- 05 ☐ Engineer — welding
- 20 ☐ Engineer — design
- 21 ☐ Engineer — manufacturing
- 06 ☐ Engineer — other
- 10 ☐ Architect designer
- 12 ☐ Metallurgist
- 13 ☐ Research & development
- 22 ☐ Quality control
- 07 ☐ Inspector, tester
- 08 ☐ Supervisor, foreman
- 14 ☐ Technician
- 09 ☐ Welder, welding or cutting operator
- 11 ☐ Consultant
- 15 ☐ Educator
- 17 ☐ Librarian
- 16 ☐ Student
- 18 ☐ Customer Service
- 19 ☐ Other

Technical Interests (Check all that apply)

- A ☐ Ferrous metals
- B ☐ Aluminum
- C ☐ Nonferrous metals except aluminum
- D ☐ Advanced materials/Intermetallics
- E ☐ Ceramics
- F ☐ High energy beam processes
- G ☐ Arc welding
- H ☐ Brazing and soldering
- I ☐ Resistance welding
- J ☐ Thermal spray
- K ☐ Cutting
- L ☐ NDT
- M ☐ Safety and health
- N ☐ Bending and shearing
- O ☐ Roll forming
- P ☐ Stamping and punching
- Q ☐ Aerospace
- R ☐ Automotive
- S ☐ Machinery
- T ☐ Marine
- U ☐ Piping and tubing
- V ☐ Pressure vessels and tanks
- W ☐ Sheet metal
- X ☐ Structures
- Y ☐ Other
- Z ☐ Automation
- 1 ☐ Robotics
- 2 ☐ Computerization of Welding

New AWS Supporters

Affiliate Companies

3D Steel Corp.
841 S. Chestnut St.
Salt Lake City, UT 84104

ABM Fabricators LLC
1316 Commerce St.
Birmingham, AL 35217

ARC Force Welding LLC
186 Upper Salem Church Rd.
Jasper, GA 30143

BHL International Inc.
5223 Hopper Rd.
Houston, TX 77093

Honduacero
Colonia El Alamo Calle Principal
Edificio MG #825
Tegucigalpa, FM, Honduras

Mavrix Automatic Welding
W182 S8363 Racine Ave.
Muskego, WI 53150

Metal Solutions Inc.
PO Box 1435
330 S. 3rd Ave.
Ault, CO 80610

Metro Technologies Ltd.
1462 E. Big Beaver Rd.
Troy, MI 48083

PM Fabrication
PO Box 1217
Concord, NC 28026

Supporting Companies

Goa Shipyard Ltd.
Vasco-Da-Gama, Goa 403802, India

**Mecatronica Ingenieria y
Fabricacion SA de CV**
Av. 5 de Febrero #405 Int. 407
Col. Centro
Apizaco, Tlaxcala 90300
Mexico

MIGfast Pty. Ltd.
497 Hammond Rd.
Dandenong, Victoria 3175, Australia

Northrop Grumman
5100 River Rd., M/S 205-1-3
Avondale, LA 70094

Prevail Technology (Shenzhen) Co., Ltd.
No. 25 Caitian Rd.,
Shatian Ind. Zone
Kengzi Town,
Longgang Dist.
Shenzhen, Guangdong, China

Tyco Valves & Controls LP
9025 Moya Blvd.
Reno, NV 89506

Educational Institutions

**Centro de Asistencia y
Servicios Tecnologicos**
Ave. Pablo Livas #4500
Col. Guadalupe Victoria
Guadalupe, Nuevo Leon, 67180, Mexico

College of Southern Idaho
315 Falls Ave.
Twin Falls, ID 83316

Dallas County Career Center
33 Vo-Tech Rd.
Louisburg, MO 65685

**Industrial Maintenance
Int'l Training Center, Inc.**
2526 Lemery St., Sta. Ana
Manila 1009, Philippines

Pars Saman Toos Co.
25/ 1-2nd Fl. Daneshgah18
Daneshgah Ave., Mashhad, Khorasan
9137663555, Iran

Wharton County Junior College
911 Boling Hwy.
Wharton, TX 77489

New Sustaining Companies

Hagler Systems
890 W. Five Notch Rd.
North Augusta, SC 29860
www.haglersystems.com
Representative: **George S. McCall II**

Hagler Systems designs, manufactures, and fields heavy equipment for and provides technical services to mining and dredging industries worldwide. Typical applications consist of slurry- and solids-handling pumps in all sizes, the complete spectrum of associated hardware and supporting systems, and full-featured, turnkey controls.

Metso Power
25 Rodeo Dr.
Fairmont, WV 26554
www.metsopowerservice.com
Representative: **Chuck Kuretz**

Metso Power's 58,000-sq-ft manufacturing facility concentrates on tube shields, plate work fabrication, and machining. Its process capabilities include saws, shears, press brakes, tube benders, CNC milling, manual machining, CNC laser cutting, high-definition plasma and welding, and SH-D equipment, including related tools to augment production.

Roots Steel System
C/O CPC, Villa No. 2, Delma St.
Abu Dhabi, UAE
www.rootssteel.com
Representative: **Satish Keskar**

Roots Steel System is a joint venture of Construction Products Holding Co. and Roots Group Arabia. It was established in 2008 to meet the growing demand for preengineered buildings in the Middle East and Africa. The joint venture is constructing three plants each with the capacity to ship 100,000 MT/year of complete metal building solutions.

Membership Counts

Member Grades	As of 8/01/09
Sustaining.....	507
Supporting.....	313
Educational.....	497
Affiliate.....	478
Welding distributor.....	46
Total corporate members.....	1,841
Individual members.....	51,958
Student + transitional members.....	5,861
Total members.....	57,819

Guide to AWS Services

American Welding Society
550 NW LeJeune Rd., Miami, FL 33126
www.aws.org; (800/305) 443-9353; FAX (305) 443-7559
Staff telephone extensions are shown in parentheses.

AWS PRESIDENT

Victor Y. Matthews
vic_matthews@lincolnelectric.com
The Lincoln Electric Co.
7955 Dines Rd., Novelty, OH 44072

ADMINISTRATION

Executive Director
Ray W. Shook.. rshook@aws.org(210)

Deputy Executive Director
Cassie R. Burrell.. cburrell@aws.org(253)

Senior Associate Executive Director
Jeff Weber.. jweber@aws.org(246)

Associate Executive Director Accounting
Gesana Villegas.. gvillegas@aws.org(252)

Executive Assistant for Board Services
Gricelda Manalich.. gricelda@aws.org(294)

Administrative Services

Managing Director
Jim Lankford.. jiml@aws.org(214)

IT Network Director
Armando Campana.. acampana@aws.org(296)

Director
Hidail Nuñez.. hidail@aws.org(287)

Database Administrator
Natalia Swain.. nswain@aws.org(245)

Human Resources

Director, Compensation and Benefits
Luisa Hernandez.. luisa@aws.org(266)

Director, Human Resources
Dora A. Shade.. dshade@aws.org(235)

INT'L INSTITUTE of WELDING

Senior Coordinator
Sissibeth Lopez.. ssissi@aws.org(319)
Provides liaison services with other national and international professional societies and standards organizations.

GOVERNMENT LIAISON SERVICES

Hugh K. Webster.. hwebster@wc-b.com
Webster, Chamberlain & Bean, Washington, D.C., (202) 785-9500; FAX (202) 835-0243. Identifies funding sources for welding education, research, and development. Monitors legislative and regulatory issues of importance to the welding industry.

CONVENTION and EXPOSITIONS

Senior Associate Executive Director
Jeff Weber.. jweber@aws.org(246)

Corporate Director, Exhibition Sales
Joe Krall.. jkrall@aws.org(297)
Organizes the annual AWS Welding Show and Convention, regulates space assignments, registration items, and other Expo activities.

Brazing and Soldering Manufacturers' Committee

Jeff Weber.. jweber@aws.org(246)

RWMA — Resistance Welding Manufacturing Alliance

Manager
Susan Hopkins.. susan@aws.org(295)

WEMCO — Welding Equipment Manufacturers Committee

Manager
Natalie Tapley.. tapley@aws.org(444)

PUBLICATION SERVICES

Department Information(275)
Managing Director
Andrew Cullison.. cullison@aws.org(249)

Welding Journal

Publisher
Andrew Cullison.. cullison@aws.org(249)

Editor

Mary Ruth Johnsen.. mjohnsen@aws.org (238)

National Sales Director

Rob Saltzstein.. salty@aws.org(243)

Society and Section News Editor

Howard Woodward.. woodward@aws.org .(244)

Welding Handbook

Welding Handbook Editor
Annette O'Brien.. aobrien@aws.org(303)
Publishes *Welding Journal*, the Society's monthly magazine, *Inspection Trends*, *Welding Handbook*, and books on general welding subjects.

MARKETING COMMUNICATIONS

Director
Ross Hancock.. rhancock@aws.org(226)

Public Relations Manager
Cindy Weihl.. cweihl@aws.org(416)

Webmaster
Angela Miller.. amiller@aws.org(456)

MEMBER SERVICES

Department Information(480)

Deputy Executive Director
Cassie R. Burrell.. cburrell@aws.org(253)

Director
Rhenda A. Mayo.. rhenda@aws.org(260)
Serves as a liaison between Section members and AWS headquarters. Informs members about AWS benefits and activities.

CERTIFICATION SERVICES

Department Information(273)

Managing Director, Certification Operations
John Filippi.. jfilippi@aws.org(222)

Managing Director, Technical Operations
Peter Howe.. phowe@aws.org(309)
Manages and oversees the development, integrity, and technical content of all certification programs.

Director, Int'l Business & Certification Programs
Priti Jain.. pjain@aws.org(258)
Directs all int'l business and certification programs. Is responsible for oversight of all agencies handling AWS certification programs.

EDUCATION SERVICES

Managing Director
Dennis Marks.. dmarks@aws.org(449)

Director, Education Services Administration and Convention Operations
John Ospina.. jospina@aws.org(462)

AWS AWARDS, FELLOWS, COUNSELORS

Senior Manager
Wendy S. Reeve.. wreeve@aws.org(293)
Coordinates AWS awards and AWS Fellow and Counselor nominees.

TECHNICAL SERVICES

Department Information(340)

Managing Director
Andrew R. Davis.. adavis@aws.org(466)
Int'l Standards Activities, American Council of the Int'l Institute of Welding (IIW)

Director, National Standards Activities
John L. Gayler.. gayler@aws.org(472)
Personnel and Facilities Qualification, Computerization of Welding Information

Manager, Safety and Health
Stephen P. Hedrick.. steveh@aws.org(305)
Metric Practice, Safety and Health, Joining of Plastics and Composites, Welding Iron Castings

Technical Publications
AWS publishes about 200 documents widely used throughout the welding industry.
Senior Manager
Rosalinda O'Neill.. roneill@aws.org(451)

Staff Engineers/Standards Program Managers
Annette Alonso.. aalonso@aws.org(299)
Automotive Welding, Resistance Welding, Oxygen Gas Welding and Cutting, Definitions and Symbols, Sheet Metal Welding

Stephen Borrero.. sborrero@aws.org(334)
Joining of Metals and Alloys, Brazing and Soldering, Brazing Filler Metals and Fluxes, Brazing Handbook, Soldering Handbook

Rakesh Gupta.. gupta@aws.org(301)
Filler Metals and Allied Materials, Int'l Filler Metals, Instrumentation for Welding, UNS Numbers Assignment

Brian McGrath.. bmcgrath@aws.org(311)
Methods of Inspection, Mechanical Testing of Welds, Welding in Marine Construction, Piping and Tubing

Selvis Morales.. smorales@aws.org(313)
Welding Qualification, Structural Welding

Matthew Rubin.. mrubin@aws.org(215)
Aircraft and Aerospace, Machinery and Equipment, Robotics Welding, Arc Welding and Cutting Processes

Reino Starks.. rstarks@aws.org(304)
Welding in Sanitary Applications, High-Energy Beam Welding, Friction Welding, Railroad Welding, Thermal Spray

Note: Official interpretations of AWS standards may be obtained only by sending a request in writing to Andrew R. Davis, adavis@aws.org, Managing Director, Technical Services.

Oral opinions on AWS standards may be rendered. However, such opinions represent only the personal opinions of the particular individuals giving them. These individuals do not speak on behalf of AWS, nor do these oral opinions constitute official or unofficial opinions or interpretations of AWS. In addition, oral opinions are informal and should not be used as a substitute for an official interpretation.

Nominees for National Office

Only Sustaining Members, Members, Honorary Members, Life Members, or Retired Members who have been members for a period of at least three years shall be eligible for election as a director or national officer.

It is the duty of the National Nominating Committee to nominate candidates for national office. The committee shall hold an open meeting, preferably at the Annual Meeting, at which members may appear to present and discuss the eligibility of all candidates.

To be considered a candidate for the positions of president, vice president, treasurer, or director-at-large, the following qualifications and conditions apply:

President: To be eligible to hold the office of president, an individual must have served as a vice president for at least one year.

Vice President: To be eligible to hold the office of vice president, an individual must have served at least one year as a director, other than executive director and secretary.

Treasurer: To be eligible to hold the

office of treasurer, an individual must be a member of the Society, other than a Student Member, must be frequently available to the national office, and should be of executive status in business or industry with experience in financial affairs.

Director-at-Large: To be eligible for election as a director-at-large, an individual shall previously have held office as chairman of a Section; as chairman or vice chairman of a standing, technical, or special committee of the Society; or as a District director.

Interested persons should submit a letter stating which office they seek, including a statement of qualifications, their willingness and ability to serve if nominated and elected, and a biographical sketch.

E-mail the letter to [Gricelda Manalich, gricelda@aws.org](mailto:gricelda@aws.org), c/o Gene Lawson, chair, National Nominating Committee.

The next meeting of the National Nominating Committee is scheduled for November 2009. The terms of office for candidates nominated at this meeting will commence January 1, 2011.

profession, or to one who is accredited with exceptional accomplishments in the development of the welding art, upon whom the Society deems fit to confer an honorary distinction. Honorary Members have full rights of membership.

National Meritorious Certificate Award

This certificate award recognizes the recipient's counsel, loyalty, and dedication to AWS affairs, assistance in promoting cordial relations with industry and other organizations, and for contributions of time and effort on behalf of the Society.

International Meritorious Certificate Award

This honor recognizes recipients' significant contributions to the welding industry for service to the international welding community in the broadest terms. The awardee is not required to be an AWS member. Multiple awards may be given. The award consists of a certificate and a one-year AWS membership.

Honorary Meritorious Awards

The Honorary Meritorious Awards Committee makes recommendations for the nominees presented to receive the Honorary Membership, National Meritorious Certificate, William Irrgang Memorial, and the George E. Willis Awards. These honors are presented during the FABTECH International & AWS Welding Show held each fall. The deadline for submissions is December 31 prior to the year of the awards presentations. Send candidate materials to Wendy Sue Reeve, secretary, Honorary Meritorious Awards Committee, wreeve@aws.org; 550 NW LeJeune Rd., Miami, FL 33126. Descriptions of these awards follow.

William Irrgang Memorial Award

Sponsored by The Lincoln Electric Co. in honor of William Irrgang, the award, administered by AWS, is given each year to the individual who has done the most over the past five years to enhance the Society's goal of advancing the science and technology of welding. It includes a \$2500 honorarium and a certificate.

George E. Willis Award

Sponsored by The Lincoln Electric Co. in honor of George E. Willis, the award, administered by AWS, is given each year to an individual who promoted the advancement of welding internationally by fostering cooperative participation in technology transfer, standards rationalization, and promotion of industrial goodwill. It includes a \$2500 honorarium and a certificate.

Honorary Membership Award

The honor is presented to a person of acknowledged eminence in the welding

AWS Publications Sales

Purchase AWS standards, books, and other publications from **World Engineering Xchange (WEX), Ltd.**
orders@awspubs.com; www.awspubs.com
Toll-free (888) 935-3464 (U.S., Canada)
(305) 824-1177; FAX (305) 826-6195

Welding Journal Reprints

Copies of *Welding Journal* articles may be purchased from Ruben Lara.
(800/305) 443-9353, ext. 288; rlara@aws.org

Custom reprints of *Welding Journal* articles, in quantities of 100 or more, may be purchased from

FosteReprints

Claudia Stachowiak
Reprint Marketing Manager
866-879-9144, ext. 121
claudia@fostereprints.com

AWS Foundation

AWS Foundation, Inc., is a not-for-profit corporation established to provide support for educational and scientific endeavors of the American Welding Society. Information on gift-giving programs is available upon request.

Chairman, Board of Trustees
Gerald D. Uttrachi

Executive Director, AWS
Ray Shook, ext. 210, rshook@aws.org

Executive Director, Foundation
Sam Gentry, ext. 331, sgentry@aws.org

Solutions Opportunity Squad (SOS)

Corporate Director
Monica Pfarr, ext. 461, mpfarr@aws.org

Director
Connie Bowling, ext. 308, cbowling@aws.org

General Information
(800) 443-9353, ext. 689; vpinsky@aws.org
550 NW LeJeune Rd., Miami, FL 33126

AWS Mission Statement

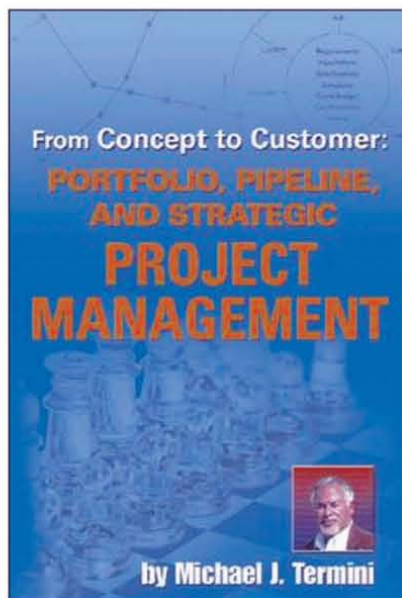
The mission of the American Welding Society is to advance the science, technology, and application of welding and allied processes, including joining, brazing, soldering, cutting, and thermal spraying.

It is the intent of the American Welding Society to build AWS to the highest quality standards. Your suggestions are welcome. Please contact any staff member or AWS President Victor Y. Matthews, as listed on the previous page.

NEW

LITERATURE

Book Addresses Strategic Project Management



The 458-page, hardcover text *Concept to Customer: Portfolio, Pipeline, and Strategic Project Management* uses a step-by-step approach, supported by tools, techniques,

and examples, to illustrate each important aspect of project management. Thorough explanations are provided for portfolio and pipeline management techniques, project planning tools, risk management tools, contingency planning, tradeoff analyses, and leadership techniques. Author Michael J. Termini is president and CEO of The Consulting Alliance Group, Inc. The list price is \$72, \$62 for SME members.

Society of Manufacturing Engineers

www.sme.org
(800) 733-4763

Features of Weld Backing Tape Detailed in Leaflet

A new four-page brochure illustrates and explains the applications for the Argweld® line of light-, medium-, and heavy-duty grades of weld backing tapes, and the products' special features. Presented are high-magnification views showing the effects of various weld current levels and the construction features of the tapes. Typical applications for each tape grade are given along with instructions for properly applying the backing tapes. Additional and supporting literature is listed,



plus information on the company's leading and trailing welding gas shields.

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— continued on page 72



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The Emmet A. Craig Resistance Welding School

Sponsored by the American Welding Society and the Resistance Welding Manufacturing Alliance (RWMA)

is coming to Chicago!

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at the**

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Topics to be covered:

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Welding Controls

Electrical Power Systems

Welding Processes & Machines

Troubleshooting and Maintenance

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Each year, this two-day resistance welding school is attended by seasoned professionals, shop supervisors, production managers, electrical engineers, and mechanical engineers. Sessions on the basics of resistance welding and real-life applications of the process are conducted by industry specialists with extensive resistance welding experience. Participants are able to learn at their own pace, discuss specific welding concerns with the instructors, and are invited to bring their own samples for discussion. In addition, attendees can visit with RWMA-member companies during tabletop exhibit lunches to learn about the latest resistance welding products being offered.

For the latest information on the RWMA Welding School visit our website at www.aws.org/show/rwma.html or call 800-443-9353, ext. 455

To register online, go to www.aws.org/show/rwma.html and click on **REGISTER**



A STANDING COMMITTEE OF
American Welding Society®

— continued from page 70

TIG Buyer's Guide Updated



The 20-page, full-color, well-illustrated *TIG Buyer's Guide* is a pocket-sized reference offering information on the company's complete line of equipment with detailed information on the latest features and welding terminology. Chapter headings include Why TIG?,

Which welding machine is right for you?, Key TIG terms, torches and accessories, plus separate pages on four Maxstar® DC-only machines, two Syncrowave® and two Dynasty® AC/DC models. Included is a detailed and illustrated selection chart comparing the features of four DC-only and seven AC/DC

machines. Download the PDF guide from the Web site or call for a hard copy.

Miller Electric Mfg. Co.
www.millerwelds.com/service/lit_req.php
(800) 426-4553

Free Video Details Basics of Resistance Welding



Updated for 2009, the entertaining, 19-min-long, four-part video *Joining to Promote Resistance Welding Excellence* is viewable online or can be ordered by phone as a free DVD. The segments are titled Introduction, Resistance Welding Processes, Applications for Resistance Welding, and Opportunities. Explained

are the four resistance welding processes: spot, projection, seam, and flash. Alliance members Roger Hirsch, Pat Adams, Bill Love, and Priyesh Dodhia make presentations of their experiences with the processes and how resistance welding technology produces cost-effective metal joining for a variety of applications.

Resistance Welding Manufacturing Alliance
www.aws.org/rwma/videos
(800) 443-9353, ext. 295

View Machining Seminars Online Free

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CONFERENCE ON WELDING CHROME MOLY STEELS

The welding of chrome-moly steel goes back to the days when tubing was oxyacetylene-welded to make up the fuselages of the early pre-aluminum airplanes. It required outstanding precision on the part of the welder. Even though the methods have changed, the welding of chrome-moly steel still requires utmost precision on the part of the welder and all involved parties.

Heat treatment and nondestructive testing are part and parcel of a successful weld. The 2 1/4Cr-1Mo steels are very popular materials for boilers and pressure vessels where the ASME Code is used. More recently, the modified 9Cr-1Mo steel, which was originally developed as the base metal for the Fast Breeder Reactor, is now widely specified in electric utilities and is moving into the oil and gas industry. To weld any of these steels for the first time, the engineer and the welder actually have to go back to school and start all over again.

Conventional arc welding processes are all used effectively on 4130, 2 1/4Cr-1Mo, and modified 9Cr-1Mo steels. Some newer processes like hybrid welding have also become popular. Proper administration of the preheat and postweld heat treat operations is most critical.

For the latest conference information, visit our website at www.aws.org/conferences or call 800-443-9353, ext. 455.

Tuesday, Nov. 17, 2009

Chicago (at the FABTECH INT'L & AWS Welding Show)

AWS Members: \$345

Nonmembers: \$480

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PERSONNEL

MEMBER MILESTONE

Grantham Named Treasurer of National Academy of Forensic Engineers



Jesse A. Grantham

Jesse A. Grantham, P.E., an AWS member since 1978, has been appointed treasurer for the National Academy of Forensic Engineers (NAFE). Grantham is a member of the AWS Colorado Section where he served as chairman 1998–2000 and currently serves as treasurer. From June 2001 through May 2004, he served as AWS District 20 director. Grantham holds a PhD in engineering from The Ohio State University and a MBA from the University of Louisiana. He owns and operates Welding and Joining Management Group, Westminster, Colo., an independent testing laboratory, where he is a recognized as an expert on metallurgy, failure analysis, and compliance with welding codes and contracts. A prolific writer, his most recent publications are *Light, A Welding Guide for the Executive Community*, and *Choices, A Welding Guide for the Legal Community*, available from his Web site www.jesseagrantham.com/bookorder.htm. The NAFE was founded to bring together those professional engineers who have attained substantial experience and recognition in forensic engineering practice. It seeks to improve the practice, elevate the standards, and advance the cause of forensic engineering.

years, Morissette most recently was product manager for punching and combination machines.

European Laser Institute Appoints Board Member



Stefan Kaierle

The European Laser Institute (ELI), Aachen, Germany, has re-elected Dr. **Stefan Kaierle** chairman of the ELI executive board. Kaierle has chaired the ELI executive board since the foundation of the network in 2003.

Obituary

Donald A. Shapira

Donald A. Shapira, 53, died July 1 in Nags Head, N.C. An active AWS member since 1988, he was chairman of the B1C Standing Task Group for the Welding Inspection Handbook and the D1K Subcommittee 11 on Stainless Steel Welding. He also served on the B1 Committee on Methods of Inspection, D1 Committee on Structural Welding, D1 Executive Subcommittee/General Requirements, D1B Subcommittee 2 on Qualification, D1C Subcommittee 3 on Fabrication, D1L Subcommittee 12 on Seismic Issues, and D1M Standing Task Group on New Materials. He worked for Washington Group International, Manteo, N.C. He is survived by his wife, Mandy.

Laser Institute Announces Education Director

Laser Institute of America, Orlando, Fla., has appointed **Gus Anibarro** education director. With the company for ten years, Anibarro previously served as education manager.

LMI Technologies Names Marketing Specialist



Mirela Cunjalo

Before joining the company, Cunjalo worked for Rockwell Automation, based in Delta.

LMI Technologies Inc., Delta, B.C., Canada, has named **Mirela Cunjalo** a product marketing specialist concerned with a broad range of industrial sensors including hardware and software applications for the machine vision market.

Key Posts Filled at Wall Colmonoy



Daniel Eichorn



June Mason

Wall Colmonoy Corp., Madison Heights, Mich., has appointed **Daniel Eichorn** corporate controller and **June Mason** quality assurance manager for the Alloy Products Group. Eichorn brings more than 20 years' experience in senior financial positions in the manufacturing, systems, and operations industry. Mason, with 18 years of experience in aerospace manufacturing, is a certified lead quality-system auditor.

TRUMPF Names Regional Manager



Mike Morissette

and Nevada. With the company for 14

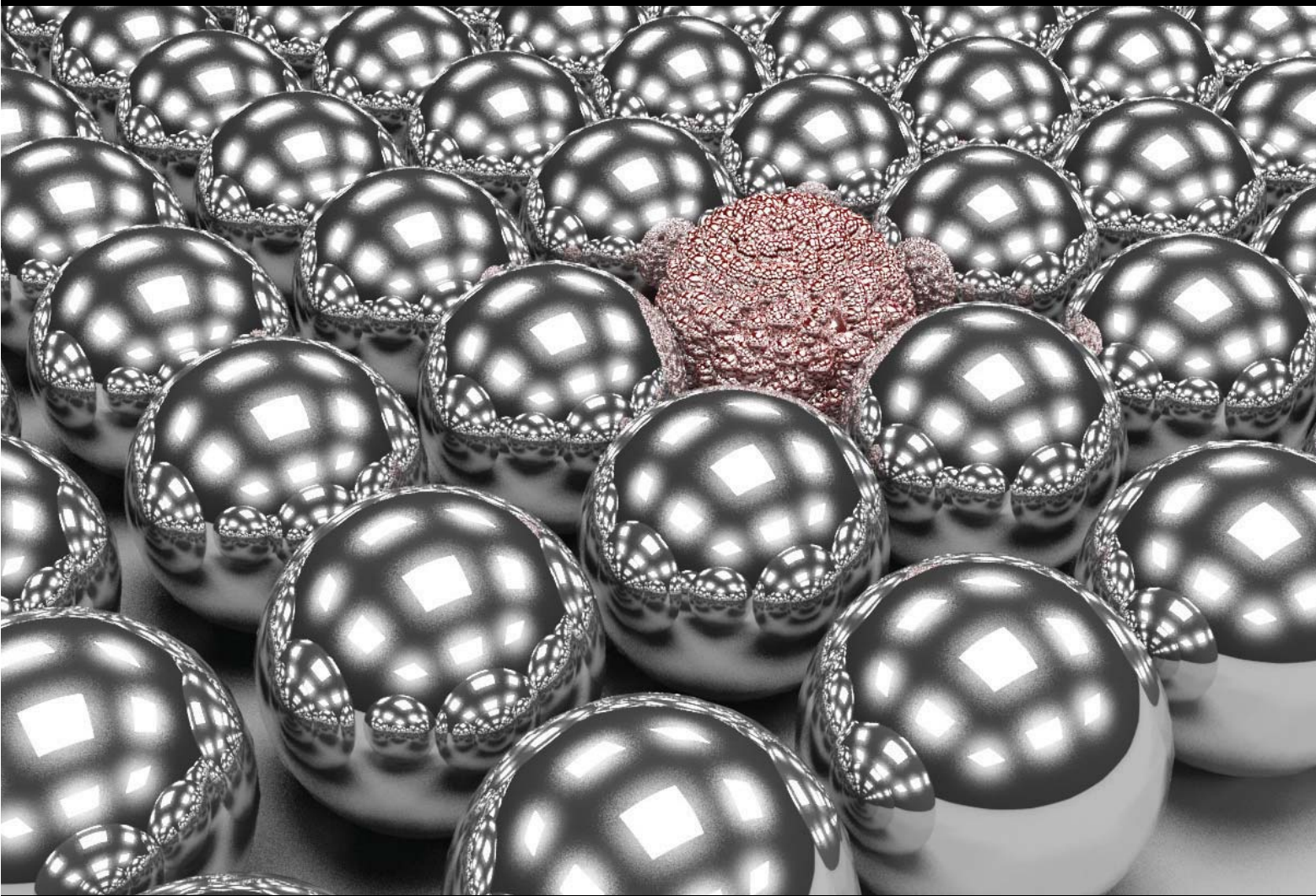
TRUMPF Inc., Farmington, Conn., has named **Mike Morissette** regional manager southwest for the newly created territory including Arizona, Colorado, Utah, New Mexico, and the southern regions of California

Change of Address? Moving?

Make sure delivery of your *Welding Journal* is not interrupted. Contact the Membership Department with your new address information — (800) 443-9353, ext. 217; smateo@aws.org.

Welding Corrosion Resistant Alloys Conference

Chicago, November 18th, 2009



Welding Corrosion Resistant Alloys Takes Center Stage. Find answers to the unknown and discover new processes.

The interest level is extraordinarily high when it comes to the welding of corrosion-resistant alloys. There are many reasons for this. One is the entry of the duplex stainless steels and other high-performance grades.

Another is the unstable prices in nickel, molybdenum and titanium. When the price of nickel hit the roof, many fabricators switched from 316 to 201 stainless because of the latter grade's lower nickel content. Research is feverish throughout the world in the development of new and cheaper methods of producing titanium. Will a lower cost titanium make the metal more popular?

The overall activity is immense. Cladding and strip overlay processes have become more popular means of protecting parts exposed to heavy corrosion. Duplex stainless is now being welded for over-the-road tankage. New processes, like friction stir welding and the more

advanced thermal stir welding out of NASA will be discussed as well. Also, improvements in weld properties are being realized by increasing the weld interpass temperatures for conventional austenitic stainless steels.

Keep abreast of this exciting new world in welding where corrosion-resistant alloys have taken center stage. Mark your calendar for November 18, 2009, at the FabTech International and AWS Welding Show in Chicago, Illinois.

For the latest conference information visit our website at www.aws.org/conferences or call 800-443-9353, ext. 455.

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The American Welding Society and **The International Thermal Spray Association** are organizing the first Thermal Spray and Coatings Conference, to be held in conjunction with the 2009 Fabtech Int'l & AWS Welding Show. This event will introduce the process and its uses to new potential users with morning and afternoon sessions focusing on actual applications and new developments in thermal spray technology.

In addition, on Sunday, Nov. 15, a free half-day tutorial on thermal spray fundamentals is scheduled, sponsored by the International Thermal Spray Association, titled **"What Is Thermal Spray?"**

For the latest conference information, visit our website at www.aws.org/conferences or call **800-443-9353, ext. 455**.

Monday, Nov. 16, 2009 - Chicago
(at the **FABTECH INT'L & AWS Welding Show**)

AWS Members: \$345

Nonmembers: \$480



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The AWS Foundation is pleased to present the **RESEARCH FELLOWSHIP RECIPIENTS** for 2009-2010

Each year, the American Welding Society Foundation provides research fellowships and scholarship funds to help hundreds of students who otherwise would be unable to afford a welding education. We are the only industry foundation with the specific mission of helping to fund the education of welding students. In so doing, we create the careers that sustain and grow our industry.

We get these funds from your contributions. The more you contribute, the more students we can help educate.

To make a scholarship contribution or set up your own National Scholarship, contact **Sam Gentry** at the AWS Foundation. Call **800-443-9353, x331**, or email to **sgentry@aws.org**. Thank you for your continued support.



Ms. Yuan Zhang
The Ohio State University
Prof. G. S. Daehn
Glenn J. Gibson Fellowship

"Material Behavior during Magnetic Pulse Welding"



Andrew Deceuster
Utah State University
Dr. Leijun Li
Miller Electric Mfg. Co. Fellowship

"Repair of Directionally Solidified Nickel-Based Superalloys Using Pulsed Nd:YAG Laser Powder Deposition"



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Minimizing Defects in Submerged Arc Welding

Understanding and controlling the submerged arc welding process can help you reduce or avoid defects

BY DAN GERBEC

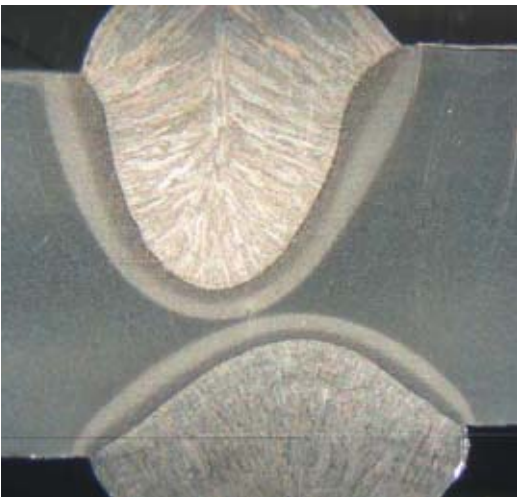


Fig. 1 — Excessive voltage or travel speed, insufficient current, or improper joint design can lead to insufficient penetration in the weld.

Submerged arc welding (SAW) can be a highly productive tool for fabricators, but as with most welding technologies, defects can occur. This leads to rework and a reduction in overall productivity.

Defects can be reduced or avoided by understanding and controlling the process. Many defects can be eliminated in the preweld stage. Let's take a look at the process and some common defects and how they can be avoided.

The SAW Process

The submerged arc welding (SAW) process was first patented in 1935 and licensed by Union Carbide a year later. Union Carbide marketed the process and related products under the "Unionmelt" trademark. Since that time, many advances have been made to the process, including multiwire, cored wire, and cladding applications, but the fundamentals remain the same: an arc is created using a bare wire under a granular flux covering. The flux contributes to the mechanical properties of the weld, deoxidizes the base metal, and protects the molten weld metal from atmospheric contaminants. When the weld is complete, it is covered by an easily removed layer of slag. Submerged arc welds are typically made using some form of automation, although it is possible to make a subarc weld with a hand-held torch.

Submerged arc welding offers many advantages over other welding processes, including the following:

- High weld quality
- High deposition rate
- Deep penetration

- High-speed welding on thin sheet steels
- Almost no fume or light emission.

Nothing is perfect, however, and sub-arc welding does have its limitations. This form of welding is limited to the flat and horizontal positions, requires precise joint preparation, and does not allow observation of the arc and the process during the weld. Despite its limitations, the submerged arc process is popular in a number of industries, notably shipbuilding, wind tower fabrication, ASME vessel fabrication, pipe mills, and fabrication of utility poles and trailer beams.

The Role of Flux

Submerged arc fluxes are generally grouped into neutral and active fluxes. Many fluxes alloy some Si and Mn to the weld metal while others melt off these elements. The intensity of this chemical reaction depends on the quantity of flux interacting with the wire. An increase in voltage or arc length will lead to increased alloying or melt-off of these elements. Neutral fluxes are used in multilayer welding of unlimited plate thickness with appropriate wires. The alloying of elements, especially Si and Mn, is carefully controlled.

Active fluxes add a significant amount of Si, acting as a deoxidizer, and Mn to the weld metal. They enhance resistance to porosity and improve bead appearance and toughness in high-dilution applications. Active fluxes are primarily used for

DAN GERBEC (dgerbec@esab.com) is product manager, Submerged Arc Consumables, ESAB Welding & Cutting Products, Hanover, Pa., www.esabna.com.



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single-pass or multilayer welding with limitation of layers, with three to five layers normally the maximum.

Process Variables

Submerged arc welding can be done with either direct current (DC) or alternating current (AC) power supplies. Direct current is the most commonly used because it is easiest to control and provides the best arc starting and stability, except at high currents, when arc blow can be a problem. Direct current electrode positive, or reverse polarity, is used most often and yields the deepest penetration. Direct current electrode negative, or straight polarity, provides up to 25% less penetration but offers the highest deposition rates and is useful in cladding applications or applications with poor joint fit-up. The characteristics of AC power fall between straight polarity and reverse polarity but offer the benefit of eliminating arc blow because the rapidly changing polarity prevents magnetic fields from forming.

Once the polarity of the power supply is chosen, amperage, voltage, travel speed, wire size, and electrode extension all play a role in the shape, size, and quality of the weld deposit.

Amperage is directly related to deposition rate and depth of penetration, so an increase in amperage will increase both deposition rate and penetration.

Arc voltage is a measure of arc length and has an inverse relationship to depth of penetration and a direct relationship to bead width. An increase in arc voltage, therefore, will cause a decrease in penetration and an increase in bead width.

Travel speed, also known as feed rate, is inversely related to bead size and penetration, so a reduction in travel speed increases bead size and penetration.

Wire size also affects deposition rate and penetration, but contrary to popular belief, a larger-diameter wire may not be better than a smaller-diameter wire. A small-diameter wire has a smaller cross-sectional area, and therefore, at the same current, a smaller-diameter wire will provide a faster melt-off and consequently a higher deposition rate and increased penetration vs. a larger wire.

Electrode extension is the distance from the end of the contact tip to the surface of the workpiece. As a rule of thumb, electrode extension should be about eight times the wire diameter. For example, the electrode extension for a 1/8-in.-diameter wire should be approximately 1 in. Using a longer electrode extension will result in

reduced penetration and increased deposition. The increased deposition is caused by the I^2R resistive heating of the wire.

Identifying Submerged Arc Welding Defects

In most cases, a SAW defect has more than one cause and more than one possible cure. The cure to the problem is often to do the opposite. For instance, if the defect is caused by excess current, simply lowering the current will usually resolve the defect. But selecting the proper cure will depend on your objective. For example, melt-through can be resolved by decreasing the welding current, increasing travel speed, or reducing the bevel angle. In most cases, reducing the bevel angle is not a realistic option, so you must either reduce the current or increase travel speed. Since most fabrication applications favor higher productivity, it generally makes sense to increase travel speed.

Here are some common weld defects and their most likely causes:

- **Insufficient penetration.** Caused by low current, high voltage, high travel speed, and/or improper joint design — Fig. 1.
- **Melt-through.** Caused by high current, too great a bevel angle, too small a root face or root opening, and/or slow travel speed.
- **Porosity.** Caused by joint contamination by rust or moisture, a shallow flux burden, insufficient penetration into the backing weld, a contaminated backing weld, improper joint fitup, flux fines, and/or flux moisture — Fig. 2. In the cases where porosity is caused by joint contamination or a high level of atmospheric moisture (humidity), the problem may be solved by using a more active flux or preheating to remove moisture.
- **Surface pock marks.** Can be caused by joint contamination, moisture on the plate, and/or moisture in the flux. Surface pock marks can be avoided by using an active flux, preheating the plate, and keeping the flux in an oven at 250°–300°F.
- **Arc blow.** Caused by an imbalance in the magnetic field surrounding the workpiece. Arc blow is typically experienced at high DC welding currents and can be cured by reducing the current, using AC, and demagnetizing the fixture.



Fig. 2 — Porosity is most commonly caused by the presence of moisture in the weld.

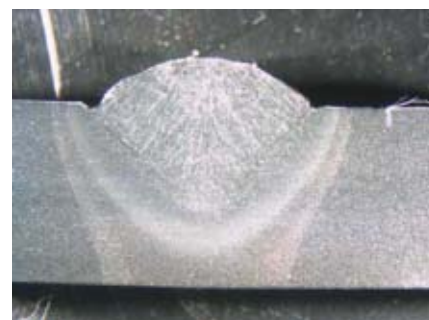


Fig. 3 — Undercut generally occurs when the amount of wire deposited is not great enough to fill the gaps in the material caused by the voltage. This can be avoided by reducing travel speed, increasing current, or decreasing voltage.

- **Reinforcement, or bead, rollover.** Typically caused by high current, low voltage, or low travel speed.
- **Undercut.** Occurs when there is insufficient molten metal added to the pool to fill the gaps in material created by the voltage — Fig. 3. The simplest ways to fix undercut are to reduce travel speed, increase current, or decrease voltage. Improper wire alignment may also be the culprit and is easy to remedy.
- **Slag sticking.** Slag will tend to stick in a deep groove, especially if the weld is concave. The cure is usually to reduce voltage. Increasing travel speed and decreasing current may also work.

Understanding the SAW process and understanding your own objectives in using that process are the keys to successfully dealing with submerged arc welding defects. ♦



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Jordan Kay lifts to elevated levels thanks to his "Cadillac" chair. It features a pneumatics system that enables up and down movement. A seat belt and padded leg locking device also allow Kay to properly stand up.

KRISTIN CAMPBELL
(kcampbell@aws.org) is associate editor of the Welding Journal.

Welder Achieves New Heights with High-Tech Chair

A disabled student rises up to do welding-related tasks with the help of a wheelchair made specially for him

BY KRISTIN CAMPBELL

Imagine how limiting it would be to weld if you weren't at the same height level of a worktable or equipment couldn't be operated because it was out of reach.

Jordan Kay encountered these obstacles while attending the welding program at North Dakota State College of Science (NDSCS), Wahpeton, N.Dak., in the fall of 2007. As a student paralyzed by a car accident that occurred when he was in kindergarten, the school's welding lab presented challenges.

Kay wasn't going to let anything stop him, however, from pursuing the field. His father, Mike, let him try welding at his job, and not only did Kay catch on fast, he liked the hands-on work this trade offered.

To assist him with getting around better, welding instructors Jay Schimelfenig and Joel Johnson came up with an interesting idea: creating a chair that would lift him to a standing position and fit his 5-ft, 6-in. frame — Fig. 1.

"Unless you have been in this situation, you have absolutely no idea of how many pieces of manufacturing equipment are built for someone standing up," Schimelfenig said. "When Jordan got in the shop, 90% of the standard shop equipment was unreachable for him. A simple task of turning the gas valve on for his wire welding machine was impossible."

Now, with his customized "Cadillac," nothing holds Kay back. Schimelfenig believes this is the first time a special wheelchair has been made for a disabled welding student at NDSCS.

What's more, Kay gets to keep the chair for future use. "It means so much to me that the school would just give me the parts needed free of charge to help better my everyday life," Kay said.



Fig. 1 — Jay Schimelfenig (left) and Joel Johnson, welding instructors at North Dakota State College of Science, helped to make a sophisticated chair for their student.

Process of Putting Together the 'Cadillac'

Building the chair took a year. Work occurred during and after class as well as on weekends and holidays.

Before it came about though, welding tables and different types of equipment were lowered to Kay's level. During his first year in the college's welding program, this was not a big problem because most of the welding was done in a booth, but in his second year there were difficulties with fabrication welding away from a booth.

"It was never hard to weld in the lab, some things were just difficult to reach and do on my own," Kay said. "This chair helps me reach and do things I couldn't do before."

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Fig. 2 — A detailed drawing of the chair shown in its up position.

Design Method

Johnson and Schimelfenig discussed what Kay needed to get him standing up and at a level where he could get ahold of everything. Together, they designed the chair using SolidWorks, a 3-D mechanical computer-aided design software for modeling, assembling, and checking for interferences and design problems — Fig. 2.

In total, Schimelfenig spent about 250 hours of design time on this venture. “I measured Jordan’s legs and knee heights several times to make sure the chair fit him,” Schimelfenig said.

Additionally, Kay became involved in the design of certain features. “I helped make this chair by giving my instructors ideas on what I needed and where I needed it,” Kay said. He performed gas tungsten arc welding (GTAW), his favorite process, on various parts; making out-of-position welds was tough, but Johnson helped him.

“It was nice to have his input on what would make him more comfortable in the chair and what might work best for him,” Schimelfenig added.

Unique Details

One of Kay’s old wheelchairs served as the base for the new one. The two front/back wheels and axle are original parts, yet almost everything else on it was fabricated.

The all-aluminum chair sits on two parallel links with air cylinders hooked to them. The bottom undercarriage, made of bent and welded tubing, also moves.

“When the cylinders are engaged, the undercarriage first moves down to lift the front caster of the wheelchair off the ground to keep it from rolling. Once the undercarriage bottoms out on its stop, the cylinders start lifting the chair,” Schimelfenig explained.



Fig. 3 — Accomplishing everyday activities around a welding lab proves to be no problem for Kay. This includes the following: A — Reaching the top of a large gas cylinder; B — sanding a piece of steel; and C — inputting coordinates into a laser cutting machine.



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Fig. 4 — Kay enjoys his work experience program for the City of Minot, N.Dak., and uses his “Cadillac” that now operates on two portable CO₂ cylinders to help him perform various duties. A — He welds standing up in the chair; and B — uses a drill press as part of his job. (Photos courtesy of Darley Williams.)

Kay controls the line pressure and directional control with a switch mounted on the arm rest. The chair’s pneumatic system needed to be powered by a non-flammable source, so air provided the best choice. At the school’s lab, shop air pressure got plugged in at 120 lb/in.²

The seat lifts to about 75 deg off of horizontal, keeping Kay’s weight back on the main frame of the chair. The chair’s base is durable to ensure Kay will not fall out of the chair while he’s standing. Lifting links and certain pivotal parts were machined and then bolted together, too.

A seat belt on the chair’s back rest helps Kay’s upper body stay in place, a padded leg locking device holds his knees in position as the chair lifts, and a foot rest keeps his feet from dangling. “In reality, Jordan’s legs are supporting his weight and holding him up,” Schimelfenig said.

Its seat cushion and back rest were up-holstered by NDSCS auto body repair and refinishing technology students using a leather jacket Schimelfenig donated. The side plates and back rest were cut with a waterjet machine and then welded and/or bolted together.

“Lucky for us, our prototype worked almost flawlessly,” Schimelfenig said. “This chair has been a great learning experience for all involved including the teachers.”

Donated Contributions

Numerous individuals devoted their time, energy, and expertise to the project. Kay appreciates the effort and dedication they have put forth to help him.

Tri-State Aviation and MDI Machine Design Inc., both located in Wahpeton,

N.Dak., donated aluminum for the project. The City of Wahpeton Mayor’s Committee on Employment of People With Disabilities provided funds for the parts cut with the waterjet machine. Independent Cycle Inc., Rapid City, S.Dak., gave a miniature 200 lb/in.² air compressor and components.

The school’s machine tooling students made the machined parts including the chair’s frame, arms, and undercarriage.

Plus, the following teachers provided insight regarding the chair lift’s pneumatic components: Steve Johnson and Link Thompson, machine tooling instructors; and Tim Thompson, an automated manufacturing instructor.

Benefits of the Chair

It took a few days for Kay to get familiar welding in the chair. “Now, I’m used to it, so I actually prefer to be using it when I am welding,” he said.

Kay enjoys GTAW the most because it is intricate and neat. “He is good at what he does. He has the talent to do the job,” Schimelfenig said.

Using the chair, he can adjust and turn valves on tall gas cylinders, sand metals, and use a laser cutting machine on his own with ease — Fig. 3A–C.

During his time at NDSCS, Kay learned to perform all the welding processes, use robotic welding as well as CNC laser and plasma cutting machines, and set up and operate welding equipment. He graduated in May with an associate in applied science degree in welding technology.

“I haven’t found any challenges quite yet,” Kay said of the chair, “but everything has a challenge so I’ll just have to discover them along the way and deal with them.”

Moving Ahead

If another welding student needed a wheelchair, Schimelfenig would help make one again. “As a teacher, that’s my job. We will do what ever it takes for any student,” he said.

Currently, Kay’s putting his welding skills to good use through a work experience program for the City of Minot, N.Dak., his hometown. This was set up for him by Job Service North Dakota, Workforce Investment Act Youth Program. As a welder, he repairs vehicles, makes utility racks for trucks, and fixes heavy equipment. He’s already utilizing the “Cadillac” here, and it has been upgraded to run on two portable CO₂ cylinders, so no long cord hook up is needed — Fig. 4A, B. “I don’t have to rely on someone else,” Kay said thanks to his high-tech chair.

After finishing this program, which ends in September, he would like to get a job welding race cars at Ole Olson’s Towing & Recovery Service in Minot. “All in all, as long as I’m welding, I’ll be happy,” Kay said.

For the future, he has even bigger dreams. “I would like to eventually start my own welding business giving hope to anyone with a setback that you can do whatever you put your mind to,” Kay said.

With the motto “Gotta do what ya gotta do!” in mind, Kay has overcome all obstacles that stood in his way.

“Jordan is no different than any other student... he wants to be independent and hopefully with what we’ve done it gets him one step closer to that goal,” Schimelfenig said. ♦

What defines *excellence* in welding sales?

The American Welding Society announces the certification program for welding sales representatives

If you are among the best and most successful sales professionals in the welding industry, it's because you provide value-added expertise to your customers.

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The AWS Certified Welding Sales Representative program tells the industry that you have what it takes to add value to every sale.

If you meet the program's requirements, you can take a two-hour exam to establish your credentials. Convenient examination sites are scheduled throughout the country. In addition, AWS offers three-day preparation seminars with the examination on the afternoon of the third day. The seminar can be taken at certain AWS-scheduled sites, or at your workplace for groups of sales personnel.

Examination topics will establish your level of knowledge concerning five arc welding processes, brazing and soldering, cutting, safety in processes and gas cylinder handling, AWS filler metal classifications, shielding gas applications, welding terminology, ventilation, electrical requirements for power sources, and welding procedures and their qualification.

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Prerequisites for the AWS Certified Welding Sales Representative program include a high school diploma or equivalent and at least five years' experience in an occupational function in direct relation to the sales of welding equipment, cutting equipment, and supplies and other related services; OR at least two years' of the same experience *PLUS* a training certificate of completion for welding processes.

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Plasma Arc Offers Cut Quality

While both plasma arc and oxyfuel cutting systems have their places in the industrial environment, it is plasma that, in many ways, is becoming more popular.

Discovered in the 1950s at Union Carbide, plasma cutting has become the process of choice in a wide variety of commercial applications. Some of the more common uses include general fabrication; heating, ventilation, and air conditioning,

where the bulk of the work involves in-house duct cutting; facilities maintenance; truck, trailer, and automotive repair; agriculture/farming; steel building construction, shipbuilding, and maintenance; plus manufacturing and creating metal artwork.



*Based on an article provided by
Hypertherm, Hanover, N.H.*

For certain thicknesses of metal, plasma arc cutting (left) is demonstratively faster than oxyfuel cutting on right. The small power unit also makes the plasma system useful for field work.



THE AMERICAN WELDER

The principle behind plasma cutting is as elegant as it is effective. When sufficient electrical energy is applied to a gas, the gas becomes superheated and ionized, such that it is capable of conducting an electric current. This electrically conductive, ionized gas is called plasma. When a high-velocity jet of plasma is delivered to a metal workpiece, the intense heat melts a thin area of metal while a high-pressure gas blows the molten metal away leaving clean high-quality cut edges. Often there is no need for secondary cleaning operations.

One of plasma's key advantages over other technologies is that plasma is able to cut any electrically conductive metal, both ferrous and nonferrous, even if it is rusted, painted, or dirty. Mild steel, stainless steel, aluminum, galvanized, copper, cast iron, and other metals are easily cut with plasma. This feature contrasts with oxyfuel cutting, which is ineffective for use with stainless steel, aluminum, and other nonferrous metals. Plasma systems are also suitable for a range of metal thicknesses from thin gauge up to 1¾ in. and in some cases even thicker. Some plasma systems can operate solely on electricity and compressed air, which reduces gas costs and eliminates gas cylinder rentals, and pick-up and drop-off fees.

The higher speed of plasma compared with oxyfuel cutting has become more pronounced over the past decade. On steel up to about 1½ in. thick, plasma is a faster process, an important consideration when project timetables are essential. And since 80% of metal cut today is ½ in. thick or less — the thickness range where plasma offers a significant speed advantage over oxyfuel — the vast majority of metal cutters can experience speed and productivity gains by switching from oxyfuel to plasma.

For many cutting applications, piercing is essential, and plasma's piercing capability and speed should not be overlooked. With an oxyfuel system, which requires significant preheating of the metal workpiece, piercing is a slow process that often yields poor results. The speed and quality of piercing using plasma can greatly increase productivity.

In addition, plasma offers high cut quality. This results in less finishing work (i.e., grinding and polishing) that must be performed on the cut materials, thus reducing labor costs and driving down operating costs. Further, the smaller size and increased portability offered by some plasma cutting units allow users to carry the equipment into the field with less effort. And while there are certainly safety considerations with any form of cutting,



Plasma cut metal (left) is virtually dross-free compared with oxyfuel cut metal on right.

plasma is considered a safer procedure than oxyfuel, because it does not use any flammable gases.

Most portable plasma systems run on a single gas, most commonly compressed air, but sometimes nitrogen is used for specific applications or when air quality is poor. Consumable life ranges widely from one manufacturer to another, and should be considered when making product comparisons. The duty cycle — a percentage that specifies how many minutes out of every ten the machine may be used without overheating — also varies. Some products offer more advanced thermal cooling technology and internal controls that yield higher duty cycles.

Versatility

Plasma's ability to cut through various metals gives it an advantage. Some plasma cutting machines can be used for both hand-held and mechanized cutting applications, providing an additional level of versatility. Some of the more advanced models on the market allow the user to switch fluidly between hand and machine torches for use on x-y tables, track cutting systems, pipe bevelers, and even robotic arms. A few systems include a CNC interface and internal voltage divider, providing even greater options for mechanized applications.

In addition to cutting, many plasma models also may be used for gouging, and a number of manufacturers have developed consumables to optimize this process.

The portability of plasma cutting equipment adds to its versatility. There are lightweight plasma tools weighing anywhere from 20 to 35 lb, making them easily moved around the shop and to hard-to-reach field locations, indoors and out. Several machines utilize a single-handle design with a shoulder strap for even greater mobility.

The portability factor is often very im-

portant. Imagine a piece of farm, mining, or construction equipment that requires in-the-field repair. A lightweight plasma device can be quickly loaded into any vehicle or carried through rough terrain to reach the site in a timely fashion. Even people who work in large shops can benefit from having a portable system since their cutting jobs are often spread throughout the facility.

A higher-quality plasma cutting tool provides multiple power-source options, power efficiency, and delivers consistent performance even on low line conditions. Further, if AC power is unavailable, a system can use generator power. A few of the smaller tools can run on generator power output as low as 6 kW. This is a critical factor in industries such as agriculture, where many farmers have already invested in generators in the 6-kW range for general use.

Cut Quality

Improved cut quality saves time in later stages of production. The clean, smooth cuts normally produced by today's plasma systems produce edges that may be ready for welding directly after cutting, or at least with minimal grinding. Additionally, the finer cuts produce a minimal heat-affected zone, further enhancing cut quality. What's more, the better systems create a much narrower kerf (cut width), which results in more precise cuts and less wasted metal. Dross, the metal residue that remains adhered to the workpiece after the cut, is another factor to consider. With many plasma systems, any dross that is generated is typically easy to remove. The amount of dross created varies by product and can be observed during a product demonstration.

Reliability

Reliability is another consideration. The most reliable systems are engineered



THE AMERICAN WELDER

with fewer parts, use software instead of hardware where possible, are carefully manufactured to exacting ISO standards, and are thoroughly tested. Cooling is an important factor affecting reliability, and its methods vary. Many plasma systems employ a cooling fan to draw outside air into one end of the system, over a heat sink, and out the other end. The Hypertherm Powermax line of products draws outside air in through the center of the system, where it first cools the most heat-sensitive components then flows along the heat sink in both directions for more effective cooling that also improves the duty cycle.

Ease of Use

A plasma cutting tool designed for simple operation allows operators with little experience to get good results while allowing experienced craftsmen to work

faster and more efficiently. Regardless of experience level, operators using plasma can get jobs completed quickly and with good quality, keeping time-sensitive projects on schedule.

Operating Costs

Consumable life, especially of the nozzles and electrodes that are utilized in both cutting and gouging, varies from one brand of plasma system to another and should be considered during the equipment selection process. Longer consumable life reduces downtime for change outs and lowers costs. Some models offer features that can extend consumable life while also delivering high-quality cuts. One recent design features a dual-angle nozzle that angles the shield gas into the plasma arc resulting in both better cut quality and longer nozzle life — two significant advantages for the operator.

Which to Choose?

If you're interested in purchasing a plasma system, you might be wondering how to choose the right system. Fortunately, choosing a plasma system can be as simple as a hands-on demonstration. Choosing a system with the necessary cut capacity and duty cycle is important, and buyers should also consider factors like versatility, cut quality, reliability, ease of use, and operating costs.

Few plasma cutting tools meet all of the above specifications. It is wise to discuss your cutting needs in detail with your local authorized plasma dealer using the criteria discussed in this article to help you determine the best cutting tools for your applications. ♦

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The *Welding Journal* 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.

Publisher

Andrew Cullison
cullison@aws.org, Extension 249
Article Submissions

Editor

Mary Ruth Johnsen
mjohnsen@aws.org, Extension 238
Feature Articles

Associate Editor

Howard Woodward
woodward@aws.org, Extension 244
Society News
Personnel

Associate Editor

Kristin Campbell
kcampbell@aws.org, Extension 257
New Products
News of the Industry

Production Manager

Zaida Chavez
zaida@aws.org, Extension 265
Design and Production

Advertising Sales Director

Rob Saltzstein
salty@aws.org, Extension 243
Advertising Sales

Advertising Sales & Promotion Coordinator

Lea Garrigan Badwy
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Production and Promotion

Advertising Production Manager

Frank Wilson
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Advertising Production

Peer Review Coordinator

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eadams@aws.org, Extension 275
Peer Review of Research Papers

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THE AMERICAN WELDER LEARNING TRACK

How to Cope with the Welder Shortage: Grow Your Own

Offering your employees the chance to train and qualify for attractive welder positions is proposed as one solution to the shortage of qualified workers

BY PHILIP L. McNEW



Great Plains, Salina, Kan., uses a dedicated training facility to develop its workers' welding skills.

You are not alone should you discover that your weld supervisor, director of human resources, and plant manager seem to be at their wits' end trying to find good welders to staff your company's requirements.

Like other manufacturers, you may have found that applicants from the general public either do not have the weld process skills required, lack related technical knowledge, or have unsuitable work histories. Also, you may have concluded that the local technical schools either do not graduate the numbers of welders you need or their graduates do not have the skill levels necessary for your company's product line.

First of all, it is a good idea to determine whether your company is having difficulty retaining qualified welders. Study the exit interview reports of the welders who have left your company. Look for

common reasons for their decisions to leave. Is your company's wage and benefits package unfavorably compared with other employers in the area? Are working conditions cited as reason for leaving? Are safety issues mentioned as a concern?

After considering all of these factors, you may conclude that your company's employee turnover is normal and the problem is the local shortage of welders.

One solution to consider is training your own welders. To do this, a number of factors must be addressed. To train welders in-house requires hiring a qualified welding instructor and providing dedicated workshop space and welding machines, plus all the necessary, hand tools, practice materials, and safety equipment. If this scenario is not realistic for your facility, then welder training could be performed off-site.

You may be able to contract off-site

training, customized to your company's procedures and product lines, at the welding lab of a local high school or technical college.

For Mid-America Pipe Fabricating Co., Scammon, Kan., this was their chosen option. "We decided to concentrate on what we know best, which is pipe fabrication," stated John Parsons, president of Mid-America Pipe. "Thus, we are actively supporting our local technical college in the startup of a new welding program, complete with new facilities and equipment. Additionally, members of our company will provide CWI services, serve on the school's advisory committee, and coordinate details for student scholarships and internships."

For agricultural equipment manufacturer Great Plains of Salina, Kan., its solution to welder shortages began with the ribbon-cutting to the company's newly constructed training center in 2007 (see lead photo). Since that time, approximately 100 potential and current employees have received training in the 7000-sq-ft welding lab and classroom facility. The four dedicated welding stations and recently installed robotic weld cell complement the modern classroom that has seating for 12 students and includes multimedia presentation technology. "We decided early on that a professional-quality program using a dedicated training space was a basic requirement," stated Tim Smith, weld manager, Great Plains Division. "We researched the training dos and don'ts from regional companies and found several areas of concern. We concluded that trying to present technical lecture information in the break room or some out-of-the-way conference room was a recipe for disaster." Smith added, "Our company is experiencing a strong demand for our product, thus, taking cur-

PHILIP L. McNEW (pmcnew@pittstate.edu), CWI/CWE, is a professor, Engineering Technology, at Pittsburg State University, Pittsburg, Kan.



THE AMERICAN WELDER LEARNING TRACK



Welding instructor Tony Bonilla discusses weld size and quality with Heather Govreau, a Great Plains trainee.

rent weld stations out of production, like other companies have tried, was not an option, thus (building) the training center was an obvious solution.”

Selecting the Trainer

If your company is dedicated to an in-house process, like Great Plains, you will have to resolve several issues. Who should be the instructor of this endeavor? Should this job automatically go to a current welding employee? If so, what changes are needed to cover his or her former workload and other production-related issues? Consider using more than one instructor. Should this program be taught by a team of instructors?

A good welding instructor, in addition to possessing professional expertise, must exhibit patience, leadership, enthusiasm, as well as organizational and public-speaking skills. The preferred credential is the American Welding Society's Certified Welding Educator (CWE) with the ideal instructor additionally holding an AWS Certified Welding Inspector (CWI) qualification.

Great Plains determined its best solu-

tion was to hire a full-time instructor with the unique designation as instructor/coach. “In addition to the training aspect, part of my job is to assist trainees with their transition from the training center to the production floor, essentially a hands-on manufacturing ‘coach,’” stated Tony Bonilla, Great Plains’ welding instructor/coach.

Who Should You Select for Welder Training?

Sponsoring a class of recently hired employees to receive welder training is much too risky. A safer bet is to review your current staff for candidates. Your longer-term employees are generally the safer choice to receive the training. Select those who have a good record of attendance, are willing to adapt to new jobs, and show an interest and aptitude for working as a welder after completing a prescreening program.

Since welding is not for everyone, the prescreening program is a major component of the trainee selection process. At a minimum, the prescreening program should challenge the applicants’ manual

dexterity, eye-hand coordination, and aptitude and desire to learn and apply the techniques for making simple fillet welds.

A welding class that begins with 15 students and graduates only 1 or 2 can often attribute its failure to improper prescreening.

Other considerations include how many students to train and the length of the welding program. Regardless of the company’s immediate needs, the trainee-to-instructor class size must be limited. From the instructor’s point of view, fewer students allow more time for individualized instruction. At Great Plains, a maximum of eight students per class is the norm. Bonilla explained, “If this class size seems too small, do some simple math. It is understood that this training program will have a large hands-on component, and let’s assume a class size of ten trainees. The instructor spends five minutes with each trainee demonstrating welding techniques and begins with student number one. How long is it until the instructor arrives at student number ten’s weld station? How constructive was this last student’s training, as he or she waited nearly an hour for the instructor to arrive.”



THE AMERICAN WELDER LEARNING TRACK



Heather Govreau welds on a production assembly as part of her training.

Training Topics

What curriculum should be presented to these trainees? How long should the training continue until the students are ready to move into production? An overriding factor is the skill level needed.

“At Great Plains, training is structured to provide adequate time for employees in the program to gain all of the skills needed to be a production welder. Based on each individual’s experience and demonstrated welding skills, the training could be from two to eight weeks or longer,” explained Bonilla.

What are the minimum basic welding skills necessary for employees to serve as productive members of your manufacturing team? A realistic, achievable goal for an entry-level team member is to have good welding skills in the flat position using a single welding process. Thus, the training sessions should concentrate on developing effective travel speeds and maintaining proper gun-to-work distance, weld placement, gun angle, and weld size. Also, instruction should be presented on the company’s weld procedures and processes, which includes setting the various machine controls. If your company typically employs pulsed gas metal arc welding, these additional methods must be taught.

Another skill that may be necessary is cutting. It may be a non-issue at your facility, but if your welders fabricate components, in addition to welding, cutting skills must be taught, too.

Chris Lorio, director of customer training, Hypertherm, Hanover, N.H.,

said, “We tend to have tunnel vision when training welders. We concentrate primarily on welding processes and generally ignore cutting. Cut quality, dimensional accuracy, and fit and finish are the bedrocks of a successful weld, yet cutting commonly takes a backseat in training.

“In the case of plasma arc cutting, proper technique, machine variables, promoting consumables life, and preventative maintenance should be discussed. Operators maximizing the advantages of plasma cutting will save their company money in joint preparation and weld time, as well as in consumables costs and overall weldment quality.”

Hypertherm saw the need for a readily available plasma cutting curriculum. In the fall of 2007, the company began assembling an educational council consisting of Hypertherm representatives and several welding instructors from across the nation.

Lorio said, “This council is in the process of creating a training package, essentially Plasma Arc Cutting 101. Our goal is to create a general, turnkey training package for plasma arc cutting users.”

Classroom vs. Hands-On

If you expect that your training will include classroom lectures in addition to hands-on welding, you have to decide what topics to present and how much time to allocate for them. The essential classroom educational objectives include safety, machine setup, blueprint reading, and basic trade math. At Great Plains, presented in addition to these topics are

detailed discussions of pulsed and spray mode GMAW, flux cored arc welding, metal core welding, plus an introduction to robotic weld cell operation.

Tim Smith of Great Plains stated, “If our welders understand these technical topics, we feel it will help them to maximize the process advantages. In putting our curriculum together, we utilized our welding suppliers and they provided DVDs, Web casts, and online learning tools.”

Lorio pointed out, “Our Web page has an ‘Information Center.’ This link illustrates and discusses an overview of plasma arc cutting, advantages of the process, as well as principles of operation. Coupled with our in-process training package, we hope to cover all the bases.”

Additional process information can be obtained from the American Welding Society’s *Welding Handbook* series as well as relevant *Welding Journal* articles. Also, many welding equipment manufacturing companies provide training resources, including ESAB, Lincoln Electric, and Miller, to name a few. Professional schools, such as the Hobart Institute of Welding Technology, provide a list of their presentation-ready classroom materials, generally, as a link on their Web page.

The Final Exam

At Great Plains, Bonilla said, “We want our trainees to understand we see the classroom technical information as a very important training component, thus we require each individual to pass a written test at the end of the lectures.

“Our practical exam requires trainees to successfully assemble a production part, make the correct quality welds, and maintain a suitable production rate.”

Here are a couple of useful suggestions. General practical tests can be found in the American Welding Society’s SENSE (Schools Excelling through National Skills Education) program, available from the AWS bookstore, keyword EG2.0. For companies working to the AWS D1.1, *Structural Welding Code — Steel*, the limited thickness welder qualification test could be used as a benchmark for welding skill testing. Alternatively, if a trainee’s ability to make sound fillets is the ultimate goal, a fillet weld break test may be sufficient. Regardless, with the decline in welder population, increase in median age, and the somewhat nomadic tendencies of welders, keeping a productive welding staff may require growing your own. ♦

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THE AMERICAN WELDER JUST THE FACTS

Understanding Flanged Joints

Flanged joints are a form of one of the five basic joint types in which at least one of the joint members has a flanged edge shape at the weld joint. Following is a description of the five types of flanged joints.

Flanged Butt Joint. A form of a butt joint in which at least one of the members has a flanged edge shape at the joint —

Fig. 1A.

Flanged Corner Joint. A form of a corner joint in which the butting member has a flanged edge shape at the joint, and an edge weld is applicable — Fig. 1B.

Flanged T-Joint. A form of a T-joint in which the butting member has a flanged edge shape at the joint, and an edge weld is not applicable — Fig. 1C.

Flanged Lap Joint. A form of a lap joint in which at least one of the members has a flanged edge shape at the joint, and an edge weld is not applicable — Fig. 1D.

Flanged Edge Joint. A form of an edge joint in which at least one of the members has a flanged edge shape at the joint — Fig. 1E.

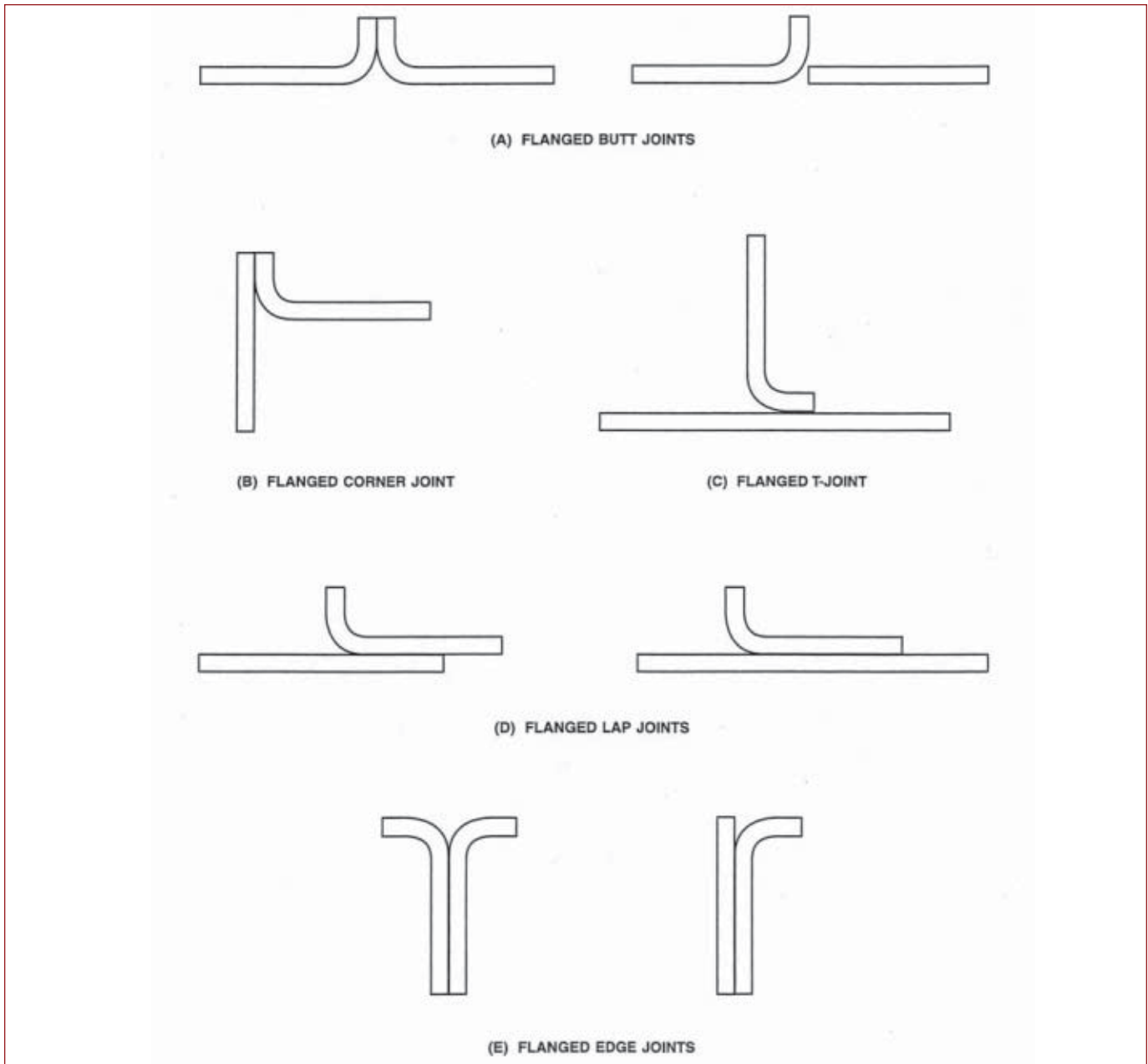


Fig. 1 — The five types of flanged joints.



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BY O. A. IDOWU, O. A. OJO, AND M. C. CHATURVEDI

ABSTRACT

Allvac 718Plus® was welded in different preweld heat-treated conditions in order to investigate the effects of preweld heat treatments on its cracking behavior during welding. The occurrence of HAZ cracking in the alloy was found to be closely related to grain boundary boron segregation and variation in grain size, both of which were controlled by preweld heat treatments. It was demonstrated that crack-free welds of the alloy can be made by a proper selection of preweld heat treatment.

Introduction

Allvac 718Plus® is a newly developed γ' —strengthened-nickel-based superalloy. It was developed by ATI Allvac (Ref. 1) as a derivative of the widely used Inconel® 718 superalloy. The alloy was developed to overcome service temperature limitations that are usually encountered with components made with 718. Alloy 718 loses its strength above 650°C due to instability of its main strengthening phase, γ'' . Above this temperature, the D0₂₂ ordered body-centered tetragonal phase of γ'' becomes unstable and transforms to an equilibrium delta (δ) phase with orthorhombic (D0a) crystal structure with a plate-like morphology, which impairs its high-temperature mechanical properties. In developing 718Plus, major compositional changes, which are detailed in the work of Cao et al. (Ref. 2), were made to

O. A. IDOWU, O. A. OJO, and M. C. CHATURVEDI are with the Department of Mechanical and Manufacturing Engineering, University of Manitoba, Winnipeg, Manitoba, Canada.

its principal alloy, 718. These changes resulted in a change in the main strengthening phase of 718Plus from γ'' to γ' phase that is known to be more stable at high temperatures and thus improves the strength of the superalloy. Thus, it is claimed (Ref. 2) that hot-section components of both aero-engine and land-based power-generation turbines made of 718Plus superalloy can operate at temperatures up to 55°C higher than those made of 718.

Although 718Plus can withstand high service temperatures, recent studies on its weldability (Refs. 3, 4) have shown that it is susceptible to heat-affected zone (HAZ) cracking during high-power beam welding, a problem that plagues many other nickel-based superalloys. It is known that HAZ cracking during welding of superalloys can be significantly reduced or eliminated by the use of appropriate preweld heat treatments (Ref. 5). Therefore, the aim of the present work was to investigate the influence of preweld heat treatments on the cracking behavior of 718Plus. Ultimately, a preweld heat treatment schedule that would be capable of preventing the occurrence of HAZ cracking during welding was sought.

KEYWORDS

Allvac 718Plus®
Inconel® 718
Superalloy
Boron
Grain Boundary Segregation
Grain Size
SIMS Analysis
Microstructural Analysis
Heat Treatment
Electron Beam Welding
Weld HAZ Cracking

Experimental Procedures

Materials and Preweld Heat Treatments

The 718Plus superalloy used in this study was supplied by ATI Allvac in the form of 305 × 127 × 16 mm hot rolled plate. The alloy contained about 30 ppm of boron, and the rest of its elemental composition is given in Table 1. Rectangular sections measuring 12 × 12 × 100 mm and 3 × 3 × 2 mm were cut normal to the rolling direction of the plate, and then solution heat treated for 1 h in an argon atmosphere in a furnace at 950°, 1050°, and 1150°C. The heat-treated coupons were cooled from the solution heat-treatment temperatures at various rates ranging from iced-water quenching ($\approx 500^\circ\text{C/s}$), air cooling ($\approx 25^\circ\text{C/s}$), to furnace cooling ($\approx 0.25^\circ\text{C/s}$), as shown in Table 2.

SIMS Analysis

The SIMS technique was used to analyze grain boundary distribution of boron in this study. In the SIMS (Refs. 5, 6), a solid sample is bombarded with primary ions of few keV energy. This results in the sputtering of atomic species from the surface of the sample. Fractions of the species are emitted as negative, neutral, or positive secondary ions and their mass are analyzed in a mass spectrometer to determine the elemental, molecular, or isotopic composition of the surface. Due to the extremely high signal/background ratio of the mass spectrometer, SIMS can detect trace amounts of elements on a surface. It provides ion images with spatial resolution of a few μm and elemental resolution to a few ppm. The primary ion beam species used in SIMS include Cs⁺, O₂⁺, O⁺, Ar⁺, Ga⁺, and Xe⁺. Very electronegative elements such as H, O, S, and P are most sensitive to Cs⁺ beam, while O₂⁺ is used for most other elements.

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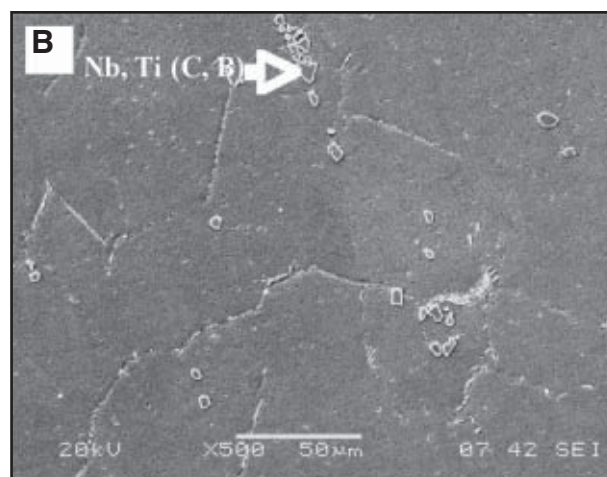
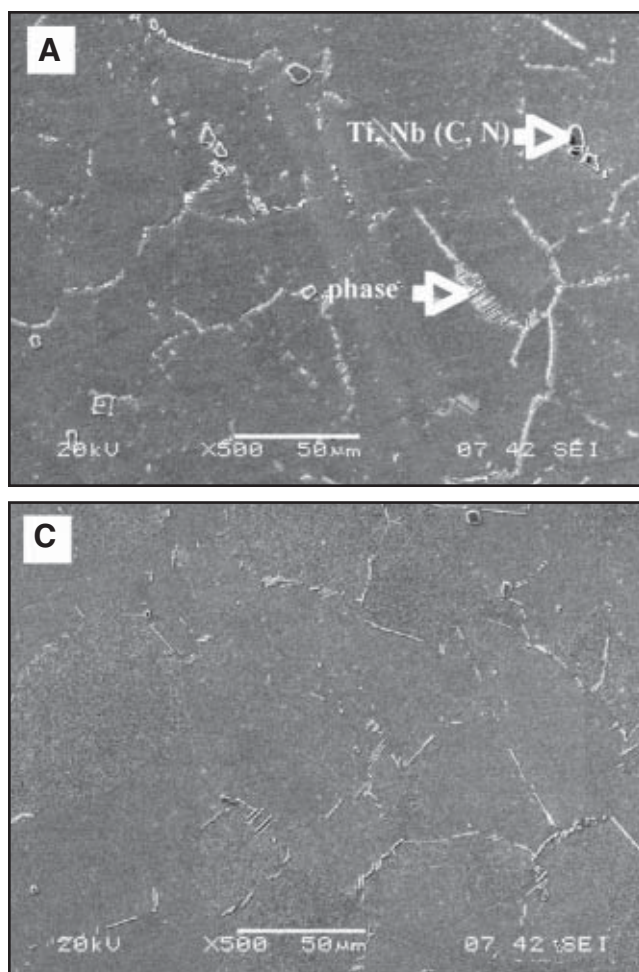


Fig. 1 — SEM microstructure of 718Plus solution heat treated at 950°C. A — Iced-water quenched; B — air cooled; C — furnace cooled. The top-right inset on 1C shows γ' particles in γ matrix of the furnace-cooled samples.

study, $3 \times 3 \times 2$ mm preweld heat-treated coupons were mounted in an epoxy base resin and polished to 1- μ m finish using standard metallographic techniques. Thereafter, they were electro-etched in 10% oxalic acid at 6 V for 5 s. This revealed the grain boundaries, which were the areas of interest for SIMS analyses. A Vickers microhardness indenter was used to mark the grain boundaries, and the coupons were re-polished to remove the etched surface layer while leaving the indentations. Finally, the coupons were removed from the epoxy base resin in which they were mounted. The coupons were then examined for grain boundary segregation of boron using a Cameca IMS-7f magnetic sector secondary ion mass spectrometer. The equipment was operated in a scanning microprobe mode. A primary ion beam of O_2^+ with impact en-

ergy of 10 kV and 180 pA beam current was rastered over an approximate surface area of 150×150 μ m of the coupon. Mass resolved images of boron were obtained by imaging positive secondary ions of $^{11}B^+$.

Welding and Microstructural Analyses

In order to investigate the effects of various preweld heat treatments on HAZ cracking of 718Plus during welding, the $12 \times 12 \times 100$ mm heat-treated specimens were welded autogenously along the 100 mm length using a focused electron beam at 44 kV voltage, 79 mA beam current, and 152 cm/min welding speed. Transverse sections of the welds were cut by electrodischarge machining and prepared by standard metallographic polishing technique for microstructural study. Thereafter, the specimens were etched electrolytically at 6 V for 5 s in a solution of 10% oxalic acid. Microstructures of preweld heat-treated and welded specimens were examined using an optical microscope and a JEOL 5900 scanning electron microscope (SEM) in both secondary and backscattered electron (BSE) imaging modes. The susceptibility of 718Plus to weld HAZ cracking was evaluated by measuring total length of cracks (TCL) observed in 8 sections of each weld.

Results and Discussion

Microstructure of Preweld Solution Heat Treated Alloy

Figures 1A–C and 2A–C show SEM microstructure of 718Plus after solution heat treatment for 1 h at 950° and 1050°C, respectively. Samples that were heat treated at 1150°C had microstructures similar to those treated at 1050°C. Generally, after the solution heat treatment at 950°C, and at all the cooling rates employed, the alloy contained dispersed blocky-shaped precipitates in intergranular and intragranular regions of its γ solid solution matrix (Fig. 1A–C). The precipitates were identified to be Nb, Ti-rich carboborides and Ti, Nb-rich carbonitrides which are the primary solidification constituents of the alloy (Ref. 3). Also, grain boundary regions of the alloy were outlined by secondary precipitates of δ phase having platelet or blocky morphology. In addition to the carbides and δ phase, precipitates of γ' particles were observed within the γ matrix of the furnace-cooled samples. A high-magnification SEM image showing spherical-shaped γ' particles is shown in the top-right inset of Fig. 1C. The γ' particles precipitated from γ matrix during continuous cooling of 718Plus in the furnace at a slow rate ($\approx 0.25^\circ\text{C/s}$). Specimens heat treated at 1050° and 1150°C contained microconstituents similar to those observed in the samples that were heat treated at 950°C, with the exemption of δ phase. δ -phase precipitates were not observed after the solution treatments at 1050° and 1150°C because these temperatures are above the solvus of δ phase in 718Plus, which has been reported

Table 1 — Bulk Chemical Composition (wt-%) of 718Plus

Ni	Cr	Fe	Co	Nb	Mo	Al	W	Ti	Mn	C	Si	V	P	B	Mg	S
Bal	17.92	9.33	9.00	5.51	2.68	1.50	1.04	0.74	0.03	0.022	0.02	0.02	0.006	0.003	0.0008	0.0003

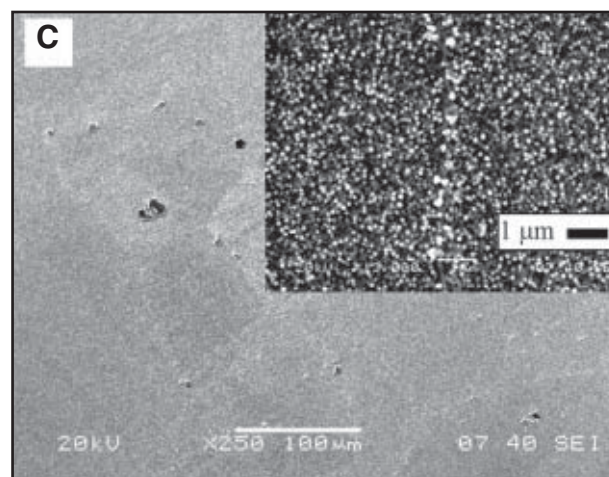
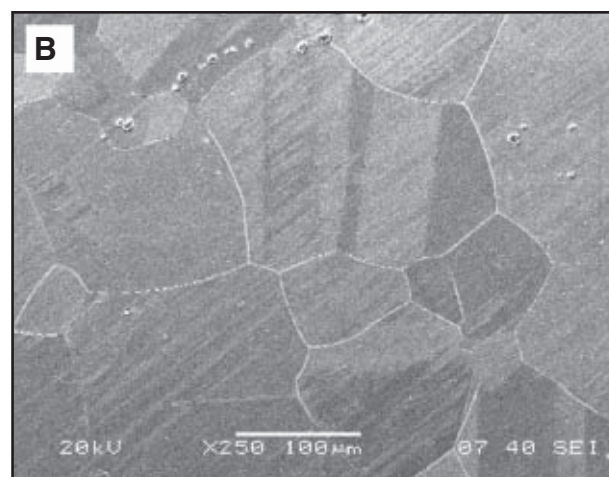
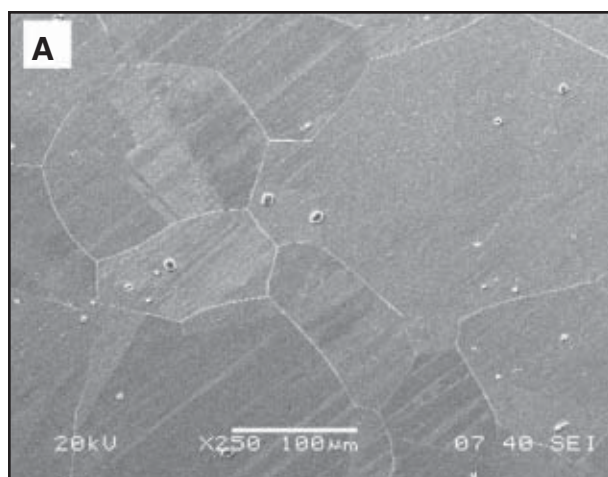


Table 2 — Preweld Heat-Treatment Temperatures and Cooling Method

Temperature (°C)	950	1050	1150
Cooling method	ID-WQ ^(a)	ID-WQ	ID-WQ
	AC ^(b)	AC	AC
	FC ^(c)	FC	FC

(a) ID-WQ: Iced-water quench at $\approx 500^\circ\text{C/s}$

(b) AC: Air cooled at $\approx 25^\circ\text{C/s}$

(c) FC: Furnace cooled $\approx 0.25^\circ\text{C/s}$

to be in the range of $1002^\circ\text{--}1018^\circ\text{C}$ (Ref. 7). A notable difference was also observed in the grain size of the samples after heat treatments. The optical micrographs in Fig. 3 A–C show the grain sizes of specimens solution heat treated at 950°C ($\approx 58\ \mu\text{m}$ grain size), 1050°C ($\approx 120\ \mu\text{m}$ grain size), and 1150°C ($\approx 360\ \mu\text{m}$ grain size), respectively, and air cooled. The micrographs depict the variation in grain size of the alloy after these heat treatments. The approximate mean diameter of the grains after all the preweld solution heat treatments are presented graphically in Fig. 4. It is seen that no significant variation in grain size occurred with variation in cooling rate. However, the grain size increased approximately by a factor of two and six when heat treatment temperature was increased from 950° to 1050°C and 1150°C , respectively. The dramatic grain growth that occurred at 1050° and 1150°C can be attributed to the dissolution of δ -phase precipitates during heat treatments at these temperatures, as shown in Fig. 2. It is known that δ phase pins grain boundaries, and thereby prevents/limits grain growth during high-temperature exposure (Ref. 8). Thus, no significant grain growth occurred during the treatment at 950°C where the grain boundaries were outlined and successfully pinned by δ phase — Fig. 1.

HAZ Microstructure of Welded Alloy

The SEM backscattered electron (BSE) image in Fig. 5 shows weld HAZ microstructure of the specimen that was

preweld heat treated at 950°C and quenched in iced water. Liquation of MC-type carbide particles was occasionally observed in the HAZ region closer to the fusion zone of the weld. Also, grain boundary liquation was observed in HAZ region up to about $250\ \mu\text{m}$ from the fusion zone, but HAZ cracking was not observed. The samples that were preweld heat-treated at 950°C and air or furnace cooled were also crack free. Their HAZ microstructures were similar to those of the samples that were quenched in iced water — Fig. 5. However, SEM microstructures of the preweld and weld HAZ of the furnace-cooled sample (Fig. 6A, B) suggests that liquation of γ' particles occurred in the heat-affected zone during welding. The underlying mechanism of the constitutional liquation of γ' precipitates in γ' strengthened nickel-based superalloys has been discussed in detail in the work of Ojo et al. (Refs. 9, 10). An explicit consideration of the potential effects of this on the weldability of 718Plus (in aged condition) is a subject of future work. However, it has been reported (Refs. 9, 10) that liquid film from constitutionally liquated γ' precipitate can contribute to weld HAZ cracking if it penetrates and wets HAZ grain boundaries.

The weld HAZ microstructures of samples that were preweld heat treated at 1050° and 1150°C , respectively, were sim-

ilar to those that were heat treated at 950°C . However, HAZ cracks were observed in the samples that were preweld heat treated at 1050° and 1150°C . Representative optical and SEM images of a cracked region is shown in Fig. 7A and B, respectively. As shown in the figures, the cracks were mostly present within the neck region of the nail-head-shaped welds. The degree of cracking in these samples was quantified by the measurement of total crack lengths (TCL) in them. The average value of TCL observed in variously heat treated material is shown in Fig. 8. It is seen that cracking was not observed in the welds in samples that were preweld heat treated at 950°C and cooled at the three cooling rates. However, as shown in Fig. 8, HAZ cracking occurred in the welds when the preweld heat treatment temperature was increased to 1050° and 1150°C . Figure 8 also shows that, at 1050° and 1150°C , the highest degree of cracking occurred in air-cooled samples. This was followed by furnace-cooled samples, while the lowest extent of cracking was found in samples that were quenched in iced water. At all the three cooling rates, the degree of

Fig. 2 — SEM microstructure of 718Plus solution heat treated at 1050°C . A — Iced-water quenched; B — air cooled; C — furnace cooled. The top-right inset on 1C shows γ' particles in γ matrix of furnace-cooled samples.

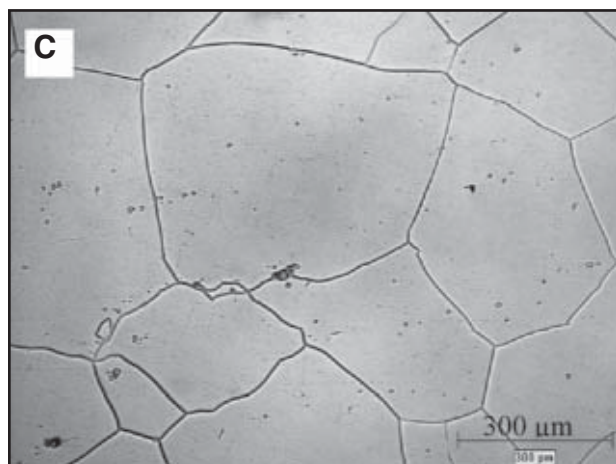
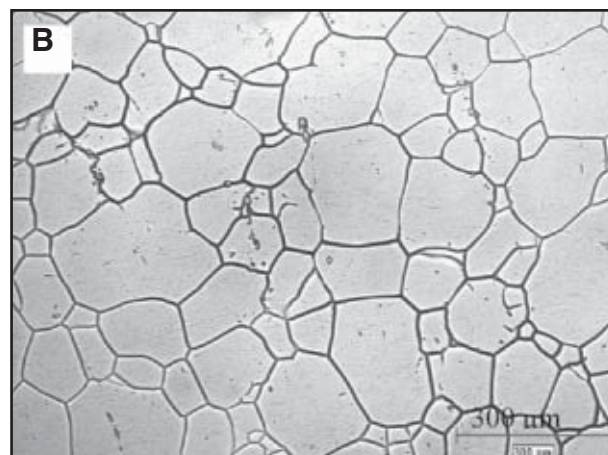
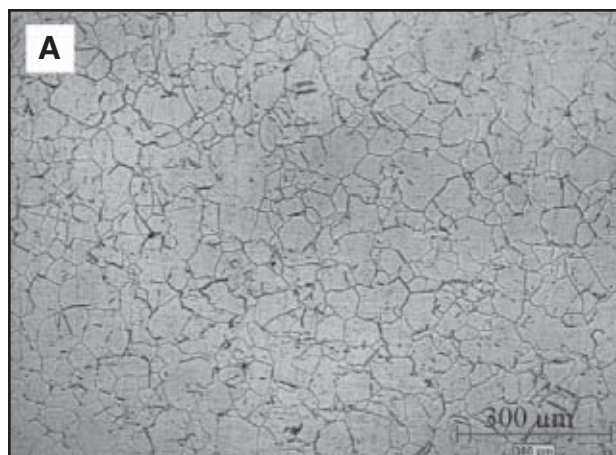


Fig. 3 — Optical micrographs (100 $\times$, 10% oxalic etch) of 718Plus showing the variation in grain size after solution heat treatment. A — At 950°C; B — at 1050°C; C — at 1150°C. All were followed by air cooling.

cracking was always higher in samples preweld heat treated at 1150°C compared to those that were heat treated at 1050°C. Although constitutional liquation of MC-type carbides was observed in this work, and has been reported to contribute to HAZ cracking in 718Plus (Ref. 11), a careful study of the variation of cracking with preweld heat-treatment temperature and cooling rate, which did not affect the volume fractions of constitutionally liquating MC-type carbides, suggested that cracking was more influenced by two main factors, viz., segregation of B and grain size of the material, which are discussed next.

Grain Boundary Segregation of Boron

The cause of intergranular cracking that often occurs in the HAZ of austenitic alloys during welding is generally attributed to a combination of mechanical driving force for cracking, threshold tensile welding stresses, and a crack susceptible microstructure such as with liquated grain boundaries. The liquation of a HAZ grain boundary during welding causes its solid-solid interfacial bond to be replaced by a

weaker solid-liquid bond. Consequently, this reduces the threshold tensile welding stress that is required to cause the liquated grain boundary's decohesion. Thus, the inherent resistance of an alloy to HAZ cracking is reduced by liquation reaction. Grain boundary liquation can occur by either equilibrium supersolidus or nonequilibrium subsolidus melting. However, the mere occurrence of liquation reaction is not sufficient to produce a crack susceptible microstructure. It is essential that the liquid film penetrates and wets the grain boundaries

and is stable over a wide range of temperatures to allow enough stresses to build up during weld cooling. The presence of positively partitioning elements (i.e., $k < 1$), particularly boron, enhances the wettability and increases the stability of grain boundary liquid film, and boron has been described as the most detrimental element causing grain boundary liquation cracking (Refs. 12–14), although it improves creep-rupture life of the alloy. Boron is particularly more detrimental as it has a tendency to preferentially segregate to grain boundaries during thermo mechanical processing of an alloy, or thermal treatments prior to welding.

The thermally induced grain boundary segregation of solute atoms, e.g., boron, is a diffusion controlled process that can occur by two mechanisms, viz., equilibrium segregation and nonequilibrium segregation. Equilibrium segregation occurs when a polycrystal is held at a sufficiently high temperature to permit appreciable diffusion of misfit impurity atoms within its grains to loosely packed interfaces, e.g., grain boundaries. The impurity atoms are

absorbed by such interfaces in order to reduce their free energy (Ref. 15), and are thereby said to “segregate” to the interface. The extent of such equilibrium segregation is known to decrease with an increase in heat-treatment temperature, but is independent of cooling rates. On the other hand, thermally induced nonequilibrium segregation (Refs. 16, 17), as its name suggests, occurs under nonequilibrium thermal conditions, particularly when cooling from elevated temperatures over a range of cooling rates. This type of segregation has been widely described by a solute drag mechanism (Refs. 18, 19), which involves the following. During high-temperature annealing, an equilibrium concentration of vacancies is generated and distributed within the grain interior of a polycrystal. As the temperature decreases during cooling, the grains become supersaturated with vacancies. Since grain boundaries act as perfect sinks for point defects, a vacancy concentration gradient is set up between the supersaturated grains and the boundaries (Ref. 20). Consequently, vacancies diffuse down the concentration gradient to grain boundaries where they are annihilated. However, if some of the vacancies are attracted to impurity atoms, vacancy-solute complexes will be formed, and a proportion of the impurity atoms (those with positive vacancy-solute binding energies [Ref. 13]) will be dragged with vacancies toward grain boundaries. Thus, the grain boundaries will become gradually enriched with impurity solute atoms while the vacancies are being annihilated.

In contrast to equilibrium segregation, the degree of nonequilibrium segregation depends on cooling rates and vacancy-solute binding energy. The degree of nonequilibrium segregation increases with an increase in heat treatment temperature. The cooling rate is, however, very critical. If cooling rate is very rapid, sufficient time may not be available for a significant diffusion of complexes to grain boundaries to occur (Ref. 14). On the other hand, if the

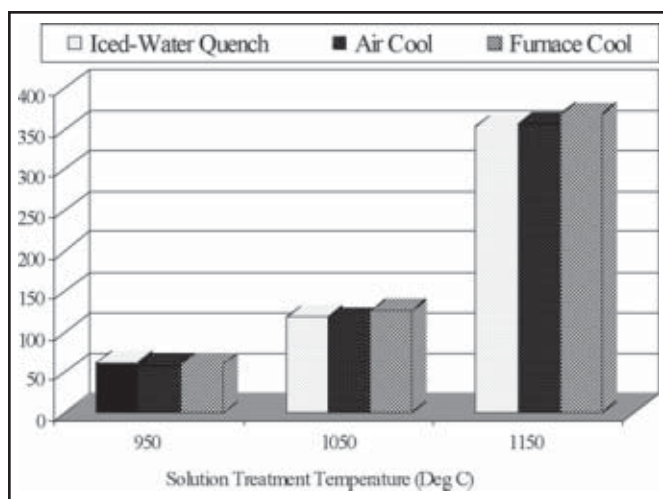


Fig. 4 — Variation in average grain size of 718Plus with preweld heat-treatment temperature and cooling rate.

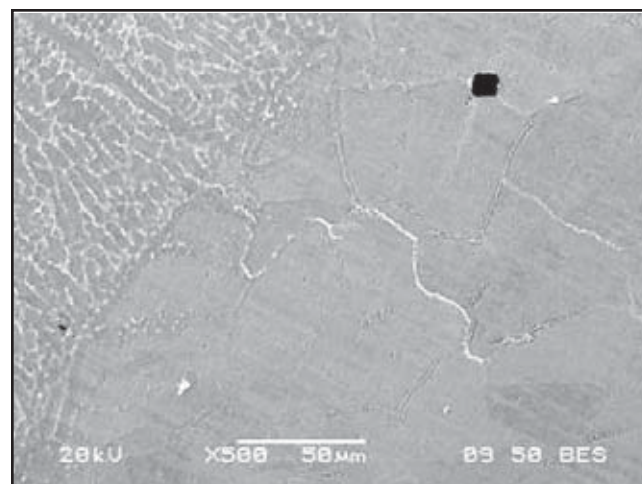


Fig. 5 — SEM micrograph showing the absence of HAZ cracking in the weld of 718Plus that was preweld solution heat treated at 950°C and iced-water quenched.

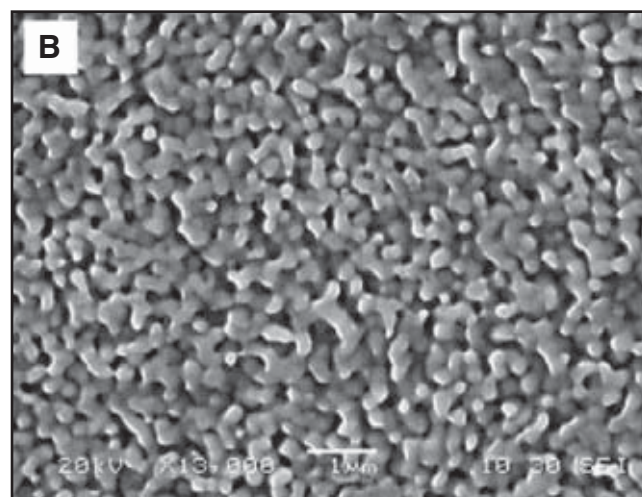
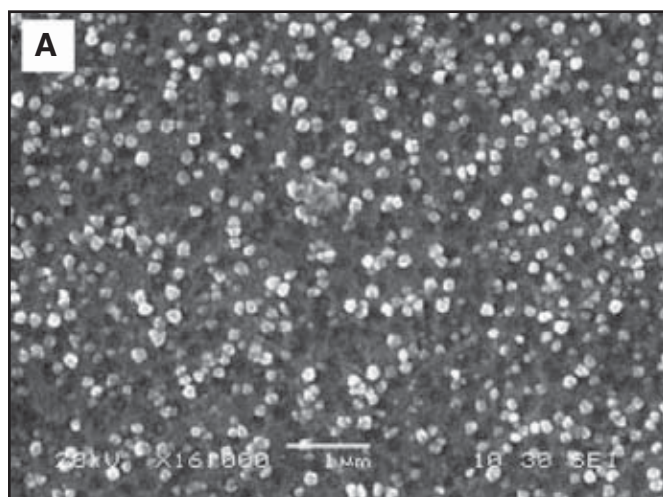


Fig. 6 — SEM micrographs showing γ' particles. A — Before welding (i.e., after 950°C + furnace cool); B — after welding.

cooling rate is very slow, desegregation of solute atoms may occur. That is, segregated solute atoms on grain boundaries may diffuse away from their grain boundary sites back to grain interior when a solute concentration gradient occurs between the grain boundaries and the grain interior (Refs. 21, 22). Therefore, the degree of nonequilibrium segregation is usually highest at intermediate cooling rates when sufficient time is available to let vacancy-solute complexes diffuse to grain boundaries but is not sufficient to let the deposited solute atoms diffuse away from the grain boundary region.

Figures 9A–C to 11A–C show a set of SIMS images illustrating grain boundary distribution of boron in 718Plus after heat treatments at 950°, 1050°, and 1150°C at cooling rates corresponding to iced-water quench, air cool, and furnace cool. The images were recorded at the same instrumental settings of SIMS. Within the resolution limit of SIMS, boron segregation was significantly minimized in samples

heat treated at 950°C, and cooled by any of the three cooling rates employed (Fig. 9 A–C). However, brighter boron signals, the degree of which varied with cooling rates and appeared to increase with heat-treatment temperature, were observed in samples heat treated at 1050° and 1150°C, respectively (Figs. 10A–C and 11A–C). The brightest boron intensity was observed in air-cooled samples while iced-water quenching and furnace cooling resulted in a significant reduction in the intensity. The intensities of boron signals could not be quantified by SIMS, thus, this work limits itself only to a qualitative comparison of the signals.

The dependence of nonequilibrium segregation on cooling rates suggests that the characteristically dynamic segregation pattern observed in the present work during preweld heat treatments of 718Plus, as shown in Figs. 9–11, is predominantly nonequilibrium in nature. It has been widely reported (Refs. 22, 23) that the segregation of boron to grain boundaries in

austenitic steels occurs mainly during cooling from high temperatures and by nonequilibrium mechanism. Karlsson et al. (Ref. 24) used SIMS to study the nature of grain boundary segregation of boron in Type 316L austenitic stainless steel at heat treatment temperatures and cooling rates which ranged from 900° to 1250°C, and 530° to 0.25°C/s, respectively. They observed an increase in the degree of grain boundary segregation of boron when the cooling rate was decreased from 530° to 27°C/s. However, a further decrease in the cooling rate to 0.25°C/s resulted in desegregation of the boron atoms, an occurrence which was marked by a decrease in the intensity of boron atoms on the grain boundaries. In the present investigation, boron segregation was significantly minimized in 718Plus that was heat treated at 950°C and cooled at various rates (Fig. 9A–C), viz., iced-water quench ($\approx 500^\circ\text{C/s}$), air cool ($\approx 25^\circ\text{C/s}$), and furnace cool ($\approx 0.25^\circ\text{C/s}$). However, boron segregated to grain boundaries when the heat-treatment

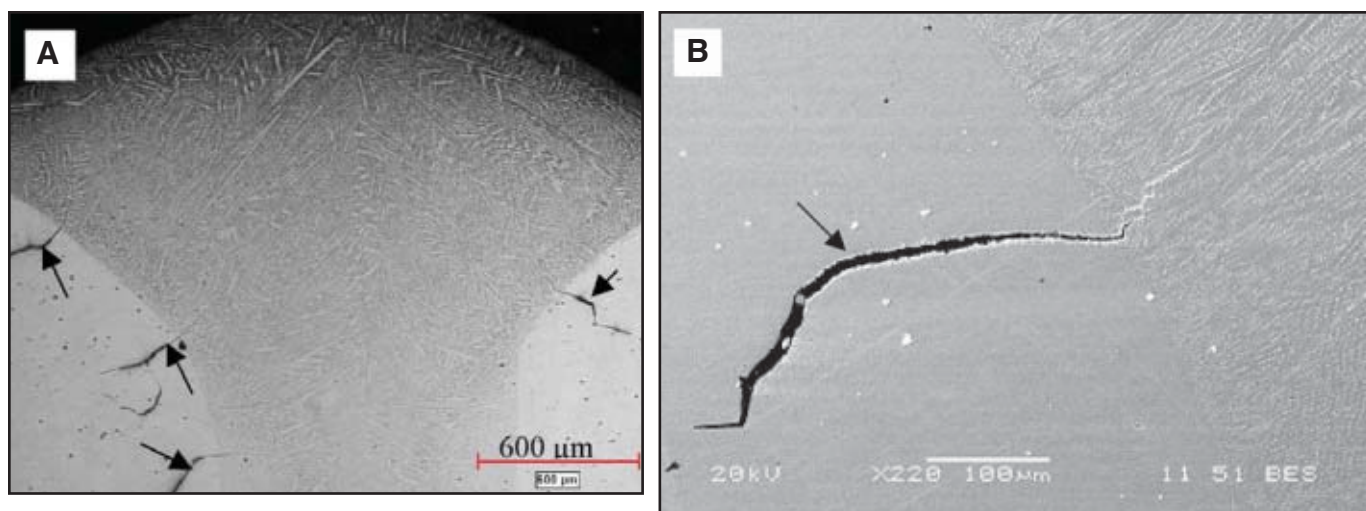


Fig. 7 — A — Optical; and B — SEM micrographs showing cracking in the weld HAZ of 718Plus that was preweld solution heat treated at 1150°C plus air cool.

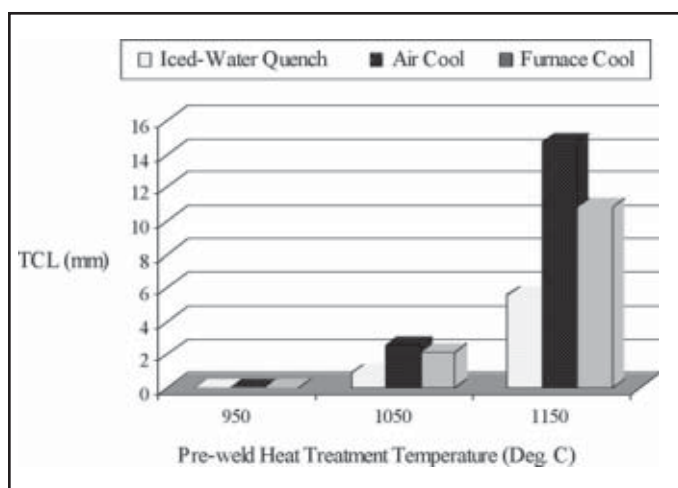


Fig. 8 — Variation in HAZ total crack length (TCL) of 718Plus with preweld heat-treatment temperature and cooling rate.

temperature was increased to 1050° and 1150°C, respectively. As shown in Figs. 10A–C and 11A–C at both temperatures, the degree of segregation varied with cooling rates. The brightest boron intensities were observed in samples that were cooled at the intermediate rate (air cool), while the fastest cooling rate (iced-water quench) resulted in an appreciable decrease in boron segregation. Moreover, desegregation of boron occurred during furnace cooling. A significant reduction in boron intensity was observed in furnace-cooled samples, although their intensities were always brighter than that observed in the iced-water quenched samples.

Boron is considered to be the most detrimental element causing grain boundary liquation cracking in Alloy 718 (Refs. 12–14), although cracking is also known to result from the constitutional liquation of MC-type carbides. Huang et al. (Refs. 13, 25) and Chen et al. (Ref. 26) evaluated the weldability of 718, in both cast and

wrought forms, after the alloy was preweld treated using various heat treatment schedules that varied the degree of boron segregation on its grain boundaries. A close relationship was observed between the preweld heat treatments, the degree of boron segregation, and the susceptibility of 718 to HAZ cracking, which was evaluated by measuring the total crack length (TCL) that

were observed in the HAZ. A heat treatment that increased boron segregation also increased cracking in the alloy and vice versa. In the present investigation, no cracking was observed in weld HAZ of the alloy, which was preweld heat treated at 950°C and cooled at various rates, which ranged from iced-water quench to furnace cool — Figs. 5, 8. SIMS analyses of the alloy in the preweld heat-treated conditions did not reveal a significant segregation of boron to its grain boundary regions either — Fig. 9. Evaluation of the welds that were preweld heat treated at 1050° and 1150°C, respectively, revealed that HAZ cracking occurred during welding — Figs. 7, 8. The degree of cracking (TCL) in the HAZ of the welds increased with an increase in the degree of boron segregation, which occurred on the grain boundaries of the alloy during the respective preweld heat treatments. As shown in Figs. 8, 10, and 11, iced-water quenching (fastest cooling rate) after preweld solu-

tion heat treatments at 1050° and 1150°C, respectively, resulted in the lowest degree of boron segregation and weld HAZ cracking. However, the highest degree of boron segregation and weld HAZ cracking were observed in air-cooled (intermediate cooling rate) coupons. In comparison to air cooling, the degree of HAZ microfissuring was reduced in coupons that were furnace cooled; a cooling condition where desegregation of boron from grain boundaries had started to occur and which reduced the amount of segregated boron on the grain boundaries.

To further confirm the contribution of boron to HAZ cracking in 718Plus, a version of the alloy that has a higher boron concentration (60 ppm of boron) was preweld heat treated for 1 h at 950°, 1050°, and 1150°C, respectively, and air cooled. Thereafter, the coupons were welded using the same electron beam welding conditions that were reported in the experimental technique section of this communication. SIMS images of segregated boron atoms on grain boundaries of the preweld heat-treated coupons, as well as the degree of HAZ cracking that occurred during their welding are shown in Figs. 12 and 13, respectively. Similar to the observations in the lower boron version (≈ 30 ppm) of 718Plus, boron segregation increased with an increase in preweld heat treatment temperature, and so did the weld HAZ cracking. However, it was noted that HAZ cracking was always higher in the higher boron version of 718Plus — Figs. 8, 13. Also, in contrast to the lower boron version of the alloy, a more significant grain boundary segregation of boron, accompanied by weld HAZ cracking was observed in the higher boron alloy, which was preweld heat treated at 950°C. In this heat treatment condition, grain boundary segregation was significantly reduced and no HAZ cracking was

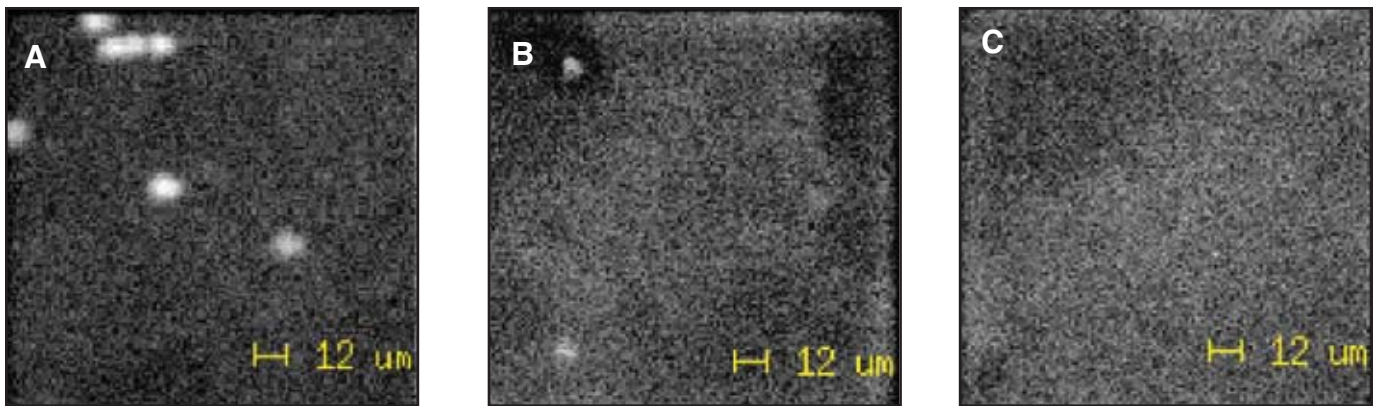


Fig. 9 — SIMS image of boron in 718Plus after heat treatment at 950°C. A — Iced-water quench; B — air cool; C — furnace cool.

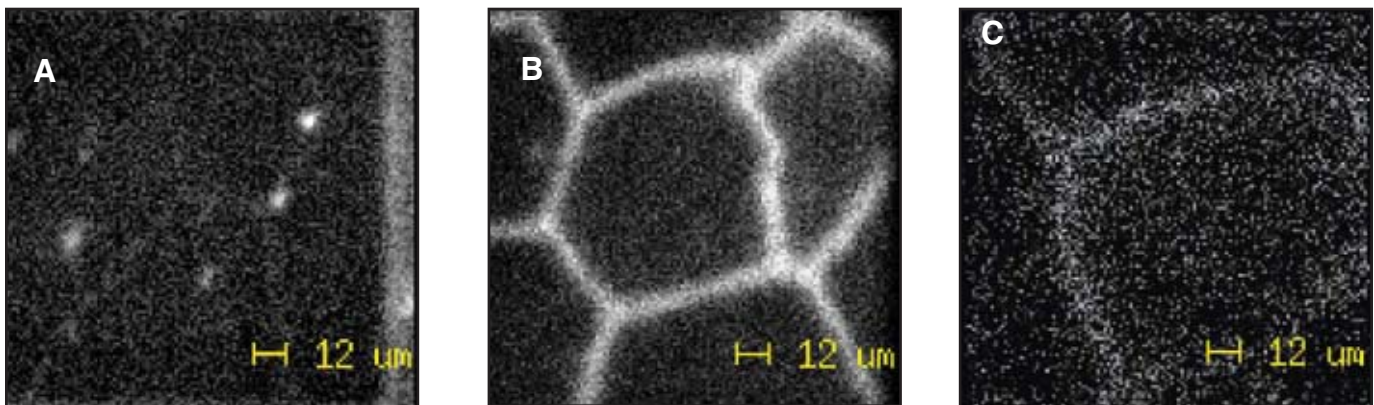


Fig. 10 — SIMS image of boron in 718Plus after heat treatment at 1050°C. A — Iced-water quench; B — air cool; C — furnace cool.

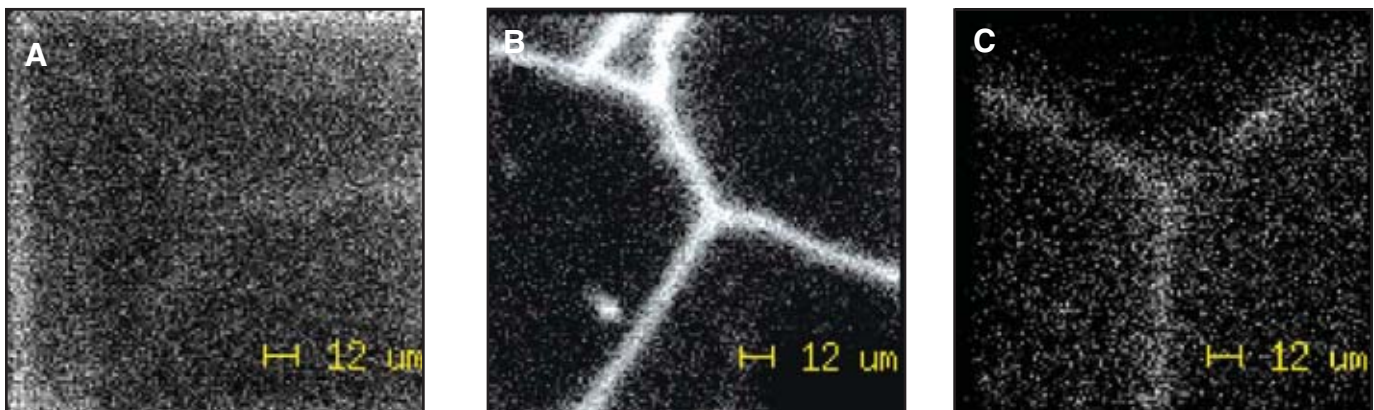


Fig. 11 — SIMS image of boron in 718Plus after heat treatment at 1150°C. A — Iced-water quench; B — air cool; C — furnace cool.

observed in the lower boron version of the alloy, as shown in Figs. 8 and 9. This further confirmed that boron played a significant role in causing HAZ cracking during welding of 718Plus. Therefore, its concentration should be as low as possible to improve the weldability of the alloy.

Generally, boron has been considered to influence the susceptibility of an alloy to weld HAZ cracking by the following mechanisms:

1) Segregated boron can act as a melting point depressant and reduce the melting temperature of grain boundary regions

relative to surrounding matrix (Ref. 26).

2) Boron can extend the solidification range of liquid film on HAZ grain boundaries due to its low partition coefficient.

3) Boron can decrease solid-liquid interfacial energy (γ_{SL}) (Refs. 13, 27), which would enhance the wettability (and facilitate spreading) and/or increase the stability of grain boundary liquid during welding.

The existence of any or a combination of the above conditions, due to grain boundary boron segregation, which was observed in the present study, will increase the susceptibility of HAZ grain bound-

aries to liquation and facilitate spreading of the liquid film along the grain boundaries during welding. The inability of the liquated grain boundaries to support tensile stresses that develop during cooling of the welds will result in their cracking (Ref. 28), as observed in the present work

Preweld Grain Size

In addition to boron segregation, the variation in grain size of an alloy that takes place during preweld heat treatments can also affect the susceptibility of the alloy to

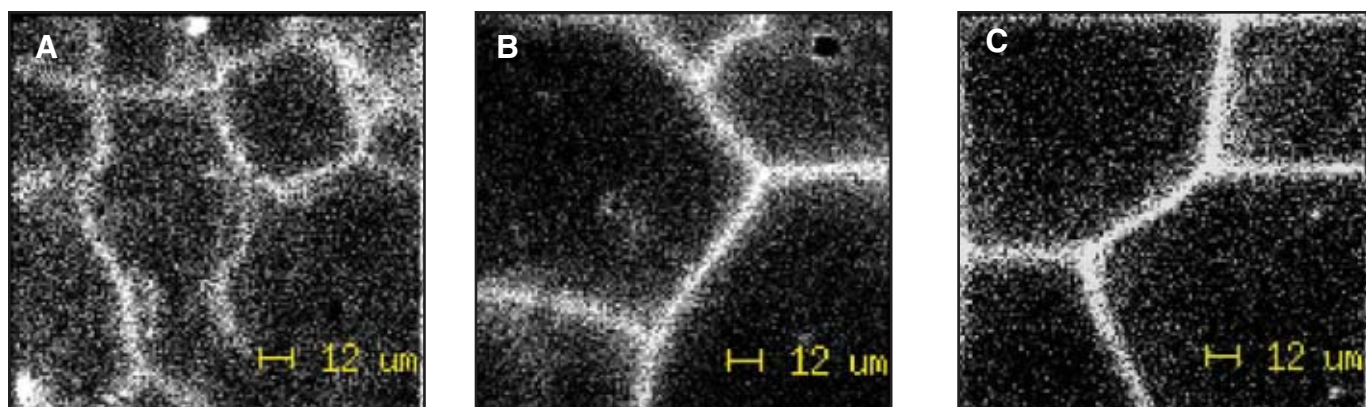


Fig. 12 — SIMS micrographs showing grain boundary boron segregation in 718Plus (higher boron version ≈ 60 ppm) after preweld heat treatment. A — At 950°C; B — at 1050°C; C — at 1150°C. All samples were air cooled.

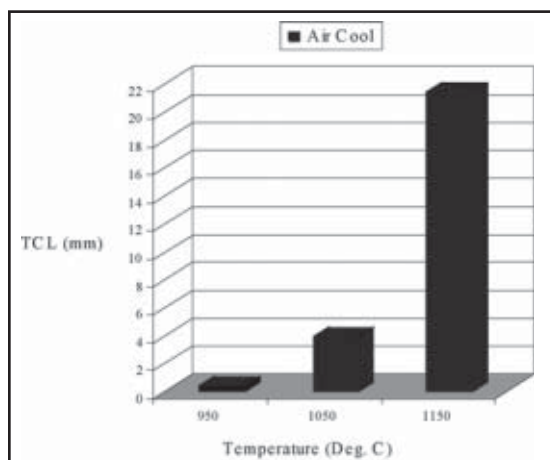


Fig. 13 — Variation in weld HAZ total crack length (TCL) of 718Plus (higher boron version ≈ 60 ppm) with preweld heat-treatment temperature. All samples were air cooled.

HAZ cracking during welding. Thompson et al. (Ref. 29) reported that HAZ cracking of Alloy 718 depends linearly on its grain size. It is a common knowledge that casting components are usually more prone to cracking than their wrought counterparts. This can be partly attributed to the usually larger grain sizes of the castings, apart from contributions from their segregated microstructure. Generally, the grain size of an alloy can also contribute to its weld HAZ cracking due to the following:

1) As predicted in the nonequilibrium grain boundary segregation model of Faulkner (Ref. 30), an increase in grain size could decrease total grain boundary surface area that is available for grain boundary segregation. Thus, provided heat treatment conditions are favorable for segregation to occur, an increase in the degree of boron segregation on the grain boundaries could arise, which could also increase their susceptibility to cracking during welding.

2) The grain size of an alloy can significantly influence the effectiveness of grain boundary liquid solidification by liquid film migration (LFM). This has been critically

discussed in the work of Nakkalil et al. (Ref. 31) and will only be summarized here. Nakkalil et al. (Ref. 31) evaluated the occurrence of HAZ cracking in Incoloy® 903 that had a duplex grain structure. A considerable amount of microfissures was observed on the grain boundaries of a large-grained alloy. However, minimal cracking and an extensive occurrence of LFM were observed in the material with fine recrystallized grain boundaries. It was argued that an effective relief of the supersaturation of solutes in grain boundary liquid film by LFM can reduce the total solidification range of the liquid film. This can effectively reduce the susceptibility of an alloy to HAZ cracking.

The velocity of LFM is dependent on grain boundary curvature, which has been reported (Ref. 32) to vary inversely with grain size. Thus, a fine-grained alloy should possess a substantial mean grain boundary curvature that would enhance the solidification of grain boundary liquid film by LFM and potentially reduce the susceptibility of the alloy to HAZ cracking.

3) When HAZ begins to accumulate strains due to welding stresses, grain boundary sliding is one mechanism that can operate to accommodate the strains (Ref. 33). However, this would increase stress concentrations at grain boundary triple points and could initiate microfissures. Once initiated, the microfissures can easily propagate along the liquated grain boundary regions. A large grain size would cause a longer interface sliding, which would lead to larger stress concentrations at grain boundary triple points (Ref. 29). This would increase the potential for crack initiation at grain boundary triple points, and therefore, liquation cracking.

In wrought alloy components, a significant increase in grain size will usually increase the susceptibility of the alloy to

HAZ cracking during welding. In the present investigation, the grain size of 718Plus increased significantly with an increase in preweld solution heat-treatment temperatures ranging from 950° to 1150°C (Figs. 3, 4), and so was the susceptibility of the alloy to HAZ cracking — Fig. 8. For example, SEM observations of the welds of samples that were air cooled after preweld solution heat treatment at 950°C (this resulted in an average grain size ≈ 58 μm) revealed an absence of HAZ cracking — Fig. 5. However, significant HAZ cracking, the extent of which increased with temperature, occurred when the alloy was preweld solution heat treated at 1050° (≈ 120 μm grain size) and 1150°C (≈ 360 μm grain size), respectively.

A variation in weld HAZ cracking was also observed with cooling rates in samples that were preweld heat treated at 1050° and 1150°C — Fig. 8. This variation cannot be sufficiently explained with grain size considerations alone, since the grain size of the alloy did not vary appreciably with the cooling rates — Fig. 4. This suggests that though the size of the grains of 718Plus may have an effect on its susceptibility to HAZ cracking during welding, the cracking is however influenced by grain size and boron segregation. Therefore, it is concluded that both grain size and grain boundary segregation of boron contributed to the observed variation in HAZ cracking of 718Plus with temperatures and cooling rates.

Summary and Conclusions

1) Weld HAZ cracking in 718Plus was significantly influenced by preweld solution heat treatment temperature and cooling rate. No cracking was observed in samples that were heat treated at 950°C and cooled either by iced water quenching, air cooling, or furnace cooling. However, HAZ cracking occurred in samples that were preweld heat treated at 1050° and 1150°C, respectively. The degree of cracking in samples varied with cooling rates.

2) In samples that were preweld heat treated at 1050° and 1150°C, respectively, the highest degree of cracking occurred in air-cooled samples. This was followed by furnace-cooled samples, while the lowest degree of cracking was found in samples that were quenched in iced-water after preweld heat treatment. At all the three cooling rates, the degree of cracking was always higher in samples preweld heat treated at 1150°C than those that were solution treated at 1050°C.

3) The occurrence of weld HAZ cracking in 718Plus is concluded to be associated with nonequilibrium grain boundary segregation of boron which depended on the preweld solution heat-treatment temperature and cooling rates, and also the grain size of the alloy prior to welding, which was also dependent on the preweld treatment temperature.

4) It is concluded from this study that crack-free welds of 718Plus can be achieved by carrying out a preweld solution heat treatment at 950°C. At this temperature, both grain growth and nonequilibrium grain boundary segregation of boron were considerably minimized.

Acknowledgments

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Mechanical Properties Characterization of Heat-Affected Zone Using the Small Punch Test

Use of the small punch test for the mechanical characterization of small areas such as the different zones that characterize the HAZ showed promise

BY C. RODRÍGUEZ, J. GARCÍA CABEZAS, E. CÁRDENAS, F. J. BELZUNCE, AND C. BETEGÓN

ABSTRACT

The small punch test (SPT) allows us to make mechanical characterizations of very small regions in any material as it uses very small test specimens ($10 \times 10 \times 0.5 \text{ mm}^3$). The SPT can be used to characterize the heat-affected zones (HAZ) of welded joints, the mechanical properties of which are usually unknown, and which are the most problematic areas because of the possible existence of hard and brittle microstructures.

Since the SPT can be used to obtain mechanical properties (yield strength, ultimate strength, elongation, fracture energy, and toughness) of small regions, this test was used to evaluate how these properties change inside the HAZ of a welded joint made on a quenched and tempered steel. Several specimens were machined along the HAZ and the corresponding SPTs were performed at room temperature, using a hardness measurement of HV0.5 as a reference. In this case, the strength properties and hardness increase as we move away from the fusion boundary, but the elongation and fracture energy decrease.

Introduction

The mechanical behavior characterization of structural components, except in the case of hardness measurements, is always destructive since it requires direct extraction of large specimens for testing, machined from the real components to be evaluated.

For this reason, if we want to evaluate a component and introduce only mini-

mum damage, it would be very convenient to use miniature tests for their mechanical characterization, making use of very small specimens (miniature samples) that could be extracted from the components during their normal service life, and which usually do not fulfill the requirements established in the corresponding standards. In the course of the last few years, different specimens with the same geometry but smaller than the standard ones were used for the evaluation of tensile, fatigue, fracture mechanics, impact properties, etc. Anyway, these results need to be reworked to derive the properties of the components, which are much larger than the tested samples (Refs. 1, 2).

These problems are especially relevant in the case of weld joints, where the existence of small heat-affected zones (HAZ) can produce serious problems during the design and manufacturing phases, although they can be solved or minimized using appropriate welding procedures and techniques. But in any case they always introduce some degree of uncertainty on the mechanical behavior of these regions under real service loads since, due to the small dimension of these HAZs (usually only some mm wide), it is not possible to characterize them using standard mechanical tests.

In the aforementioned situations, one of these miniature tests is the small punch test (SPT). Since the SPT uses small square specimens measuring $10 \times 10 \text{ mm}^2$ with a thickness of 0.5 mm, it may be considered a quasi nondestructive test as the material removed is very low. In this work the use of the SPT was analyzed to obtain

the tensile properties (yield stress, ultimate tensile strength, and elongation) of the HAZ produced during the course of a welding procedure performed on a quenched and tempered steel.

The Small Punch Test

The small punch test is a testing procedure that can be considered nearly nondestructive because of the small samples that are used (usually with a section of $10 \times 10 \text{ mm}$ and a thickness of 0.5 mm) (Refs. 3–6). Compared with other real nondestructive tests, such as X-ray diffraction, ultrasound, or magnetic techniques that are based on indirect measurements of the mechanical properties, the SPT allows us to directly obtain these properties.

In this test, the square specimen is firmly clamped between two circular dies and is strained until failure into a 4-mm-diameter cavity using a 2.5-mm-diameter hemispherical punch, as shown in Fig. 1. The tests were performed at a displacement rate of 0.2 mm/min.

The applied load and deflection of the specimen central point (DCP) measured with the help of a crack opening displacement (COD) type extensometer are recorded during the test. Figure 2 shows a typical load-DCP curve of ductile materials like those we used in this work. In this curve are marked different zones corresponding to the different states of deformation that the specimen will suffer.

Zones I and II correspond to states of bending deformation. Zone I corresponds to elastic bending and includes the linear portion of the curve, while Zone II corresponds to plastic bending. For specimens of standardized geometry and for the same testing machine, these curves are determined by the elastic-plastic material properties, i.e., the elastic modulus, yield stress σ_{ys} , and hardening coefficient of the material. From a certain moment onward, bending leads to a membrane regime, which predominates in most of the curve and corresponds to Zone III. This phase ends with fracture of the specimen. In the curve represented in Fig. 2, final fracture

KEYWORDS

Heat-Affected Zone (HAZ)
Mechanical Properties
Small Punch Test (SPT)
Quenched and Tempered Steels

C. RODRÍGUEZ, E. CÁRDENAS, F. J. BELZUNCE, and C. BETEGÓN are with Instituto Universitario de Tecnología Industrial de Asturias (IUTA), Universidad de Oviedo. J. GARCÍA CABEZAS is with General Dynamics Santa Bárbara Sistemas Oviedo, Asturias.

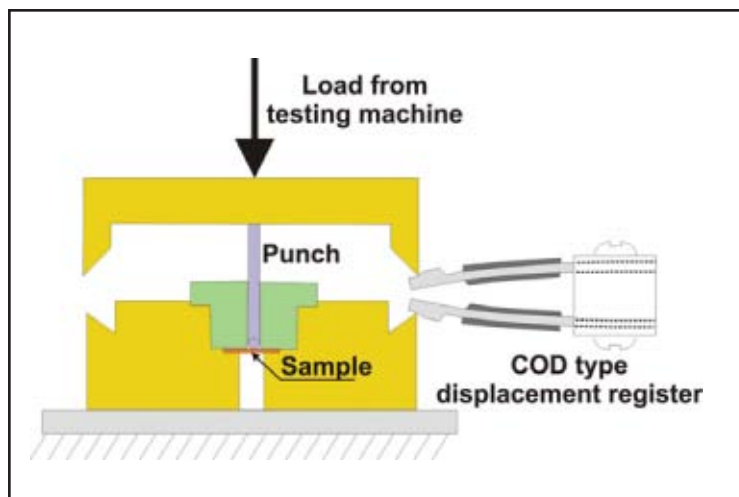


Fig. 1 — Schematic representation of the SPT equipment.

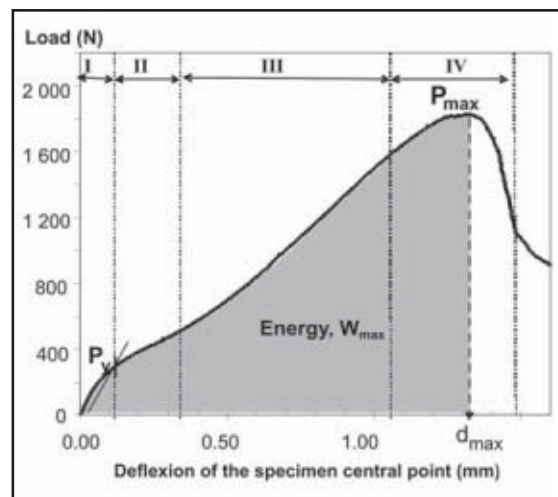


Fig. 2 — SPT load-deflection curve and identification of critical parameters.



Fig. 3 — Macrograph of the welded joint.



Fig. 4 — Microstructure of the different zones of the HAZ, which includes the situation of the extracted samples.

occurs as a result of the formation of a neck similar to that developed in tension tests of ductile materials and the subsequent formation of a crack in this location. The fracture of the specimen defines Zone IV, which includes the point of maximum load. In addition to the mechanical properties of the material, this point of maximum load depends on the coefficient of friction between the punch and the sample being tested, such that the higher this coefficient is, the greater is the load and the fracture location moved away from the center of the dome (Ref. 7).

This load-deflection curve is the only information collected in the small punch test and thus the only one at our disposal to ascertain the different material properties. Due to the complexity of the stress state that develops during the test, the work developed so far has focused on establishing empirical relationships between different mechanical properties and certain characteristic points of the curves, also marked on the curve in Fig. 2 (Refs. 8–11):

- $(P/d)_{ini}/t$, where $(P/d)_{ini}$ is the initial slope measured in the elastic region (Zone I) and t is the initial thickness of the spec-

imen. This parameter is closely related with the tensile Young's modulus E .

- P_y/t^2 , where P_y is the load where plastic strain starts, and it is obtained drawing a straight line parallel to the initial slope of the graph, but displaced $t/10$ — Fig. 2 (Ref. 12). This parameter is directly related to the material yield stress, σ_{ys} . The following expression is commonly used:

$$\sigma_{ys} = \alpha \cdot \frac{P_y}{t^2} \quad (1)$$

where α is a material parameter.

- P_{max}/t^2 , where P_{max} is the maximum load registered in the test. This parameter is directly related to the ultimate tensile strength, σ_u by means of expressions like the following:

$$\sigma_u = \beta_1 \cdot \frac{P_{max}}{t^2} + \beta_2 \quad (2)$$

where β_1 and β_2 are parameters related to the tested material and the friction coefficient between the punch and the sample.

- d_{max}/t is the deflection at the point of maximum load adimensionized by the thickness of the sample, and it is directly related to the tensile elongation e , by means of the following expression:

$$e(\%) = \gamma \cdot \frac{d_{max}}{t} \quad (3)$$

where, again, γ is a characteristic material parameter.

- W_{max}/t^2 is now W_{max} , the energy absorbed at the point of maximum load (area under the SPT curve), which is related to the material toughness.

Material and Experimental Procedure

The material used in this study was the HAZ of a welded joint made using a 30CrMo5-2 plate with a thickness of 25 mm as base material and an austenitic stainless steel EN 1600 18 8 Mn B22 (ER 307-15 MOD) as filler metal. The chemical composition of both materials is shown in Table 1.

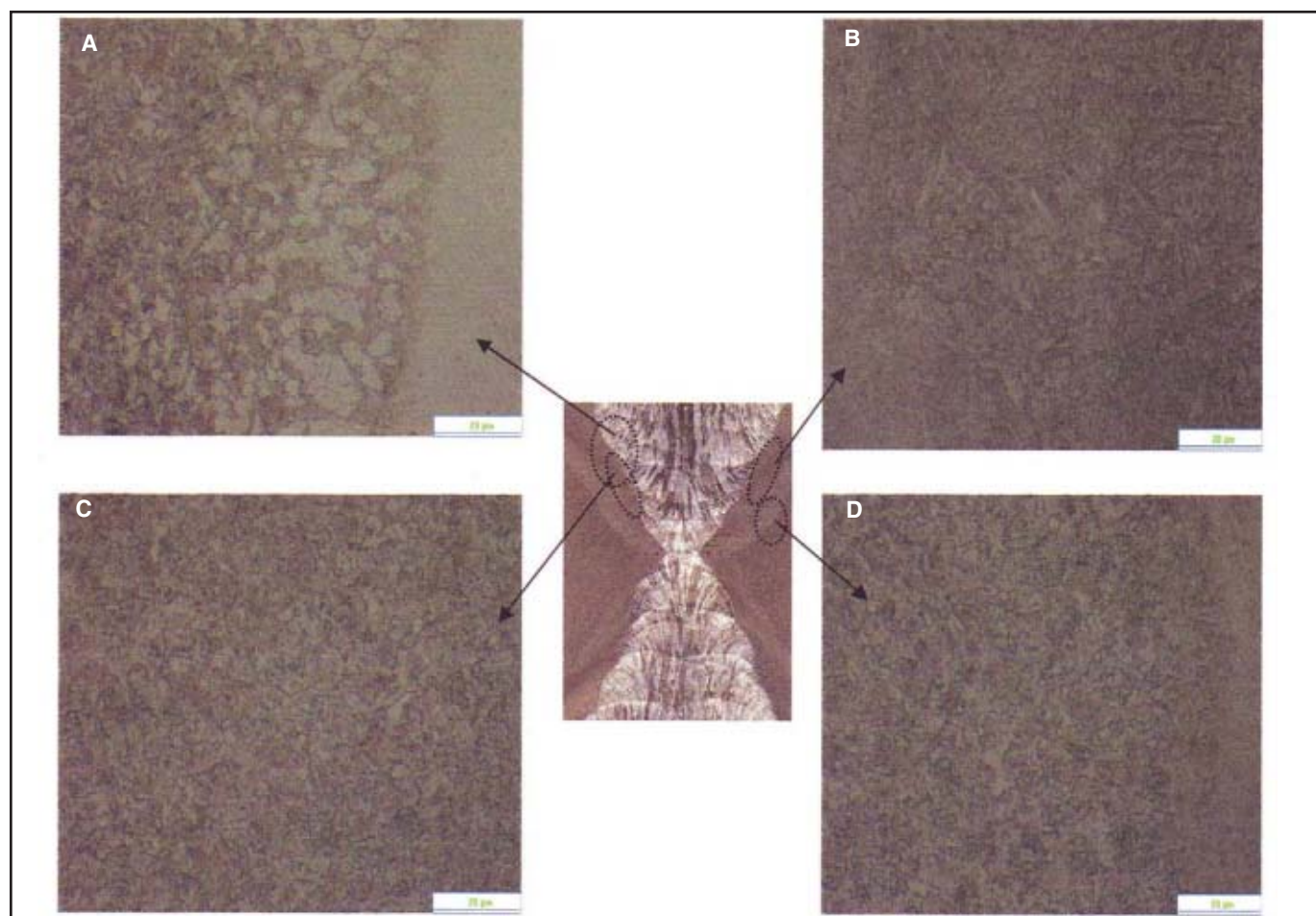


Fig. 5 — Microstructural evolution from the fusion boundary to the base metal. A — Fusion boundary; B — HAZ coarse grain; C — HAZ fine grain; D — HAZ intercritical.

Table 2 gives the conventional mechanical properties (tensile and hardness) of the base metal in the original state that corresponds to a quenched and tempered treatment (tempered at 500°–550°C), as recommended by the TL2350-000 standard (Ref. 13).

The coupons were butt joints that were double-beveled (X), multipass welded using a straight bead technique. A SMAW

process with 4-mm-diameter electrodes was used.

Figure 3 is a macrograph of the welded joint, which shows a HAZ with a width of about 4.5 mm.

The microstructure of the joint was studied using a Nikon Eclipse ME 600 optical microscope. Hardness test profiles (Vickers hardness with a load of 0.5 kg) were performed at the root and also near

the top and the bottom surfaces of the joint using a Future-Tec FM700 micro-hardness tester. Figure 4 shows the general microstructure of the joint, in which we can appreciate the fusion boundary and different zones of the HAZ.

Once the different zones of the HAZ were located, three rectangular samples parallel to the fusion boundary, with a thickness of 0.5 mm and different distances from the fusion boundary, were electrodischarge machined from the HAZ — Fig. 4. As can be seen in Fig. 4, these samples were consecutively numbered from 1 to 3 as they separate from the fusion boundary and at least three 10 × 10 mm² SPT specimens were cut off for each one.

The SPT tests were carried out using an experimental device designed and manufactured at Instituto Universitario de Tecnología Industrial de Asturias (IUTA) (Ref. 12) mounted in a universal Instron testing machine having a load cell of 10 kN. The test fixture was manufactured using a quenched and tempered DIN 42CrMo4 steel (UNE 36051-91 (1) standard) with a final N6 grinding surface.

Table 1 — Chemical Compositions of Base and filler Metals (wt-%)

Material	C	Si	Mn	Cr	Mo	Ni	Al
BM ^(a)	0.27–0.33	0.1–0.4	0.5–0.8	1–1.5	0.1–0.3	—	<0.05
FM ^(b)	0.08	0.9	7	19.2	0	9	0.28

(a) Base metal chemistry is from TL2350-000 standard(Ref. 13).

(b) Filler metal chemistry is from 3.1B ISO supplier certificate (AWS A5.9-93 ER 307-15 mod No. 1.4370 EN 12072 G 18 8 Mn).

Table 2 — Minimum Mechanical Properties of Quenched and Tempered 30CrMo5-2 Steel (Ref. 13)

Material	σ_{ys} (MPa)	σ_u (MPa)	e (%)	HB10
BM	900	1000	15	290

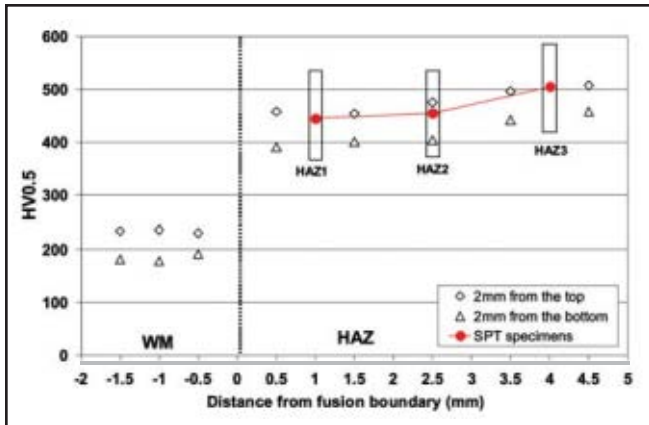


Fig. 6 — HV0.5 hardness profiles in different areas of the welded joint.

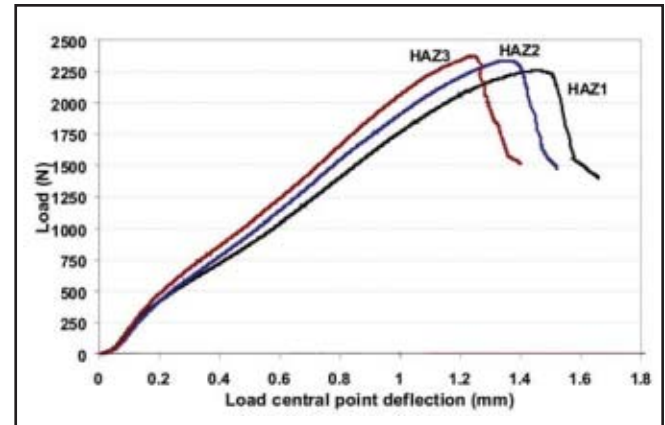


Fig. 7 — Representative SPT curves from the different HAZ zones.

The applied load vs. the deflection of the specimen's central point was registered in all these tests until the final failure of the specimens.

Results and Discussion

Microstructure and Hardness Profiles

As can be seen in Fig. 4, the HAZ shows a slight decarburization located next to the fusion boundary, which is due to the use of a filler metal with a very low carbon (austenitic stainless steel). Figure 5A–D give the microstructural evolution from the fusion boundary to the base metal of the welded joint. A general microstructure of tempered martensite was seen in both the HAZ and base material.

Figure 6 shows the HV0.5 hardness profiles measured at two positions located 2 mm from the top and bottom surfaces. Apart from the very low hardness of the

filler metal (austenitic stainless steel), the hardness of the HAZ slightly increases as we move away from the fusion boundary, due to the tempering effect produced by the welding passes.

Figure 6 also represents the values obtained directly on the small punch tested specimens also using the HV0.5 hardness test. Similar to the anterior results, hardness measured on SPT specimens also increased away from the fusion boundary.

Small Punch Test Results

Table 3 collects the values of the characteristic parameters obtained in the SPTs once they were normalized, taking into account the thickness of the specimen. The average values and the standard deviations are also given in the same table.

Figure 7 shows three characteristic load-displacement curves representative of the three zones of the studied HAZ —

Fig. 4. It is clearly seen that as it separates from the fusion boundary (from HAZ 1 to HAZ 3) the behavior of the material becomes more rigid, attaining higher loads and lower failure displacements.

Although there was some dispersion, as is normal in this type of test, consistent and repetitive results were nevertheless obtained, which justify that the experimental technique used is accurate enough. On the other hand, the P_y/t^2 and the P_{max}/t^2 parameters (proportional to the yield stress and to the ultimate tensile strength, respectively) increase, whereas the d_{max}/t and W_{max}/t^2 parameters (proportional respectively to the tensile elongation and to the fracture energy) decrease as we get away from the fusion boundary. These results fully agree with the hardness and microhardness results already represented in Fig. 6.

From these SPT characteristic parameters, it is possible to get the tensile mechanical properties (σ_{ys} , σ_u , and e) of the

Table 3 — Normalized Characteristic SPT Parameters (Mean Values and Standard Deviation)

Specimen Number	Thickness, t (mm)	$(P/d)_{in}/t$ (MPa)	$P_y(t/10)/t^2$ (MPa)	P_{max}/t^2 (MPa)	d_{max}/t	W_{max}/t^2 (kJ/m ²)
HAZ1P1	0.469	7221.75	2000.35	10263.18	3.0944	4
HAZ1P2	0.467	7793.36	2292.64	10756.21	3.0148	4.31
HAZ1P3	0.462	5987.01	2000.52	10234.38	3.2693	4.34
HAZ1	Mean val.	7000.71	2097.84	10417.92	3.13	4.21
	St. Dev.	923.24	168.7	293.32	0.1302	0.188
HAZ2P1	0.473	7097.25	2503.03	10714.5	2.93478	4.16
HAZ2P2	0.474	7445.99	2492.48	10189.8	2.98114	3.8
HAZ2P3	0.468	6854.7	2387.87	10685.7	2.90653	3.978
HAZ2	Mean val.	7132.65	2461.12	10530.01	2.94	3.98
	St. Dev.	297.23	63.66	294.97	0.0377	0.180
HAZ3P1	0.468	8199.57	2636.7	10754	2.72454	3.706
HAZ3P2	0.4802	7887.76	2680.06	10577.1	2.64742	3.638
HAZ3P3	0.477	7662.47	2685.37	10448.7	2.61141	3.515
HAZ3	Mean val.	7916.6	2667.38	10593.3	2.66	3.62
	St. Dev.	269.71	26.70	153.29	0.0578	0.096

different HAZs (HAZ 1, HAZ 2, and HAZ 3) by just applying Equations 1, 2, and 3 using the appropriate coefficients.

In the case of coefficient α , most of the authors indicate a value around 0.36 for ferritic steels and around 0.41 for martensitic steels (Refs. 14–16). As we have characterized a quench and tempered martensitic steel, an α value of 0.38 was employed (Ref. 17). Table 4 shows the yield strength calculated in this way.

In the same table, tensile strength and elongation were also obtained after applying Equations 2 and 3, respectively, using the β_1 , β_2 , and γ parameters proposed by Ruan et al. (Ref. 11), and Fleury and Ha (Ref. 8) for steels similar to the steel used in this study.

The results presented in Table 4 show a clear increase in the yield strength as we get off the fusion boundary, while the increase in tensile strength and the decrease in elongation are already less significant. These values are also in the same range, although a little bit higher, than the same base metal properties (Table 2) and can be easily justified due to the tempering effect produced on the HAZ by the welding passes.

Conclusions

The possibility of using the small punch test (SPT) for the mechanical characterization of small areas such as the different zones that characterize the HAZ of a welded joint is very promising as was shown in the case of a quenched and tempered steel.

Three characteristic zones from the fusion boundary to the base metal of a shielded metal arc welded joint with a HAZ roughly 4.5 mm wide were differentiated and checked by means of hardness and small punch tests. Away from the fusion boundary, hardness increases, as do the SPT strength parameters, while the ductility and toughness SPT parameters decrease. Afterward, using expressions previously validated, approximated values of the yield strength, tensile strength, and elongation were also calculated.

This work confirms the promising future of the SPT for the mechanical characterization by means of miniature samples of small zones, such as the HAZ of welded joints.

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Table 4 — Mechanical Properties of the Different Areas of the HAZ Obtained from Equations 1–3

Material	$\sigma_{ys} = \alpha \cdot \frac{P_y}{t^2} (MPa)$ $\alpha = 0.38$	$\sigma_u (MPa) = \beta_1 \cdot \frac{P_{max}}{t^2} \left(\frac{kN}{mm^2} \right) + \beta_2$ $\beta_1 = 77, \beta_2 = 218$	$e(\%) = \gamma \cdot \frac{d_{max}}{t} (\%)$ $\gamma = 7$
HAZ1	797.2±64	1020±23	21.9±0.9
HAZ2	935±25	1029±23	20.6±0.3
HAZ3	1014±20	1034±12	18.6±0.4

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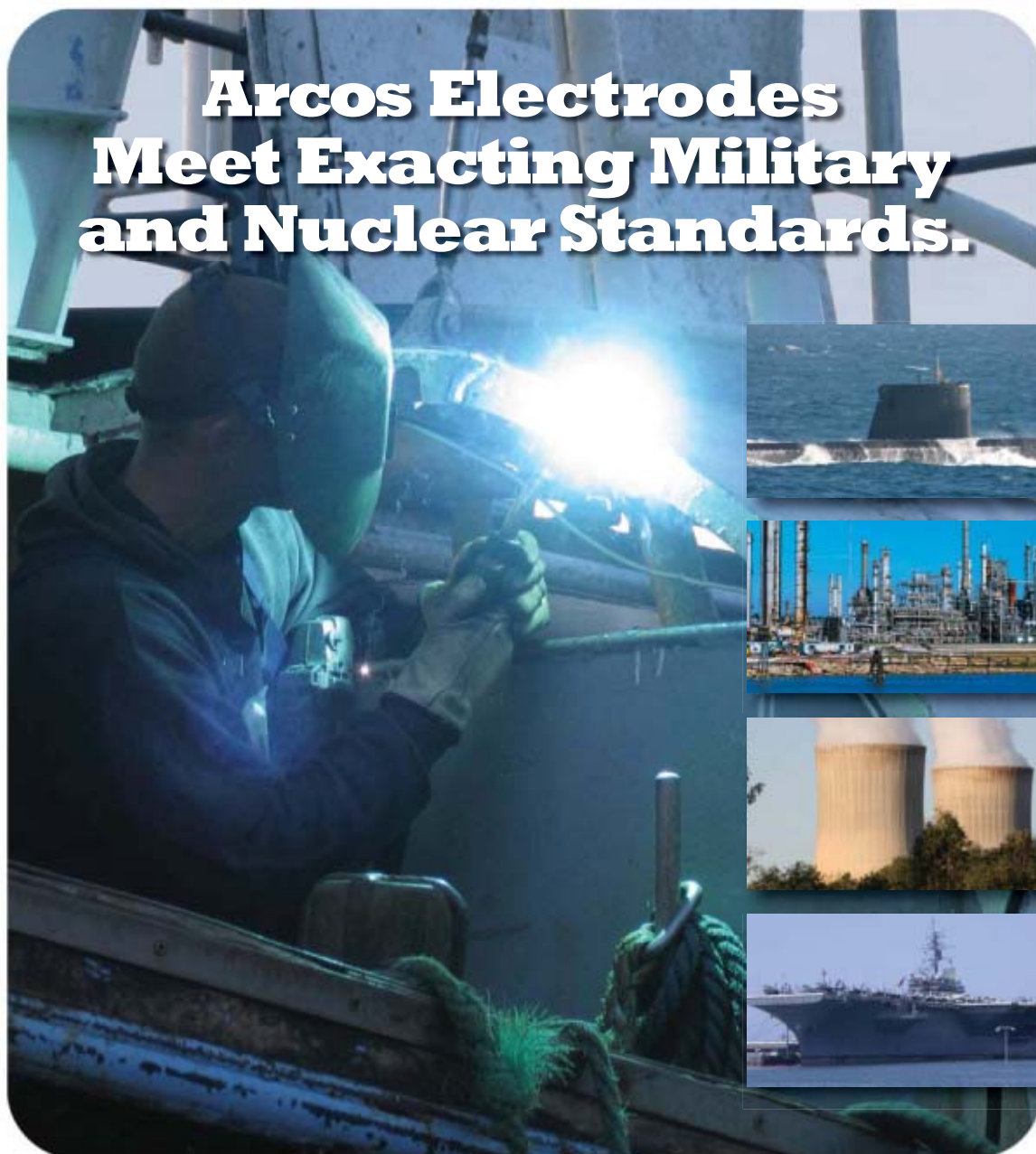
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