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On the cover: At Lauren Fabricators, a division of Lauren Engineers Constructors, Inc., Abilene, Tex., welding instructor Mac Martinez watches welding trainee Carlos Rodríguez place a gas tungsten arc root in pipe.
Intellectual Property Protection Law Enacted

Legislation designed to combat counterfeiting and piracy of U.S. goods has been adopted into law. The Prioritizing Resources and Organization for Intellectual Property (PRO IP) Act increases both federal civil and criminal penalties for trademark and copyright infringement and significantly increases the number of federal law enforcement personnel assigned to the investigation of criminal activity in the intellectual property area.

Most significant, however, is the creation of a new “intellectual property czar,” known as the White House Intellectual Property Enforcement Representative. This new federal office will formulate a Joint Strategic Plan for combating counterfeiting and piracy of intellectual property and for coordinating national and international enforcement efforts to protect intellectual property rights.

Emergency Financial Bailout Legislation Includes Key Extenders

The Emergency Economic Stabilization Act, in addition to trying to address the economic challenges, extends several key tax credit provisions that had expired at the end of 2007. Most prominent of these is the federal Research and Development Credit, which is currently 20% of the amount by which a company’s qualified research expenses for a taxable year exceed a certain base amount for that year. This is extended through the end of 2009.

Also of note are the Qualified Tuition Deduction, which is an above-the-line tax deduction of $4000 or $2000 depending on an individual’s gross income, for qualified higher education expenses, and the Teacher Expense Deduction, which is an above-the-line deduction for teachers for up to $250 for educational expenses. Both of these also are extended through the end of 2009.

New Database to Identify Flawed Government Contractors

The National Defense Authorization Act (S. 3001), signed into law in late October, includes a provision requiring the Department of Defense (DOD) to create a database of companies and individuals that have received contracts from the DOD of $500,000 or more, listing any criminal convictions or civil judgments against such contractors, as well as administrative fines, contract defaults, and suspensions or debarments from federal contracting. The database, which will not be publicly accessible, is expected to be operational by the end of 2009.

New Regulation Assists Women Contractors

The U.S. Small Business Administration has issued a final regulation designed to expand the ability of women-owned businesses to participate in government contracting opportunities. Effective November 1, 2008, the new rule is intended to significantly increase in the number of industries in which women-owned enterprises are considered to be “underrepresented” and therefore eligible for special consideration by federal agency contracting officials.

110th Congress Shatters Legislative Record

The 110th Congress, which served from 2007 until the end of the legislative session in October 2008, introduced almost 14,000 bills, shattering the previous record of 10,537 set by the 109th Congress in 2005–2006. The last several years have shown a consistent increase in the number of bills introduced in each Congress. The 104th Congress (1995–1996), for example, introduced more than 6500 bills, and more than 7500 bills were introduced in the 105th Congress. Of course, only a small fraction of bills introduced actually pass. In the 110th Congress, less than 3% were enacted into law.

Usual Effort to Finalize Regulations Expected

The end of every administration results in an unusually high number of federal regulations being issued as agencies try to finalize rules, many of which have been pending for years, before the next group of public officials take office, and this year is expected to see the same phenomena. These so-called “midnight regulations” are controversial because they are seen by critics as an attempt to preempt a successor administration, but supporters say it is just a matter of finishing up long-planned projects. Either way, the Federal Register, which publishes agency regulations, should be especially thick over the few weeks.

Federal Grant Database Set to Expand

Effective January 1, 2009, USAspending.gov, the federal government Web site that reports recipients of grants, loans, contracts, and other forms of assistance, is set to expand to include subgrantees and subcontractors that receive federal funds through a primary award recipient. The site became operational in December 2007 and is intended to bring transparency to almost $900 billion in federal money that is paid annually through grants, contracts, and similar vehicles. A recent Congressional Research Report cited several weaknesses in the process used to collect the data, but those problems are expected to be corrected in early 2009.

New Small Business Administration Web Site Benefits Entrepreneurs Over Age 50

The U.S. Small Business Administration (SBA) has launched a new Web site directed at individuals over age 50 who wish to start their own business. According to the SBA, small businesses are increasingly being started by older people for a variety of reasons, such as corporate layoffs, the need to supplement income, a desire for a more flexible lifestyle, and advanced technology that is leveling the playing field for small businesses. The Web site is www.sba.gov/50plusentrepreneur.
AlcoTec is recognized as a technological leader in the manufacture of aluminum welding, brazing and metallizing wire. That's why when it comes to teaching the theory and hands-on approach to the welding of aluminum alloys, nobody is better qualified than AlcoTec's staff of engineers and technicians. At the AlcoTec School for Aluminum Welding Technology Theory & Practice, these experts present a seminar that combines their many years of aluminum manufacturing experience with their knowledge of industry equipment, specifications and quality requirements.

If you need to understand the unique characteristics of the aluminum welding process, the AlcoTec School is a training opportunity you can't afford to miss.
Automation Center Expands Capabilities

Welding automation was center stage at Lincoln Electric on October 23 as a ribbon-cutting ceremony signaled the grand opening of the company’s new Automation Center of Excellence. The renovated 100,000-sq-ft building in Euclid, Ohio, contains a 100-ft-high bay with a 20-ton overhead crane for system assembly, an 8000-sq-ft applications area for robotic system testing and demonstration, and a 6000-sq-ft service and support area for preventive maintenance, component rebuilding, and spare parts inventory. The facility represents a major upgrade in capabilities from the original 30,000-sq-ft automation center.

An integral function of the center is on-site training. There are two fully equipped training facilities along with adjoining classrooms to accommodate up to 24 students each. The building also contains more than 10,000 sq ft for administrative, engineering, and meeting purposes. Overall, the new facility represents an investment in excess of $5 million.

An estimated total of 300 guests, state and local dignitaries, Lincoln Board of Directors, support personnel and media attended the event. The governor of Ohio, Ted Strickland, joined Lincoln president and CEO John Stropki in the ribbon cutting duties.

Strickland praised Lincoln for its long history of manufacturing and its commitment to the community and the state of Ohio. Stropki noted that the investment in the facility was stimulated by the governor’s support of industry growth through tax and other incentives. “All manufacturers are looking to increase productivity and lower manufacturing costs,” said Stropki, “and that clearly is our objective here with this facility.”

The mayor of Euclid, Bill Cervenik, presented Stropki with a plaque of recognition for the company’s investment and commitment to the community.

The space now available in the facility gives the capabilities to bring in large components and configure systems the company couldn’t do before. “The application is what drives our efforts,” said Richard Seif, vice president, global marketing. He noted that by bringing in the customer’s part, it is much easier to determine the best way to weld it. “We want to show that welding is the process of choice rather than the process of necessity,” he said.

A full turnkey system can be set up in the facility. The company has a working relationship with Fanuc for robotic expertise, as well as multiple other companies to provide everything needed to configure a complete automation system, including fume extraction and pipe cutting. The customer is trained in the programming and operation of the system on-site. Chris Bailey, general manager, automation division, summed it up when he said, “If you want to keep customers in this country, you need to provide the whole solution.”

Funds Available for 2009 Manufacturing Summer Camps

Grants ranging from $2500 to $5000 are now available to not-for-profit organizations and educational institutions capable of offering overnight or day camp experiences in summer 2009 that introduce young people to careers in manufacturing and engineering. These grants are a collaborative effort between the Fabricators & Manufacturers Association Foundation and the Nuts, Bolts and Thingamajigs Foundation founded by John Ratzenberger, the actor best known as Cliff on Cheers.

The application is available online at www.fma-foundation.org. The deadline for submitting the form is December 12, 2008. Funds may be used for expenses related to curriculum development and instruction, along with direct expenses such as housing, meals, transportation, and supplies. Grant recipients will be named at the Metal Matters 2009 executive summit in March.
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What a Year It’s Been

Two thousand and eight has been an intriguing year to be AWS president, and the best year of my life. I learned a great deal from welding industry professionals in other countries as I traveled the globe, and received reaffirmation as to how strong our membership is as I visited local Sections. I toured schools that are turning out young, high-quality welders with a desire to enter the workforce as qualified welders.

I am proud of what AWS has accomplished this year, especially since the U.S. economy has struggled during this presidential election year. Following are some highlights:

- **Membership**: up 4%, and we have reached a record high of more than 54,000 members.
- **Seminar attendance**: up 6%, setting revenue records for conferences, seminars, and other programs. This is setting the standard for improving knowledge about welding.
- **Revenue**: for the FABTECH International & AWS Welding Show, held in the exciting city of Las Vegas, was up 9%. Many exhibitors told me how happy they were with the high quality of contacts made there.
- The number of new CWIs is up 10%; globally we’re just getting started. In addition, we made great progress readying the new Certified Welding Sales Representative program, the tests for which should be available in 2009.
- **Book sales**: are up more than 30%. AWS set sales records for technical standards and had more than 19 new code books published this year.
- **The Ironman movie**: was a huge hit in 2008. AWS coordinated its delivery of 50,000 specially printed Ironman comic books targeted at middle and high school students to create interest in welding careers. This was just one way AWS is addressing the shortage of welders. Another is its new SOS team that will work with major welding end users and local governments to find solutions to the ever-increasing need to add new welders to the workforce.
- **The Welding Journal en Español** was introduced at the AWS Weldex show in Mexico City. This was the first Weldex show produced in partnership with AWS. Successes included signing up 75 new members at our booth. AWS is only now beginning to reach out to this long-neglected market, and it looks like our efforts in Latin America will be very successful.

I’d also like to share with you some impressions from my travels as your representative. First, however, I’d like to thank my employer, ESAB, for allowing me this opportunity. Without its support, I could not have performed my duties as AWS president.

My first trip was to India, where I found a country that is growing its middle class and discovering that welding is an essential trade in building an economy. While upper-level education is still high on India’s agenda, it is also realizing that there is a great need for trades, with welding being at the top of the list.

That was also the case in Moscow, where welders are in demand and earning twice as much as the year before. At meetings during the Essen Moscow Show, we exchanged many ideas with the Russians, and I was told how welding is playing such a vital part in the area’s new growth.

My biggest surprise was China where they are building their infrastructure all over the country, not just in Beijing for this year's Olympic games. Bridges, power plants, and shipyards were under construction in every city I visited. New housing is everywhere and the airports are spectacular. You may remember images from the 1990s, but today China looks modern and offers many opportunities for AWS interaction.

At the International Institute of Welding Assembly in Austria, I saw and heard some of the world’s greatest welding scientists and engineers from 53 countries share the latest developments in welding. This yearly event is well worth supporting.

I finished up the summer by attending meetings at The Welding Institute in Cambridge, UK, where I was shown all the most current technology and projects of the day. It was very informative and well worth the trip.

My wife, Bette, and I just returned from a trip to six countries. I spoke at the New Zealand Metals Conference and four metal seminars throughout the country, followed by speaking events in Australia. Trips to Singapore and Dubai preceded a visit at the E. O. Paton Electric Welding Institute in Kiev, Ukraine. I was delighted to talk about the “World’s Shortage of Welders” at this prestigious facility. After a visit to the Institute de Soudure in Paris, we finally made our way back to California.

It has been an incredible year for both AWS and me. I can never thank you enough for the opportunity to represent you. The only thing I can say that covers it all is, “Thanks for the Memories.”

Gene E. Lawson, **AWS President**
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Find out more at www.wecwam.com.
Welding Education and Training Update

Program for Welders Provides Earning While Learning

The vision of Lauren Fabricators’ program is to provide an opportunity for welders of all experience levels to increase their skill sets. To the left, welding instructor Mac Martinez guides welding trainee Willie Davila on the use of tungsten rod in gas tungsten arc welding.

As shown above, teacher Martinez watches welding trainee Carlos Rodriguez place a gas tungsten arc root in pipe.

Lauren Fabricators, a division of Lauren Engineers Constructors, Inc., Abilene, Tex., has developed and launched a new welder training program. Aimed at offsetting the current shortage of trained welders, and in response to this need throughout the country, it focuses on taking welders with basic skills and training them to become certified combination welders.

Since beginning this effort for current employees in January 2008, 11 welders have completed the program with another five currently enrolled. Serving as the head trainer is Mac Martinez, a code welder with more than 20 years of experience. The company has a goal of 50% participation for current employees.

It builds upon a one-on-one approach where welding instructors provide hands-on training that goes beyond the fundamentals of welding. The three levels of certification, from beginner to advanced, include as follows: basics of shielded metal arc welding including structural welding, fit-ups, and material overview; advanced shielded metal arc welding/introduction to gas tungsten arc welding including pipe welding, pipe fitting, and weld symbol interpretation; and advanced combination pipe welding that includes dual-process welding procedures and blueprint reading and interpretation.

Additionally, individuals are becoming interested in the program to increase their wages in a relatively short period of time. For example, a beginner structural welder can complete the training and improve his/her welding classification one level in around three months, meaning that an average structural welder could be trained to become a code welder in around nine months.

This on-the-job training method is offered at no cost to the trainee, and all trainees are paid their normal hourly rate for time they spend in training, a concept supporting the program’s motto of “Earn While You Learn.”

As demand grows, the company is committed to expanding the resources dedicated to making it successful. More details about this training opportunity can be found at www.laurenec.com.

Chippewa Valley Technical College to Offer Welding Certificate

Chippewa Valley Technical College (CVTC) in Wisconsin will operate a one-semester welding certificate course starting in January.

“Parts of Clark County have been severely impacted by economic downturns in general, and plant closings in particular, and this package will enable a group of workers to rapidly acquire a marketable skill,” said CVTC President Bruce Barker.

Production MIG Welding, a five-credit offering, as well as two two-credit courses, Welding Print Reading and Fabrication and Math for Technical Trades, can all be completed in the same winter-spring semester. Also, credits earned will be transferrable to the one-year welding program offered by CVTC in Eau Claire, Wis. Neillsville High School will be the site of instruction.

Barker said welders remain in great demand. “We are going to take people and get them ready to go to work...and do that in 16 weeks,” he said. “Getting people ready for employment in one semester is a remarkably short time. But there’s urgency. We need to help people get the skills they need to earn a living.”

Chrystal Meinen, a graduate of the technical diploma program, will be teaching all the classes of this nine-credit certificate. She is the first woman to teach welding at CVTC.

Neillsville Center staffer Linda Danzinger reported early enrollment in the welding offering was brisk due to media coverage. The college's Web site is www.cvtc.edu.

Local Union Rolls out Mobile Welding Unit

United Association Plumbers and Steamfitters Local Union 33, Des Moines, Iowa, has recently acquired a mobile unit to assist in recruitment and training to enable more welders to be taught quickly.

“We now offer a Hybrid Welding Program that provides apprentices with the skills they need to join the welding workforce in 18 weeks,” said Greg Foshe, Local 33 business manager. This program may be short, he added, but it is concentrated and class is attended for eight hours per day, 40 hours per week.

The trailer contains eight welding booths where visitors can see workplace skills in action. According to Foshe, it will visit schools and community colleges in the Des Moines area and throughout central and western Iowa. Welding instructors will be on hand for demonstrations, too.

Local 33 purchased the trailer for more than $200,000. “Bring-
This mobile welding unit of Local Union 33 (left) features eight interior welding booths (right).

ing in new welding apprentices is a top priority for the construction industry,” Foshe said. He also added the trailer is used as a training facility for journeyman workers who have completed their apprenticeships and now work on job sites. For more information, visit www.ualocal33.org.

Coffeyville Community College Expands Technical Program Offering

The Coffeyville Community College (CCC) Columbus Technical Campus in Kansas recently received a $451,500 federal Economic Development Administration Grant for the CCC Foundation to construct a welding and construction training facility in Columbus.

During a reception and introductions by CCC-Columbus Director Cindy Harrold, representatives and attendees toured the campus departments, met with students, and learned about current projects. Then, the group joined construction and welding faculty at the groundbreaking site.

In addition to this grant, CCC received a Kansas Department of Commerce Workforce Solutions Grant for $100,000 to purchase training equipment for the expansion project. Mid-America Pipe and Steel, Scammon, Kans., and Crossland Construction, Columbus, Kans., donated to the project as well.

The $903,000 project began this fall, and in fall 2009, the facility is scheduled to be completed and students will begin studies. The 10,128-sq-ft area will contain separate shop and classroom training spaces for both technologies.

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WELDING JOURNAL
Lincoln Electric Launches Online Seismic Welding Resource Center

The Lincoln Electric Co., Cleveland, Ohio, has introduced the new D1.8 Resource Center at www.lincolnelectric.com/d1.8.

This site is outfitted with tools for understanding and complying with American Welding Society D1.8, Structural Welding Code — Seismic Supplement. The site was created to assist structural fabricators, erectors, inspectors, specifying engineers, and others involved in the welding of steel-framed structures in seismically active areas.

Rolled Alloys Obtains Weir Materials

Rolled Alloys, Temperance, Mich., has acquired Weir Materials, Manchester, England. The new company formed will be called RA®Materials and offer ZERON®100, a high-strength, corrosion-resistant, superduplex stainless steel. It is an international supplier of contract managed pipe work system packages and fabrications. The company will operate a warehouse, metallurgical, and corrosion testing laboratory in Manchester, and provide technical support.

Honda Begins Production of Civic Sedans in Indiana

Honda Manufacturing of Indiana, LLC, recently began mass production, using domestic and globally sourced parts, of the 4-cylinder Honda Civic sedan at its new facility in Greensburg, Ind. This $550 million facility will ultimately produce 200,000 vehicles and employ 2000 associates at full capacity.

For several months, nearly 900 associates have been conducting trial production, refining new processes and equipment, and learning to meet company standards. The startup of mass production culminates many weeks of department-by-department production startups in stamping, welding, painting, plastic injection molding, body assembly, and other areas. It is currently operating on one shift with plans to add a second shift next year.

Honda Manufacturing of Indiana, LLC (HMIN), associates applauded the manufacturing start of the Honda Civic at the new Greensburg plant. HMIN President Yuzo Uenoohara (foreground) congratulated company associate Eugenia Olson after she drove the first production car off the assembly line.

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Feld Entertainment Acquires Live Nation Motor Sports

Feld Entertainment, Inc., Vienna, Va., has acquired Live Nation Motor Sports, Inc., a division of Live Nation, Inc. This move marks the largest expansion in the company’s 40-year history. Pictured are Feld Entertainment Chairman and CEO Kenneth Feld with monster truck Grave Digger and its creator, Dennis Anderson. Renamed Feld Entertainment Motor Sports, it will continue operations in Aurora, Ill., and maintain its current management, tour schedules, promotional partnerships, and performance structure. Also, it will continue to produce Monster Jam Series, Monster Energy AMA Supercross, FIM Championship, and other motor sports events.

ABB U.S. Profiles Employment Opportunities for University Graduates

Representatives from all five of ABB Inc.’s U.S. divisions recently met with students who have graduated from universities across the country to profile vast engineering opportunities within the host of local business units comprising these divisions. Hired by the company not that long ago, the students were handpicked for its “Engineering Leaders for the Future” program; they are shown in the photo working to solve challenges. ABB division business professionals met with them at its division headquarters for Power Products in Raleigh, N.C.

West Penn Testing Group Purchases Building for Spectrochemical Labs

West Penn Testing Group, New Kensington, Pa., an independent nondestructive, chemical, and material testing organization, enhanced its evaluation capabilities with a new building.

— continued on page 80
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- Exchange and discussion of research, development and application of brazing and soldering
- Comprehensive technical programs for brazing and soldering
- Valuable networking opportunities
- Pre-conference educational programs
- Over 60 exhibitors
- Key information on trends, products, processes and techniques

Areas covered at IBSC

The following is a listing of some of the topical areas that have been covered at the IBSC. Stay tuned for full program information to be provided in the future. This premier event is truly one that anyone involved in the brazing and soldering community should plan to attend.

- Aircraft and Aerospace
- Automotive and Transportation
- Brazing and Soldering Standards
- Ceramic/Glass to Metal Joining
- Chemical and Petroleum Production
- Composite Materials
- Electronic Packaging/Sensors
- Filler Metal Properties
- Fluxes and Atmospheres
- Fixture Design and Use
- Musical Instruments
- Power and Electrical Equipment
- Sensors/Microelectronics
- Solder Joining Methods
- Special/Advanced Brazing Processes
- Structural Solder Applications
- Test Methods and Evaluation

- Furnace/Vacuum Brazing
- Joint Design and Reliability
- Lead-free Solders
- Light Metals
- Materials and Process Design/Control
- Medical/Dental
- Mining & Heavy Equipment
- Modeling and Process Control
- Consumer Products
- Factory Automation
- Job-Shop & Process Customization
- Thermal Management
- Vacuum Brazing
- Gases and Plumbing
- LEAN Brazing Processes
- Low-volume Critical Components

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(outside North America 305-443-9353) or for more information,
call (800)443-9353, ext. 455, email: nlopez@aws.org or sharon@aws.org
Registration includes: Evening Reception on Monday, April 27, 2009 & Networking Dinner on Tuesday, April 28, 2009

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Reach the innovators, influencers and decision-makers in the brazing and soldering industry from around the world.

Exhibit and Sponsorship Opportunities

IBSC provides a forum to showcase the latest trends, products, processes and techniques in the industry. The exposition features exhibitors from all sectors of the brazing and soldering community and draws decision-makers with purchasing power from around the world. There is no better opportunity to conduct business with the brazing and soldering community than to have a presence at this conference.

ASM International and AWS are dedicated to delivering the audience you want and the value you need. Your exhibitor fee includes one technical session pass for you or someone in your organization to attend the full conference. Plan now and reserve your space and/or sponsorship for 2009!

Exhibit Dates and Times

Monday, April 27
Noon – 6:00 PM
Lunch: Noon – 1:00 PM
Networking Reception: 6:00 PM – 7:00 PM

Tuesday, April 28
9:30 AM – 3:00 PM
Lunch: Noon – 1:00 PM

Wednesday, April 29
9:30 AM – 3:00 PM
Lunch: Noon – 1:00 p.m.

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For more information or to reserve exhibit space and sponsorship at the IBSC call (440) 338-1733, or (440) 338-5422, email: kelly.thomas@asminternational.org or vickie.shalhoup@asminternational.org

Co-sponsored by: American Welding Society
AWS FELLOWSHIPS

To: Professors Engaged in Joining Research

Subject: Request for Proposals for AWS Fellowships for the 2009-2010 Academic Year

The American Welding Society (AWS) seeks to foster university research in joining and to recognize outstanding faculty and student talent. We are again requesting your proposals for consideration by AWS.

It is expected that the winning researchers will take advantage of the opportunity to work with industry committees interested in the research topics and report work in progress.

Please note, there are important changes in the schedule which you must follow in order to enable the awards to be made in a timely fashion. Proposals must be received at American Welding Society by February 17, 2009. New AWS Fellowships will be announced at the AWS Annual Meeting, November 2009.

THE AWARDS

The Fellowships or Grants are to be in amounts of up to $25,000 per year. A maximum of four students are funded for a period of up to three years of research at any one time. However, progress reports and requests for renewal must be submitted for the second and third years. Renewal by AWS will be contingent on demonstration of reasonable progress in the research or in graduate studies.

The AWS Fellowship is awarded to the student for graduate research toward a Masters or Ph.D. Degree under a sponsoring professor at a North American University. The qualifications of the Graduate Student are key elements to be considered in the award. The student must prepare the proposal for the AWS Fellowship. However, the proposal must be under the auspices of a professor and accompanied by one or more letters of recommendation from the sponsoring professor or others acquainted with the student's technical capabilities. Topics for the AWS Fellowship may span the full range of the joining industry. Should the student selected by AWS be unable to accept the Fellowship or continue with the research at any time during the period of the award, the award will be forfeited and no (further) funding provided by AWS. The bulk of AWS funding should be for student support. AWS reserves the right not to make awards in the event that its Committee finds all candidates unsatisfactory.

DETAILS

The Proposal should include:

1. Executive Summary
2. Annualized Breakdown of Funding Required and Purpose of Funds (Student Salary, Tuition, etc.)
3. Matching Funding or Other Support for Intended Research
4. Duration of Project
5. Statement of Problem and Objectives
6. Current Status of Relevant Research
7. Technical Plan of Action
8. Qualifications of Researchers
9. Pertinent Literature References and Related Publications
10. Special Equipment Required and Availability
11. Statement of Critical Issues Which Will Influence Success or Failure of Research

In addition, the proposal must include:

1. Student's Academic History, Resume and Transcript
2. Recommendation(s) Indicating Qualifications for Research must include one or more letters of recommendation from the sponsoring professor or others acquainted with the student's technical capabilities
3. Brief Section or Commentary on Importance of Research to the Welding Community and to AWS, Including Technical Merit, National Need, Long Term Benefits, etc.
4. Statement Regarding Probability of Success

The technical portion of the Proposal should be about ten typewritten pages; maximum pages for the Proposal should be twenty-five typewritten pages. Maximum file size should be 2 megabytes. It is recommended that the Proposal be typed in a minimum of 12-point font in Times, Times New Roman, or equivalent. Proposal should be sent electronically by February 17, 2009 to:

Vicki Pinsky (vpinsky@aws.org)
Manager, AWS Foundation
American Welding Society
550 N.W. LeJeune Rd., Miami, FL 33126

Yours sincerely,

Ray W. Shook
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THE LARGEST SUPPLIER IN WELDING
Recruiting and Retaining Welders in an Increasingly Competitive Environment

BY CARL PETERS

Manufacturers representing a variety of industries, including energy, automotive, and construction, continue to be challenged with retaining and recruiting skilled welders. Baby boomers lost to retirement increasingly thin the labor pool, as employers struggle to keep existing talent who perpetually vie for better opportunities.

Many companies, however, have found success implementing some conventional and creative approaches to retain and recruit. Here’s a quick look at some of the best practices.

Sell Welding as a Viable Career Choice

Traditionally, the welding industry has drawn its workforce from high school and technical school graduates. More recently, a new labor source has emerged from experienced workers displaced or disheartened from other careers in shifting and shrinking product trends, such as the automotive industry.

But welding has been cursed with the image of a dirty, low-tech profession of last resort. As many workers today gravi- tate to desk jobs, the perception of welding has dissuaded students, parents, and career counselors and sent potential workers elsewhere.

The reality is that welding is a challenging career with great potential for income and mobility. Many high-growth industries, such as energy and structural fabrication, rely on welding. Welding is required for construction, maintenance, and repair in all of these sectors, and technology lies at the heart of most of them.

Newly trained welders can earn $41,000 to $62,000 per year. This is on par with a first-year degree in mechanical or civil engineering. As welders gain experience, compensation grows. Specialty welding, like in pipeline construction, where travel is required, can draw significant increases.

Promoting the positives of a welding career to students, parents, and guidance counselors is critical. Trained welders and their employers should become involved with local high schools and trade programs. This exposes students directly to successful and established welders, who can attest to the benefits.

For the employers, it provides access to future workers. Companies can educate instructors about opportunities available to their students and the selling points of a particular organization. There is often occasion for corporate involvement on an advisory board or opportunities to speak to classes about a welding career.

There are also numerous local, regional, and national welding competitions through organizations such as SkillsUSA and Future Farmers of America (FFA) that offer opportunities to match recruiters with future welders.

Blending Recruitment and Retention

Because many welding jobs are passed over for careers dominated by computers and other technology, promoting welding as a high-tech industry makes it more appealing to young people.

Welding has embraced much of the same level of technology as other professions and can offer similar challenges. Significant advances have been in weld-process control. New power sources include advanced waveforms and digitally controlled displays. In addition, robotic welding is one of the industry’s fastest-growing segments.

On the retention side, it is important to provide effective training on new technologies, machines, and consumables to a company’s existing workforce to keep employees engaged in their jobs. Employees need to feel they are contributing members to an organization’s success. A firm’s investment in training its employees communicates its commitment to their future and can be considerably more cost effective than recruiting and training new employees.

For employers, workers who view themselves as an integral part of a team are more likely to work harder and produce more. Safety plays a role as well. A workplace that stresses safety as a culture can be more inviting and allows employees to perform at their best. This should include repetitive safety training and regular evaluation of work practices, safety standards, and OSHA requirements. Employers should also allow employees to engage in open discussions and to provide suggestions for safe work habits.

Implementing a welding fume-extraction system may be one solution to providing adequate ventilation. It can also communicate a message of employee appreciation, which can contribute to improved recruitment and retention.

All of these practices help ensure a safe, more productive work environment. They help reduce injuries, worker’s compensation claims, and lost days.

Conclusion

A company’s goal is to build and sell products that safely and effectively serve its customers, while increasing profitability. A strong workforce is crucial to accomplishing this goal. A strategic recruiting program, coupled with structured retention efforts, go a long way to keep a skilled workforce safe, engaged, and productive.

CARL PETERS is director of Technical Training, The Lincoln Electric Co., Cleveland, Ohio.

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Q: I have been offered a new fabrication contract; it is an aluminum structural job that is predominantly arc welded. However, it would also involve a substantial amount of stud welding. I have welded aluminum with both the gas metal arc welding (GMAW) and gas tungsten arc welding (GTAW) processes, so arc welding is not a problem, but I have never used stud welding. What exactly is stud welding and can the process be used to weld aluminum?

A: The stud welding process can be described as an arc welding process in which a fastener can be end-joined to a metal workpiece instantaneously — Fig. 1. It is a complete fastening system, using a wide variety of fasteners with literally hundreds of uses — each permanently installed by one person, working on one side of the workpiece, in less than one second. Stud welding in general can be regarded as a sequential combination of two mechanisms, one mechanical and one electrical.

There are two commonly used types of stud welding; the first is drawn arc stud welding (DASW), also known as arc stud welding, or gas-arc stud welding when using a shielding gas like argon, or short-arc stud welding when the arc time is less than 100 ms. The second type is capacitor discharge stud welding (CDSW). The source of the electrical energy for CD welding comes from a bank of electrostatic charged capacitors.

**Drawn Arc Stud Welding of Aluminum**

In the drawn arc stud welding process, a fastener and ceramic ferrule are firmly placed against the work surface under spring tension — Fig. 2. Triggering the weld gun automatically lifts the fastener from the base metal and initiates a controlled electric arc to melt the end of the fastener and a portion of the base metal. The ceramic ferrule shields the arc, concentrates the heat, and contains the molten metal in the weld zone for maximum weld strength and reliability. At the precise moment the end of the fastener and the base metal become fully molten, the fastener is automatically plunged into the work surface. The metal solidifies and a high-quality fusion weld is completed. The expendable ferrule is broken away to expose a smooth and complete fillet at the stud base. A ferrule and argon shielding gas must be used together for drawn arc aluminum welding. For higher production rates, the gas arc process is used to weld aluminum studs using gas shielding alone without ceramic ferrules.

**Capacitor Discharge Stud Welding of Aluminum**

Capacitor discharge stud welding is generally used to weld small-diameter fasteners to thin base metals. The weld end of the fastener must have a small timing tip specifically designed for the CD welding process. Dimensional consistency of the tips is essential for controlling the weld time and to give consistently reproducible results. The CD studs can be manufactured in a wide variety of shapes.

For welding steel studs, the contact CD process is normally used. In this process, the tipped stud stays in contact with the base material until the operator triggers the weld. This allows the instantaneous discharge of current from a bank of DC capacitors. The energy from the capacitors vaporizes the high-resistance tip and creates an ionization path for peak current flow and arcing across the areas to be joined.

For welding aluminum, the gap CD process is normally used. Using the gap CD process, the weld is shorter and the amperage is higher. This eliminates the need for gas shielding.

With the initial gap process, the stud is retracted manually or pneumatically to hold the stud at a specific height above the base material until the weld is triggered. Using auto gap CD guns, the stud starts in a position against the base material. When the weld is triggered, the gun goes through a sequence where the stud is retracted and released.

The pressure to make the welds is generally less than 20 lb. This reduces the need for rigid fixtures and backside support. In hand-held CD guns, the source of the pressure is usually a spring — Fig. 3. For mounted production guns, air pressure is normally used. When the weld current is discharged, the pressure applied by the gun fuses the melted end of the stud to the base metal surface. The welds, completed in two to six ms, create a bond that is stronger than the fastener.

The studs may be loaded or fed into the chuck on the front of the CD guns manually, semiautomatically, or the welding process may be fully automated. CD welding has the ability to weld small-diameter studs to very thin material. Because the weld cycle is extremely short, there is little heat transfer and welds made using CD will not have pronounced distortion, melt-through, or reverse-side discoloration even on thin material. In addition to welding aluminum, CD is also used to weld material with high thermal conductivity such as copper and copper-zinc alloys.

**Stud Welding Aluminum — Process Selection**

The basic difference between the drawn arc process and the CD process in aluminum is that the typical arc time for drawn arc is considerably longer (0.12 s and longer) than for capacitor discharge (0.006 s), and the peak current with CD may be ten times that for drawn arc. Because the CD welds are essentially an explosion, the use of shielding gas is not needed. Due to the longer weld time of the drawn arc process, the use of an inert gas shielding (argon) is needed when welding aluminum.

The choice of process depends on stud size and material thickness. For larger studs in structural applications, the drawn arc process is the process of choice. Some stud welding equipment manufacturers have suggested that the capacitor discharge process has limitations that may make it less reliable than the drawn arc process in quality-driven applications such as automotive due to the lack of process controllability.

**Quality of Stud Welds in Aluminum**

If the drawn arc process is the method to be used, the key to success in stud welding aluminum are clean base material, low...
Stud welding aluminum is different than stud welding steel, and there are some specific considerations when selecting the most appropriate equipment and developing suitable procedures. If you are getting into this welding process on aluminum for the first time, I would suggest that you consult the experts who can provide specialized technical support.

Tony Anderson is corporate technical training manager for ESAB North America who coordinates specialized training in aluminum welding technology for AlcoTec Wire Corporation. He is a Registered Chartered Engineer and holds numerous positions on AWS technical committees. He is chairman of the Aluminum Association Technical Advisory Committee for Welding and author of the book Welding Aluminum Questions and Answers available from AWS. Questions may be sent to Tony Anderson c/o Welding Journal, 550 NW LeJeune Rd., Miami, FL 33126, or via e-mail at tander@esab.com.

Acknowledgment

I would like to thank Nelson Stud Welding, Inc., for providing technical assistance and permission to publish the photographs in this article.

AWS Code for Stud Welding Aluminum

The AWS D1.2, Structural Welding Code — Aluminum, has a section specifically designated to the stud welding of aluminum in the 2008 edition; this is Section 6 — Stud Welding.

This section of the code contains general requirements for arc stud welding and CD stud welding of aluminum alloy studs to aluminum alloys and stipulates specific requirements within the following areas:

- The mechanical properties of aluminum stud alloys
- Workmanship requirements
- Preproduction testing requirements
- Procedure qualification and performance qualification testing
- Inspection of stud welding during production
- Acceptance criteria for bend tests and tension tests.

Note: One area to be aware of is the differences between bend test procedures for aluminum studs compared to the procedures used for steel studs. Bend tests for aluminum studs are typically conducted by bending the stud to an angle of only 15 deg from the axis of the stud, whereas steel studs are typically required to be bent to 30 deg.

Conclusion

The stud welding process is a commercially available welding process that is used for attaching studs to the surface of material. This process is suitable for use with aluminum provided the correct workmanship requirements are followed. When the correct process and procedures are used, consistently reliable joints can be made.

Some considerations are as follows:

- Avoid the use of excessive weld heat; typically reverse polarity is used when welding aluminum.
- The correct process and procedures are followed.
- Acceptance criteria for bend and tension tests.
- Procedure qualification and performance qualification testing.
- Inspection of stud welding during production.

The AWS D1.2, Structural Welding Code — Aluminum, is the standard referenced for stud welding aluminum.

Fig. 2 — Servo electric head for automated or robotic drawn arc stud welding.

Fig. 3 — Hand-held gun for capacitor discharge (CD) stud welding.
Q: I have heard people talk about the boron content of nickel-based filler metals, but I have no information as to why it is added. What is boron? Why is it added to brazing filler metals? We are currently repairing cracked jet engine parts using BNi-2 filler metal on nickel-alloy parts. We are brazing for ten min at heat, and when we go back for a second brazing operation, we find that the shorter time of five min improves the surface appearance.

A: Boron is an element similar to nickel, chromium, and iron. When it is added to a nickel-chromium alloy, it lowers the melting temperature of the alloy, which lets us use the low-melting nickel-chromium-boron alloy as a brazing filler metal. Boron is a unique element because of its small molecular size. It diffuses very readily into the adjoining base metals, thus changing the chemistry and physical properties of the brazing filler metal in the joint. This process is defined as diffusion brazing.

Diffusion brazing allows us to alter the properties of the braze joint, depending on the requirements of the parts during service application. The original brazing filler metal, BNi-2, is hard and has low ductility, as well as a low melting temperature. During diffusion brazing, the remelt temperature is increased, and can reach remelt temperatures exceeding 2500°F (1370°C); and when completely diffusion brazed with a nickel-based metal, the remelt temperature will be the melting point of that base metal. At the same time, the hardness will be equivalent to the base-metal hardness and butt tensile strength, and the stress rupture will be equivalent to the base metal. After full diffusion in the nickel base metal, the brazing filler metal will have disappeared, and the grain structure goes right across the joint. In this case, the elements of the base metal have diffused into the braze area, and the filler metal has been homogenized with the base metal.

You state that you are brazing at 2050°F for ten min at heat for the first brazing operation, and if you have to go back and apply more filler metal, you braze for only five min at the brazing temperature. This short time at the brazing temperature does not allow for much diffusion with the base metal, and thus there will be a centerline phase that is still low melting and has low ductility.

When repairing parts for a jet engine, it is necessary to know and understand the service requirements for the particular part being repaired, as well as the designer’s reason for designing the part that is to operate in the jet engine. If the part is in the hot section of the jet engine, it may see temperatures in the range of the melting temperature of the original BNi-2 filler metal. In this case, longer diffusion times and/or higher temperatures may be required to ensure that no remelting of the braze will occur in the engine, and it has a suitably high remelt temperature and ductility for its service requirements. If your particular part is not in the high-temperature section, then the short time at temperature may be suitable, as long as there is not a high stress applied to the part. The high stress may cause cracking in the cen-
An important part of the repair procedure is to have suitable inspection capabilities. If a crack goes all the way through a part and is visible from the back side, the filler metal can be applied to one side and the part visually inspected, after brazing, on the opposite side. When the crack does not go all the way through, or cannot be inspected from the back side, the filler metal should not be applied over the full length of the crack. When applying filler metal over the entire length of the crack, after brazing, it is not possible to visually inspect the part to ensure adequate flow in the crack area. A questionable atmosphere, or other furnace problems, can result in the filler metal sitting on top of the crack and not entering it. To ensure that we have a good visual means of inspection, it is important to apply the filler metal at one end of the small crack, or at both ends in larger cracks, and sometimes in the center. If the filler metal flows adequately along the joint between the two points of application, you have a good visual method of ensuring that the filler metal flowed into the crack. If there was a furnace problem and the filler metal did not flow between the points of application, we could add additional filler metal next to the original point of application. After the furnace is functioning adequately, we could rebraze the part and have sufficient open space between the points of application so that visual inspection can be again used to ensure that the filler metal has adequately flowed into the joint clearance.

Another very important part of the repair brazing procedure is the cleaning of the crack area. For base metals not containing aluminum, titanium, or other similar highly oxidizable materials, hydrogen atmosphere cleaning is preferred, as the hydrogen molecule is small enough to get into any of the cracks and reduce the metal oxides. The hydrogen molecule is also small enough to go through the entire thickness of the metal, and remove some of the unwanted elements picked up during the jet engine operation. A typical example of this is the combustion chambers in the high-flying aircraft that pick up sulfur from the atmosphere. During the hydrogen cleaning, it was noted that the sulfur was removed from the nickel alloys of the combustion chamber, thus regenerating the properties of the original base metal. While cleaning of the parts in vacuum has been used, a lot of contamination from the engine-operated parts, and from precleaning operations before brazing, put a lot of contamination into the vacuum furnace. Thus, if we use the same furnace for cleaning and brazing, we are going to reduce the atmosphere quality during the brazing operation, and may not have as suitable quality of parts as would be obtained from a vacuum furnace dedicated only to the brazing operation.

Base metals containing aluminum, titanium, and similar highly oxidizable materials cannot be dissociated of their oxides in hydrogen, or in the vacuum furnace, and require special attention. A special cleaning method known as fluoride ion cleaning is accomplished in a sealed retort with fluorine (F) being added to the atmosphere by one of a number of methods. The fluorine reacts with the oxides of aluminum and titanium, and removes them, and also removes some of the titanium and aluminum from the surface of the base metal, so that parts can be repair brazed in the standard vacuum atmosphere during the brazing operation. When brazing is satisfactory, additional time at the brazing temperature will allow the titanium and aluminum to diffuse back out to the surface, thus resulting in the desired physical properties of the base metal. If insufficient aluminum and titanium has been removed from the surface, aluminium and titanium oxides will form during the brazing operation, and thus will prevent proper flow of the filler metal into the crack. Therefore, it is necessary to control the process so there is a known amount of surface depletion after the F cleaning; and also that the time in the brazing furnace is short so that the parts can be inspected and rebrazed, if necessary, before the base metal titanium and aluminum diffuses to the surface and prevents further brazing. A part coming out of the brazing furnace should still be bright and clean, if there has been sufficient depletion. If the part comes out of the brazing operation showing a brown, blue, or black surface, the aluminum and titanium have oxidized, and further fluoride-ion cleaning would be required before additional brazing can be effective.

Braze repair of hot-section jet engine parts started in 1957 and has been growing in popularity ever since. Adequately brazed repair parts have a very good service life. When thermal fatigue cracking is the result of the cracks to be repaired, it is important to repair all of the small grain boundary cracks around the major crack area. If this is accomplished, the braze repair is highly superior to a weld repair of the major crack only, which leaves all of the minor grain boundary cracks around the major crack in place, thus shortening the service life after the weld repair. It has been very interesting to watch the growth of the braze-repair procedures.

R. L. Peaslee is vice president emeritus, Wall Colmonoy Corp., Madison Heights, Mich. Readers may send questions to Mr. Peaslee c/o Welding Journal, 550 NW LeJeune Rd., Miami, FL 33126 or via e-mail to bobpeaslee@wallcolmonoy.com.
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This method provides a stable arc that can be obtained without increasing the number of short circuits in a unit time to achieve spatter-free welds

BY TETSUO ERA, TOMOYUKI UEYAMA, AND MATTHEW BROOKS

The automotive and motorcycle industries have been promoting the use of thinner sheet metals for reducing the weight of vehicle bodies as well as methods to decrease welding spatter for reducing industrial waste and the costs associated with postweld spatter removal. Currently, the pulsed gas metal arc welding (GMAW-P) process is used for reducing spatter. The nonpulsed gas metal arc welding (GMAW) process, which can reduce heat input to the base metal, is desired for solving problems associated with melt-through in welding sheet metals. However, the use of the nonpulsed GMAW process causes much more spatter; therefore, decreasing spatter is desired. In nonpulsed GMAW, using low currents, spatter is mostly generated from the moment of re-arcing right after the short circuit. In order to suppress such spatter generation, a specific method is suggested that senses the molten metal squeezed at the tip of the wire during the short circuit and rapidly decreases the current just before re-arcing to transfer the molten metal to the weld pool using only surface tension (Refs. 1, 2). In addition, some other methods have been suggested recently: The cold-arc method (Ref. 3) senses re-arcing and, at almost the same time, rapidly decreases the current to suppress spatter generation using the quick-response characteristics of the digital control. The cold metal transfer (CMT) method (Ref. 4) realizes spatter-free welding by retracting the welding wire when the short circuit occurs, thus mechanically releasing the short circuit, and by controlling the low-end welding current.

In the spatter-reducing methods that rapidly decrease the current just before the re-arcing, it is necessary to predict re-arcing accurately. However, re-arcing timing can vary depending on the disturbances caused by wire extension; welding speed; welding position; the size, shape, and viscosity of the molten metal droplet; and vibratory motion of the weld pool. Therefore, in order to obtain stable spatter controls, it is required to develop the special method for predicting the re-arcing that is robust against the disturbances. In general, GMAW is carried out with electrode positive (EP) polarity; however, this polarity is not suitable for welding extra-thin steel sheets, such as those thinner than 1.0 mm. Although an AC-current GMAW process (Ref. 5) has been suggested as a nonpulsed GMAW process for extra-thin steel sheets, the arc tends to be unstable with electrode negative (EN) polarity. In addition, greater spatter levels are experienced with EP polarity in this process, even at low currents. Hence, a spatter-reducing measure needs to be considered with this process.

In the case of GMAW of stainless steels, abnormally high arc voltage (referred to as abnormal arc voltage, hereinafter) often occurs, which does not relate to the distance between the tip of the molten metal droplet and the weld pool (referred to as apparent arc length, hereinafter). This is why the arc length control based on the conventional voltage feedback can cause irregular melting of the wire, and thereby the droplet transfer tends to be unstable. Unstable transfer of molten metal droplets reduces the accuracy of predicting the re-arcing; consequently, the effect of the spatter generation control can presumably be reduced. In GMAW-P, the method for eliminating the effect of the abnormal arc voltage, which does not relate to the apparent arc length (Ref. 6), has been developed and used resulting in a good effect. Hence, it can be considered that the employment of such a specific method into the nonpulsed GMAW process can also provide stable arc length controls.

In this research, the method for controlling short-circuit droplet transfers to minimize spatter and realizing stable arcs with various types of shielding gases and electric polarities was investigated. Based on a paper presented at the AWS Detroit Section’s Sheet Metal Welding Conference XIII, Livonia, Mich., May 14-16, 2008.
on the results of this research, the controlled bridge transfer (CBT) process for minimizing spatter generation in GMAW of thin steel sheets was developed.

**Process Principles**

Figure 1 shows the principle of the CBT process. In GMAW with short-circuit transfer conditions, spatter generates mostly when re-arcing takes place immediately after the short circuit. In order to control spatter generation during this period, where the molten metal is squeezed by the pinch force effect, the current just before re-arcing must be accurately sensed. Following this, the welding current is rapidly decreased immediately before re-arcing occurs. This causes the molten metal at the tip of the wire to be transferred to the weld pool using only the surface tension. However, the timing of squeezing the molten metal droplet can vary depending on the disturbances caused by changes in wire extension; welding speed; welding position; the size, shape, and viscosity of molten metal droplets; and vibratory motion of the weld pool. In order to overcome these disturbances, the arc current is adjusted to the optimum value by monitoring the variable arc voltage at every instance during the arcing period. This controls the short-circuit transfer cycle and stabilizes the arc. With this control method, the variable molten metal transfer can be accurately sensed to predict the re-arcing timing, thereby preventing spatter generation.

Figure 2 shows the configuration of the welding power source equipped with the CBT process. The inverter circuit composed of IGBTs is driven at the primary and supplies power to the secondary side through the inverter transformer INT. In the secondary circuit, the AC power is rectified by the diodes D2a to D2d, and is smoothed by the DC reactor. The IGBTs for switching the output polarity are used to realize low heat input welding (which is described later). However, this report explains only the case where PTR is switched on and NTR is switched off. At the latter stage, the load resistor is inserted in parallel. By switching off the TR, welding current flows through the resistor, and thereby rapidly decreasing the current. The voltage between the gun and the base metal is detected through the voltage detection circuit, and the welding current is detected through the Hall elements.

Once welding has been started, the welding current waveform control parameters for the short-circuit/re-arcing cycle optimized for the welding process are set. The command computation for the arcing period uses instantaneous voltage to improve the high-speed welding performance and the average voltage to detect changes in the melting balance during repetitive short-circuit/re-arcing cycles. The command computation part computes so that the optimum arc characteristics can be obtained from the shielding gas and wire diameter and sends the computation results to the feedback part to stabilize the metal transfer. In every short-circuit/re-arcing cycle, re-arcing is predicted during the short-circuit duration to control the switching element TR for the secondary load resistor, and thereby spatter generation can be suppressed at the moment of re-arcing. Furthermore, the accuracy of predicting re-arcing is corrected in real time. The result of predicting re-arcing and the actual re-arcing timing enables stable low spatter welding continuously.

**Control of Short-Circuit Transfer by the CBT Process**

**CO₂ GMAW**

Figure 3 shows the molten metal transfer recorded by a high-speed camera in GMAW (80% Ar + 20% CO₂) by the CBT process in relation to the voltage and current waveforms. Gas metal arc welding was carried out with a 1.0-mm-diameter solid wire, an average welding current of 80 A, an average voltage of 16.2 V, and a welding speed of 50 cm/min. Frame A shows the situation just after the short circuit. As the time elapses from frames B to C, it can be observed that the molten metal transfer to the weld pool and the tip of the molten metal is squeezed. Frame C shows the situation just before the re-arcing when the current has already been decreased, and therefore, when the arc is reignited in frame D, no spatter is generated.

When welding with a push angle, spatter generates at the moment of breaking the bridged metal as shown in Fig. 4 (as pointed with the arrows in frames D and E), even though the welding current is decreased immediately before the re-arcing. In this case, the amount of spatter varies depending on the grounding point of the base metal in relation to the welding direction, degree of the push angle, and welding speed. From this result, it can be considered that several forces such as electromagnetic force and surface tension were combined into a strong force directed forward in the welding direction. This resulting force bent the bridged molten metal droplet causing spatter. A solution to this problem has been developed, as shown in Fig. 5, by reducing the upward inclination.
of the short-circuit current to weaken relatively the electromagnetic force, thereby weakening the composed force toward the welding direction.

Figure 6 shows a comparison of spatter generation with variations of wire extensions from 5 to 35 mm in CO₂ welding using a 1.2-mm-diameter solid wire. The welding current was set at 100 A, the welding speed was set at 100 cm/min, and the wire extension was varied at a rate of about 1.5 mm/s. Figure 6A shows the case where the real-time correction of the accuracy of predicting the re-arcing was not applied. In this case, the sensitivity of predicting re-arcing was adjusted with a wire extension of 5 mm; therefore, as the wire extension became longer, the prediction of re-arcing timing became distant from the real timing, thereby causing larger amounts of spatter. In addition, the use of a wire extension of about 30 mm caused an unstable welding performance. Figure 6B shows the case where the real-time correction was applied. In this case, spatter generation was kept almost constant with variations of wire extensions up to 35 mm, resulting in a stable welding performance. Hence, if the accuracy of predicting re-arcing is inadequate — caused by variations of welding parameters — not only is the suppression of spatter generation limited, but welding stability can also be disturbed resulting in increased amounts of spatter. By saving the postweld data from the corrections of the prediction accuracy, spatter generation can effectively be suppressed for individual welding applications, and thereby the performance of the CBT process can be maximized.

EN-CBT Process

The CBT process can also be used with EN polarity, which enables low heat input and low spatter welding (referred to as the EN-CBT process, hereinafter). With EN polarity, heat input in the electrode wire can be higher than in the base metal. Consequently, the wire melting rate can be higher than with EP polarity. Figure 7 shows a comparison of the wire melting rates with EP and EN polarity in CO₂ welding using a 1.2-mm-diameter solid wire. The welding current with EN polarity is about two-thirds of the welding current with EP polarity at the same wire melting rate. In other words, EN polarity can provide lower heat input while obtaining the same deposition rate as EP polarity; therefore, larger tolerance against root openings and torch aiming deviations are created. For example, in GMAW of lap joints with 0.7-mm-thick steel sheets and a 0.9-mm-diameter solid wire, the use of EN polarity can allow a tolerance of the gun-aiming deviation up to 1.5 times the wire diameter on the lower sheet (about
three times that with EP polarity) and a
tolerance of the root opening up to about
two times the plate thickness (about two
times that with EP polarity).

However, when a power source opti-
mized for EP polarity is used for EN-
polarity welding, by changing its output
polarity, the molten metal droplet be-
comes large at the tip of the wire and tends
to swing irregularly resulting in an unsta-
ble arc. In general, this unstable arc can
only be stabilized by reducing the arc volt-
age to increase the occurrence of short
circuits; however, the bead appearance
tends to become convex.

With the EN-CBT process, slight volt-
age fluctuations occur caused by the be-
havior of cathode spots on the tip of the
wire during EN-polarity welding. During
this process, the instantaneous voltage is
used for the command computation to im-
prove the transient response against dis-
turbances, and thereby the welding current
waveform control can be optimized to ob-
tain the best arc characteristics for EN-
polarity welding. Consequently, a stable
arc can be obtained without increasing the
number of short circuits per unit time, and
thus the weld bead shape can be adjusted
to either a convex or flat appearance.

Figure 8 shows the molten metal trans-
fer taken by a high-speed camera and the
synchronized voltage and current wave-
forms in GMAW (80% Ar + 20% CO₂)
during the EN-CBT process. For this
welding, a 0.9-mm-diameter solid wire, an
average welding current of 45 A, an aver-
age voltage of 17.5 V, and a welding speed
of 20 cm/min were used. Frames A to D
show similar times as those shown in Fig.
5. In frame D, where the arc is reignited,
no spatter is generated. The ripples of
the welding voltage waveform relate to the
movement of cathode spots on the surface
of the molten metal droplet. Although the
arcing period is as long as approximately
30 ms, stable short-circuit/re-arcing cycles
are exhibited.

The amounts of spatter were compared
between the EN-CBT process and the
conventional multipurpose inverter-
controlled welding power source whose
output polarity was changed to EN in CO₂
welding. The amount of spatter was ap-
proximately 0.5 g/min or larger in the 80
A or lower current range with the conven-
tional multipurpose inverter-controlled
welding power source. The use of the EN-
CBT process decreased the amount of
spatter to approximately 0.1 g/min or less,
roughly one-sixth of that with the conven-
tional multipurpose inverter-controlled
welding power source.

Figure 9 shows an application for the
EN-CBT process. As shown in this figure,
GMAW resulted in glossy, regular bead
appearance without any traces of spatter
or melt-through on the 0.7-mm-thick
sheet lap joint of JIS SPCC grade with a
root opening that linearly increased from
0 to 1.4 mm.

The sound of GMAW without either
spatter or melt-through using constant
welding conditions was found to be much
less when compared to conventional
equipment.
Mild steel, Thickness: 0.7mm (Gap: 0.0 → 1.4 mm)
C-Mn steel solid wire, size: 0.9 mm
Welding current: 35 A (Wire feed rate: 200 cm/min)
Arc voltage: 14.7 V
Welding Speed: 20 cm/min

Fig. 9 — Lap-joint welds by the EN-CBT process.

Fig. 10 — Metal transfer affected by abnormal arc voltage.

Use on Stainless Steel

In GMAW of stainless steels, argon gas mixtures with 2 to 3% O₂ or CO₂ are generally used for shielding. With an argon-rich shielding gas mixture, the cathode spots move on the weld pool at a high speed, causing an abnormal arc voltage; consequently, the arc voltage does not represent the apparent arc length.

Figure 10 shows some molten metal transfers and the related welding current and voltage waveforms recorded in GMAW by the conventional CBT process conducted on SUS 304 base metal using a SUS 308 solid wire. In frames A through D, the cathode spot was observed to move back and forth rapidly, and the arc voltage did not represent the apparent arc length. With this conventional CBT process, even when an abnormal arc voltage took place, it was fed back directly to control the arc length; consequently, the welding current decreased, and thus, the vibratory motion of the weld pool became irregular. This caused inaccurate prediction of re-arching in the next and succeeding short-circuit/re-arching cycles resulting in spatter generation (frame F).

The method for eliminating the effect of abnormal arc voltage to obtain the correct apparent arc length by high-speed digital calculation has been developed and applied to the CBT process. The results of welding by using this improved CBT process are shown in Fig. 11. During the arcing period of frames A through D, cathode spots moved irregularly here and there, but the output current waveform was similar to those of other short-circuit/re-arching cycles, and thereby the vibratory motion cycle of the weld pool was kept constant. Consequently, the prediction of re-arching in the succeeding short-circuit/re-arching cycle was successful, and thereby no spatter was generated.

The CBT process equipped with the new arc length control can decrease spatter to much lower levels than a conventional multipurpose inverter-controlled welding power source. For example, when the CBT process is applied for welding SUS 304 base metal with a 1.0-mm-diameter SUS 308 solid wire, the amount of spatter (like dust particles) was as low as 0.1 g/min with welding currents of 150 A or lower. Even with a higher welding current of 200 A, the amount of spatter could be reduced to 40% of that by the conventional process.

Figure 12 shows examples of application for the process in GMAW of stainless steel sheets. In one welding example, a lap joint of 1.0-mm-thick sheets, an average current of 135 A, an average voltage of 15.5 V, and a welding speed of 200 cm/min were used. In another welding example, a lap fillet joint of 0.6-mm-thick sheets, an average current of 115 A, an average voltage of 14.0 V, and a welding speed of 300 cm/min were used. In both welding conditions, high-speed welding resulted in glossy, regular bead appearance with the absence of spatter or spatter marks.

Conclusions

The authors developed the CBT process to reduce spatter in the short-
circuit transfer condition in GMAW and researched the method for controlling the short-circuit transfer in relation to shielding gas composition, welding torch orientation, and electrode polarity. The results are summarized below.

1. The short-circuit/re-arcing cycle can be controlled by adjusting the arc current to the optimum values according to the monitored arc voltage, which changes at every instance during the arcing period. This is affected by the disturbances caused by the variations in wire extension; welding speed; welding position; the size, shape, and viscosity of molten metal droplet; and vibratory motion of the weld pool. By using this method, the fluctuation in molten metal transfer can be detected, and thereby the re-arcing timing can be accurately predicted in order to rapidly decrease the re-arcing current for preventing spatter generation.

2. When the welding gun is kept at a push angle, several forces such as electromagnetic force and surface tension are combined into a strong force directed forward in the welding direction. By this combined force, the bridged molten metal is bent, and spatter generates at the moment the molten metal bridge is fractured. This problem can be solved by reducing the upward inclination of the short-circuit current to weaken the electromagnetic force, and thereby the combined force directed forward in the welding direction can be weakened; consequently, spatter generation can be prevented.

3. With the EN-CBT process, although slight arc voltage fluctuations occur caused from the behavior of cathode spots on the tip of the wire during EN-polarity welding, the instantaneous voltage is used for the command computation to improve the transient response against disturbances. Thereby, the welding current waveform control is optimized to obtain the best arc characteristics for EN-polarity welding. Consequently, stable arc can be obtained without increasing the number of short circuits per unit time to obtain spatter-free arcs.

4. The new CBT process has been developed for stainless steel welding by applying specific arc length control that is not affected by abnormal arc voltage in argon-rich shielding gas welding. This process can suppress the spatter generation caused by a fluctuation in the vibratory motion of the weld pool or inaccurate prediction of the re-arcing in the succeeding short-circuit/re-arcing cycle, and thereby spatter-free GMAW in the short-circuit transfer mode can be carried out even on stainless steels.

References
The American Welding Society (AWS) Brazing and Soldering Manufacturers Committee (BSMC), composed of key representatives from American brazing equipment, brazing filler metal, and processing suppliers, met in 2006 to discuss how to rectify the lack of university training for engineers in the fields of brazing and soldering. As users of these braze and soldering processes, we as an industry are seeing a serious shortage of new persons acquiring the engineering skills necessary to enter into this exciting field.

It was pointed out by Robert Peaslee, Wall Colmonoy Corp., that universities in the United States are far behind those in Europe offering brazing and soldering curriculums. European universities offer several engineering courses with many master thesis topics related to brazing and soldering research projects. The small number of American research paper presentations compared to those from foreign universities is apparent at the AWS Welding Show and the International Brazing and Soldering Conferences.

Brazing is widely used in the manufacture of everyday home products, automobiles, jet engines, airplanes, and medical devices, to name a few. Most of the workers in this industry have learned this technology on the job, working with mentors and participating in technical organizations, such as the AWS C3 Brazing Committee. Those of us who try to recruit brazing and soldering engineers to work for our companies are finding it extremely difficult to find qualified personnel.

The committee members concluded that it is imperative to expose more of the nation’s engineering students to brazing and soldering technology, including an in-depth study of processes, kinetics, metallurgy, and structural aspects.

A discussion followed on how American universities and the brazing community could develop and support higher education training in these processes. The committee members concluded that an introduction to brazing and soldering education needs to be included for all engineering disciplines. Further, brazing and soldering should be offered as a separate degree program or as a minor to the existing engineering degree programs.

Following an in-depth discussion, it was decided to present these ideas to a key university to learn what can be done to implement this training. Since The Ohio State University (OSU) offers welding engineering degree programs, it was the logical choice for the first university to approach with our proposals. Matthew Lucas (Fig. 1), a past chair of C3 and a graduate of the OSU welding engineering (WE) program with strong ties to the current faculty, volunteered to head up this task. Alex Shapiro, Titanium Brazing, Inc., a C3 member, also volunteered to assist in this endeavor since he was already actively engaged with OSU graduate stu-

**Fig. 1 — Matthew Lucas makes history teaching his first class for OSU brazing and soldering engineering students.**

**Fig. 2 — Instructors Matthew Lucas (far left) and Alex Shapiro (second from right) are shown with the students in the first OSU brazing and soldering engineering class.**

MATTHEW LUCAS (mattbraze@fuse.net) is an AWS Counselor and the welding, brazing, and heat treating consultant at Belcan Corp., Cincinnati, Ohio.
stems working on research projects related to his company's needs.

**University Contact**

Lucas arranged an initial planning session with OSU professors in early 2007 to discuss developing a brazing and soldering class within the welding engineering curriculum.

"We met with staff members, professors Richard Richardson, Charles Albright, John Lippold, and research scientist Boian Alexandrov," Lucas said. Also present at the meeting was OSU WE graduate Peter Ditzel, Parker-Hannifin Corp., who expressed his interest in participating in this educational opportunity.

During this productive meeting, Lucas presented the position of the AWS brazing community and the OSU staff members detailed their programs and what they required for implementing a graduate-level class. The decision was made to introduce a course on brazing and soldering during the 2008 winter or spring quarter.

A team was assembled to develop all of the course materials, slides, tests, and handouts as well as teach the classes. Leading this effort were Lucas, Shapiro, Alexandrov, and Ditzel. Shapiro and Ditzel volunteered to develop the initial draft of the course syllabus. The AWS Brazing Handbook and AWS Soldering Handbook were specified as the course textbooks. Lucas contacted AWS to obtain the textbooks for the first course offering.

The course syllabus was finalized during the March 2007 followup meeting. The curriculum included 28 lecture hours, two hours of midterms, and the final exam. The lectures were divided among the team members, based on their areas of expertise. Several meetings were held during the spring and summer months to check on the progress of each lecture and to make adjustments in the syllabus as needed. As the fall term progressed, it was decided that the first offering of the course WE703 would be conducted during the spring quarter 2008.

As final preparations were being made in January 2008, two other members of the C3 Brazing Committee volunteered to present some of the lectures. Anatol Rabinkin, Metglass, Inc., and Yury Flom, Goddard Space Flight Center, were welcomed into the course-development team and assigned lectures. This final team created nearly 900 slides for the class. Much credit is due to each of these volunteers who provided their services in addition to working their regular full-time jobs.

**Spring 2008 — The Inaugural Class**

Nineteen students enrolled in the ten-week class, which began in late March — Fig. 2. The class was offered as an elective to seniors and graduate students. All of the students completed the class and responded favorably to the postclass questionnaire.

In addition, each of the instructors said he enjoyed presenting the class lectures and learned from the experience. Lucas said, “It was a good feeling to give the students a view of this very technical subject with my experience of having applied that knowledge in making products.”

The course structure has since been refined to incorporate improvements based on the feedback from the students, lecturers, and Welding Department chair. The major topics of the course are shown in the chart.

**Let's Do It Again and Again**

The brazing and soldering class was offered again this autumn quarter at OSU.

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**Universities in the United States are far behind the European universities in offering brazing and soldering curriculums**

In addition, in order to make the course available to those who want to enter the brazing and soldering field but are not pursuing an engineering degree, the committee is making the course available for students on the Internet.

**What's Next**

The Committee has several goals for this class in the future.

1. Continue to offer the program to OSU welding engineering students, and get more OSU professors involved in teaching the classes.
2. Create additional brazing and soldering classes for the OSU welding engineering program.
3. Share the class material with other colleges in order to reach more students.
4. Make the class available as a workshop so that persons not pursuing a degree can benefit from taking the class.
5. Consider using this program as a model for other areas of the welding profession to further educate our welder base.

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**Fundamentals of Brazing and Soldering**

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**Principles in Brazing and Soldering Design**

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**Final Exam**
Experiments were conducted to better understand weldability issues when joining martensitic-type advanced high-strength steels for the automotive industry

The use of martensitic-type advanced high-strength steels (AHSS) provides potential benefits for safety and weight reduction in the automotive industry. With the application of thinner AHSS, material savings and improved crash energy management can be achieved.

The automotive industry is searching for materials that help reduce the weight of vehicles with the objective of reducing fuel consumption as well as meeting the new safety regulations in crash tests. There is, thus, the need to use more resistant materials with less thickness than those traditionally used, such as carbon steels and high-strength low-alloy (HSLA) steels. The development of AHSS has achieved this result; however, with new materials and complex structures, they present a great challenge for current welding technology. Thus, greater understanding and knowledge is required of how these materials can be welded, while retaining the properties of the original base materials and thus securing the hold of the welds established in the base design (Ref. 1).

The martensitic-type advanced high-strength steels currently being used in the automotive industry are joined using the resistance spot welding (RSW) process. Therefore, it is necessary to know the variables involved as well as how they interact and what welding procedures should be validated to obtain acceptable weld joints that meet the design requirements laid out by the client. It is also necessary to know the mechanical properties of the applied welds (Ref. 2).

Steels in automotive industry can be classified in different forms. One is by a metallurgical designation. Common designations include low-strength steels (interstitial-free and mild steels); conventional high-strength steels (HSS) (C-Mn, bake-hardenable, high-strength interstitial-free, and HSLA); and AHSS (dual-phase, transformation-induced plasticity, complex phase, and martensitic steels) (Ref. 3).

Another method for classifying steels is by their strength — Fig. 1. This method defines high-strength steels (HSS) as yield strengths from 210 to 550 MPa and tensile strengths from 270 to 700 MPa, while advanced high-strength steels have yield strengths greater than 550 MPa and tensile strengths greater than 700 MPa (Ref. 3).

The difference between HSS and AHSS is their microstructure. HSS are single-phase ferritic steels. AHSS are primarily multiphase steels, which contain ferrite, martensite, bainite, and/or retained austenite in quantities sufficient to produce unique mechanical properties. Some types of AHSS have a higher hardening capacity resulting in a strength ductility balance superior to conventional steels. Other types have ultrahigh yield and tensile strengths and show a bake hardening behavior (Ref. 4).

The terminology varies considerably throughout automotive and steel companies. Each steel grade is identified by metallurgical type, yield strength (YS) in MPa, and tensile strength (TS) in MPa. In this article, the material used is MS 900T/700Y, which a martensitic-type steel with 900 MPa minimum ultimate TS and 700 MPa minimum YS (Ref. 3).

The metallurgy for low- and high-strength steels is generally well known. The metallurgy and processing of AHSS grades are relatively new compared to conventional steels. All AHSS are produced by controlling the cooling rate from the austenite or austenite plus ferrite phase, either on the hot mill or in the cooling section of the continuous annealing furnace. In martensitic steels, the austenite that exists during hot-rolling or annealing is transformed almost entirely to martensite during quenching on the hot mill or in the cooling section of the continuous annealing line. The martensitic steels are characterized by a martensitic matrix containing small amounts of ferrite and/or bainite. Within the group of multiphase steels, MS steels show the highest tensile strength level. This structure can also be developed with postforming heat treatment. Martensitic steels provide the highest strengths, up to 1700 MPa TS. Martensitic steels are often subjected to postquench tempering to improve ductility, and can provide adequate formability even at extremely high strengths. Martensitic steels use different combinations of Mn, Si, Cr, Mo, B, V, and Ni to increase hardenability and C is added to increase hardenability and for strengthening the martensite. The chemical composition of martensitic steel MS 900T/700Y is 0.08% C, 0.005% S, 0.54% Mn, 0.009% P, 0.04% Si, 0.04% Cr, 0.018% Ni, 0.02% Mo, 0.011% Cu, 0.004% V, 0.002% Nb, 0.056% Ti, and 0.003% W.

Martensitic-type AHSS differs from mild steels by their chemical composition and microstructure. In martensitic-type AHSS, higher strengths are achieved by modifying the steel microstructure. The as-received microstructure is changed during resistance spot welding of AHSS martensitic type due to the heat input applied. The higher the heat input, the greater the effect on the microstructure. At different heat inputs and cooling, we can obtain different microstructures in the weld metal and heat-
affected zone (HAZ).

Resistance spot welding is a process in which faying surfaces are joined at one or more spots by the heat generated by resistance to the flow of electric current through workpieces that are held together under force by electrodes. The contacting surfaces in the region of current concentration are heated by a short pulse of low-voltage, high-amperage current to form a fused nugget of weld metal. When the flow of current ceases, the electrode force is maintained while the weld metal rapidly cools and solidifies. The electrodes are retracted after each weld, which usually is completed in a fraction of a second (Ref. 5).

The rate of heating must be sufficiently intense to cause local electrode/workpiece interface melting. The opposed electrodes apply pressure and, when sufficient melting has been achieved, the current is interrupted. Electrode force is maintained while the molten metal solidifies, producing a sound, strong weld. If both the local resistance of the workpiece and the welding current magnitude were constant, then the total quantity of heat input \( Q \) developed in the workpiece would be given (in joules) by the following:

\[
Q = IRT
\]

where \( I \) is the effective value of current in amperes, \( R \) is the resistance of the workpiece in ohms, and \( t \) is the duration of flow of current in seconds (Refs. 5, 6).

**Experimental Development**

To carry out this project, a 1.5-mm-thick martensitic steel GMW 3399M-ST- S CR 9007/700Y MS of 900 MP minimum tensile strength and 700 MPa minimum yield strength was used. This steel is currently used for the manufacture of car body structural parts.

The main variables of the process that were considered in the experiment were current (A) and time (cycles). Evaluated were how these selected variables affect the welding of martensitic-type advanced high-strength steels and what interaction exists between these variables in the performance of the spot weld, including the variation of the mechanical properties and metallographic structures due to applied heat input. The following experiment design was used and is shown in Table 1.

- **Design**, \( 3^2 \)
- **Level**, 3 (-1, 0+1) Low, Nominal, High
- **Factor**, 2 (Weld Time, Welding Current)
- **Constant**, Welding Pressure

To produce the weld tests, practices indicated in AWS D8.9, *Recommended Practices for Test Methods for Evaluating the Resistance Spot Welding Behavior of Automotive Sheet Steel Materials*, were considered and evaluated according to the criteria in GM 4488, *Automotive Resistance Spot Welds Steel*. The following two types of tests were conducted:

1. Test samples for peel test (D), microhardness and metallographic test (M) — Fig. 2. Sample ID P1a and P1b through P9a and P9b. Samples totaled 18.
2. Test samples for shear tension test T1a and T1b through T9a and T9b — Fig. 3. Total samples 18.

The welding tests were carried out with...
In the peel test, a caliper was used to tear down the spot welds to determine the diameter and evidence of fusion of the welded metal sheets. Figure 4 shows the results of those tests. It can be seen that as heat input was increased, the diameter of the welded spot also increased. This is due to the fact that as we increase the current (A) and the time (cycles), the quantity of heat increases according to the equation \( Q = P R t \). As far as the automotive industry is concerned, the bigger the diameter of the weld spot, the stronger the weld.

Another important characteristic to evaluate is the depth of the indentation, which is defined as the depression that the electrodes leave on the surface of the metal sheets. Figure 5 shows that as we increased the heat input, the depth of the indentation also increased. This provides a quality characteristic that should be limited to a minimum in accordance with the quality requirements of the automotive industry.

In correlating the test results of the spot diameter against those on the depth of the indentation, as shown in Fig. 6, it can be observed that they show a directly proportionate behavior. In other words, as we increased the diameter of the spot with a given amount of heat, a greater indentation was produced, which is a quality condition of the weld spot that is restricted in the automotive industry. Therefore, the optimal parameters of welding would be those that produce the greatest diameter of spot with a lower value of indentation, allowed by the applicable quality requirements.

In the shear tension test, the metal sheets joined by the spot weld are submitted to testing in a universal mechanical testing machine. Figure 7 shows that as the heat input increases, the resistance of the shear tension increases to a maximum.

---

**Design of Experiments (DOE)**

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>P</th>
<th>C</th>
<th>T</th>
<th>Spot Diameter (mm)</th>
<th>Shear Tension (kg/mm²)</th>
<th>Microhardness (HV 500)</th>
<th>Heat Input kJ ( Q=P R t )</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>670</td>
<td>8000</td>
<td>12</td>
<td>P1</td>
<td>T1</td>
<td>P1</td>
<td>1664</td>
</tr>
<tr>
<td>2</td>
<td>670</td>
<td>8000</td>
<td>18</td>
<td>P2</td>
<td>T2</td>
<td>P2</td>
<td>2496</td>
</tr>
<tr>
<td>3</td>
<td>670</td>
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<td>3328</td>
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<tr>
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<td>9500</td>
<td>12</td>
<td>P4</td>
<td>T4</td>
<td>P4</td>
<td>2346</td>
</tr>
<tr>
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<td>T5</td>
<td>P5</td>
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<td>T6</td>
<td>P6</td>
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<tr>
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<tr>
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<td>24</td>
<td>P9</td>
<td>T9</td>
<td>P9</td>
<td>7488</td>
</tr>
</tbody>
</table>
In correlating the diameter of the spot against the shear tension obtained in the tension test, it is shown in Fig. 8 that there is a maximum shear tension value and that after that value (Tests P7–P9), even though the diameter of the spot increases, its resistance remains without any great changes. This is because applying the greatest amount of heat to the welding spot causes the latter to be most affected by the increase in temperature, which modifies the response in its mechanical properties.

To evaluate the effect of heat input on the spot welding properties, the variations in microhardness were measured in the base metal, HAZ, and weld. The test data were evaluated with variables of low (P1, 1664 kJ), medium (P5, 3519 kJ), and high heat input (P9, 7488 kJ). It can be seen in Fig. 9 that the HAZ is shown to have diminished in hardness compared to the original hardness of the metal base and the hardness obtained in the spot weld. This indicates that the material is overheating because of the welding process.

Figure 10 shows the microstructures of the base metal, HAZ, and weld, where the base metal presents a microstructure of tempered martensite and, in the HAZ, the material appears to be heated at a high temperature between A1 and A3. It is given that the speed of cooling is not high enough to make the material pass through this zone of two-phase stability (α + γ). This is because of the carbon content, where the ferrite and the austenite coexist at this temperature. While the austenite transforms the martensite during the cooling down process, the ferrite remains. This indicates the presence of both martensite and ferrite phases in the HAZ. Therefore, the formation of the ferrite phase causes the hardness in this zone to diminish, and as heat input is increased, the HAZ size also increases. This is reflected in the drop in resistance with shear tension at high heat levels.

During the welding process, the material is heated above temperature A3. Therefore, it is totally austenized during the heating process and newly transformed to martensite due to the high hardenability of the martensitic steels. Consequently the microstructure and hardness of the weld is similar to and even, in some ways, stronger than the metal base itself.

Conclusions

In accordance with the analysis outlined in this article and the evaluation of the test results in the performed tests, the following can be concluded:

1. The diameter and the depth of the spot weld have a behavior directly proportional to the increase in heat input (current (A) and time (cycles)).

2. Resistance to shear tension (kg/mm²) at the welding point has a reaction directly proportional to the increase in heat input (current and time cycles). However, it can be observed that at high levels of heat input (Tests T7–T9) this increase is minimal.

3. In comparison with high levels of hardness (301–420 HV) in the base and
weld metals, low levels (250–282 HV) of hardness were observed in the HAZ.

4. The microstructural analysis shows the presence of soft phases (ferrite) in the HAZ, which reduces its hardness in this area due to the effects of the heat input.

5. From the statistical analysis of the obtained results from the performed tests, it can be observed that the optimal values for the process are found among those values from tests P5 and P6: 9500 (A), 18 and 24 cycles, where the greatest spot diameters and resistance to shear tension can be found with the least acceptable indentation.

Works Consulted


References

2. Maurizio Mini, M. AHSS: Advanced High-Strength-Steels; GED.

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The Role of Tip Dressing in Modern Auto Body Construction

BY MARK TRUEX AND JOSEPH P. SEME

Tip dressing offers auto manufacturers flexibility in metal combinations, weld joint design, and material selection, as well as rapid setup and verification of new processes.

Automatic electrode tip dressing refers to the process of in-situ removal of the weld cap mushroom (in resistance spot welding) by a milling machine known as a tip dresser.

Tip dresser technology has a direct impact on the throughput and quality of the welding process in modern auto body construction. Tip dressing offers benefits to product design by offering flexibility in metal combinations, weld joint design, and material selection. Tip dressing also offers many benefits to the manufacturing environment, including rapid setup and verification of new processes. Additionally, tight control of welding electrode shape and diameter offers improved cosmetic appearance, weld quality, and reduction of weld flash. With these benefits in hand, the manufacturing plant is ready to gain significant improvements in uptime and a reduction in tool degradation rate. Therefore, smaller, leaner equipment components (such as smaller welding transformers) are possible. The dressing of electrodes increases life expectancy of the weld electrode tips and weld guns.

Technical explanations in this article include:
- Governing the electrode consumption rate
- Fundamental parameters of tip dressing
- Controlling chatter and electrode bounce
- Prevention of cutting tool clogging
- Dressing of electrode tips at high angles
- Cutting blade life.

A review of some key lessons learned during plant implementation of this technology is also presented.

What Is Tip Dressing?

Tip dressing refers to the milling of copper welding electrode tips to remove the weld mushroom and restore the intended weld face geometry. Figure 1 shows the difference between new and mushroomed electrode tips.

The tip dressing process mills the electrode tip back to its designed face geometry, in order to prolong the service life of the electrode tip — Figs. 2, 3.

During tip dressing, the electrode tips are consumed at a governed and predictable rate. The electrode tip design must accommodate a “dressable length” in order to use tip dressing without affecting weld process performance. A typical consumption rate might be as much as 0.15 mm per dressing operation (about seven dresses per millimeter of cap consumption). Consumption of the electrode is mostly due to loss of length from mushrooming during the weld process. The electrode is ideally dressed to develop a clean weld face and no more.

New electrode tips may be pre-dressed, which is simply to establish the proper weld face at the proper angle for each individual application.

After a predetermined number of welds the weld face will grow, or “mushroom” to a larger size, typically not to exceed 1.3 times the diameter of the dressed face. The mushroomed face may then be re-dressed to its proper size.

Goals of Tip Dressing

The following are the goals of tip dressing:
- Accurate control of weld face diameter
- Accurate control of cap consumption rate
- Balanced consumption for the upper and lower electrodes
- Pre-dressing (dressing a new cap before welding)
- Re-dressing (dressing a mushroomed cap after welding).

Why Tip Dress?

Among automotive suppliers, supporters for tip dressing include two important groups: manufacturing engineering and product engineering. Each has much to gain by tip dressing.

Benefits to Manufacturing Engineering

Reduced setup time for new weld systems. Since weld mushrooms are only allowed to grow by approximately 2 mm before the tips are re-dressed, the entire weld stepper validation can be accomplished with very few weld quality checks. Some users synchronize tip dressers on a line based on part counts (rather than weld counts), so that all guns may be verified with only two product teardowns (perhaps the first and twentieth job, for a dressing frequency of 20 jobs).

Reduction in weld current requirements. Since only a mild weld stepper is required to support a mushroom growth of only 2 mm, the traditional practice of oversizing transformers and weld cables is unnecessary. This can save money and engineering time for manufacturers.

Common electrode usage throughout the body shop. One common electrode tip may be used throughout the body shop. The common tips may be pre-dressed to the face size required for each operation. The proper weld face is determined for each gun based on material, stackup, or cosmetic requirements.

Improved throughput. Since tip dressing generally improves tip life, tip changes...
may be less frequent and more carefully planned in order to minimize throughput interruptions.

** Improved weld quality.** Tight control of the weld face on the tip enables tighter control of weld nugget size. Processes that may require oversized nuggets for quality reasons, such as advanced high-strength steels (AHSS), may readily be accommodated by a simple change in the cutting blade to a larger face size. Face size control also improves weld appearance and the cosmetics of the welded part. It also enables ultrasonic testing of welds.

** Improved health, safety, and housekeeping in the plant.** Tip dressing allows better control of weld flash. By choosing a cap face less prone to weld flash, this perennial problem may at last be addressed. There is a corresponding reduction in sharp burrs on weld surfaces. Housekeeping is improved since there is less buildup of flash on tooling and on the floor.

**Benefits to Product Engineering**

** Improved weld appearance and cosmetics.**

** Improved flexibility regarding metal thickness combinations that may be welded.** Thickness ratios greater than 3:1 may often be welded successfully using tip dressing, since the cap is never allowed to mushroom to the point where welding problems begin.

** Improved welding capability with AHSS.** Nugget fracture issues may be minimized by increasing cap face diameter.

** Flange width weld requirements.** A reduction in flange widths is possible due to less weld face growth.

** Special section weld requirements.** Product designs requiring custom weld tip geometry may sometimes be improved by tip dressing, if a dressable tip geometry is allowed.

** Reduced heat distortion.** Tip dressing allows for more precise heat control and much less overwelding, thereby reducing the distortion caused by welds.

---

**Technical Challenges**

There were many technical challenges to overcome in order to design successful tip dressing equipment. These challenges can be divided into the following areas.

** Governing the Electrode Consumption Rate**

To make tip dressing practical in an automated environment, the consumption rate of the electrode tips must be controlled. Body shop processes using the newer technology of servo guns must maintain weld face positions. Robots must control the position of the fixed backup electrode when approaching the sheet metal. Control is usually determined by a calculation of cap consumption after dressing. Balanced cutting of fixed to movable electrode is important to determine this position correctly. Even pneumatic weld guns must have this consistent process control as the equalized closed position must be maintained to provide proper alignment and tip pressure.

The perfect cutting blade would stop cutting once the electrode face is restored. Under these conditions, the electrode consumption rate would be governed by mushrooming rather than dressing, since the cap length would only shrink from welding, not from milling it away.

The electrode consumption rate was able to be regulated successfully as follows:

- Weld caps are not held on center by guides or by a chuck. Rather, the shape of the electrode (typically a ball nose) has mating features on the cutting tool and is used to hold the cap on center.
- The cutting flutes are ground precisely so that they rub and cut at the same time. The rubbing action holds the cap smoothly on center and gives precise control of the weld face and the consumption rate — Fig. 4.

**Fundamental Parameters of Tip Dressing**

With most commercial cutting blades, the following parametric relationships exist:

** Force**
- Has large effect on chip thickness (and chip stiffness).
- Overpushing can cause an out-of-round weld face, overconsumption, and chip clogging.
- Underpushing can cause underconsumption, a lack of full cleanup of the tips.

** Dress Time**
- Has a large effect on chip length and volume of chips generated.
Off-normal welding creates off-normal mushroom facets.

Misaligned guns.

You must know your upper limit to avoid clogging.

Since dress time actually has to do with the number of rotations of the cutting blade during the time when the tips are closed on the flutes, there is an inverse relationship between dress time and turning speed (rev/min) of the dresser. So halving the rev/min of the dresser would require doubling the dress time in order to maintain a constant number of blade rotations per dress.

Dress Frequency

There are two methods, one based on weld counts (100, for example) resulting in more dressings per electrode. The second method is based on part counts (20, for example), when all dressers on a given line are synchronized. With either method, the mushroom growth on the weld cap should be limited to the following:

Maximum mushroom diameter = 1.3 × dressed diameter.

Therefore, on a practical level, do not let a 5-mm dressed face grow beyond 7 mm; do not let a 6-mm dressed face grow beyond 8 mm; and do not let a 7-mm dressed face grow beyond 9 mm.

Both methods will accomplish longer electrode life and obtain a minimum of one shift per electrode set.

Controlling Chatter and Electrode Bounce

In order to accurately cut the weld face, it is essential that the weld cap remain in contact with all of the flutes with no jumping around (i.e., no “chatter”). Designing chatter-free cutting blades is complicated, involving several critical parameters, such as number of cutting flutes, grinding, and assembly tolerances, and hard coating of the flutes in order to prevent adhesion of copper to the (tool steel) flutes.

Prevention of Cutting Blade Clogging

To prevent clogging of the cutting blade, it is important to design a method of chip management. It is preferred to limit the length, width, and thickness of the copper chips produced from tip dressing. Additionally, the amount of open space in between flutes must be sufficient to prevent clogging.

Dressing of Electrode Tips at High Angles

The problem of how to tip dress angled electrode tips was addressed as follows:

When using the F-nose (ball) tip geometry, dressing at angles up to 15 deg does not pose any particular problem for cutter design, since F-nose tips are essentially two balls coming together.

However, for dressing at higher angles, the side of the electrode tip begins to mill away. This can create contact between the electrode tip and noncutting edges in the cutting blade assembly. Cutting away the side of the tip can also breach the cooling water jacket inside the tip.

Therefore, to correct these problems it was necessary to develop a flared-out flute geometry to create clearance for high angle dressing. We are now able to maintain stable dressing conditions up to a dressing angle on either or both electrodes up to 45 deg.

Cutting Blade Life

The dulling mechanism of the cutting blade is primarily the abrasive erosion of the tool steel by the oxidized surface of the electrode tip mushroom. Blade life may be improved by increasing substrate hardness, selecting a properly adhering hard coat layer, and through the avoidance of grinding burrs.

Lessons Learned during Implementation of Tip Dressing

The following are examples from user implementations of tip dressing under highly automated conditions:

Normal-to-metal welding. In order to efficiently consume the weld cap, the dressing and the welding must occur in the same plane, squarely at the contact point on the end of the cap. The weld plane and the dressing plane must be perpendicular to the motion of the moving weld cap. Any out-of-plane welding or dressing places a larger burden on the tip dress process to machine out the resulting cap damage, and results in poor cap life — Figs. 5, 6.

Gun electrode alignment. Proper gun alignment is important not only to proper welding but to tip dressing as well. Misaligned weld electrodes result in poor dressing results and reduced electrode life — Fig. 7.

Primary cap wear mechanism when tip dressing. The actual electrode tip mush-
room rate is dependent on several interacting process variables, as follows:
• Number of welds per vehicle
• Stackup mix, material mix, and model mix
• Weld force
• Water cooling
• Weld schedule and stepper.

However, the first stage of tip mushrooiming is primarily governed by electrode tip pressure, which is defined as

\[ P = \frac{F}{A} \]

(Tip Pressure) = (Weld Force)/(Cap Face Area)

Whenever the chosen weld force and cap face result in a tip pressure that exceeds the yield strength of the annealed copper mushroom (about 15 ksi or 100 MPa), the tips will rapidly mushroom to relieve the tip pressure back to the copper yield strength. This rapid initial mushrooiming is traditionally known as the break-in period, and it lasts for approximately 50 welds. In a tip dressing operation, the existence of a break-in period is not desirable because it greatly increases the required tip dressing frequency. Table 1 shows how to eliminate the break-in period by properly sizing the weld face.

### Tip Dress Process Monitoring

The tip dressing process is robust with very consistent results. The basic process parameters are established during setup of the robot and weld controller. Monitoring the current or power of the tip dress motor has been found to identify most common process faults (such as a blown fuse or a missing cutting blade). Within the controllers, there are defined current values for each phase of the process. This monitoring can be used to validate key dressing parameters such as force and time. A proper dress sequence will find an elevated current draw with a drop in current value as the process is completed to a fully dressed electrode (see Fig. 8 for details).

Other methods of validation include precisely machined test cups that allow for go/no-go conditions that measure the ability to pass current after tip dress sequencing. The precise contour of the high performance thermoplastic cup matches the contour of the dressed electrode form and diameter. This prevents undressed or not fully dressed electrodes to pass current — Fig. 9.

### Conclusions

Tip dresser technology has been making a positive contribution to the success of the modern body production shop. Significant competitive gains may be realized through proper application of tip dressing.

Product design benefits include
• Flexibility in metal combinations, weld joint design, and material selection.

Manufacturing benefits include the following:
• Rapid setup and verification of new processes
• Tight control of welding electrode shape and diameter
• Improved cosmetic appearance, weld quality, and reduction of weld flash
• Improvements in uptime
• Reduction in tool degradation rate
• Smaller, leaner equipment components (such as smaller welding transformers)
• Increased life expectancy of the weld electrode tips and weld guns.

### Acknowledgments

A special thank you to technical consultants Michael Karagoulis, General Motors; Michael Palko, Ford Motor Co.; and David Androvich, WTC Corp.
Conference sessions will cover topics such as:

- Failures at high temperature
- New consumable bit technology for spot joining
- Joining high temperature materials
- Explosion welding
- Laser welding and brazing
- Resistance projection welding applications
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- Magnetic pulse welding
- Challenges of joining CSEF steels
- Ultrasonic soldering and brazing
- Friction stir spot welding
- Bonded transition joints
- Inertia friction welding
- Brazing applications

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The most difficult-to-weld challenges—including various material combinations involving aluminum, creep-enhanced ferritic steels, nickel alloys, titanium, copper, ceramics, and more—will be covered. New chemistries are coming to the aid of existing filler metals, making them more amenable to dissimilar metals welding. Advances in ultrasonic and laser brazing, projection and consumable bit resistance welding, friction stir welding, hot-wire GTAW, controlled short-circuit transfer GMAW, explosion welding, and magnetic pulse welding will also be discussed in terms of their successful application to the joining of dissimilar materials.

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Understanding and Avoiding Dissimilar Weld Failures at High Temperature
John N. DuPont, R.D. Stout Distinguished Professor of Materials Science and Engineering and Associate Director of the Energy Research Center, Lehigh University

Dissimilar Joining of High Temperature Materials Using a New Nickel-Base Filler Metal
Greg Chirieleison, Technical Services Manager, Haynes Wire Co.

Explosion Welding – A Highly Versatile Welding Technology
Jeffrey A. Nicoll, Vice President, Sales and Marketing, DMC Clad Metal

Laser Welding and Laser Brazing Applications
Craig Bratt, Fraunhofer Center for Coatings and Laser Applications

Dissimilar Materials Projection Welding—Bonding Mechanisms and Process Characteristics
Jerry E. Gould, Technology Leader, Resistance Welding and Solid State Welding Processes, Edison Welding Institute

Spot Joining of Dissimilar Combinations of Steel and Light Metals Using a New Consumable Bit Technology
Michael Miles, Associate Professor, Manufacturing Engineering Technology, Brigham Young University; and Zhili Feng, Group Leader, Materials Joining and NDE Group, Materials Science and Technology Division, Oak Ridge National Laboratory

Brazing of Dissimilar Metals – Challenges and Opportunities

A GMA and GTA Process for the Welding of Dissimilar Metals
Tom Rankin, Vice President and GM, ITW Jetline Engineering

The Role of Ferrite in Dissimilar Metal Welding
Donald J. Tillack, Consultant to the Nickel Institute

Dissimilar Joining Challenges with Creep Strength-Enhanced Ferritic Steels
William F. Newell, Vice President, Euroweld Ltd.

Ultrasonic Soldering and Brazing of Dissimilar Materials
Shankar P. Srinivasan, Tim Frech, Dan Hauser, and Karl Graff, Edison Welding Institute

Friction Stir Spot Welding of Dissimilar Alloys
Tom North, Department of Materials Science and Engineering, University of Toronto

Metallurgically Bonded Transition Joints
Brett H. Keener, General Manager, Sypris Technologies, Tube Turns Division

Bimetal Welds: Is a High Level of Integrity Possible in Tubulars?
Al Wadleigh, President, Interface Welding

Magnetic Pulse Welding Joins Dissimilar Metals
Jeff Compton, Advanced Computational & Engineering Services

To register or to receive a descriptive brochure, call (800) 443-9353 ext. 455, (outside North America, call 305-443-9353), or visit www.aws.org/conferences
While the term sheet metal is usually associated with very thin galvanized sheet steel, it actually means a coated or uncoated ferrous or nonferrous metal as thick as 6.35 mm and as thin as 0.26 mm.

In today’s marketplace, one will find an abundance of sheet metal welded components in heating, ventilating, and air conditioning; industrial applications; food and beverage dispensing systems; air pollution and “airveyor” systems; and architectural metal installations.

Gas metal arc welding (GMAW) is used extensively for welding sheet metal and various power supplies have been developed to expand the versatility of the process for sheet metal applications (Table 1).

Unlike welding stainless and mild steel, when welding aluminum sheet metal, best results are obtained using argon as a shielding gas. With the work electrically negative, arc action effectively removes surface oxides.

Using DCEP and argon shielding gas, it is possible to weld thin aluminum of approximately 1.27 mm. Electrode wire sizes of 0.8-1.6 mm are commonly used. With these diameter wires, base metal melt-through and spatter are minimized. The pulsed arc variation of GMAW produces good results when welding aluminum sheet metal. Table 2 suggests current ranges for welding aluminum sheet metal.

### Table 1 — Suggested Welding Conditions for Carbon Steel and Low-Alloy Steel Sheet Metal

<table>
<thead>
<tr>
<th>GMAW Process Variation</th>
<th>Wire Diameter</th>
<th>Operating Current Range A</th>
<th>Operating Voltage Range V</th>
<th>Thickness of Metal to Be Welded</th>
<th>Shielding Gas</th>
<th>Gauge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pulsed</td>
<td>0.9</td>
<td>0.05</td>
<td>60-200</td>
<td>15-23</td>
<td>1.0 to 3.2</td>
<td>80%-95%</td>
</tr>
<tr>
<td>Spry</td>
<td>1.2</td>
<td>0.045</td>
<td>90-300</td>
<td>17-28</td>
<td>1.6 to 4.8</td>
<td>0.062 to 0.187</td>
</tr>
<tr>
<td></td>
<td>1.6</td>
<td>%</td>
<td>110-330</td>
<td>18-30</td>
<td>4.8 and over</td>
<td>0.187 and over</td>
</tr>
<tr>
<td>Spray</td>
<td>0.8</td>
<td>0.030</td>
<td>150-260</td>
<td>25-31</td>
<td>2.8-4.6</td>
<td>0.11 to 0.18</td>
</tr>
<tr>
<td>Transfer</td>
<td>0.9</td>
<td>0.035</td>
<td>125-300</td>
<td>20-28</td>
<td>1.0 to 3.2</td>
<td>0.039 to 0.125</td>
</tr>
<tr>
<td></td>
<td>1.2</td>
<td>0.045</td>
<td>155-450</td>
<td>22-32</td>
<td>1.6 to 4.8</td>
<td>0.062 to 0.187</td>
</tr>
<tr>
<td></td>
<td>1.6</td>
<td>%</td>
<td>210-500</td>
<td>24-34</td>
<td>4.8 and over</td>
<td>0.187 and over</td>
</tr>
<tr>
<td>Short</td>
<td>0.8</td>
<td>0.030</td>
<td>35-130</td>
<td>14-22</td>
<td>0.6 to 3.4</td>
<td>0.024 to 0.135</td>
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<tr>
<td>Circulating</td>
<td>0.9</td>
<td>0.035</td>
<td>55-200</td>
<td>15-23</td>
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<tr>
<td>Transfer</td>
<td>1.2</td>
<td>0.045</td>
<td>75-200</td>
<td>16-24</td>
<td>1.6 to 4.8</td>
<td>0.062 to 0.187</td>
</tr>
<tr>
<td></td>
<td>1.6</td>
<td>%</td>
<td>210-500</td>
<td>24-34</td>
<td>4.8 and over</td>
<td>0.187 and over</td>
</tr>
</tbody>
</table>


### NEW PRODUCTS

— continued from page 27

tighter, more space-restricted surface areas. They are available with 0.4- and 0.7-hp motors, suitable for precision surface conditioning and finishing. A number of speeds is available to meet surface and abrasive requirements.

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WESTEC. March 30–April 2, Los Angeles Convention Center, Los Angeles, Calif. Contact Society of Mfg. Engineers, (800) 733-4763; or visit www.sme.org/westec.


JOM-15, 15th Int'l Conf. on the Joining of Materials, and 6th Int'l Conf. on Education in Welding. May 3–6, Helsinør, Denmark. Contact JOM Institute, jom_aws@post10.tele.dk.


Center, Dayton, Ohio. Contact ASM Customer Service (800) 336-5152, ext. 0; customerservice@asminternational.org; or visit http://asmcommunity.asminternational.org/content/Events/aeromat09/.

• Weld Cracking Heat-Affected Zone Conf. June 9, 10, Columbus, Ohio. Contact American Welding Society, (800/305) 443-9353, ext. 229; or visit www.aws.org.


SOUTH-TEC. Oct. 6–8, Charlotte Convention Center, Charlotte, N.C. Contact Society of Mfg. Engineers, (800) 733-4763; or visit www.sme.org/southtec.


• FABTECH International & AWS Welding Show now including METALFORM. Nov. 15–18, McCormick Place, Chicago, Ill. 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


Boiler and Pressure Vessel Inspectors Training Courses and Seminars. Columbus, Ohio. Call (614) 888-8320; visit www.nationalboard.org.

CW/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.augusimack.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; ssstogner@epri.com.


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


# 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)

<table>
<thead>
<tr>
<th>Location</th>
<th>Seminar Dates</th>
<th>Exam Date</th>
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<tbody>
<tr>
<td>Fresno, CA</td>
<td>Jan. 11-16</td>
<td>Jan. 17</td>
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<tr>
<td>Beaumont, TX</td>
<td>Jan. 11-16</td>
<td>Jan. 17</td>
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<tr>
<td>Knoxville, TN</td>
<td>EXAM ONLY Jan. 17</td>
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<td>Miami, FL</td>
<td>Jan. 25-30</td>
<td>Jan. 31</td>
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<td>Jan. 25-30</td>
<td>Jan. 31</td>
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<tr>
<td>Corpus Christi, TX</td>
<td>EXAM ONLY Jan. 31</td>
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<tr>
<td>Pittsburgh, PA</td>
<td>Feb. 1-6</td>
<td>Feb. 7</td>
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<tr>
<td>Denver, CO</td>
<td>Feb. 1-6</td>
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<td>Seattle, WA</td>
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<td>Miami, FL</td>
<td>EXAM ONLY Feb. 19</td>
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<td>Mar. 29-Apr. 3 Apr. 4</td>
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<td>Waco, TX</td>
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<td>Nashville, TN</td>
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<td>Jacksonville, FL</td>
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<td>May 16</td>
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<td>Baltimore, MD</td>
<td>May 10-15</td>
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<td>Detroit, MI</td>
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<tr>
<td>Miami, FL</td>
<td>May 31-Jun. 5 June 6</td>
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<tr>
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<td>May 31-Jun. 5 June 6</td>
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<td>Birmingham, AL</td>
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<tr>
<td>Miami, FL</td>
<td>EXAM ONLY Jul. 16</td>
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<td>Fargo, ND</td>
<td>Jul. 12-17</td>
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<tr>
<td>Milwaukee, WI</td>
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## 9-Year Recertification Seminar for CWI/SCWI

<table>
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<tr>
<th>Location</th>
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<th>Exam Date</th>
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<tr>
<td>New Orleans, LA</td>
<td>Jan. 12-17</td>
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<td>Denver, CO</td>
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<td>Dallas, TX</td>
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<td>Sacramento, CA</td>
<td>May 4-9</td>
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<td>Pittsburgh, PA</td>
<td>Jun. 1-6</td>
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<td>San Diego, CA</td>
<td>Jul. 13-18</td>
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<td>Dallas, TX</td>
<td>Oct. 5-10</td>
<td>NO EXAM</td>
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<tr>
<td>Miami, FL</td>
<td>Nov. 30-Dec. 5 NO EXAM</td>
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For current CWIs and SCWs 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)

<table>
<thead>
<tr>
<th>Location</th>
<th>Seminar Dates</th>
<th>Exam Date</th>
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<tbody>
<tr>
<td>Atlanta, GA</td>
<td>Jan. 26-30</td>
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<td>Houston, TX</td>
<td>Mar. 2-6</td>
<td>Mar. 7</td>
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<td>Baton Rouge, LA</td>
<td>Apr. 20-24</td>
<td>Apr. 25</td>
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<tr>
<td>Columbus, OH</td>
<td>Jun. 1-5</td>
<td>Jun. 6</td>
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<td>Minneapolis, MN</td>
<td>Jul. 20-24</td>
<td>Jul. 25</td>
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<td>Philadelphia, PA</td>
<td>Aug. 31-Sep. 4 Sep. 5</td>
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<tr>
<td>Tulsa, OK</td>
<td>Oct. 5-9</td>
<td>Oct. 10</td>
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<tr>
<td>Long Beach, CA</td>
<td>Nov. 30-Dec. 4 Dec. 5</td>
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</tbody>
</table>

CWS exams are also given at all CWI exam sites.

## Certified Radiographic Interpreter (CRI)

<table>
<thead>
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<th>Location</th>
<th>Seminar Dates</th>
<th>Exam Date</th>
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<tr>
<td>Long Beach, CA</td>
<td>Feb. 2-6</td>
<td>Feb. 7</td>
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<td>Miami, FL</td>
<td>Mar. 9-13</td>
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<td>Indianapolis, IN</td>
<td>Apr. 20-24</td>
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<td>Miami, FL</td>
<td>Jun. 22-26</td>
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<td>Aug. 1</td>
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<tr>
<td>Miami, FL</td>
<td>Oct. 19-23</td>
<td>Oct. 24</td>
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</table>

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

## 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.

## Code Clinics & Individual Prep Courses

The following workshops are offered at all sites where the CWI seminar is offered (code books not included with individual prep courses): Welding Inspection Technology (general knowledge and prep course for CWI Exam-Part A); Visual Inspection Workshop (prep course for CWI Exam-Part B); and D1.1 and API-1104 Code Clinics (prep courses for CWI Exam-Part C).

## On-site Training and Examination

On-site training is available for larger groups or for programs customized to meet specific needs of a company. Call ext. 455 for more information.

## 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/international_contact.html
We would like to thank the following donors who responded to our
direct solicitation, in November 2007, for the Welding for the Strength of America Capital Campaign. Their
ccontributions will benefit the workforce development initiative. (Donors from November 2007 – October 20, 2008.)

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Patrick Wilger
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K. C. Wu

For more information on the AWS Foundation and its programs, contact Sam Gentry at (800) 443-9353 ext. 331
The recent FABTECH International & AWS Welding Show offered the ideal opportunity to recognize many AWS volunteers who have served the Society and the welding industry over the years. The presentations included recognitions for anniversary years of membership, service on technical committees and the Welding Handbook Committee, contributions to the AWS Foundation, and performing as national officers. The photographs tell the stories.

Roy M. Morton (left) accepts his Gold Membership certificate for 50 years of service to the Society from AWS President Gene Lawson.

Idaho/Montana Section Chair Paul Tremblay (center) and Vice Chair Bruce Madigan (left) are shown with AWS Foundation Chair Ron Pierce as the Section is recognized for its endowed scholarship program.

Lee Kvidahl (right), a past AWS president, receives his Life Membership award for 35 years of service from Gene Lawson, AWS president during the Section Appreciation Luncheon held Oct. 8.

Gene Lawson (left) receives a plaque commemorating his year of service as AWS president from Ray Shook, AWS executive director, at the Show.

Phillip I. Temple (right), retiring chairman of the Welding Handbook Committee, accepts a plaque in appreciation for his services from Victor Y. Matthews, AWS president-elect, in recognition for his 21 years of service to the preparation and publication of the Welding Handbook. Temple is principal engineer/welding materials for Detroit Edison. Temple has participated on the Welding Handbook Committee continuously since 1987, during which time he served two terms as chairman. His tenure spanned the four-volume Eighth Edition and the three published volumes of the Ninth Edition of the Handbook.

As a long-time AWS volunteer, Temple was designated an AWS Distinguished Member in 1990 and presented the National Meritorious Award in 2000. Currently, he serves on the AWS Technical Activities Committee.

The award-presentation ceremony took place Oct. 6 at the Welding Show in Las Vegas, Nev.
AWS Membership Committee Meets at the Show

Shown during the National Membership Committee meeting held during the recent FABTECH Int'l & AWS Welding Show are (from left) Ray Shook, AWS executive director; Rhenda Mayo, director, AWS member services; Tully Parker, District 14 director; Jack Compton, District 21 director; AWS Vice Presidents John Bruskotter and John Mendoza; Jim Appledorn, Lincoln Electric; Committee Chair Lee Kvidahl, Northrup Grumman Ship Systems; Russ Norris, District 1 director; Cassie Burrell, AWS deputy executive director; Dennis Eck, National Alloys & Equipment; and Karen Gilgenbach, AGA, member of Linde Gas.

Eleanor Ezell (far right), Mobile Section secretary, has earned Winner's Circle status six years in a row in the Member-Get-A-Member campaign for recruiting 20 or more new Individual Members each year. Ezell volunteered to work at the AWS booth during the FABTECH Int'l & AWS Welding Show with AWS staff members (from left) Nazdhia Pradopulido, Rhenda Mayo, Vi- vian Pupo, and Vicki Pinsky. Photo was taken by Terry Gildon, Nebraska Section.

Bob Ames (right), past president of the Gases and Welding Distributors Association (GAWDA), receives his AWS Life Member plaque and pin from AWS 2008 President Gene Lawson (center) and AWS Executive Director Ray Shook. Celebrating 35 years of AWS membership, the presentation was made at the 2008 GAWDA Annual Convention, held Sept. 21–25 in Nassau, Bahamas.
Ron Pierce, chair, AWS Foundation board of trustees, and Sam Gentry, executive director, Foundation, presented representatives from the Idaho/Montana, Lehigh Valley, Sacramento, and York Central Pennsylvania Sections special banners to recognize their establishment of Named Scholarships. These new Named Scholarships are: Idaho/Montana Section — Paul O'Leary Memorial Scholarship; Lehigh Valley Section — Prof. Robert D. Stout Scholarship; Tri-Tool — Sacramento Section Named Scholarship; and York Central Pennsylvania Section — Shirley Bollinger — District 3 Scholarship. The Baton Rouge Section was recognized for being the second Section to exceed $100,000 in donations to the Foundation's scholarship programs.

Longtime Members Feted at Appreciation Luncheon

AWS members who achieved 50-, 35-, and 25-year membership milestones during the calendar year, and who opted to receive their certificates at the Show from President Gene Lawson, were introduced at the Years-of-Service Recognition Ceremony held during the Section Appreciation Luncheon. In attendance to receive their certificates were 50-Year Gold Members Roy M. Morton and Harry W. Ebert; 35-Year Life Members John Fialko, David Fredianelli, Gordon Gibbs, Lee G. Kvilahl, Stuart Rogers, Richard J. Rowe, Joe L. Scott, Albert J. Sirois Jr., John Walvoord, and William S. Weinschenker; and 25-Year Silver Members Larry Barley, Dwight Bower, Norman Brown, Philip Grim, P. K. Gupta, James Jensen, Jerzy Nowicki, Anna Petroski, Anatol Rabinkin, Dwain Rittenhouse, Michael Santella, and Ken Stockton.
B1 Committee Makes Headway on its NDE Standards

Welding holds the world together and AWS holds the world of welding together. The B1 Technical Committee members shown above were doing just that at their recent meeting in Las Vegas, Nev., during the FABTECH Int'l & AWS Welding Show. During the meeting they resolved some of the remaining comments prior to publishing new editions of the popular B1.10 and B1.11 standards on visual and nondestructive examination. Shown are (front row, from left) Richard Doornink, B1 Vice Chairs Bill Komlos and Kent Baucher; Bob Clarke, and B1B Chair Al Moore; (second row, from left) Bill Baker, Richard “Woody” Cook, Harland Thompson; (third row, from left) Todd Studebaker, B1C Chair Uwe Aschemeier, Blake Craft; and (back row, from left) Dick Holdren, Ed Harmon, and Al Johnson. The photo was taken by Brian McGrath, B1 committee secretary.

Standards for ANSI Public Review

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 two standards are open for public review until the dates shown. Draft copies may be obtained from Rosalinda O’Neill, ext. 451, roneill@aws.org.

Technical Committee Meetings

Errata D1.3 and C3.7

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

Page 25, subclause 4.6.1.1, incorrect reference. Change from “3.2” to “Clause 3”.
Page 26, subclause 4.6.2.1, incorrect reference. Change from “3.3” to “Clause 3”.
Page 26, 4.6.3.1, incorrect reference. Change from “3.4” to “Clause 3”.

C3.7M/C3.7:2005, Specification for Aluminum Brazing

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

Subject: Procedure for Dip Brazing
Page 7, subclause 5.7.8, second paragraph, last sentence. Replace the sentence with the following: “The temperature of the bath shall not exceed the maximum temperature of the brazing procedure specification (BPS).”
In addition, the official definition for Brazing Procedure Specification (BPS) is to be inserted into Clause 3.
AWS A3.0, Standard Welding Terms and Definitions, defines BPS as “a document specifying the required brazing variables for a specific application.”

Robotic Arc Welding Awards Changes Announced

December 31 is the deadline for submitting nominations for the 2009 Robotic and Automatic Arc Welding Award. The award will now be presented by the AWS Milwaukee Section during the National Robotic Arc Welding Conference and Exhibition. The next conference will be held May 11–13, 2009, at Milwaukee Area Technical College.
The award, funded by private contributions, includes a $1500 honorarium and a commemorative plaque. The nomination packet should include a summary statement of the candidate’s accomplishments, interests, educational background, professional experience, publications, honors, and awards. Send your nomination packet to Matthew Rubin, secretary, D16 Committee, American Welding Society, 550 NW LeJeune Rd., Miami, FL 33126. For more information, contact Rubin at mrubin@aws.org, or call (800/305) 443-9353, ext. 215.
In 2004, the AWS D16 Robotic and Automatic Arc Welding Committee, with the approval of the AWS Board of Directors, established the Robotic and Automatic Arc Welding Award to recognize individuals for their significant achievements. This work can include the introduction of new technologies, establishment of the proper infrastructure (training, service, etc.) to enable success, and any other activity that has significantly improved the state of a company and/or the industry.
Shown at the joint Boston-Central Mass./Rhode Island Sections’ program are (from left) Al Caron, Jon Marland, Dave Marland, Boston Section Vice Chair Tom Ferri, Thomas Handfield, Tim Byrne, Frederick Foeri, and Bob Walker.

Shown at the Long Island Section program are (from left) Tom Mazzarella, Jack McEnerney, Ray O’Leary, District 2 Director Ken Stockton, Section Chair Brian Cassidy, Anthony Zampelli, Alex Duschere, Harland Thompson, and Al Fleury, a past chairman.

District 1
Russ Norris, director
(207) 283-1861
rnorris@maine.rr.com

BOSTON-CENTRAL MASS./RHODE ISLAND
OCTOBER 7
Speakers: Al Caron, welding instructor; and Dave Marland, training coordinator
Affiliation: Local 51, United Association of Journeymen and Apprentices of the Plumbing and Pipefitting Industry
Topic: The methods used to instruct and certify apprentices in the fitting and welding of pipe and tubing of all sizes and materials using SMA, GMA, GTA, and orbital GTA welding processes
Activity: The members of the Boston and Central Mass./Rhode Island Sections toured the Local 51 facilities. Program Chair Tom Ferri presented a plaque of appreciation to the speakers and tour guides.

District 2
Kenneth R. Stockton, director
(908) 412-7099
kenneth.stockton@pseg.com

LONG ISLAND
SEPTEMBER 18
Activity: The Section hosted its annual hands-on meeting and cook-out at Standard Industrial Works in Lindehurst, N.Y. Chairman Brian Cassidy conducted the program. District 2 Director Ken Stockton attended the event.
Shown at the Southwestern Virginia Section meeting are (from left) J. J. Vagi, Bob Fitch, Dave Cash, Troy Linkenhoker, Bill Rhodes, Wayne Johnson, Ed Wyatt, and Ted Alberts.

Welding instructor Ron Vann (left) is shown with Steve Mattson, District 5 director; Justin Gifford, AWS scholarship recipient; and Gale Mole, South Carolina Section chairman.

Shown (from left) are Ron Vann; Steve Mattson, District 5 director; welding contest winners Will Hunt III and Chris Lawrimore; and Gale Mole, South Carolina Section chair.

Shown at the South Carolina Section program are (from left) Chair Gale Mole, District 5 Director Steve Mattson, and speaker Sergio Smith.

Speaker Michael White (left) is shown with Lee Clemens, Florida West Coast Section chairman.

**District 3**
Alan J. Badeaux Sr., director  
(301) 753-1759  
abadeaux@ccboe.com

**District 4**
Roy C. Lanier, director  
(252) 321-4285  
rlanier@email.pittcc.edu

**SOUTHWESTERN VIRGINIA**
OCTOBER 16
Activity: The Section held an executive committee meeting. In attendance were J. J. Vagi, Bob Fitch, Dave Cash, Troy Linkenhoker, Bill Rhodes, Wayne Johnson, Ed Wyatt, and Ted Alberts.

**District 5**
Steve Mattson, director  
(904) 260-6040  
stevemattson @ bellsouth.net

**FLORIDA WEST COAST**
OCTOBER 8
Speaker: Michael G. White, psychotherapy  
Affiliation: Personal Growth Behavioral Health, Inc.  
Topic: Anger management in the workplace  
Activity: The program was held at Frontier Steak House in Tampa, Fla.

**SOUTH CAROLINA**
SEPTEMBER 18
Speaker: Sergio Smith, CEO  
Affiliation: International Diving Institute  
Topic: Careers in underwater welding and cutting  
Activity: Following the talk, Smith presented demonstrations of underwater welding and cutting. Steve Mattson, District 5 director, presented AWS student memberships to students studying welding at Trident Technical College with instructor Ron Vann. An AWS scholarship was presented to Justin Gifford. Also recognized were Will Hunt III and Chris Lawrimore, the first-place winners in the South Carolina Technical College annual welding competition. The program was held at International Diving Institute in Charleston, S.C.

**District 6**
Neal A. Chapman, director  
(315) 349-6960  
weldingengineer@inbox.com
NORTHERN NEW YORK
OCTOBER 7
Activity: The Section members toured Hannay Reels in Westerlo, N.Y., to study the manufacture of hose reels for industrial and domestic applications. Eric Hannay and Dennis Fancher conducted the program.

COLUMBUS
SEPTEMBER 25
Speaker: Stanley Ream, technology leader
Affiliation: Laser Welding
Topic: High-speed laser beam welding of fuel cell materials
Activity: The Section, under the guidance of John Lawmon, treasurer, has led an initiative to bring eight local technical societies together to develop a varied technical and social program for the coming year. The effort will support continuing education, provide increased networking opportunities, and address falling attendance experienced by all of the societies. The participating societies include The Society of Women Engineers, ASME, ASM Int’l, Institute of Industrial Engineers, American Institute on Aeronautics and Astronautics, Inc., NACE Int’l, ISA, and AWS.

DAYTON
AUGUST 29
Activity: The Section hosted its annual golf outing at Sugar Isle Golf Course in New Carlisle, Ohio. The event raised $420 for the Section’s Les Vesey Memorial Scholarship Fund.

JOHNSTOWN/ALTOONA
OCTOBER
Activity: The Section members toured Brookville Equipment Corp. in Brookville, Pa., to study the manufacture of mining equipment and locomotives. Attending were students Jimmy Smiley, James McConnell, Tyler Shelby, Jacob Wingard, and Eric Jones, and Triangle Tech Student Chapter Advisor Brenda Benyon. District 7 Director Don Howard attended the event.

District 7
Don Howard, director
(814) 269-2895
howard@ctc.com

District 8
Joe Livesay, director
(931) 484-7502, ext. 143
joe.livesay@ttcc.edu

CHATTANOOGA
SEPTEMBER 23
Speaker: Danny Sechler, business development
Affiliation: Applied Thermal Coatings, Inc.
Topic: The need for personnel trained in welding, NDE, and heat treatment
Activity: Sechler announced plans for the new American Welding & Energy Solutions Center to be located in Chattanooga. Sechler, with Training Director...
The Northeast Mississippi Section members are shown during their September field trip.

Northeast Mississippi Section members are dwarfed by the huge coal bucket during their tour of Red Hills Coal Mine in October.

The incoming officers of the Lawson State C. C. Student Chapter pose for a group shot. Seated (from left) are Will Peppins and Maria Miller. Standing (from left) are Maurice McSwain, Marcus Smiley, Jereme Jones, Brooks Powell, and Chair Dennis Wyatt.

Welding instructor Dave Hamilton (right), chats with (from left) Greg Whitoak, Gene Lestage, and Greg Wilmoth at the Chattanooga Section program.

Speaker Jackie Morris (left) is shown with Josh Sanders, Mobile Section chairman.

Al Lovins and others, support plans to bring welder education and training to the community. Acknowledged were Lincoln Electric and Airgas for their financial support of the center. John Roe represented Airgas and Rick Friedmann represented Lincoln Electric. The program was held at the Komatsu manufacturing facility in Chattanooga, Tenn.

NORTHEAST MISSISSIPPI
SEPTEMBER 18
Activity: The Section members toured the Mississippi State University Center for Vehicular Systems/Navistar in West Point, Miss. The facility manufactures military vehicles including the mine-resistant ambush protection (MRAP) vehicle.

OCTOBER 16
Activity: The Northeast Mississippi Section members toured the Red Hills Coal Mine in Ackerman, Miss. Butch Davis, manager, North American Coal Co., conducted the program.

District 9
George D. Fairbanks Jr., director
(225) 473-6362
fits@bellsouth.net

Lawson State C. C. Student Chapter
OCTOBER 10
Activity: Chapter Advisor Roy L. Ledford hosted the election of the Student Chapter officers. Elected were Dennis Wyatt, chair; Marcus Smiley, vice chair; Maria Miller, secretary; Jereme Jones, treasurer; Maurice McSwain, membership chair; Will Peppins, program chair; and Brooks Powell, publicity chair. The program was held at Lawson State C. C. in Bessemer, Ala.

MOBILE
OCTOBER 16
Speakers: Jackie Morris and Dale Jermyn
Affiliation: Bender Shipbuilding & Repair Co., Inc.
Topic: Applying welding economics to improve the environment
Activity: The meeting was held at Saucy Q Barbecue in Mobile, Ala.

District 10
Richard A. Harris, director
(440) 336-5921
richaharris@alltel.net
Tom Treiber served as committee chair for the Fox Valley Section’s golf outing.

**District 11**

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

**DETROIT**

October 9
Speaker: Anthony J. Kiszka, information systems manager
Affiliation: Orbitform Group
Topic: Advancements in control of welding and joining processes using process monitoring and control
Activity: The Detroit Section celebrates its 85th anniversary this year. The new member drive has attracted more than 160 new members during 2008. The program was held at the Ukrainian Culture Center in Warren, Mich.

**District 12**

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

**FOX VALLEY**

August
Activity: The Section’s officers met to plan the upcoming year’s events, to include technical sessions, plant tours, a students’ night, a sporting clay shoot, and golf outing. Sean Moran, District 12 director, participated in the meeting.

September 8
Activity: The Fox Valley Section hosted its annual golf outing at Irish Waters Golf Course in Freedom, Wis.

**LAKE SHORE**

October 9
Activity: The Section members toured U.A. Local #400 Plumbers and Steamfitters training facility in Kaukauna, Wis. The tour included the classrooms and ex-
MILWAUKEE

October 16
Activity: The Section members toured the Vilter Manufacturing Co. in Cudahy, Wis., to study the manufacture of high-performance refrigeration compressors, condensers, air units, and custom petrochemical packages. Tour guides included Charlie Klockner, Chris Molnar, and Steven A. Walter.

District 13

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

CHICAGO

September 24
Activity: The Section held a board of directors meeting at Bohemian Crystal Restaurant in Chicago, Ill., for ten attendees.

District 14

Tully C. Parker, director
(618) 667-7795
tparke@millerwelds.com

LEXINGTON

September 18
Speakers: Jerry Mathison, Mick Sherry, and Trent Spackman
Affiliation: ESAB Welding and Cutting Products
Topic: GMA and plasma arc welding
Activity: The Section presented $500 scholarships to welding students Scott Stringer, Matthew Mattox, and James Mattox. District 14 scholarships were presented to Lisa Colwell, Eddie Bailey, Warren Combs, and Jeremy Moore. Ninety Section members and guests attended this program held at Bluegrass Community College in Lexington, Ky.

October 3
Activity: The Lexington Section hosted a welding contest held for 90 participants at Somerset Community College.

District 15

Mace V. Harris, director
(612) 861-3870
macevh@aol.com
The Franklin CCTC team took second place in the Lexington Section contest. Shown are (standing, from left) instructor Randy Shewmaker, Garrett Turner, Kyle Shupert, and T.C. Clay; (front, from left) Righter Dundon and Keith Bradshaw.

District 16
David Landon, director
(641) 621-7476
dlandon@vermeermfg.com

IOWA
OCTOBER 7
Activity: The Section members toured Modine Manufacturing Co. in Washington, Iowa. Michael J. Skubal, plant superintendent, conducted the tour. He explained how the company vacuum brazes and welds heat exchanger parts together.

KANSAS CITY
OCTOBER 9
Activity: The Section members toured Webco Manufacturing Co. in Olathe, Kan., to observe its GMA and SA welding processes, robotic welding cells, laser cutting machines, and CNC machining centers. Jordan Wineland, welding shop manager, conducted the program.

NEBRASKA
OCTOBER 6–8
Activity: Several members attended the FABTECH Int’l & AWS Welding Show in Las Vegas, Nev., including Chairman Karl Fogleman, Treasurer Rick Hanny, Awards Chair Josh Mayne, and Membership Chair Eric Nordhues.

District 17
J. J. Jones, director
(940) 368-3130
jjones@thermadyne.com

Shown at the September meeting of the Lexington Section are (from left) Frank McKinley with scholarship winners Matthew Mattox, Scott Stringer, and James Mattox.

Shown at the Iowa Section program are (from left) Bruce Spire, Mike Bloem, presenter Michael Skubal, Charles Berg, and Joe Paulsen.

Kansas City Section Vice Chair Mike Vincent (left) is shown with presenter Jordan Wineland (center), and past Chair Dennis Wright.

Nebraska Section members visited the AWS booth at the show. Shown (from left) are Chair Karl Fogleman; Eric Nordhues; Rhenda Mayo, director, member services; Josh Mayne; and Rick Hanny.
British Columbia Section executives pose at the September meeting. Shown (from left) are Eric Waterfield, Roger Moren, Steve Prost, Barry Donaldson, Brenda Moe, Brad Moe, John Little, Bill Rhodes, and Chairman Pat Newhouse.

Colorado Section members are shown during their tour of Big R Bridge Co. Speaker Wade Lutz is 4th from the left, Chairman James Corbin is 6th from the left, and Bob Teuscher is 7th from left.

Dale Hardy discussed the LeTourneau legacy for the East Texas Section members.

Shown at the Tulsa Section program are (from left) Adam Ensminger and speaker Kevin Ishmael.

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Shown at the Tulsa Section program are (from left) Adam Ensminger and speaker Kevin Ishmael.
COLORADO

SEPTEMBER 11
Activity: The Section members toured Big R Bridge Co. in Greeley, Colo. Wade Lutz, CWI, quality control manager, presented a talk and guided a tour of the facilities. The company makes highway, railroad, and pedestrian bridges in addition to culvert pipe and cattle guards. Bob Teuscher, a past AWS president, attended the tour.

District 20 Conference
JUNE 7
Activity: The Utah Section members hosted the District 20 conference in Salt Lake City, Utah. District 20 Director Bill Komlos conducted the business meeting. A highlight of the event was a tour of the new 22 story 222 Main Building.

LONG BEACH/ORANGE COUNTY

OCTOBER 7
Activity: Several Section members attended the FABTECH Int’l & AWS Welding Show in Las Vegas, Nev.

SAN FRANCISCO

OCTOBER 1
Speaker: Kerry Shatell, senior welding engineer
Affiliation: Pacific Gas & Electric Co.
Topic: Welding on in-service natural gas transmission pipelines
Activity: An Image of Welding talk was presented by Tom Smeltzer who emphasized the need for professional welders in the U.S. economy.

Lisa Pine, San Francisco Section chair, is shown with speaker Kerry Shatell.
Shown are the Oct. 20 standings for the 2008-2009 MGM campaign. See page 65 of this Welding Journal or visit www.aws.org/mgm for rules and prize list. Call the Membership Dept., (800) 443-9353, ext. 480, regarding your status.

**Winner's Circle**

Sponsored 20+ new members.

The superscript indicates the number of times the member has achieved Winner's Circle status since June 1, 1999. J. Compton, San Fernando Valley\(^7\)

E. Ezzell, Mobile\(^6\)

J. Merzthal, Peru\(^2\)

G. Talyor, Pascagoula\(^4\)

L. Taylor, Pascagoula\(^9\)

B. Mikeska, Houston\(^1\)

R. Peaslee, Detroit\(^1\)

W. Shreve, Fox Valley\(^1\)

M. Karagoulis, Detroit\(^1\)

S. McGill, NE Tennessee\(^1\)

T. Weaver, Johnstown/Altoona\(^1\)

G. Woomer, Johnstown/Altoona\(^1\)

R. Wray, Nebraska\(^1\)

M. Haggard, Inland Empire\(^1\)

**President's Honor Roll**

M. Boggs, Stark Central — 2

M. Boyer, Detroit — 2

B. Donaldson, British Columbia — 2

F. Hendrix, New Jersey — 2

R. Johnson, Detroit — 2

J. Padilla, Cuauitlan Izcalli — 2

J. Polson, L.A./Inland Empire — 2

J. Sisson, Niagara Frontier — 2

K. Smith, North Texas — 2

A. Stute, Madison-Beloit — 2

D. Thomasom, Chicago — 2

M. Vung, Portland — 2

P. Zanniul, Spokane — 2

**Student Member Sponsors**

Sponsored 5 or more students.

D. Berger, New Orleans — 109

A. Rowe, Philadelphia — 36

A. Zinn, Eastern Iowa — 34

B. Benyon, Pittsburgh — 33

T. Moore, New Orleans — 32

J. Carney, Western Michigan — 26

C. Daon, Israel — 5

W. Rice, Tri-State — 5

R. Newman, Maine — 4

B. Varnyi, Cleveland — 4

C. Becker, Northwest — 3

R. Elenbecker — 3

M. Rahn, Iowa — 3

M. West, Western Carolina — 3

D. Wright, Kansas City — 3

**Supporting Companies**

Coleman Cable, Inc. 1520 Shields Dr., Waukegan, IL 60085

Swaby Professional Welding 46950 Community Plaza, Ste. 213 Sterling, VA 20164

TDI Alumitek Div. 1901 W. Main St. Stoudsburg, PA 18360

WHESCO Corp. 2989 Kingsgate Way Richland, WA 99354

**Member-Get-A-Member Campaign**

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L. Taylor, Pascagoula\(^9\)

B. Mikeska, Houston\(^1\)

R. Peaslee, Detroit\(^1\)

W. Shreve, Fox Valley\(^1\)

M. Karagoulis, Detroit\(^1\)

S. McGill, NE Tennessee\(^1\)

T. Weaver, Johnstown/Altoona\(^1\)

G. Woomer, Johnstown/Altoona\(^1\)

R. Wray, Nebraska\(^1\)

M. Haggard, Inland Empire\(^1\)

**President's Honor Roll**

M. Boggs, Stark Central — 2

M. Boyer, Detroit — 2

B. Donaldson, British Columbia — 2

F. Hendrix, New Jersey — 2

R. Johnson, Detroit — 2

J. Padilla, Cuauitlán Izcalli — 2

J. Polson, L.A./Inland Empire — 2

J. Sisson, Niagara Frontier — 2

K. Smith, North Texas — 2

A. Stute, Madison-Beloit — 2

D. Thomasom, Chicago — 2

M. Vung, Portland — 2

P. Zanniul, Spokane — 2

**Student Member Sponsors**

Sponsored 5 or more students.

D. Berger, New Orleans — 109

A. Rowe, Philadelphia — 36

A. Zinn, Eastern Iowa — 34

B. Benyon, Pittsburgh — 33

T. Moore, New Orleans — 32

J. Carney, Western Michigan — 26

C. Daon, Israel — 5

W. Rice, Tri-State — 5

R. Newman, Maine — 4

B. Varnyi, Cleveland — 4

C. Becker, Northwest — 3

R. Elenbecker — 3

M. Rahn, Iowa — 3

M. West, Western Carolina — 3

D. Wright, Kansas City — 3

**Supporting Companies**

Coleman Cable, Inc. 1520 Shields Dr., Waukegan, IL 60085

Swaby Professional Welding 46950 Community Plaza, Ste. 213 Sterling, VA 20164

TDI Alumitek Div. 1901 W. Main St. Stoudsburg, PA 18360

WHESCO Corp. 2989 Kingsgate Way Richland, WA 99354

**New AWS Supporters**

**Affiliate Companies**

Highland Tank One Highland Rd., PO Box 338 Stoystown, PA 15563

INTI Av. Gral. Paz 5445, San Martin Buenos Aires, Argentina

Marton Precision Mktg. 1365 S. Acacia, Fullerton, CA 92831

Park Steel Inc. 515 E. Pine St., Compton, CA 90222

SKC SIU Engineering Ltd. Unit 112, 17 Fawcett Rd. Coquitlam, BC V3K 6V2, Canada

Summit Anchor Co., Inc. 4507 Metropolitan Ctr., Ste. F Frederick, MD 21704

Swaby Professional Welding 46950 Community Plaza, Ste. 213 Sterling, VA 20164

TDI Alumitek Div. 1901 W. Main St. Stoudsburg, PA 18360

WHESCO Corp. 2989 Kingsgate Way Richland, WA 99354

**Supporting Companies**

Coleman Cable, Inc. 1520 Shields Dr., Waukegan, IL 60085

**Shade ‘n Net**

5711 W. Washington St., Phoenix, AZ 85043

**Welding Distributor**

American Welding & Gas, Inc. 320 N. 11th St., Billings, MT 59101

**Educational Institutions**

Area Career Technical Center 2201 S. Knoxville, Russellville, AR 72801

Branch Area Career Center 366 Morris St., Coldwater, MI 49036

Evanson Township High School 1600 Dodge Ave., Evanson, IL 60204

J. Everett Light Career Center 1901 E. 86th St., Indianapolis, IN 46240

Lee High School 6529 Beverly Hill Ln., Houston, TX 77057

Monroe 2 BOCES Career & Technical Education Center 3589 Big Ridge Rd. Spencerport, NY 14559

National Institute of Technology (NIT) Bahra Industrial Complex Main Rd. Bahra, Jeddah, Saudi Arabi

Southern Arkansas University Tech 100 Carr Rd., PO Box 3499 Camden, AR 71701

TONATCO Cryogenic Services, Inc. 1906 Old Holzwarth Rd. Spring, TX 77388

**Membership Counts**

Table:

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<th>Category</th>
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<td>Individual Member</td>
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<td>Student Member</td>
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**Actions of the AWS Board of Directors**

On Oct. 5, 2008, after due consideration of the recommendations by Districts Council, the AWS Board of Directors approved to disband the AWS Baltimore Section, District 3. The AWS South Sound Student Chapter was approved for charter at Olympic College, Shelton Campus, District 19; and the AWS ESPOL Student Chapter was chartered in Ecuador. The AWS Jamestown Community College Student Chapter, District 6, was disbanded.
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, or 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.

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 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.

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 possible. The Society welcomes your suggestions. Please contact any staff member or AWS President Gene E. Lawson, as listed on the previous page.
North America’s largest metal forming, fabricating & welding trade show heads to Chicago for 2009. Reach new markets and buyers located in one of the strongest manufacturing regions of the country. Reserve your booth now! Space is limited. Call today for exhibiting information.

cosponsored by

American Welding Society
(800) 443-9353
www.aws.org/show

Fabricators & Manufacturers Association, Intl
(800) 432-2832
www.fmafabtech.com

Society of Manufacturing Engineers
(800) 733-3976
www.sme.org/fabtech

Precision Metalforming Association
(800) 541-5336
www.metalform.com
PROFESSIONAL PROGRAM ABSTRACT SUBMITTAL
Annual FABTECH International & AWS Welding Show
Chicago, IL – November 15-18, 2009

Submission Deadline: March 13, 2009

(Complete a separate submittal for each paper to be presented.)

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<th>Primary Author (Full Name):</th>
<th>Co-Author(s):</th>
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</tbody>
</table>

**Answer the following about this paper**

- Original submittal? Yes □ No □
- Progress report? Yes □ No □
- Review paper? Yes □ No □
- Tutorial? Yes □ No □
- What are the welding/Joining processes used?
- What are the materials used?
- What is the main emphasis of this paper? Process Oriented □ Materials Oriented □ Modeling □
- To what industry segments is this paper most applicable?
- Has material in this paper ever been published or presented previously? Yes □ No □
  - If “Yes”, when and where?
- Is this a graduate study related research? Yes □ No □
- If accepted, will the author(s) present this paper in person? Yes □ Maybe □ No □

**Keywords:** Please indicate the top four keywords associated with your research below

Guidelines for abstract submittal and selection criteria:

- Only those abstracts submitted on this form will be considered. Follow the guidelines and word limits indicated.
- Complete this form using MSWord. Submit electronically via email to techpapers@aws.org

**Technical/Research Oriented**
- New science or research.
- Selection based on technical merit.
- Emphasis is on previously unpublished work in science or engineering relevant to welding, joining and allied processes.
- Preference will be given to submittals with clearly communicated benefit to the welding industry.

**Applied Technology**
- New or unique applications.
- Selection based on technical merit.
- Emphasis is on previously unpublished work that applies known principles of joining science or engineering in unique ways.
- Preference will be given to submittals with clearly communicated benefit to the welding industry.

**Education**
- Innovation in welding education at all levels.
- Emphasis is on education/training methods and their successes. Papers should address overall relevance to the welding industry.

- Check the category that best applies:
  - □ Technical/Research Oriented
  - □ Applied Technology
  - □ Education
Proposed Title (max. 50 characters):

Proposed Subtitle (max. 50 characters):

Abstract:
Introduction (100 words max.) – Describe the subject of the presentation, problem/issue being addressed and its practical implications for the welding industry. Describe the basic value to the welding community with reference to specific communities or industry sectors.

Technical Approach, for technical papers only (100 words max.) – Explain the technical approach, experimental methods and the reasons why this approach was taken.

Results/Discussion (300 words max.) – For technical papers, summarize the results with emphasis on why the results are new or original, why the results are of value to further advance the welding science, engineering and applications. For applied technology and education papers, elaborate on why this paper is of value to the welding community, describe key aspects of the work developed and how this work benefits the welding industry and education.

Conclusions (100 words max.) – Summarize the conclusions and how they could be put to use – how and by whom.

NOTE: Abstract must not exceed one page and must not exceed the recommended word limit given above

Note: The Technical Program is not the venue for commercial promotions of a company or a product. All presentations should avoid the use of product trade names. The Welding Show provides ample opportunities for companies to showcase and advertise their processes and products.

Return this form, completed on both sides, to

AWS Education Services
Professional Program 2009
550 NW LeJeune Road
Miami FL 33126
FAX 305-648-1655

MUST BE RECEIVED NO LATER THAN MARCH 13, 2009
The 250-page Cylinder Catalog features the company’s lines of medium-duty, heavy-duty, large-bore, linear positioning, and metric ISO cylinders. Detailed information is provided for each, including data sheets, service instructions, mounting details, schematics, and technical specifications. Profusely illustrated with numerous photographs, graphics, tables, and charts, the catalog is organized into six sections to simplify finding the information of interest. View or download the PDF catalog online at the Web site shown.

Bosch Rexroth Corp.
www.boschrexrothproducts.com/5_days
(610) 694-8298

Ceramic Tools for Grinding Hard Materials Detailed

An eight-page, well-illustrated, full-color brochure displays the company’s line of belts, flap wheels, and fiber discs for grinding hard metals including stainless steel, high-alloy steels, titanium, nickel-based alloys, and rolling scale. Featured are the ceramic-oxide CO-COOL tools for cool grinding and good stock removal for hard metals with poor thermal conductivity. Included is the new COMBIDISC® mini discs. The brochure lists several specific examples of applications for dressing hard weld joints, automatic surface finishing, fine grinding in the manufacture and maintenance of jet engines and turbines, construction of stationary gas, steam, and water turbines, and grinding V4A components in water-management systems. Shown are the quick-change and standard arbor hole mounting types of discs plus soft, medium, and hard flexibility grades of mounting pads from 2 to 7 in. diameters. The belt section includes 23 different width/length sizes with four grits from 40 to 80. The brochure can be downloaded from the Web site.

PFERD Inc.
www.pferdusa.com
(978) 840-6420

Prefab Storage Systems for Hazardous Materials Pictured in Brochure

A four-page, full-color brochure illustrates nine examples of the company’s wide

For info go to www.aws.org/ad-index
variety of storage buildings custom-engineered to safely store all types of hazardous materials. Built and installed according to each customer’s special needs, the prefabricated steel structures include wiring, lighting, plumbing, HVAC, and other amenities as required. One page presents a brief company history and its policies with its motto, "Hazardous material containment systems designed for the way you work".

Safety Storage Inc.
www.safetystorage.com
(800) 344-6539

Symbols for Welding Course Updated

The popular Symbols for Welding curriculum has been released as a totally revised edition on a DVD with an Instructor’s Guide. Using video views shot by industry professionals, the topics include an introduction to all of the various welding symbols essential to reading blueprints. Instructors may purchase student workbooks and tests for their students to complete the curriculum. The package is recommended for AWS entry-level SENSE (QC10 and EG20) programs. The curriculum is based on AWS A2.4:2007, Standard Symbols for Welding, Brazing, and Nondestructive Examination. For more information or to order, visit the Web site or call.

Fun Welding Projects Featured in New Book

The 200-page, paperback book, Arc Welded Projects, Vol. IV, presents 16 agriculture, 11 trailers, 16 shop, 14 home and recreation, and 5 miscellaneous hands-on fun welding projects. Each project includes the materials list, complete plans, step-by-step instructions for assembly and welding, and the names of the contributing student and instructor with their school and location. The other three volumes in this Arc Welded Projects series are also available. These projects represent the range of entries submitted to the Foundation’s awards programs sponsored annually for secondary and postsecondary students. Priced at $10, the volume may be ordered online or call for information.

Hobart Institute of Welding Technology
www.welding.org
(800) 332-9448, ext. 5433

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For additional information, please contact FosteReprints, the official reprint provider for Welding Journal. Email: sales@fostereprints.com or call 866-879-9144
PFERD Names Manager Aviation Markets

PFERD Inc., Leominster, Mass., has appointed Lou Padmos to the newly created position of manager, aviation markets. Padmos, based in Graham, N.C., will be responsible for developing sales of the company’s lines of abrasives and power tools in the aircraft manufacturing and maintenance markets nationwide.

Acquisitions VP Appointed at Praxair

Praxair Distribution, Inc., Danbury, Conn., has named Steve Byers vice president of acquisitions. He succeeds Rob D’Alessandro who remains chairman of the board of the Praxair Distribution Mid-Atlantic joint venture. Previously, Byers served as general manager for the company’s southern division.

Alberici Constructors Announces Five New Hires

Alberici Constructors, St. Louis, Mo., has hired Adam Gacioch as a project engineer; Caitlin Huber, project engineer at the Platte West Water Treatment Plant in Omaha, Neb.; Molly Roberts, project administrator; Zane Truman, project engineer working in the general building market; and Mark Clancy as an assistant project manager at Hillsdale Fabricators, Alberici’s steel subsidiary.

ESAB Canada Names VP

ESAB Canada, Mississauga, Ont., Canada, has promoted Neil Armstrong to vice president, operations. With the company since 1991, Armstrong has served as technical sales representative, marketing manager, and logistics manager.

Federal Signal Appoints President CEO

Federal Signal Corp., Oak Brook, Ill., has appointed William H. Osborne president and CEO. He succeeds James E. Goodwin who was serving as interim president and CEO. Before joining the company, Osborne served since 1990 with Ford Motor Co. as president and CEO of Ford Australia.

Jet Edge Appoints Sales Manager

Jet Edge, Inc., St. Michael, Minn., a manufacturer of ultrahigh-pressure waterjet and abrasive jet systems, has appointed Eric Magnuson north central regional sales manager. Magnuson will be responsible for accounts in Minnesota, the Dakotas, Wyoming, Nebraska, western Iowa, northern Wisconsin, and Manitoba.

Four Managers Named at Hypertherm

Hypertherm, Hanover, N.H., has hired Brian Dotson, Tom Nugen, and Corey Stahle as district sales managers. Hypertherm’s Centricut brand has named Martin Geheran product marketing manager responsible for consumable sales of non-Hypertherm cutting systems. Dotson will support distributors in the Carolinas, Tennessee, and northern Georgia. Nugen will service accounts in Kentucky and southern Ohio from his base in Ohio. Stahle will support operations in Arizona, Colorado, New Mexico, Utah, and the city of Las Vegas.

Key Posts Filled at Adept Technology

Adept Technology, Livermore, Calif., has named current President John Dulcini to CEO, succeeding Robert Bucher who has been appointed executive chairman of the board of directors. Michael Kelly, former chairman of the board, will continue to serve on the board as lead independent director. Dulcini, who remains president, has been elected to serve as a member of the board.

Obituary

Sixtus John “Jack” Oechsle Jr., 83, died September 21 in Port St. Lucie, Fla. Oechsle, an AWS Life Member, was president and chairman of Metalweld, Inc., a consultant with S. G. Pinney & Associates, a member of the National Association of Corrosion Engineers, and a registered nuclear coatings engineer. He is survived by his wife Mary Jane, two sons, two daughters, a brother, and a sister.
Think globally. Act pampered.

Focus on global growth and have a world of fun at the 2009 WEMCO Annual Meeting in San Diego.

WEMCO, a Standing Committee of the American Welding Society, is committed to collaborating with fellow industry leaders to stay relevant and dynamic in this the ever-changing global economy. On February 26-28, 2009, WEMCO executives will spend several days at the Rancho Bernardo Inn Golf Resort and Spa, in San Diego, Calif., analyzing:

- Industry globalization and economic potential in emerging markets
- Trends and related issues of private labeling
- Issues surrounding rapid growth and expansion

A world of information on global opportunities

WEMCO understands the importance of networking with fellow industry leaders to promote the welding industry, and encourages its growth and development. Each year, the WEMCO Annual Meeting continues to bring together top-level executives from major welding equipment manufacturers throughout the United States and Canada. In 2009, some of the featured presenters will include Dick Couch, president & CEO of Hypertherm, and Chris Ebeling, VP & general manager of Linde Canada, Ltd. Also joining WEMCO will be the highly-anticipated Alan Beaulieu of the Institute for Trend Research. Beaulieu’s delivery of his economic forecast has proven accurate, as well as entertaining.

We cordially invite executives of welding equipment/products manufacturing companies to join WEMCO on February 26-28 to represent their organizations. The networking opportunities are immense, and the information is invaluable. Read some of the feedback from past attendees:

- “The best such conference that I have ever attended.”
- “Great meeting. Excellent speakers.”
- “Great program. Just the right mix we needed.”
- “Terrific program content, relevant topics, interesting speakers.”
- “The program was excellent all the way through. I wish other associations were as good.”

How to register

Attendance fees are $720 per attendee, and $225 for spouses and guests. WEMCO has also secured a group rate with the Rancho Bernardo Inn of $250 per room, per night, plus applicable taxes. Go to the WEMCO website (www.aws.org/wemco) to download your 2009 Registration Form today. Forms can be submitted via e-mail at wemco@aws.org, or via fax to (305) 442-7451. Deadline to register for the 2009 WEMCO Annual Meeting is January 26, 2009.

For further information about the annual meeting, please contact Natalie James-Tapley at (800) 443-9353, ext. 444, or via e-mail at tapley@aws.org.

Note: Guests eligible for WEMCO membership may attend only one WEMCO Annual Meeting before joining the committee.
NEWS OF THE INDUSTRY
— continued from page 13

Located in Upper Burrell, Pa., it will provide 9800 sq ft of expansion space for the company’s Spectrochemical Testing group, along with up to 11,000 sq ft of space for the planned growth of the firm’s Non-Destructive Testing and Material Evaluation operations. According to N. David Campbell, company president, this building will also allow for the addition of a scanning electron microscope.

Brazing Alloy Manufacturer Unites Brands

The Handy & Harman Precious Metals Group plans to unify all of its brazing companies under a single brand name — Lucas-Milhaupt. In addition to Lucas-Milhaupt, Milwaukee, Wis., and Handy and Harman Canada in Toronto, the group includes Protchno SA, Riberac, France, and Omni Technology, Epping, N.H. Starting in January 2009, the group’s companies will introduce a new unified face, led by a strengthened brand mark. It will also utilize a new tag line, Global Brazing Solutions.

Beckwood Delivers Hydraulic Press to Orange County Choppers

Beckwood Press Co., St. Louis, Mo., recently delivered a technologically advanced deep draw hydraulic press to Orange County Choppers’ (OCC) new facility in Newburgh, N.Y. This allows OCC to have the in-house capability to form tanks, fenders, and other drawn parts for its production line of motorcycles. The 350-ton, 4-post draw press is equipped with the company’s active leveling control system and utilizes “green” technology with a variable frequency drive.

Industry Notes

• Superflash Compressed Gas Equipment/IBEDA Inc. celebrated a one year anniversary at its new facility in Westlake, Ohio. The company manufactures a variety of products for the industrial gas industry. Also, at its welding equipment subsidiary plant in Germany, many welding products are made and then packaged, stocked, and shipped from Westlake.

• L.B. Foster Co., Pittsburgh, Pa., has been awarded business for continuous welded rail with two transit projects in northern and southern California.

• Kern Steel Fabrication, Bakersfield, Calif., has selected SmartTCP, Farmington Hills, Mich., to automate its structural steel welding process.

• A redesigned Web site has been introduced by Farr Air Pollution Control, Jonesboro, Ark., at www.farrapc.com. It provides easy-to-navigate paths to help with dust collection needs.

• Güdel has purchased an additional facility in Ann Arbor, Mich., expanding current operations to 48,000 sq ft. The company increased its space in anticipation of upcoming work projects.

• Air Exchange has been added as a representative for the full line of dust and mist/fume collection equipment from United Air Specialists, Cincinnati, Ohio.

• An online training site has been created by WeldTrain LLC, Washougal, Wash., at www.weldtrain.com for the welding, gases, and safety industry.

• To design and build welding equipment formerly built by Newcor Bay City, Wright-K Technology, Inc., Saginaw, Mich., has expanded its operations.

• Illinois Tool Works, Inc., Glenview, Ill., has acquired Sonotech, Inc. It will join the company as a part of the Test Measurement Group and operate under the management of Magnaflux.

• Three new international offices in Mumbai, India, Singapore, and Vienna, Austria, have been launched by RathGibson, Lincolnshire, Ill., a manufacturer of welded tubing.

• Moog Inc., East Aurora, N.Y., has acquired Berkeley Process Control, Inc., whose motion control software and hardware enhances welding with technical applications, for $14 million.

• The Web site www.cmw.ee has been launched by Central Maintenance and Welding, Inc., Lithia, Fla. Features include examples of completed fabrication projects and services offered.

• Valley National Gases, LLC, Independence, Ohio, has signed an agreement to acquire General Welding Supply and its affiliates. The company has also completed acquiring L.P. Gas Co.

Do You Have Some News to Tell Us?

If you have a news item that might interest the readers of the Welding Journal, send it to the following address:
Welding Journal Dept.
Attn: Mary Ruth Johnsen
550 NW LeJeune Rd.
Miami, FL 33126.
Items can also be sent via FAX to (305) 443-7404 or by e-mail to mjohnsen@aws.org.
## POSTER ABSTRACT SUBMITTAL
Annual FABTECH International & AWS Welding Show
Chicago, IL – November 15-18, 2009

(Complete a separate submittal for each poster.)

### Primary Author (Full Name):

### School/Company:

### Mailing Address:

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### Poster Subtitle (max. 50 characters):

### Co-Author(s):

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### Poster Requirements and Selection Criteria:

- Only those abstracts submitted on this form will be considered. Follow the guidelines and word limits indicated.
- Complete this form using MSWord. Submit electronically via email to techpapers@aws.org or print and mail.
- Maximum size – 44 inches tall x 30 inches wide. (Vertical format, please).
- Must be legible from a distance of 6 feet. A minimum font size of 14 pt. is suggested.
- Posters must be submitted to AWS as a single flat printed medium (e.g. laminated print or foam core board mount).
- Any technical topic relevant to the welding industry is acceptable (e.g. welding processes & controls, welding procedures, welding design, structural integrity related to welding, weld inspection, welding metallurgy, etc.).
- Submittals that are incomplete and that do not satisfy these basic guidelines will not be considered for competition.

Posters accepted for competition will be judged based on technical content, clarity of communication, novelty/relevance of the subject & ideas conveyed and overall aesthetic impression.

Criteria by category as follows:

**A) Student**
- Students enrolled in 2 yr. college and/or certificate programs at time of submittal.
- Presentation need not represent actual experimental work. Rather, emphasis is placed on demonstrating a clear understanding of technical concepts and subject matter.
- Practical application is important and should be demonstrated.

**B) Student**
- For students enrolled in baccalaureate engineering or engineering technology programs at the time of submittal.
- Poster should represent the student’s own experimental work. Emphasis is placed on demonstrating a clear understanding of technical concepts and subject matter.
- Practical application and/or potential relevance to the welding industry is important and should be demonstrated.

**C) Student**
- For students enrolled in graduate degree programs in engineering or engineering technology at time of submission.
- Poster should represent the student’s own experimental work. Poster must demonstrate technical or scientific concepts. Emphasis is placed on originality and novelty of ideas presented.
- Potential relevance to the welding industry is important and should be demonstrated.

**D) Professional**
- For anyone working in the welding industry or related field.
- Poster must demonstrate technical or scientific concepts. Emphasis is placed on original contributions and the novelty of the presentation.
- Potential relevance to the welding industry is important and should be demonstrated.

**E) High School**
- Junior or Senior high school students enrolled in a welding concentration at the time of submittal.
- Presentation should represent technical concepts and application to the welding industry.
- Practical application and creativity are important and should be demonstrated.
Check the category that applies:

☐ (A) Student 2-yr. or Certificate Program
☐ (B) Student 4-yr. Undergraduate
☐ (C) Graduate Student
☐ (D) Professional
☐ (E) High School Certificate Program

Poster Title (max. 50 characters):

Poster Subtitle (max. 50 characters):

Abstract:
Introduction (100 words) – Describe the subject of the poster, problem/issue being addressed and it’s practical implications for the welding industry.

Technical Approach & Results (200 words) – Explain the technical approach. Summarize the work that was done as it relates to the subject of the poster.

Conclusions (100 words) – Summarize the conclusions and how they could be used in a welding application.

Return this form, completed on both sides, via email to techpapers@aws.org

MUST BE RECEIVED NO LATER THAN April 3, 2009
Part 1 — WELDING JOURNAL

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Evaluation of Dissimilar Welds between Ferritic Stainless Steel Modified 12% Cr and Carbon Steel S355

A modified ferritic stainless steel was subjected to a barrage of testing to determine its suitability for a variety of structural applications

BY E. TABAN, E. DELEU, A. DHOOGE, AND E. KALUC

ABSTRACT. In this research, 20-mm-thick, modified X2CrNi12 ferritic stainless steel conforming in composition to Grades UNS S41003 in ASTM A240 and 1.4003 in EN 10088-2 and EN 10028-7 with a carbon content below 0.015% was welded to nonalloy S355 steel by means of shielded metal arc (SMA) and submerged arc (SA) welding processes using AISI 309 type of filler metal. Microstructural examinations were carried out including macro and micrographs, hardness and ferrite content measurements, and grain size analysis. Charpy impact and crack tip opening displacement (CTOD) fracture toughness tests, transverse and longitudinal tensile, and bend tests were carried out. Corrosion testing by means of salt spray and blister tests was done in order to investigate all aspects of the weld properties of the joints. Cross-weld tensile specimens tested at room temperature all broke in the base metals. Heat-affected zone (HAZ) Charpy impact values ranged from 17 to 30 J and could be correlated with the microstructure.

Introduction

The ferritic stainless steel family, including the iron-based alloys with 10.5 to 30% Cr content with small amounts of austenite-forming elements such as carbon, nitrogen, and nickel, is the second most commonly used group of stainless steels because of their good corrosion resistance and lower cost compared to austenitic grades. Since these steels were considered low-weldable steels, they had mostly been used for applications not requiring welding until the early 1980s. A fully ferritic structure has poor low-temperature toughness and high-temperature strength with regard to austenite. Primarily, when exhaust tubes and connections began to be welded with these stainless steels, their weldability started to receive increased attention and interest for engineering applications (Refs. 1–6).

Ferritic stainless steels with 11–12% chromium have been widely used as low-cost utility stainless steels and have been developed to fill the gap between stainless steels and the rust-prone carbon steels, thus providing an alternative that displays both the advantages of stainless steels and engineering properties of carbon steels (Refs. 6–12). The former generation of these steels is known as 3Cr12 stainless steel, which was commercialized in 1979 in South Africa with 0.03% carbon. It is used by several steel suppliers and conforms in ASTM A240 as UNS S41003 and in Europe as Material Number 1.4003. A series of studies describing the research and the use of 3Cr12 ferritic stainless steel in various applications can be found in the literature (Refs. 7–34).

Although 3Cr12 has excellent corrosion resistance in many environments, its weldability is limited. EN 1.4003 steel is modified from conventional 12% Cr stainless steel by decreasing the C content to well below 0.03% to improve the weldability, which is regarded as the limit for low-carbon steels. With advanced steel-making technology, modified X2CrNi12 ferritic stainless steel can be fabricated to still comply with EN 10088-2 and EN 10028-7, and low-carbon (<0.015% C) levels and reduced impurity levels, consequently improving weldability and mechanical properties. Although initial applications of these steels were for materials handling equipment in corrosive/abrasive environments, they are now commonly used in the coal mining industry for bulk transport of coal and gold, for cane and beet sugar processing equipment, road and rail transport, power generation; petrochemical, metallurgical, pulp and paper industries; and also in structural applications and in aerospace engineering. The use of these steels in the past few years increased markedly with their successful application in passenger vehicles, coaches, buses, trucks, freight and passenger wagons, and rail infrastructure (Refs. 7, 8, 12–34).

When compared with carbon steels for long-term maintenance costs, modified X2CrNi12 stainless steel requires fewer coating renewals, which provides substantial economic and environmental advantages. For other applications, when compared with higher alloyed stainless steels, the use of this modified 12% Cr steel with improved weldability would be more economical (Refs. 7, 8, 35–41).

Since not much study has been carried out on the weldability and the properties of the welded joints of modified X2CrNi12 stainless steel, and considering

KEYWORDS

Modified X2CrNi12
12% Cr
S355
Dissimilar Welding
Weldability
the intent to use this modified steel in more structural applications, dissimilar welding was taken into account for this study. In this paper, modified X2CrNi12 stainless steel and S355 steel plates were formed metal arc (SMA) and submerged arc (SA) welded. The joints were evaluated by means of microstructural, toughness, mechanical, and corrosion properties.

### Experimental Procedure

Chemical compositions and tensile properties transverse to the rolling direction of the 20-mm-thick base metals are given in Table 1. The X2CrNi12 stainless steel microstructure contained about 20 to 30% martensite, while the S355 carbon steel was a hot-rolled nonalloy structural steel.

Although matching welding electrodes are commercially available for welding the EN10088:X2CrNil2 stainless steel, it is not recommended in applications where impact, fatigue, or any other form of nonstatic loading is anticipated. Reported weldability studies have shown instead that austenitic stainless steel consumables, especially 309 type, are recommended to produce welds with a minimum risk for heat-affected zone (HAZ) hydrogen cracking and to ensure deposition of weld metal that is corrosion resistant at the weld metal center (WM), and to the root sides of the welds under a load of 5 kg. Ferrite content of the weld metal was determined by means of Ferritscope.

Dissimilar metals joining with SMAW was done with rutile-basic E309L-16 electrodes of 2.5 to 4.0 mm diameter with DC+ polarity. The V-shaped plate preparation of only 14 deg. Both welds were supported by an X2CrNi12 stainless steel plate as backing material. Each joint was produced with dimensions of 2000 x 1000 x 20 mm.

After welding, chemical analysis samples consisting entirely of the weld metal were prepared as longitudinal sections and transverse to the plate surface. The measurements were done by glow discharge optical emission spectrometry. Nitrogen was determined by the melt extraction method.

Macro sections were removed from the joints, prepared, and etched with Villetta’s reagent and nital in order to make macromicrographs with a magnification of 200x. According to the EN 1043-1 standard, Vickers hardness measurements were made at the subsurface from the face and the root sides of the welds under a load of 5 kg. Ferrite content of the weld metal was determined by means of Ferritscope.

Several series of standard notch impact test samples with a cross section of 10 x 10 mm by 2-mm-deep V-shaped notches were extracted, conforming to EN 10045-1, from both face and root sides, through thickness and transverse to the weld. They were then prepared with notches positioned at the weld metal center (WM), weld interface (WI), and at the HAZ 2 mm away from the weld interface (WI+2). Charpy impact testing was done at -20°C and 0°C test temperatures.

The welds were investigated with regard to their full-thickness crack tip opening displacement (CTOD) fracture toughness properties at -20°C with reference to BS 7884. The CTOD fracture toughness is expressed in millimeters and measured with three-point bending under static loading conditions. Similar to the Charpy test, CTOD samples were notched at the WM and the WI from both 12 Cr and S355 sides and the samples were precracked. After CTOD testing, the fracture surfaces of the samples were examined by scanning electron microscope (SEM).

Depending on the toughness test results of the welded joints, ASTM grain size numbers were measured on the existing macro sections at the thickness positions from subsurface to midthickness to investigate for a possible correlation between toughness and microstructure. Due to the inclined weld interface, the positions were sampled in specimens notched at WI and WI+2. Fine-grained microstructures have high ASTM grain size numbers (i.e., 7 to 10) while coarse-grained microstructures are identified by small ASTM grain size numbers (i.e., 1 to 4).

Transverse full-thickness tensile specimens, transverse to the weld with respect to EN 10002-1-EN 895 and cylindrical test samples completely positioned at the weld metal in the longitudinal direction in accordance with EN 10002-1-EN 876, were extracted from both dissimilar welds. The net section diameter of all cylindrical samples was 10 mm, while strain at fracture was determined over a reference length of 50 mm, or five times the specimen diameter.

The static tensile testing of transverse and longitudinal samples was carried out at room temperature using a hydraulically controlled test machine. Moreover, two face and two root bend test specimens from each weld were prepared from the welded plates. A nominal specimen width of 30 mm, a mandrel diameter of 91 mm, and bending angle of 180 deg were used.

Salt spray and blister corrosion tests were executed to assess the resistance to

---

**Table 1 — Properties of 20-mm-Thick X2CrNil2 Stainless Steel and S355 Plates**

| Chemical Composition of Modified X2CrNil2 Stainless Steel and S355, Respectively (wt-%) (Data from chemical analysis) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C  | Si  | Mn  | P  | S  | Cr  | Cu  | Ni  | Mo  | Ti  | V  | Al  | Nb  | N  (ppm) |
| 0.09 | 0.33 | 1.53 | 0.011 | 0.003 | 0.11 | 0.06 | 0.08 | <0.01 | <0.001 | 0.040 | 0.029 | 0.031 | 88 |
| 0.01 | 0.32 | 0.97 | 0.033 | 0.003 | 12.2 | 0.39 | 0.52 | 0.14 | 0.001 | 0.040 | 0.029 | 0.031 | 88 |

**Transverse Tensile Properties of Modified X2CrNil2 Stainless Steel and S355, Respectively**

<table>
<thead>
<tr>
<th>Rm (MPa)</th>
<th>Rm (MPa)</th>
<th>Strain at fracture (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>353</td>
<td>504</td>
<td>28</td>
</tr>
<tr>
<td>379</td>
<td>507</td>
<td>37</td>
</tr>
</tbody>
</table>

**Table 2 — Chemical Composition of the Weld Deposits of Dissimilar Joints**

<table>
<thead>
<tr>
<th>Welding process</th>
<th>C (%)</th>
<th>Si (%)</th>
<th>Mn (%)</th>
<th>P ppm</th>
<th>S ppm</th>
<th>Cr (%)</th>
<th>Cu (%)</th>
<th>Ni (%)</th>
<th>Mo (%)</th>
<th>Ti ppm</th>
<th>V ppm</th>
<th>Al ppm</th>
<th>Nb ppm</th>
<th>N ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>111 SMAW</td>
<td>0.03</td>
<td>0.98</td>
<td>0.73</td>
<td>230</td>
<td>160</td>
<td>23.1</td>
<td>0.04</td>
<td>11.9</td>
<td>0.06</td>
<td>140</td>
<td>850</td>
<td>320</td>
<td>90</td>
<td>806</td>
</tr>
<tr>
<td>121 SAW</td>
<td>0.02</td>
<td>0.52</td>
<td>1.48</td>
<td>210</td>
<td>50</td>
<td>22.5</td>
<td>0.09</td>
<td>10.2</td>
<td>0.08</td>
<td>50</td>
<td>910</td>
<td>430</td>
<td>&lt;10</td>
<td>462</td>
</tr>
</tbody>
</table>
atmospheric attack. Salt spray tests were done with reference to ASTM B117 on uncoated and coated corrosion samples for 350 and 1000 h of exposure, respectively. Coating consisted of a two-layer protection system similar to paint that is used in practice by a railway coach manufacturer. The samples were provided with a cross-shaped scratch over the entire test surface across the weld and also with paraffin at the sawed and machined surfaces. This allowed an estimation of the welds' resistance when the coating is accidentally damaged prior to or during operation. Salt spray testing was done in a 5% NaCl aqueous solution with a fog volume of 24 to 28 mL per 24 h, a pH of 6.5 to 7.2, and at a temperature of 35°C. Dissimilar weld specimens were positioned with the carbon steel S355 side downward. Blister tests were executed on coated samples prepared similarly as those for salt spray testing. Samples were exposed to real atmospheric conditions for 3120 h from their face side, which exposed the most weld metal, and with their test surface oriented to direct sunlight (Ref. 39).

Results and Discussion

The chemical compositions of all weld deposits are summarized in Table 2. The SMA weld with an E309L-16 type of electrode contained more Si than the SA weld. Elements like vanadium and nitrogen increased strongly with regard to the base metals.

Relevant macro and micrographs of the dissimilar welds are shown in Fig. 1.

The 20-mm-thick dissimilar SMA weld

---

**Table 3 — CTOD Fracture Toughness at -20°C of the Dissimilar Welds**

<table>
<thead>
<tr>
<th>Welding Process/Type of Consumables</th>
<th>Notch Position</th>
<th>CTOD (mm)</th>
<th>Failure Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>111 SMAW/ E309L-16</td>
<td>WMC</td>
<td>0.274</td>
<td>Maximum force plateau</td>
</tr>
<tr>
<td></td>
<td>W1 (12Cr)</td>
<td>0.274</td>
<td>Maximum force plateau</td>
</tr>
<tr>
<td></td>
<td>W1 (S355)</td>
<td>0.101</td>
<td>Fracture</td>
</tr>
<tr>
<td></td>
<td>WMC</td>
<td>0.070</td>
<td>Fracture</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.750</td>
<td>Maximum force plateau</td>
</tr>
<tr>
<td>121 SAW/ ER309L</td>
<td>W1 (12Cr)</td>
<td>0.626</td>
<td>Maximum force plateau</td>
</tr>
<tr>
<td></td>
<td>W1 (S355)</td>
<td>0.599</td>
<td>Maximum force plateau</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.047</td>
<td>Fracture</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.023</td>
<td>Pop-in</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.312</td>
<td>Fracture</td>
</tr>
</tbody>
</table>
Dissimilar arc welds. Notch impact toughness of the dissimilar welds A and B - Fig. 3

Table 4 • Correlation between Notch Impact Toughness at -20°C for the left and right HAZ were also measured. Weld cross sections is illustrated in Fig. 2.

High-temperature heat-affected zones (HTHAZ) of the 12Cr stainless steel will be revealed in dissimilar welds is about 350 HV5 and was measured at the HAZ of the root of the macro section removed from the SMA weld. Ferrite content of the WM of the SMA welded sample is between 10.12 and 13.87% while the values between 15.69 and 19.69% were measured for the SA welded samples.

Notch impact test results, expressed in Joules (J) are illustrated in Fig. 3. Interpreting the data, when 27 J is considered as the required mean toughness level, both welds failed in the 12Cr side at the WI and WI + 2. Based on the results, notch impact transition temperature for the welds was assumed between 0° and 10°C by WI or by HAZ toughness properties.

The CTOD test data for the dissimilar welds is given in Table 3. In general, weld metal toughness is good to excellent, which most surely is attributed to the austenitic filler metal used. However, none of the welds proved to have a WI CTOD fracture toughness of 0.100 mm or higher except for the SA welded samples were better than the SA welded ones due to the higher heat input. Slightly better ASTM grain size numbers were obtained from the SMA weld.

Low-carbon 12% Cr steels with ferritic-martensitic structure have the tendency to transform to ferrite in the HTHAZ of fusion welds resulting in grain coarsening and toughness reduction (Refs. 12, 13). A correlation between impact toughness and grain size of the welds was examined with ASTM grain size number measurements at the HAZs. As seen from Table 4, coarse-grained microstructures are identified by small ASTM grain size numbers and this coincides with the low impact test results. This situation can also be confirmed with the article by Meyer and du Toit (Ref. 11) stating that ferrite grain size has a marked effect on the impact properties of the HAZ. Ductile-to-brittle transition temperatures (DBTT) obtained through temperature-cycle simulation by Gooch and Gin (Ref. 19) indicate that DBTT of 12% Cr steel increases with ferrite grain size. And with

Table 4 — Correlation between Notch Toughness at -20°C and Grain Size Analysis of Samples Removed from the Welds

<table>
<thead>
<tr>
<th>Welding Process/Type of Consumables</th>
<th>Test Temperature (°C)</th>
<th>Thickness</th>
<th>Notch Position (12 Cr sides)</th>
<th>Impact Toughness (J)</th>
<th>Max. Grain Size No. of Microstructures 12 Cr HAZ</th>
</tr>
</thead>
<tbody>
<tr>
<td>111 SMAW/ E309L-16</td>
<td>-20</td>
<td>Face</td>
<td>WI</td>
<td>21-18-25/21</td>
<td>WI:3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>WI + 2mm</td>
<td>26-11-14/17</td>
<td>WI + 2:1</td>
</tr>
<tr>
<td>121 SAW/ ER309L</td>
<td>-20</td>
<td>Through root</td>
<td>WI</td>
<td>18-17-22/19</td>
<td>WI + 2:3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>WI + 2mm</td>
<td>13-25-13/17</td>
<td>WI + 2:1</td>
</tr>
<tr>
<td></td>
<td>-20</td>
<td>Face</td>
<td>WI</td>
<td>15-11-13/13</td>
<td>WI:1-2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>WI + 2mm</td>
<td>16-17-18/17</td>
<td>WI + 2:2</td>
</tr>
<tr>
<td></td>
<td>-20</td>
<td>Through root</td>
<td>WI</td>
<td>42-21-15/26</td>
<td>WI:3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>WI + 2mm</td>
<td>65-6-18/30</td>
<td>WI + 2:3-4</td>
</tr>
</tbody>
</table>

Fig. 3 — Notch impact toughness of the dissimilar welds. A and B — Shielded metal arc welds; C and D — submerged arc welds.

shows a normal weld profile with some misalignment and/or angular distortion. The dissimilar SA weld shows straight weld interfaces that are perpendicular to the plate surface. The large width of the weld is due to the wide root opening. Macro and micrographs reveal some grain coarsening and martensite islands in the high-temperature heat-affected zones (HTHAZ) of the 12Cr stainless steel — Fig. 1C and D.

Hardness measured over the entire weld cross sections is illustrated in Fig. 2. Values for locations 0.7 mm, respectively, above and below the line of indentations for the left and right HAZ were also measured.

Weld metal hardness for the welds varied between 170 and 270 HV5. The maximum HAZ hardness for the welds measured about 270 HV5 from the 12%Cr side. Maximum hardness of the nonalloyed structural steel in dissimilar welds is about one. Scanning electron microscope fractographs with 1000x magnification of CTOD samples are illustrated in Fig. 4. As clearly seen, ductile fracture was observed for the samples notched at the weld metal with quite good CTOD test results, and brittle fracture was determined on the samples notched at the weld interface, which have relatively insufficient results for both welds.

The CTOD fracture toughness tests at ~20°C on 20-mm-thick welds delivered some disappointing results at the WI. Because of its slant orientation with regard to the plate surface, a mixture of WM, HAZ, and BM microstructures was tested. This can be attributed to the fact that in the case of CTOD fracture toughness testing, a lot of test material is sampled by the notch traveling the entire thickness of the weld. But if the grain coarsening can be controlled, then it is anticipated that CTOD fracture toughness will also be increased to values probably above 0.200 mm. CTOD test results of the WI and WI+2 notched for the SMA welded samples were better than the SA welded ones due to the higher heat input. Slightly better ASTM grain size numbers were obtained from the SMA weld.
reference to Krauss (Ref. 42), the factors that influence the DBTT of ferritic stainless steels are grain size, interstitial C and N, and the presence of various types of secondary phases. Thus, in accordance with the literature, it can be concluded that a fine grain size helps to enhance toughness properties. To enhance grain sizes, heat input should be kept as low as possible (Refs. 11–13).

The transverse tensile test results have demonstrated without exception the actual overmatching strength of the weld vs. the base metals. Fracture occurred as well in the stainless steel as in the structural steel because the actual strength for both steels is very similar. As a result of the weld metal tensile test on the cylindrical test samples completely positioned at the weld metal, the SMA weld demonstrated superior yield strength values compared to the SA weld. None of the face and root bend test specimens failed during 180 deg bending. All welds were found to be sound and extremely ductile.

Photographs of uncoated and coated samples are shown in Fig. 5 after exposure times of 350 and 1000 h for salt spray and 3120 h for blister tests. The purpose here is to distinguish between the resistant and less-resistant welds.

The 350 h of exposure of the uncoated salt spray test samples showed that the SA weld revealed less deterioration than the SMA weld. Long-term (1000 h) salt spray corrosion behavior of coated samples heavily scratched across the weld revealed in both cases some corrosion products at the scratch. The SA weld revealed more corrosion products than the SMA weld. Obviously, the coating provides a good protection for the weld as in general only the scratched regions were deteriorated. From the photographs of the coated blis-
ter test samples, it became apparent that both welds have been found resistant against atmospheric attack over a period of 3120 h even when damaged by a severe scratch across the entire welded joint.

**Conclusions**

The conclusions that follow have been drawn concerning the weld properties of dissimilar SMAW and SAW joints made between modified X2CrNi12 stainless steel and nonalloy S355 steel.

In general, sound dissimilar welds can be made by SMAW and SAW processes with the use of AISI 309 type of consumables. This means that joining of this stainless steel to carbon steel can be accomplished economically by welding, producing weldments with attractive properties. This is because a lean type of stainless steel with low carbon can be produced today by modern steel manufacturers at a reasonable cost, and it requires less long-term maintenance costs than structural carbon steels or less short-term investments than other more expensive stainless steels. Because of its attractive strength properties, this (martensitic-) ferritic stainless steel can be classified as an intermediate, but missing, link between these two types of popular steels, offering a cost-effective alternative.

The major drawback of the stainless steel is the tendency for grain coarsening in the HAZ on the 12Cr side if the heat input during welding is not properly controlled. The HAZ toughness for subzero temperatures may be disappointing depending on the amount of grain-coarsened microstructures. In general, Charpy results of the samples from a SMA welded joint with the notch positions at the weld interface were higher than those from the SAW joint. This depends, among other factors, on the lower heat input of SMAW joints.

The CTOD fracture toughness tests at -20°C on 20-mm-thick welds have delivered some disappointing results at the weld interface because of its slant orientation with regard to the plate surface. This
can be attributed to much more test material is sampled by the notch traveling the entire thickness of the weld. So if the grain coarsening can be controlled, then it is anticipated that CTOD fracture toughness will also increase to values probably above 0.200 mm. The CTOD test results of the WI and WI+2 notched at the SMA welded samples were better than the SA welded ones due to the higher heat input. Slightly better ASTM grain size numbers were obtained from the SMA weld.

Both of the dissimilar welds investigated were produced under conditions comparable to normal practice and so, partially for cosmetic reasons, some capping passes were eccentrically positioned to yield a smooth transition between weld and base metal. This was not done systematically in the same way for both welds, resulting in a different weld profile. This was not considered as a shortcoming to the investigation but rather as a good compromise, simulating actual on-site welding situations.

The weld metal in the present welds without exception was overmatched in tensile strength, while the bend tests revealed the excellent ductility and the absence of any weld defect over the whole welded area. Also, the fact that the traverse tensile test specimens either failed at the stainless steel or at the carbon steel proved that the strength of the modified 12%Cr steel was comparable to that of a commercial structural steel, and this is important to promote the expanded use of this type of stainless steel.

Resistance against atmospheric attack of modified X2CrNi12 stainless steel welds is promising, even when evaluated under severe circumstances, i.e., artificially damaged. Under pure atmospheric conditions, all welds demonstrated the possibility to prevent further development of corrosion, once initiated.

The encouraging aspect is that this stainless steel can be applied to many structural applications.
Acknowledgments

The authors would like to acknowledge the help of all colleagues at the Belgian Welding Institute. In addition, the contributions and technical support of IWT and all members including Industeel, CMI Energy Services, University of Gent, ESAB, Lincoln Smitheld, Ministerie van de Vlaamse Gemeenschap (Metaalstructuren), Bombardier Eurorail, and WTCM are gratefully acknowledged for their contributions, and technical support.

References

ABSTRACT. The duplex stainless steels are well known for their excellent combination of strength and corrosion resistance, which is strictly related to control of the composition and the microstructural balance. When duplex stainless steels are welded, the thermal cycles and rapid cooling caused by the welding process may alter the original microstructure, thereby affecting the above-mentioned properties of the base material. However, if welding is accomplished by using specific filler metals for duplex steels, the application of a postweld heat treatment on duplex stainless steels is usually not needed. Nevertheless, for certain applications it is prescribed by technical standards to submit the workpiece to solution heat treatment or stress-relieving annealing before use. The heat treatment of duplex stainless steels requires very accurate control of both time and temperature.

In this work, the influence of postweld heat treatments on the corrosion resistance of a duplex stainless steel (SAF 2205, alias UNS 31803) has been analyzed. Different results may be obtained if furnace heat treatment is used instead of an induction one. Thus, the study was specifically aimed at a detailed investigation of the corrosion behavior of welded components after induction postweld heat treatment and furnace postweld heat treatment. It was found that pitting corrosion resistance is affected by the presence of secondary austenite and its morphology. Such morphology depends on time and temperature parameters so that if postweld induction heat treatment is used, the temperature gradient across the thickness of the joint has to be taken into account.

Introduction

It is well known that welding operations modify the ferrite/austenite phase balance (1:1) in duplex stainless steels (DSSs) and could promote the intermediate-phases precipitation in the weld metal and heat-affected zone (HAZ) (Refs. 1–5). The main consequence of this phenomenon is that corrosion resistance and mechanical properties of these materials are dramatically affected.

Since it would not be practical to postweld heat treat or hot work the large weldments, it is necessary to use a filler metal that can provide an as-deposited balanced microstructure. For this reason, recommended filler metals for the duplex stainless steels are of matching compositions except that nickel is increased to 8–10%.

However, American and European standards (ASTM A928/A928M and NORSOK MDS D42 standards, for example, Ref. 6) require the application of a postweld heat treatment (PWHT). In particular, these specifications cover standard requirements for ferritic/austenitic (duplex) stainless steel pipe that is electric fusion welded with the addition of filler metal suitable for corrosive service. Heat treatment shall be performed after welding and in accordance with specified temperature and quench conditions.

In order to properly balance the microstructure, any heat treatment of a duplex stainless steel should consist of a full solution annealing, meeting the minimum temperatures specified for the mill product in the ASTM specifications, followed by water quenching. In the case of the investigated steel, the UNS 31803 (also known by the commercial name SAF 2205), the minimum annealing temperature is 1040°C.

When there is a full solution anneal and quench subsequent to welding, that heat treatment is a part of the welding procedure. Possible applications can be found in the chemical and petrochemical industries, refineries, and gas and hydrocarbon transport. In addition, some types of equipment manufactured from duplex stainless steel require a full anneal. For example, the forming of large heads or the fabrication of some valve and pipe assemblies may require annealing. Annealing can restore the equilibrium phase balance and eliminate the problems associated with excessive ferrite and intermetallic phases. Such intermetallic phases are very dangerous for the mechanical and corrosion resistance of the joint and the risk of their precipitation may increase in the case of multipass welding.

Young et al. (Ref. 7) studied the effect of postweld heat treatment at 1050°C on UNS S31803. They obtained a good balance of ferrite/austenite after 15 min, while the best results were reached after 30 min. Melotti et al. (Ref. 8) studied the solution heat treatment of different duplex stainless steels. The lowest solubilization temperature (1050°C) was determined by the request to solubilize secondary phases precipitated after prior heat treatments while the higher solubilization temperature (1100°C) was determined by the request to keep δγ phase balance. Moreover, they found that for
duplex stainless steels with low chromium content the critical cooling rate, necessary to avoid intermediate phases, is about 0.3°C/s, while for higher chromium and molybdenum contents it is about 1°C/s.

In various works (Refs. 9-11), it was shown that the corrosion resistance of duplex stainless steels is also influenced by secondary austenite \( \gamma_2 \)-precipitation. This phase is formed as a result of the \( \delta + \gamma \rightarrow \delta + \gamma + \gamma_2 \) transformation in the austenitic-ferritic structure, following the heating to temperature below the A-B line in the phase equilibrium diagram of Fe-Cr-Ni in Fig. 1A. The secondary austenite may emerge as a result of an eutectoid transformation (\( \delta \rightarrow \sigma + \gamma_2 \)) in the temperatures 700°-900°C, diffusion transformation at the temperatures above 650°C, which results in the Widmanstätten structures, and the isothermal conversion at a temperature below 650°C. The nucleation and growth of the \( \gamma_2 \)-phase may occur on the \( \delta - \gamma \) phase grain boundary, or inside the ferrite grains (Ref. 9). Nowacki and Lukoj (Ref. 9) showed that the main mechanism of secondary austenite precipitation is the diffusional transformation. An increase of the amount of \( \gamma_2 \)-phase in the HAZ was found to noticeably influence the joint hardness and corrosion resistance. In particular, secondary austenite in DSSs promoted the loss of chemical balance between ferrite and austenite and the local decline of corrosion resistance of the alloy, particularly of the pitting corrosion. The authors reported that the microstructure of the specimens after post-

### Table 1 — Chemical Composition of Base and Filler Material

<table>
<thead>
<tr>
<th>Element</th>
<th>Base Material UNS S31803</th>
<th>Filler Material AWS ER2209</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>≤0.03</td>
<td>0.014</td>
</tr>
<tr>
<td>Cr</td>
<td>21-23</td>
<td>22.95</td>
</tr>
<tr>
<td>Ni</td>
<td>4.5-6.5</td>
<td>8.61</td>
</tr>
<tr>
<td>Mo</td>
<td>2.5-3.5</td>
<td>3.08</td>
</tr>
<tr>
<td>Mn</td>
<td>≤2.0</td>
<td>1.52</td>
</tr>
<tr>
<td>Si</td>
<td>≤1.0</td>
<td>0.47</td>
</tr>
<tr>
<td>N</td>
<td>0.15-0.20</td>
<td>0.163</td>
</tr>
<tr>
<td>P</td>
<td>≤0.03</td>
<td>0.015</td>
</tr>
<tr>
<td>S</td>
<td>≤0.02</td>
<td>0.0008</td>
</tr>
<tr>
<td>Cu</td>
<td>—</td>
<td>0.10</td>
</tr>
</tbody>
</table>
weld heat treatment did not show intermediate phases as well as carbides and nitrides precipitates. J. O. Nilsson et al. (Ref. 10) showed that the secondary austenite had lower concentrations of chromium, molybdenum, and nitrogen than the primary austenite. These observations were also confirmed by thermodynamic computer calculations, and the results were used to explain why secondary austenite is more susceptible to pitting attack than primary austenite. Garzón and Ramirez (Ref. 11) found a nonmonotonic relationship between the proportion of \( \gamma_2 \) and reheating temperature, a maximum \( \gamma_2 \) fraction being attained at \( \approx 1050^\circ\mathrm{C} \). \( \gamma_2 \) formed at higher reheating temperatures (above \( \approx 1100^\circ\mathrm{C} \)) displayed an outer shell rich in chromium and nitrogen and a core region depleted in these alloying elements; in contrast, \( \gamma_2 \) formed at lower reheating temperature (below \( \approx 1000^\circ\mathrm{C} \)) showed a nearly homogeneous chemical composition.

It is hence clear that when PWHT is required, time and temperature must be controlled very accurately in order to preserve the corrosion resistance of the joints. However, to the authors’ best knowledge, a satisfactory comprehension of the correlation between this property and PWHT.

---

**Table 2** — Phase Proportion at Different Zones of the Bead (wt-%) \( (\gamma_2 \text{: intragranular secondary Austenite}) \) (The error ranges have been calculated for a confidence interval of 68.7%.)

<table>
<thead>
<tr>
<th>Zone</th>
<th>As-welded</th>
<th>Induction heat-treated</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( \delta )</td>
<td>( \gamma_2 )</td>
</tr>
<tr>
<td>1</td>
<td>55.6±3.7</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>56.4±3.2</td>
<td>0</td>
</tr>
<tr>
<td>3</td>
<td>56.5±2.7</td>
<td>1.8±1.3</td>
</tr>
</tbody>
</table>

**Table 3** — Chemical Composition of Primary and Secondary Austenite in FZ (wt-%) (The error ranges have been calculated for a confidence interval of 68.7%.)

<table>
<thead>
<tr>
<th>Zone</th>
<th>As-welded</th>
<th>Heat-treated</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( \gamma_2 )</td>
<td>( \gamma_2 )</td>
</tr>
<tr>
<td></td>
<td>( \gamma_2 )</td>
<td>( \gamma_2 )</td>
</tr>
<tr>
<td></td>
<td>Cr 23.3±0.1</td>
<td>22.9±0.3</td>
</tr>
<tr>
<td></td>
<td>Mo 3.7±0.1</td>
<td>3.4±0.2</td>
</tr>
<tr>
<td></td>
<td>Ni 8.1±0.1</td>
<td>8.4±0.1</td>
</tr>
<tr>
<td>Zone 1</td>
<td>22.9±0.1</td>
<td>21.5±0.1</td>
</tr>
<tr>
<td></td>
<td>3.4±0.2</td>
<td>3.2±0.1</td>
</tr>
<tr>
<td></td>
<td>8.4±0.1</td>
<td>9.7±0.1</td>
</tr>
<tr>
<td>Zone 3</td>
<td>22.9±0.1</td>
<td>21.9±0.1</td>
</tr>
<tr>
<td></td>
<td>3.5±0.2</td>
<td>3.3±0.2</td>
</tr>
<tr>
<td></td>
<td>7.6±0.1</td>
<td>8.7±0.1</td>
</tr>
</tbody>
</table>
Fig. 6 — Micrographs of the FZ: A — Zone 1; B — Zone 3 (induction heat-treated sample). Dark phase: ferrite; white phase: austenite; small white needles: Widmanstätten-type secondary austenite (Types I and II).

Fig. 7 — A — Time-temperature diagram; B — temperature profile across the thickness of the pipe at the time of highest reached temperatures.

process parameters is still not reached. Thus, the first objective of this work is to study in depth the correlation among microstructure, time, and temperature parameters, and corrosion resistance by means of several furnace postweld heat treatments. It was found that pitting corrosion resistance is affected by the presence of secondary austenite and its morphology, which in turn depends on time and temperature parameters.

Postweld heat treatment can be carried out by means of different technologies such as furnace, laser (Ref. 12), and induction heating. These last two technologies show the advantage of reducing the time cycle as compared to a furnace heat treatment; however, in these cases heating is not uniform through the thickness of the specimen, so that a different distribution of γ2 fraction can be observed in the bead as compared to a homogeneous treatment.

The second aim of this work was thus the study of the influence of differently postweld heat treated samples of a DSS on corrosion resistance with particular attention to the comparison between induction and furnace heat treatment. If induction heat treatment is used, a temperature gradient is
Materials and Methods

Materials and Welding Processes

The testing samples were extracted from two different weldments of UNS S31803 steel (also known as SAF 2205): a) longitudinally welded pipes, and b) butt-joint welds, which were respectively induction and furnace heat treated. A Sandvik 22.8.3.L AWS ER2209 wire was used as filler metal (AWS A5.9:ER 2209/EN 12072:22 9 3 N L standards). Such specimens have been taken from the production of pipes for oil industry applications. Some details about the groove adopted are shown in Fig. 2A. The chemical composition of the base metal and the filler metal are reported in Table 1. Fusion zone (FZ) and HAZ were analyzed in the as-welded condition and after postweld heat treatment (Table 1). Seven welding runs were carried out for both joints. For operative reasons and in order to optimize the entire process, three different welding technologies were used. The first one was obtained by plasma arc welding (PAW), the second one by gas tungsten arc welding (GTAW), and the remaining runs by submerged arc welding (SAW). A schematic representation of the welding sequence is shown in Fig. 2B.

Microstructural and Corrosion Resistance Investigations

Microstructural investigations were carried out on specimens having similar process parameters and geometry to have comparable thermal field conditions. The effect of eventual variations in dilution ratios on the microstructure was not considered.

Microstructural investigations were executed by optical microscopy. Beraha’s tint etch (20-mL HCl and 100-mL H₂O, 1-g

established across the thickness of the workpiece, which influences the distribution and morphology of secondary austenite and thus the corrosion resistance of the joint.
K$_2$S$_2$O$_5$ was used to produce contrast between the primary phases (ferrite and austenite) and secondary γ; finally, an electrolytic etch (50-g KOH, 100-mL H$_2$O, 2 V) was used to identify non-austenitic secondary phases (σ, χ). A program for analyzing digital images (Leica Qwin) was used for the evaluation of the phases fraction. Each result was obtained by using the mean value of 16 fields of dimensions equal to 238 × 180 μm. Detailed analyses of the microstructures and chemical compositions of the phases after different heat treatments were performed by environmental scanning electron microscopy (ESEM) combined with energy-dispersive microanalysis (EDS). A FEI Quanta 400 microscope equipped with EDAX Genesis 4000 Microprobe were used. Due to the tiny dimensions of the phases, the microanalysis was carried out by using a spot size of 10 nm and long exposure times (about 5–7 min). The compositions of each analyzed phase was evaluated as the mean value of five different measurements.

Resistance to the pitting corrosion of the joints was evaluated according to ASTM G48 Method A. The specimens were dipped for 24 h in ferric chloride reagent (100-g FeCl$_3$·6H$_2$O in 900-mL H$_2$O) after being pickled for 5 min (20% HNO$_3$ + 5% HF; 60°C, 5 min). Exposure was initially performed at 22 ± 2°C (as prescribed in the previously mentioned standard); as the evidence of pitting corrosion was barely visible after etching at this temperature, other specimens were then etched at 30 ± 2°C in order to enhance the corrosion attack.

**Induction Heat Treatment**

As mentioned previously, the DSS pipes (having a diameter of 273 mm and thickness of 20 mm) were induction heated. To this purpose, two inductors of length 740 mm (28 coils) were used at a voltage of 663 V, a current of 1000 A, and a frequency of 469 Hz. The pipe was fed into the inductor coils at a speed of 0.20 m/min. A nozzle close to the coils’ end sprayed water onto the steel pipe in order to quench it immediately after leaving the heating section. Figure 3 shows a schematic view of the experimental setup.

In order to simulate the thermal field generated by induction in the workpiece,
Furnace heat treatment (temperature of the test corrosion: StTC) (the error bars have been calculated for a confidence interval of 68.7%).

**Fig. 14** — Weight loss as a function of the holding time and temperature of the furnace heat treatment (temperature of the test corrosion: 30°C) (the error bars have been calculated for a confidence interval of 68.7%).

The furnace heat treatments were carried out using laboratory furnaces on samples obtained from a butt joint (sheet thickness: 20 mm) welded with the same parameters used for the pipes. In order to find the best process parameters, several annealing treatments were performed at various temperatures (920°C, 1000°C, 1050°C, 1100°C) and with different time intervals (30, 90, 180, 300, 600 s). The heating rates from ambient temperature to each annealing temperature (920°C, 1000°C, 1050°C, and 1100°C) were monitored by measuring the core and skin temperatures of the workpiece with two thermocouples.

**Results and Discussion**

**As-Welded Specimens**

Figure 4 shows a typical cross section of a weld where the locations for the extraction of the specimens used for investigation are marked.

The FZ of the as-welded joint was characterized by a ferrite/austenite ratio of 57%/43%. However, some microstructural distinctions among the different zones of the bead can be observed — Fig. 5. For example, secondary austenite was found chiefly in those zones that were subjected to repeated thermal cycles induced by multipass welding (i.e., Zone 3, Fig. 5B), as compared to the portion of the bead welded on the last run (i.e., Zone 1, Fig. 5A). No other secondary phases were detected in FZ and HAZ.

**Induction Heat Treated Specimens**

The micrographs of the induction heat treated specimens (Fig. 6) showed the presence of secondary austenite in the whole bead. However, considering in this calculation only the γ₂ precipitated into the δ-grains (intragranular secondary austenite), the fraction of secondary austenite was found to vary along the bead. Higher fractions of γ₂ were detected near to the weld bead surface (Zone 1) than in the inner zones. Nevertheless, the total amount of austenite (γ + γ₂) was larger in Zone 3 than in Zones 1 and 2. Table 2 summarizes the collected results. From a general viewpoint, a good balance between austenite and ferrite was achieved (56.6% (γ) to 43.4% (δ)).

According to the classification given by Nowacki and Lukojc (Ref. 13), two kinds of secondary austenite were observed both in the induction and furnace heat treated samples: thin Widmanstätten-type needles (called in this work γ₂-Type I) and coarse Widmanstätten-type needles (called γ₂-Type II), as shown in Fig. 6. Moreover, secondary austenite in Zone 3 of the bead is coarse (γ₂-Type II), whereas the secondary austenite in Zone 1 (γ₂-Type I) exhibits a fine morphology.

The EDS microanalysis showed that the secondary austenite γ₂ contains different amounts of Cr, Mo, Ni compared to the primary austenite. Results are listed in Table 3. Generally, as confirmed by other authors (Refs. 9, 10, 14), it was found that the secondary austenite is depleted in α-stabilizing elements and richer in γ-stabilizing elements.

The induction heat treatment of a pipe (set 2.5 m long) was simulated by means of a finite element (FE) calculation method. Due to the axisymmetrical conditions, only a half section of the whole geometry was modeled. To model the pipe, 960 isoparametric rectangular elements (with four nodes) were used. Thermal and magnetic properties of the material under investigation were taken from the literature (Refs. 15, 16), likewise the properties of the cooling medium and the inductors (copper). Finally, a magnetic-thermic coupled analysis was carried out following the routine described by Magnabosco et al. (Ref. 17). The results of the numerical simulation are shown in Fig. 7. It was found that the highest temperatures were reached at the inner radius of the pipe (1060°C) with a temperature gap (AT) of about 50°–60°C between the inner and outer radius.

The lowest temperatures (between 1000°C and 1020°C) were reached at the outer surface of the pipe, thus along the head of the bead (Zone 1); this could explain the greater fraction of small γ₂-particles (Type I) precipitated there. On the opposite, as the inner surface of the pipe faced the highest temperatures (1050°C–1060°C), it can be expected that the bead bottom (Zone 3) is characterized by low fraction of intragranular Type I secondary-austenite and a general coalescence process of the secondary austenite laths (evolution from the Type I to Type II morphology). Besides, further secondary austenite nucleated and grew at the grain boundary of the primary phase.

The line-scan analysis across the δ/γ₂ interface (Fig. 8) showed that at lower temperature (about 1000°C) a homogeneous composition characterizes the two
phases, whereas at higher temperature a slight chromium segregation developed in the outer shell of \(Y_2\) phase. Such results are in agreement with those obtained by Garzón and Ramírez (Ref. 11).

The induction heat-treated specimens showed good corrosion resistance at 22°C; however, each of them displayed some pitting in the outer surface of the pipe at 30°C. In particular, a mean weight loss of 128 g/m² was found. Since pitting corrosion nucleated at the interface \(\delta/\gamma\), this behavior can be correlated to the higher amount of grain boundaries induced by secondary austenite (Type I) at the head of the bead compared to the inner zones (Table 2).

Due to the low atomic mass, it was not possible to detect the nitrogen content. However, by using the thermodynamic data obtained by Nilsson et al. (Ref. 10), it was possible to estimate the PREN (pitting resistance equivalent number = %Cr + 3.3%Mo + 16%N) (Ref. 4) at the different zones of the bead. In particular, it was found by using the Thermo-Calc program and supposing a thermodynamic equilibrium between ferrite and austenite that the nitrogen content decreased from 0.55 wt-% at 1300°C to 0.14 wt-% at 900°C (with an intermediate value of about 0.18 wt-% at 1000°C).

Coupling these data with the experimental values (Table 3), the PREN value of \(Y_2\) near the upper surface of the bead was found at about 33 (against a value of about 38 of the primary austenite).

As concluded by Nilsson et al., the sensitivity of the secondary austenite to the pitting corrosion can thus be explained with the minor Cr-Mo-N concentration; however, this conclusion is not sufficient to explain why the zones where secondary austenite of Type I precipitated were characterized by lower corrosion resistance.

**Furnace Heat-Treated Specimens**

The furnace heat-treated specimens showed a homogeneous microstructure in the whole bead due to a more uniform temperature distribution across the thickness of the weld. The secondary austenite needles appear initially fine (i.e., Type I) and then tend to coarsen with increased annealing time. This microstructural evolution is more substantial at increased times and temperatures of the heat treatment (Figs. 9–11). The micrograph of Fig. 10C shows, in particular, a magnification (500x) of the finer microstructure of a sample annealed for 30 s.

Further, the presence of the harmful \(\sigma\) phase was encountered in samples held at 920°C for times exceeding 300 s (Fig. 12). In fact, when the DSS is annealed in the temperature range between 650°C and 950°C, \(\alpha\) phase can form after relatively long holding times, as the eutectoid reaction \(\delta \rightarrow Y_2 + \sigma\) takes place. The precipitation rate of \(\sigma\) phase is maximum for isothermal aging carried out at a temperature around 850°C. The higher the aging temperature, the coarser the \(\sigma\) precipitates (Refs. 18, 19). In particular, it was detected on the base metal a \(\sigma\) phase fraction of about 2 wt-% after aging for 5 min at 850°C (Ref. 20). The \(\delta/\gamma/\sigma\) phase boundary acts as an initiation site for the metastable pitting because of the depletion of Cr and Mo around the \(\sigma\) phase (Ref. 5).

The fraction of total secondary austenite was obtained by analyzing the digital micrographs taken on eight samples, each characteristic for a different heat treatment condition (temperature and time). The amount of total secondary austenite (i.e., both isolated and co-precipitated \(Y_2\)) was calculated as the difference between the fractions of austenites of the specimen in the as-welded condition (showing only primary austenite) and after heat treatment. The results are summarized in Fig. 13. Figure 13 shows the increment of secondary austenite precipitation with the annealing time. Furthermore, it is shown that after 300 s the higher annealing temperature causes a more extensive volume increment of \(Y_2\).

The corrosion tests have shown an increment of the pitting corrosion resistance at increasing holding times. The best results were found at 1100°C, as shown in Fig. 14.

It was observed (Fig. 15) that corrosion started at the interface between ferrite and secondary austenite precipitated at the grain boundary of primary austenite and the \(Y_2\) precipitated into the ferrite grains. The different pitting corrosion resistances of the furnace heat-treated specimens can be interpreted in terms of secondary austenite precipitation. In fact, \(Y_2\) is less resistant to pitting corrosion compared to other phases (PREN(\(Y_2\)) = 33, PREN(\(\gamma\)) = 38) and introduces in the material new grain boundaries that are preferential nucleation sites for the chemical etching. These grain boundaries decrease with the increase in temperature and time of the heat treatment. Thus, it is was found that pitting corrosion is influenced not only by the depleted amount of Cr-Mo-N in \(Y_2\) compared to the primary austenite composition (as found in previous works (Ref. 10)), but also by the amount of \(\delta/\gamma_2\) interfaces that are favorable sites for pitting nucleation.

The presence of intragranular chromium nitrides in heat-treated welded specimens was not detected by using light microscope (LOM) or ESEM. This seems in agreement with Ref. 21, in which it is shown that after the early stages of the re-heating (10 s at 1000°C–1100°C) most of such precipitation dissolves. That work proposes that N enrichment of ferrite as a result of nitride dissolution promotes secondary austenite precipitation; moreover, a heterogeneous nucleation of intragranular austenite on the intragranular nitrides is proposed. In any case, such chromium nitrides are not seen after heat treatments longer than 10 s, so that their influence on corrosion properties of heat-treated specimens is disregarded in this work.

The different types of secondary austenite across the thickness of the induction heat-treated specimens, where a great amount of secondary austenite of Type I was observed near the head of the bead, may explain the reduction of pitting corrosion resistance in that zone. Finally, the as-welded samples showed better pitting corrosion resistance compared to the induction heat-treated ones. This behavior can be attributed to the absence of secondary austenite in the as-welded samples and thus a minor amount of pitting nucleation sites. Following the experimental results obtained in this work, better corrosion resistance of the induction heat-treated pipes may be obtained by modifying the process parameters, aiming to reach higher annealing temperatures at both sides of the bead (e.g., about 1100°C on the bottom side and about 1050°C at the head).

**Conclusions**

This work studied the influence of postweld heat treatments on the corrosion resistance of a duplex stainless steel SAF 2205 and the comparison between postweld induction heat treatment and conventional furnace heat treatment.

The main results of the experimental investigations are as follows:

a) As a result of metallographic investigations of FZ after postweld annealing, three phases were observed: primary ferrite (\(\delta\)), primary austenite (\(\gamma\)), and secondary austenite (\(Y_2\)). The postweld heat treatment of duplex stainless steels contributes to the creation of secondary (\(Y_2\)) austenite.

b) The induction heat-treated specimens showed a different morphology of secondary austenite across the section of the FZ (thick Widmanstätten-type needles (\(\gamma_2\)-Type I) and coarse Widmanstätten-type needles (\(\gamma_2\)-Type II)) with a prevalence of \(Y_2\) (Type I) in the outer surface of the pipe. This was attributed to the lower temperature reached in that zone compared to the one reached near the inner radius of the workpiece.

c) The furnace heat treatment showed that secondary austenite evolves from Type I to Type II according to time and temperature. The higher the temperature, the...
the faster and higher the pitting corrosion resistance reached by the specimens. A rational of this behavior could be the evolution of the morphology of secondary austenite from Type I to Type II with a following reduction of the $\delta/\gamma'$ interface, where pitting corrosion generally starts.

These results, together with the calculated temperature distribution in the induction heat-treated specimens, explain the low pitting corrosion resistance found near the outer radius of the pipes and the better chemical properties of the as-welded samples. Better results can be reached by increasing and adjusting the temperature across the thickness of the pipe by modifying the process parameters such as frequency, voltage, speed, or inductor length.

The final outcomes of the work are consequently:

1) The corrosion properties in postweld heat-treated duplex stainless steel SAF 2205 are related not only to the presence of the secondary austenite but also to its morphology, which in turn depends on the heat treatment parameters: a coarse secondary austenite induces better corrosion properties compared to the finer one.

2) If induction heat treatment is carried out, a significant thermal gradient may arise across the thickness of the weld so that, according to the results of point 1, different corrosion properties may be found across the thickness of the joint.

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References


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