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New 55 pound spool for mild steel
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Are you tired of inserting heavy 60-pound coil wire? Our new 55-pound spool gives you quick and easy setting to your wire feeder.
- Frontiarc-711 is an all position flux cored wire with medium freeze formulation. Because of its stable arc and fluid nature, Frontiarc-711 is excellent for long, continuous welds that demand consistency.
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- DW-81B2 is the flux cored wire for 1.25%Cr-0.5%Mo steel.

DW-91B3
AWS E91T1-B3, E91T1-B3M
- DW-91B3 is the flux cored wire for 2.25%Cr-1%Mo steel.
- Both wires are versatile enough to be used with either 75%Ar+25%CO₂ or 100%CO₂.
- Stable arc produces less spatter than other wires.
- Good slag system provides excellent weldability in all positions.

Circle No. 25 on Reader Info-Card

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V. Malin
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All GenWeld manufactured welding apparatus and equipment is warranted to be free from defective materials and workmanship for a period of two years from the date of purchase.
Eclipse Aviation Purchases Friction Stir Welding System

Eclipse Aviation, Albuquerque, N.Mex., recently awarded a $6 million contract to MTS Systems Corp., Eden Prairie, Minn., for a friction stir welding system. The contract is the culmination of a three-year, $2 million joint development project undertaken by MTS and Eclipse to research the efficiency and reliability of friction stir welding in the fabrication of structural wing and fuselage members for the new Eclipse 500 jet.

"The benefits of friction stir welding are numerous," said Oliver Masefield, vice president of engineering for Eclipse. "It eliminates the need for thousands of rivets, resulting in reduced assembly costs. It also produces stronger, lighter joints more efficiently than traditional processes."

MTS developed a multi-axis control allowing the precision joining of curved surfaces. Eclipse selected the company for the production system based on both the technical validation of the process as well as MTS's ability to design and deliver large, complex systems that operate under tight process controls.

Eclipse Aviation's plan is to produce aircraft that cost less than most of today's small jet aircraft and that are safer and easier to operate.

Friction stir welding "is already actively employed in the manufacture of marine vessels, automotive parts, and commercial aircraft," said Mike Skinner, MTS business development manager for Advanced Manufacturing Technology. "However, these applications all constitute joining of relatively thin, flat aluminum surfaces. MTS has advanced this process to complex curved surfaces and thicker alloys."

Demand for Natural Gas Drives Pipeline Construction

Construction of natural gas pipelines is experiencing its greatest growth since the early 1960s, according to an advisory from Industrial Information Resources, Inc., Houston, Tex. Since 1997, the Federal Energy Regulatory Commission (FERC) has granted permits for 55 major onshore and offshore natural gas pipeline projects that are more than 7,800 miles long and have 1.8 million horsepower of compression and 21.5 billion cubic feet of capacity. This represents an investment in the industry of more than $10 billion.

FERC approval is still pending for another 22 major onshore natural gas pipeline projects totaling 1,600 miles of pipeline and an additional $3.3 billion dollars of investment.

Consumer demand, gas-fired electrical generation, the fact existing pipelines are nearing capacity, and an energy-friendly White House are helping to fuel this growth.

Shiloh Installs State-of-the-Art Laser-Welded Blanking System

Shiloh Industries, Cleveland, Ohio, recently developed a new laser-welded blanking system to produce body side frames for General Motors' 2002 Chevrolet TrailBlazer, GMC Envoy, and Oldsmobile Bravada midsize sport utility vehicles. The system, being operated at the company's Valley City, Ohio, plant, is believed to be the world's largest laser welding production system.

The blanks are laminates of four layers of hot dip galvanized steel of varying gauges engineered to increase structural strength and rigidity at critical points, such as door hinge locations and corners. The blanks also minimize scrap, reduce tooling costs, and decrease the number of parts and supplemental operations required for final assembly.

The new system synchronizes two independent lines operating in parallel so the entire four-layer blank is produced in a single pass. The two lines are linked through PLC programming using a common laser resonator source.

The system includes the following:

- A proprietary process capable of producing a robust weld joint with improved root opening filling capabilities.

- A postweld inspection system that measures weld joint concavity and convexity. It also detects minute weld gaps, rejecting parts that fail to meet minimum standards.

- A robotic system that minimizes handling, which helps eliminate scratching and other flaws to achieve high-quality surfaces.

- In-line dimpling for easier handling and stacking of the finished blanks. The dimples are located in strategic areas that ultimately will be trimmed out of the finished body side frame assembly, such as door openings.

Postweld blanking, the final stamping operation, is performed on a 600-ton blanking press.
The Ranger™ 250 gasoline engine-driven welder has the best arc in the business and the versatility for hundreds of jobs. And for a limited time, it also has a no-risk offer: Buy a new Ranger 250 from your Lincoln distributor between now and December 31 and if you’re not satisfied with its performance, return it within 30 days for a no-questions-asked refund.*

But you’ll find plenty of reasons to hang on to the Ranger:

- 250 amps of pure DC output and 8,000 watts of continuous AC power.
- Exclusive Lincoln Chopper Technology™ for easy starts, a smooth arc, and low spatter.
- Four welding modes: stick, pipe, wire, and TouchStart™ TIG.
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- An enclosed case for easy access, quieter running, and better protection.
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Visit the Demo Zone at your Lincoln distributor today for a no-risk look at the Ranger 250.

*See your local Lincoln Electric distributor for details. Customer must register to participate.
Importance of Standards Debated

The House Science Committee recently held hearings to review the impact of standards on the U.S. economy and the ability of the United States to compete internationally. The committee chairman expressly recognized that "standards play a critical, yet largely unheralded, role in helping support worldwide economic growth and competitiveness." But the committee also charged the greatest problem in the standards area “is the immediate need for new standards to address rapidly developing technology, contrasted against the deliberate pace of much of the standards-setting process.”

NRC Looks to Update Regulations

The U.S. energy situation, typified by the California crisis, has again focused attention on nuclear energy. Just a few years ago, many thought nuclear energy was on its last leg. Today, nuclear plant owners are eager to renew and extend their licenses, and several companies are developing new technologies and new plans for construction in the next decade. In addition, nuclear power is an important part of the Bush administration’s National Energy Policy.

Largely ignored for years, much in this area needs updating, especially federal regulations. The Nuclear Regulatory Commission (NRC) has not issued a license to construct a new plant in 20 years, and there is concern the NRC may not have enough qualified technical staff and resources to do the job. Furthermore, approximately 25% of the NRC’s current staff are eligible for retirement. The U.S. House of Representatives Energy and Air Quality Subcommittee recently held a hearing on nuclear energy to address these, and other, issues. In the near future, targeted legislative proposals should follow from the hearings.

E-Government Legislation Introduced

Bills have been introduced in the U.S. Senate and House that address a host of federal information technology issues, including the appointment of a federal chief information officer. Arising out of concern that “electronic government” currently is nothing more than an uncoordinated, loosely knit mix of ideas, projects, and affiliations with overlapping goals and redundant expenditures, the proposed legislation would create an annual $200 million interagency e-government fund establishing a federal chief information officer, or CIO, in the Office of Management and Budget.

The bills would also require establishment of 1) an on-line federal telephone directory; 2) an on-line national library; and 3) individual federal court Web sites. The legislation has strong bipartisan support.

Record-Keeping Rule for Workplace Injuries to Go into Effect

The proposed Occupational Safety and Health Administration (OSHA) rule on record keeping will go into effect as scheduled on January 1, 2002. This final rule is the culmination of an effort that began in the 1980s to improve how the government tracks occupational injuries and illnesses. The rule increases employee involvement, creates simpler forms, and gives employers more flexibility to use computers to meet OSHA regulatory requirements. However, OSHA is also proposing to delay for one year the record-keeping rule’s definition of “musculoskeletal disorder” (MSD) and the requirement that employers check the MSD column on the OSHA Log. OSHA has announced its intention to develop a comprehensive plan to address ergonomic hazards and has scheduled a series of forums on ergonomics. Issues to be decided upon include appropriate definitions of the terms “ergonomic injury” and MSD.

Steel Erection Standard to Take Effect January 2002

OSHA’s final steel erection standard will go into effect January 18, 2002, rather than the original effective date of July 18, 2001. The new date is intended to give additional time for industries to become familiar with the new requirements and to provide training for employees in the construction industry. OSHA is also preparing outreach and training material to assist industry in the training process.

The additional six months will allow employers time to make changes needed to avoid costly refabrication of already-made components. Such changes would cause serious project delays and affect all trades involved in the construction process. OSHA’s new rule, developed as a “negotiated rulemaking” in concert with industry and union groups, is expected to prevent 30 fatalities and 1,142 injuries annually. It is also expected to save employers nearly $40 million a year.

Finding Qualified Workers Remains a Challenge

In a recent survey commissioned by the Center for Workforce Planning, an affiliate of the U.S. Chamber of Commerce, more than two-thirds of employers report difficulty identifying and hiring qualified employees. Among all respondents, 36% report very severe conditions when recruiting employees, and an additional 32% report somewhat severe conditions. The challenges employers face when recruiting qualified workers cover a gamut of issues. Thirty-four percent of survey respondents reported applicants they see have poor employment skills. An additional 30% indicated applicants have the wrong skill set for available positions, while another 30% reported they simply cannot get enough applicants for job openings.


Contact the AWS Washington Government Affairs Office at 1747 Pennsylvania Ave. NW, Washington, DC 20006; e-mail: hwebster@wc-b.com.
Are Standards Good or Bad for Us?

The American Welding Society (AWS) is heavily involved in the writing of standards for use by the welding industry, with more than 180 documents under its control. The Society provides a forum for the exchange, consideration, and discussion of ideas and proposals relevant to industry. Standards may be codes, specifications, recommended practices, methods, classifications, or guides. Most are based on the experiences of those within the industry, including engineers, fabricators, erectors, inspectors, and educators. This consensus gives the standards credibility and allows those who use them to do so with confidence. With this level of expertise going into their making, how could there be any dispute on how they should be interpreted? One would think the standards should stand alone as clear, concise, and technically accurate.

As a member of AWS for more than 30 years and the AWS D1 Structural Welding Code writing body for more than 24 years, I have had my share of disagreements over how standards are written and enforced. Some users interpret the code in a manner inconsistent with its intended use. They take information out of context, read between the lines, and deem requirements not in the code to be required by implication. We can argue that code provisions should be interpreted in the context in which they appear and the interpretation of words, clauses, and sentences independent of other portions of the code is wrong. Would the solution to misapplication or misinterpretation be to void all standards and trust everyone to do the right thing? Can we let those involved with constructing a product be on their honor to build an item with the public's health, welfare, and safety as their primary concern? If we do so, will we have bridges that are able to withstand today's traffic demands? Will we have buildings that can withstand the rigors of a seismic event? Will dams be able to withstand floods?

Since catastrophic failures resulting in loss of property and life sometimes occur even when the requirements of standards are imposed, I would not want to think about what could happen if we worked on the honor system without standards. When failures happen because the standards that exist were not followed, I wonder what it would be like if we did not have them at all. I am glad we do have standards and that they are enforced. Maybe things don't always go as they should but, for the most part, that is not the case.

If you feel standards and their interpretation need to improve, you can help by becoming involved with their writing. You may find participation in the development of a standard will increase your technical knowledge and tolerance level for those who disagree with your interpretation of the standard. Even when you do not get your way, you may find those who disagree with you are still good people and, in fact, may have a valid point worth considering.

My experiences over the years have led me to believe we live in a much better organized and safer society because of standards. We can take pride in the fact that as AWS members, we are supporting one of the premier standards-developing organizations in the world. To become a part of the team that develops the standards, I encourage you to contact Len Connor, managing director of Technical Services, at (800) 443-9353, ext. 302, or via e-mail at lconnor@aws.org.

David L. McQuaid
Chair, AWS Technical Activities Committee and D1 Committee on Structural Welding
No flakes!

Copper coating on weld wire can flake and clog gun liners and tips. Flakes cause reduced arc time due to feedability problems that increase cleaning and repairs, elevate consumables costs and reduce tip and liner life.

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Quantifying the Economic Impact of Our Industry

The American Welding Society and Edison Welding Institute are leading a major study to measure the economic impact of the welding industry. Other sponsors include the U.S. Department of Commerce, the Office of Naval Research, and a number of equipment manufacturers and end users. Insights-MAS, with support from the Department of Commerce, is conducting the research.

The pilot study, covering heavy industrial manufacturing, has just been completed. Here’s a summary of the major findings:

- **Welding represents a substantial contribution to the heavy industrial manufacturing sector of the U.S. economy.** The industries included in this industry sector provide the backbone for our nation’s defense, infrastructure, and economic well-being. The contribution of welding to the U.S. economy in 1999 via these industries was no less than $7.85 billion. In the shipbuilding and repair industry, the economic contribution of welding was more than $1 billion, or nearly 12% of the total expenditures by that industry in 1999.

- **With few exceptions, most heavy industrial manufacturing firms have not studied, and have only minimal understanding of, the economics associated with the use of welding-related processes.** Forty percent of the firms studied reported they employ no measures of cost per unit of welding output. An additional 30% reported their measures of welding economics were minimal.

- **In the majority of those firms studied, welding is viewed simply as a necessary production input for which costs must be controlled.** Consequently, most who do evaluate welding costs do so with the objective of reducing costs rather than increasing productivity. The true value added by the use of welding processes is not known.

- **There are no consistent measures of welding productivity currently being used by heavy industrial manufacturers.** Approximately two-thirds of the heavy industrial manufacturers surveyed reported using one or more welding productivity measures. However, no single metric was reported in widespread use.

- **The shortage of qualified operators, technicians, and engineers in the field of welding is a potential threat to industries in this sector of the U.S. economy.** More than 40% of firms responding indicated a shortage of qualified welders impacts productivity either moderately or extensively. More than 50% of the firms surveyed reported existing avenues for welding training that meet their needs are either minimal or nonexistent.

- **Most firms involved in heavy industrial manufacturing do not evaluate the role and contribution of welding in the complete manufacturing process.**

The pilot study should be completed by Spring 2002. These findings apply only to the heavy industry sector; it will be interesting to see what is found as other industries are studied.

Richard D. French
AWS Deputy Executive Director
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Anneensiong 25th Anniversary in the USA
Friends and Colleagues:

We're into the tenth year of the program, and 92 individuals have now entered into the fraternity of Fellows. Again, I encourage you to submit nomination packages for those individuals whom you feel have a history of accomplishments and contributions to our profession consistent with the standards set by the existing Fellows. In particular, I would make a special request that you look to the most senior members of your Section or District in considering members for nomination. In many cases, the colleagues and peers of these individuals who are the most familiar with their contributions, and who would normally nominate the candidate, are no longer with us. I want to be sure that we take the extra effort required to make sure that those truly worthy are not overlooked because no obvious individual was available to start the nomination process.

For specifics on the nomination requirements, please contact Wendy Sue Reeve, at AWS headquarters in Miami, or simply follow the instructions on the Fellows nomination form in this issue of the *Welding Journal*. Please remember, we all benefit in the honoring of those who have made major contributions to our chosen profession and livelihood. The deadline for submission is January 14, 2002. The Committee looks forward to receiving numerous Fellow nominations for 2003 consideration.

Sincerely,

John W. Moeller
Chairman, AWS Fellows Selection Committee

IMPORTANCE NOTICE: Please note that the submission deadline of January 14, 2002, is two weeks earlier than in previous notices. The change was necessary because of newly announced dates for the 2002 AWS Convention.
Nomination of AWS Fellows

I. DEFINITION AND HISTORY
The American Welding Society, in 1990, established the honor of Fellow of the Society to recognize members for distinguished contributions to the field of welding science and technology, and for promoting and sustaining the professional stature of the field. Election as a Fellow of the Society is based on the reputation and outstanding accomplishments of the individual. Such accomplishments will have advanced the science, technology and application of welding in specific areas such as research and development, education, manufacturing, design and other areas the Society may determine, as evidenced by:
* Sustained service and performance in the advancement of welding science and technology
* Publication of papers, articles and books which enhance knowledge of welding
* Innovative development of welding technology

II. RULES
A. Candidates shall have 10 years of membership in AWS
B. Candidates shall be nominated by any five members of the Society
C. Nominations shall be submitted on the official form available from AWS Headquarters
D. Nominations must be submitted to AWS Headquarters no later than February 1 of the year prior to that in which the award is to be presented
E. Nominations shall remain valid for three years
F. All information on nominees will be held in strict confidence
G. No more than two posthumous Fellows may be elected each year

III. NUMBER OF FELLOWS TO BE ELECTED
Maximum of 10 Fellows selected, as determined by the selection committee

Return completed Fellow nomination package to:

Wendy S. Reeve
American Welding Society
550 N.W. LeJeune Road
Miami, FL 33126

Telephone: 800-443-9353, extension 215

SUBMISSION DEADLINE: February 1, 2002
CLASS OF 2003
FELLOW NOMINATION FORM

DATE_____________________________NAME OF CANDIDATE_____________________________
AWS MEMBER NO._____________________YEARS OF AWS MEMBERSHIP_______________________
HOME ADDRESS_________________________________________________________________________
CITY________________STATE________ZIP CODE____PHONE_______________________________
PRESENT COMPANY/INSTITUTION AFFILIATION_________________________________________________________________________
TITLE/POSITION______________________________________________________________________________
BUSINESS ADDRESS____________________________________________________________________________
CITY________________STATE________ZIP CODE____PHONE_______________________________
ACADEMIC BACKGROUND, AS APPLICABLE:
INSTITUTION______________________________________________________________________________
MAJOR & MINOR______________________________________________________________________________
DEGREES OR CERTIFICATES/YEAR____________________________________________________________________
LICENSED PROFESSIONAL ENGINEER: YES____NO____STATE________________

SIGNIFICANT WORK EXPERIENCE:
COMPANY/CITY/STATE________________________________________________________________________
POSITION____________________________________________________________________________________
YEARS_______________________________________________________________________________________
COMPANY/CITY/STATE________________________________________________________________________
POSITION____________________________________________________________________________________
YEARS_______________________________________________________________________________________

SUMMARIZE MAJOR CONTRIBUTIONS IN THESE POSITIONS:
__________________________________________________________________________________________

SUGGESTED CITATION (50 TO 100 WORDS, USE SEPARATE SHEET) INDICATING WHY THE NOMINEE SHOULD BE SELECTED AS AN AWS FELLOW. IF NOMINEE IS SELECTED, THIS STATEMENT MAY BE INCORPORATED WITHIN THE CITATION CERTIFICATE.

**MOST IMPORTANT**
The Fellows Committee selection criteria are strongly based on and extracted from the categories identified below. All information and support material provided by the candidate's Fellow Proposer, Nominating Members and peers is considered. Provide as much detailed information as possible regarding:
The candidate's accomplishments under areas identified below (use separate sheet for each category):
A. Research & Development
B. Education
C. Manufacturing
D. Design and Inventions
E. Other (e.g., Standards Development, National and International Liaison)
Evidence of accomplishment should include sustained service and performance in the promotion of joining technology; publication of papers, articles and books; innovative development of joining technology; service to AWS and other technical societies; and list and description of patents, awards and honors.

SUBMITTED BY: PROPOSER_________________________AWS Member No._____________________
The Proposer will serve as the contact if the Selection Committee requires further information. Signatures on this nominating form, or supporting letters from each nominator, are required from four AWS members in addition to the Proposer. Signatures may be acquired by photocopying the original and transmitting to each nominating member. Once the signatures are secured, the total package should be submitted.

NOMINATING MEMBER:_______________________NOMINATING MEMBER:_____________________
AWS Member No.________________________AWS Member No.________________________
NOMINATING MEMBER:_______________________NOMINATING MEMBER:_____________________
AWS Member No.________________________AWS Member No.________________________

SUBMISSION DEADLINE FEBRUARY 1, 2002
There has never been a better time than now to show your friends and colleagues how powerful an AWS Membership is. With your help, and our *Special Offer*, we can keep AWS the premier materials joining organization for generations to come.

**Be a mentor.**
Further your peers' potential by giving them a copy of the AWS Membership application (see reverse).

---

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Choose your FREE book (up to a $188 value) when you join AWS today, and SAVE $50 when you join for two years!

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Plus AWS JobFind at www.aws.org/career
The ULTIMATE CAREER WEBSITE for the materials joining industry!

JOIN TODAY BY USING THE MEMBERSHIP APPLICATION ON THE REVERSE
The World Leader in TIG Electrodes

SYLVANIA

Circle No. 32 on Reader Info-Card
A tremendous amount of work has gone into this motor and the grinder that it powers. And a tremendous amount of work is what you'll get out of it. Surprisingly quickly, too.

Why? Well, for starters, because we assembled it by hand using parts we made ourselves from top-quality raw materials tested in our own laboratory. That's exceptionally pure copper wire you see. A real rarity these days and a large part of the reason our tools are more efficient than others - up to 25% more efficient. The steel gearing system helps reserve the extra energy. Generous amounts of insulation and an extra-long, heavy-gauge power cord help, too. In short, more power gets into the motor and more power comes out of it as mechanical energy you can apply to your work.

Pick up the grinder that goes with this motor and you'll find it balanced and satisfying to hold. You'll feel confident with it. Our tools have many features that reinforce that feeling: The 'Quick' system that lets you change wheels almost instantly without tools, for example. Wheel guards that adjust without tools. Our exclusive Winding Protection Grid that shields grinder motors from foreign matter, giving them five times the life expectancy. And the improved cooling system in our new grinders.

It all adds up to a very-high-performance tool designed for very-high-performance professionals. People like you.
Site Highlights Training Opportunities

Texas Engineering Extension Service. The Texas Engineering Extension Service (TEEX), part of the Texas A&M University system, provides broad-based training and assistance in a wide range of disciplines. Training programs include hands-on, Web-based, and computer courses. Through the site's home page, you can access information about its custom training programs, development office, on-line courses, and other services. Click on the "Training" section to access information regarding its welding courses. You can search the course catalog by division, keyword, or program. Listings include a course description, course length, topics covered, when classes are scheduled, links to related courses, a phone number to call for prices, and protective clothing needed.  

http://teexweb.tamu.edu

Site Details Corrosion Information, Products, and Services

Corrosionsource.com. The mission statement for this site states "if it is related to corrosion, we will strive to ensure you will find it here." The site offers approximately 30,000 pages of technical information about corrosion. Some services are provided for free; a fee is charged for others. The "Handbook" section features a copy of the Periodic Table of Elements, an extensive glossary, a corrosion problem solver, hardness conversion table, and many other items. Included is a description of hydrogen embrittlement. One way in which hydrogen can affect the mechanical performance of materials is "formation of internal hydrogen blisters or blister-like cracks at internal laminations or at sites of nonmetallic inclusions in low-strength materials. These internal cracks may propagate by a process called hydrogen-induced cracking (HIC) or hydrogen blistering. No external stress on test specimens is usually required to examine this type of cracking. In some cases, however, these blister cracks may take on an alignment caused by the presence of residual or applied tensile stresses."

The "Discussion" section allows visitors to post questions or topics for discussion on-line. The "News" section offers links to articles from media around the world that feature corrosion or industries affected by corrosion. Links to a variety of databases are found in the "Tools" section, as is a units conversion table.

The "Career Center" features job postings and résumés. The site features an events calendar and on-line directory that links you to the e-commerce storefronts of companies and organizations affiliated with the site. There are also technical reports and software that can be downloaded for a fee, information on training classes, and a "Request for Quotes Center" that also includes a buyers' guide and product showcase. Additional links will take visitors to academic institutions and news groups.

http://www.corrosionsource.com

Click Away for Power Tool and Abrasives Information

Metabo Corp. The company recently relaunched its Web site to provide additional information about its products and services. The company, whose U.S. headquarters is in West Chester, Pa., manufactures portable electric tools for various industrial, construction, and welding applications. It also manufactures abrasive products.

The site includes a detailed company history, press releases, other news about the company, and an events calendar. Visitors can schedule appointments during various trade shows to visit with company representatives by filling out an on-line appointment form.

The "Products" section includes an on-line catalog with detailed information. Besides a technical dictionary that defines terms specific to Metabo tools, the "Service" area also includes warranty information and details on how to get a power tool repaired. Visitors can locate their nearest distributor by entering in the name of their town or zip code.

The site also includes an on-line store that includes a product index, privacy policy, and shipping information. Shoppers can check the contents of their shopping cart and calculate the shipping fees at any time.

http://www.metabousa.com
March 4-7, 2002
Chicago’s McCormick Place South

Featuring nearly 1,000 exhibits, MAX INTERNATIONAL is the largest and most comprehensive welding, stamping and fabricating event in North America.

It’s definitive. It’s authoritative. It’s state of the art.

You'll see the latest manufacturing equipment, technology and applications to improve your operations.

Stay competitive. Increase your profits. Come to MAX INTERNATIONAL.

Visit www.maxinternational.com to register.
AWS/DI.1 CODE WEEK

The #1 selling welding code now comes alive in a five-day seminar that begins with a roadmap of DI.1:2000, Structural Welding Code — Steel. This is your opportunity to learn from an expert AWS instructor and ask your toughest questions about DI.1.

Code week continues with corresponding subjects geared toward engineers, supervisors, planners, welding inspectors, and welding technicians. Since your work is based on a reputation for reliability and safety, you want the latest industry consensus on prequalification. If you want to improve your competitive position by referencing the latest workmanship standards, inspection procedures, and acceptance criteria, you won’t want to miss this seminar. Each day will be in-depth and intense.

(Day 1, Monday) DI.1 Road Map
Atlanta, Ga. — November 5 Beaumont, Tex. — October 15

(Day 2, Tuesday) Design of Welded Connections
Atlanta, Ga. — November 6 Beaumont, Tex. — October 16

(Day 3, Wednesday) Qualifications
Atlanta, Ga. — November 7 Beaumont, Tex. — October 17

(Day 4, Thursday) Fabrication
Atlanta, Ga. — November 8 Beaumont, Tex. — October 18

(Day 5, Friday) Inspection
Atlanta, Ga. — November 9 Beaumont, Tex. — October 19

Prices

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<th></th>
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UPCOMING CONFERENCES

ELEVENTH INTERNATIONAL CONFERENCE ON COMPUTER TECHNOLOGY IN WELDING
September 19-20 — Columbus, Ohio

The eleventh in a series of computer conferences will provide the welding industry with the latest information regarding the use of computers for welding. The conference brings together experts on sensors, equipment control, process modeling, and data acquisition. Engineers, managers, and system integrators will benefit from discussions of hardware and software installations and user experiences with these systems.

Integration of welding systems with network and Web applications will be emphasized. Topics to be discussed include modeling of welds and welding processes; off-line planning/weld simulation/visualization; computerized data acquisition and sensing systems; real-time welding information and control systems; weld process automation; network and Web-based implementations; case histories/experiences with commercial software (e.g., WPS, PQR); databases, database applications, and knowledge bases; and standards.

AWS/AA ALUMINUM WELDING CONFERENCE & EXHIBITION
November 7-8 — Nashville, Tenn.

The AWS/AA super seminar on aluminum welding has been improving over more than 20 years to become North America’s premier tutorial on this metal’s weldability. Some of the top experts in the world have been recruited to dispel the myths about aluminum welding. In this fast-paced program, the following topics will be covered: Overview of Aluminum Joining; Aluminum Designation System and Characteristics of Aluminum Alloys; Metallurgy; Safety and Health Considerations; Metal Preparation for Welding; Filler Alloy Selection; Gas Metal Arc Welding; Gas Tungsten Arc Welding; Variable Polarity Plasma Arc Welding; Resistance Spot Welding; High Energy Beam Welding; Friction Stir Welding of Al Alloys; Robotic Welding; Design and Performance; Weld Discontinuities: Causes and Cures; and Application of the AWS Structural Welding Code.

SIXTH ROBOTIC ARC WELDING CONFERENCE AND EXHIBITION
February 11-12, 2002 — Orlando, Fla.

This two-day conference and exhibition is targeted at welding engineers, manufacturing engineers, welding specialists and technicians, and others concerned with the practical application of robotic arc welding systems. Topics and speakers will cover the latest developments in the United States, Canada, and overseas. There will also be a keynote address by an industry leader. In addition, a breakfast tutorial has been planned for first-time attendees and all others interested in reviewing the basic terms and concepts of robotic arc welding and associated technology.

AWS/DVS SECOND CONFERENCE AND EXHIBITION ON PLASTICS WELDING
March 4-6, 2002 — New Orleans, La.

The AWS and DVS (German Welding Society) will present their second conference and exposition on plastic welding March 4-6, 2002, in New Orleans, La. The program will include one day of basic plastic welder education with hands-on instruction for participants. There will be two days of presentations. Topics will include success stories, failure costs and solutions, and standards and new developments. Papers will be provided by North American and European thermoplastic industry experts. Exhibits will include plastic welding equipment, plastic welding testing facilities, and plastic suppliers. If you are involved in plastic welding as an end user or fabrication shop, this conference is an event you cannot afford to miss. Exhibit space is offered on a first come, first serve basis. Call now to reserve space.

For further information, contact: Conferences, American Welding Society, 550 NW LeJeune Rd., Miami, FL 33126. Telephone: (800) 443-9353 ext. 449 or (305) 443-9353 ext. 449, FAX: (305) 443-1552. Visit the Conference Department home page, http://www.aws.org, for upcoming conferences and registration information.
Engineering students from the University of Wisconsin-Madison recently won the Innovations in Aluminum design award at the 2001 FutureTruck Challenge in Washington, D.C. Fifteen schools participated in the competition that challenged student teams to redesign and modify sport utility vehicles for maximum fuel efficiency and lower emissions.

FutureTruck is a cooperative effort between the auto industry, government, and academia seeking to solve vehicle environmental and energy-related issues. Automakers are working to increase fuel economy, reduce carbon dioxide emissions, and maintain the vehicle size consumers demand. The Aluminum Association is a sponsor of the competition and bestows the Innovations in Aluminum awards to teams that make the best use of aluminum to enhance vehicle environmental performance.

The Wisconsin students converted their Chevy Suburban into a diesel-electric hybrid that used a lightweight, high-strength aluminum underbody frame and other aluminum components to offset weight added by the hybrid technology. The converted SUV got approximately 28 miles per gallon, up from approximately 17 miles per gallon for the production model. It also weighed about 500 lb less than the production model. The Wisconsin team's entry also emitted the least carbon dioxide from the tailpipe; such emissions are thought to contribute to global warming.

"The Wisconsin students have shown that reducing vehicle weight with aluminum is a highly effective way to boost fuel economy and cut emissions," said Richard Klimisch, Aluminum Association vice president, Auto and Light Truck Group.

The Georgia Institute of Technology earned second place in the Innovations in Aluminum competition for highlighting the benefits, versatility, and ease of replacing traditional components with aluminum. The Georgia Tech students replaced their Suburban’s engine with a Vortec 4200 aluminum engine and converted other components as well.

Lehigh Heavy Forge Corp., Bethlehem, Pa., a contract to produce eight propulsion shafts for the U.S. Navy’s newest Nimitz-class, nuclear-powered aircraft carrier CVN 77. The contract is valued at more than $2 million.

Lehigh Heavy Forge will produce the carrier’s stern and propeller shafts from ladle-refined, double-degassed steel on its 10,000-ton hydraulic forging press. Production of the shafts will begin in October, with the first shipment scheduled for September 2002. Newport News Shipbuilding, Newport News, Va., is expected to complete the CVN 77, which as yet has not been named, by 2008.

In addition to the aircraft carrier contract, Lehigh has also recently supplied finished machined support vessel ship shafts for the Navy’s Scaliﬁt program and has produced shafts for U.S. Coast Guard icebreakers.

"We are expanding our support of the ship shafting market by installing a new, state-of-the-art welding facility for finished fabricating," said Allan Robertson, Lehigh’s vice president of marketing and sales.
**Industry Notes**

- Genesis Systems Group, Davenport, Iowa, was recently awarded a U.S. patent for its design of the exchange axis on the Versa DST dual-station, swing table, robotic welding/cutting work cell. The exchange axis swings the workpiece from the load/unload position adjacent the operator to the welding position adjacent the robot.

- The Illinois Institute of Technology, Chicago, Ill., recently installed a Gleeble® 3500 high-speed physical simulation system for graduate studies and cooperative research programs with industry. Manufactured by Dynamic Systems, Inc., Poestenkill, N.Y., the system can heat specimens at 1000°C/min, exert 10 tons maximum force, and work at 2000 mm/s maximum stroke rate. It will initially be used to research improving the weldability of TC-128, a plate steel used in railroad tank cars; studying the hot workability of higher alloy steels and stainless steels; and characterizing the kinetics of bainite formation in high carbon steels.

- Victor Equipment Co. recently completed installation of $4 million of new machining at its Denton, Tex., factory. The equipment includes nine Citizen, numerically controlled, single-spindle units and one multispinde Euroturn. The machines have up to 11-axis machining capabilities, allowing them to produce multi-operation components in one operation. The machines produce approximately 50% of all Victor machined components and operate 24 hours a day, seven days a week.

- ESAB Asia/Pacific and Hitachi Via Mechanics recently formed an alliance to cooperate on the sales of welding products in Japan and to work together in production and sales of welding machines in selected areas of the Asia/Pacific region. Hitachi Via Mechanics manufactures high-tech welding machines and has a factory in Ebina, Japan. In the Asia/Pacific region, ESAB has manufacturing facilities in Korea, Indonesia, Thailand, China, and Malaysia. The regional head office and distribution center is located in Singapore.

- Lincoln Electric Holdings, Inc., Cleveland, Ohio, recently reported it had net income of $21.8 million, or 51 cents per diluted share, in the second quarter, compared with $29.4 million, or 69 cents per diluted share, in the same quarter a year ago. Net income in the second quarter included a pretax net gain of $10.2 million, principally from an insurance settlement for product liability coverage. Excluding that gain, net income would have been $23.1 million, or 54 cents per diluted share. Sales in the second quarter of 2000 were $249.4 million, compared with $274.2 million last year.

“Our industry is still feeling the effects of softness in the North American and other global markets,” Chairman and Chief Executive Officer Anthony A. Massaro said.

- Air Liquide American, Houston, Tex., recently agreed to sell 25 of its welding retail locations in Texas, Louisiana, and Oklahoma and a cylinder filling operation in West Texas to Aeriform Corp. Aeriform is a regional distributor of industrial, specialty, and medical gases; welding equipment; supplies; and cryogenic products headquartered in Houston. Air Liquide is also signing a long-term agreement that will make Aeriform part of its ALNET™ U.S. distributor network. Air Liquide has also sold four welding retail stores and a cylinder filling plant in Montana to Valley Welders Supply, Inc., and its Austin and San Antonio, Tex., stores to Texgas, Inc. Valley Welders and Texgas will also become part of ALNET. Divestment of the retail stores is part of Air Liquide’s business restructuring strategy.

**Tower Automotive Developing Friction Stir Welding for Automotive Applications**

Tower Automotive, Milwaukee, Wis., recently installed a SuperStir™ friction stir welding (FSW) machine to help develop the friction stir welding process for automotive applications. Upon completion of the development work, the machine will be upgraded and moved to the production plant.

The machine, built by ESAB Automation & Engineering, Laxa, Sweden, utilizes two vertically oriented, independent welding heads, one from the top and one from the bottom. The welding heads use a conventional FSW pin tool, but can operate simultaneously.

*The friction stir welding machine delivered to Tower Automotive utilizes two vertically oriented, independent welding heads.*

**Nooter Forms Nooter Fabrication Services**

Nooter Corp., St. Louis, Mo., recently established Nooter Fabrication Services, Inc. (NFS), which will market, sell, and provide project management services for equipment to be fabricated by its affiliate shops, Amalgamated Metal Corp., in Malaysia and Consorcio Industrial, S.A. de C.V., in Mexico. The new company plans to partner with additional fabrication shops in the future.

Mark Huck, formerly vice president-Global Alliances at Nooter Fabricators, Inc., will serve as NFS president. The new company will act as project manager and liaison to customers. Its engineers and technical experts will be stationed at all affiliate fabrication facilities to monitor production and transfer Nooter technology. Personnel will also be responsible for project management.

Current affiliate companies manufacture pressure vessels, reactors, and heat exchangers, as well as provide other types of custom metal and alloy fabrication.
**D1.1 Code Clinic**
The eight (8) hours of instruction provide a "road map" through the Code, emphasizing the interpretation of the important paragraphs, charts, and graphs which are crucial to understanding the Code when working under stressful deadlines. A practice exam will be administered, and the instructor will drill the class on the use of the Code under time constraints creating deadline pressure similar to the test environment. If you're taking the CWI exam, this clinic has proven to be valuable test preparation. As a leading construction code, D1.1 is the ideal tool to teach effective code use.

By attending, you can learn:
- How to correctly interpret specifying documents.
- Sure-fire methods to avoid common pitfalls with any code.
- How to eliminate rework.
- Tested ways to meet delivery schedules.
- How to use any code, standard or specification by honing in on the core of the problem or question.

Register for the full week and receive your complimentary copy of D1.1 Structural Welding Code - Steel. Single day registrants can purchase the D1.1 code at fifty percent off the list price - a savings of $167. D1.1 Codes and other materials will be distributed at the seminar site.

Cost: AWS Members....$335; others.....$415

**Welding Inspection Technology Course**
Three days on all facets of welding examination. Always scheduled on the second through fourth days—This course continues to be refined and sharpened by attendee evaluations and by examination performance.

The course covers:
- Safe Practices
- Metal Joining and Cutting Processes
- Weld Joint Geometry and Welding Symbols
- Documents Governing Welding Inspection and Qualification
- Metal Properties and Destructive Testing

This course is a real aid for welding inspectors and welding educators seeking AWS certification or increased proficiency.

Cost: AWS Members.....$440; others.....$520

**API 1104 Code Clinic**
AWS offers this eight-hour course over two evenings during the 5-day exam period at all exam locations. Attendees receive the following materials: API 1104, Welding of Pipelines and Pressure Vessels, 1104 Reference Manual. The course covers general code provisions, including plant containing filler metal additions, design and preparation of joint for production nondestructive testing, and automatic welding with and without filler metal additions.

Cost: AWS Members.....$335; others.....$415

**Value Pak 2**
Same as Pak 1 except choose only one Clinic.

Cost: AWS Members.....$1,465; others.....$1,700

**Value Pak 3**
Visual Inspection WQD Nondestructive Examination

Cost: AWS Members...

### Scheduled Opportunities

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<th>MONTH</th>
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<th>Course Details</th>
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<tr>
<td>Book General Knowledge Test</td>
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<td>Preparation for Practical Exam</td>
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**Visual Inspection Workshop**
This workshop provides eight hours of expert instruction which includes approximately three hours of lecture with “hands-on” learning scheduled for the balance of the workshop. This “hands-on” training incorporates plastic replicas of welds and also includes a sample practical examination to prepare test candidates for the CWI practical exam.

**By attending, you can learn:**
- How to use weld measuring instruments.
- Compliance to a specific code.
- Do's and don'ts of documentation.
- When a discontinuity is not OK.
- When a flaw is OK.
- Why visual inspection can be the most effective NDE technique.

**Cost:** AWS Members: $335; others: $415

**Value Pak 1**
D1.1 Code Clinic, Welding Inspection Technology Course, Visual Inspection Workshop, API 1104 Code Clinic, and exam.

Cost: AWS Members: $1,690; others: $1,900

**Value Pak 4**
Welding Inspection Technology Course, Visual Inspection Workshop, and exam.

Cost: AWS Members: $1,130; others: $1,285

**AWS' Welding Inspection Seminar**
exam preparation will exceed your expectations!

To get started on becoming an AWS CWI, go to www.aws.org and click "Certification." Download both QC1 "Standard for the Certification of Welding Inspectors" and an application. Complete the form, mail to AWS, and allow 6 weeks for processing. For more information on preparing for the CWI or CWE exam, go to /Education/educ.htm and click to see the latest brochure in pdf mode.
Portable Welding Screen Eliminates Ultraviolet Rays

The portable welding screen made of yellow, aztec orange, or green PVC helps eliminate harmful ultraviolet rays levels in welding areas. The PVC material is fire-resistant, self-extinguishing, and registered as such by the California State Fire Marshall’s office. Frames are easily assembled, lightweight, and durable. Frames can be moved from one area to another, set up in various configurations of multiple screens via optional swing hinges, and come with optional casters for added mobility. The company’s line also includes portable welding screens, sliding partitions, and custom enclosures that control sparks, ultraviolet rays, noise, dust, and other hazards.

Aleeo
P.O. Box 589, Tuscumbia, AL 35674

Welding End Prep Tools Feature Rigid Blade Lock Design

A line of welding end prep tools with cutter heads featuring a wedge-lock blade locking system that minimizes vibration and heat buildup is available from the company. MILLHOG® end prep tools mount securely to the inside of a tube or pipe and have a cutter head with a wedge-lock blade locking system that holds tighter when pressure is applied. Combined with double-threaded fasteners and TiN-coated blades that have full-contact clamping faces at an angle that securely seats the blade down and back, the tools can produce a continuous thick chip without cutting oils. Tools are available in 37½-deg bevel, facing, land, and boring blades. Cutter heads are made from heat-treated tool steel with a black oxide finish. Tools are suitable for tube and pipe from ½-in. inner diameter to 18-in. outer diameter.

ESCO Tool
50 Park St., Medfield, MA 02052

MANUFACTURERS OF CORED WELDING WIRE AND STICK ELECTRODES

We have been told that we are the best-kept secret in the welding industry. In an effort to correct this situation we advise that:

WE MAKE

<table>
<thead>
<tr>
<th>Stainless</th>
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A pipe and tank fabricator invested in inverter-based welding machines to save energy costs and reduce maintenance expenses

BY NEAL BORCHERT

Boosting energy efficiency translates into cost savings, so when local power company Kaukauna Utilities suggested Team Industries, Inc., evaluate how efficiently its equipment operated, the company complied. Starting in March, the pipe and tank fabricator based in Kaukauna, Wis., began replacing aging, power-guzzling welding machines with more efficient, inverter-based welding power sources.

The company’s investment will result in a $303 annual electricity savings per power source and a $413 rebate per power source from the power company. Additional benefits include savings in maintenance costs through improved reliability and product improvements.

Energy Efficiency

"About a year ago, after considering Kaukauna Utilities’ recommendations, we made a commitment to look at our equipment needs and what would be required to sustain us over the next 15 years. Obviously, energy cost was a high-priority issue," Team Industries President Donald J. Murphy said. "We knew welding machine technology had changed greatly, so we wanted to invest in this technology, particularly the newer energy-efficient power sources. But we also wanted machines that were operator- and maintenance-friendly, along with multiprocess capability. The bottom line was how to perform the same
amount of work using less energy.”

The utility company encourages this mindset among its customers. “Saving energy is a win-win proposition for us and the customer,” explained James J. Brown, Kaukauna Utilities’ customer service representative and a consultant to Team and other industrial customers. “Our philosophy is to work with customers to ensure they use energy as efficiently as possible. When Team indicated it wanted to improve its energy efficiency and power factor, we knew we could help.”

When high-use utility customers become more efficient, the benefits flow both ways. Kaukauna Utilities generates part of its power through seven hydroelectric facilities in the Fox River Valley. It buys the rest, but buying energy on the open market incurs penalties to the utility.

“If our customers can reduce their energy demand, we can reduce the amount of electricity we have to purchase on the market. We save costs and, therefore, pass on less cost to the end user,” Brown said. “Additionally, reduced demand enables us to generate fewer kilowatt hours to meet that demand. Our ‘avoided cost’ is converted into rebates for customers that use energy efficiently.”

Making the Switch

Before selecting it, Team tested the Miller Electric XMT 304 inverter-based power source in-house for one year. The XMT is a CC/CV, multiple-process power source with a 5- to 400-A output (300 A at 60% duty cycle). It features an average energy efficiency of 85% and a good power factor. (Power factor is the ratio between “working” power to the total power being provided by the utility.) The company installed 18 of the machines in March and April, and will eventually purchase up to 52 units.

“At our plant, welding machines are among the most common electrical devices — 52 welding units are in use here daily,” noted John Panetti, the company’s executive vice president of manufacturing. “That makes them one of the highest users of electrical power, so we definitely needed the most energy-efficient welding machine we could find to replace our older units.”

Company officials also critically evaluated the arc characteristics of the inverter power sources. Testing showed they could consistently deliver a smooth, stable arc in all welding modes. “This was key for us, because our work demands high-quality, multiprocess welding capabilities,” Panetti said.

Maintenance Efficiency

The second major force driving change at the company was rising maintenance costs associated with its aging welding units. “We could have gotten by with our existing machines,” maintenance supervisor Jason Sturn said, “but it’s not always the right thing to do. You have to weigh how much downtime and repair bills you’re accumulating using older equipment that starts to break or wear out.”

For example, as the welding machines’ mode switches reached their upper tolerances and began to fail, “I went through as many as two or three mode switches per machine per year at a cost of about $186 per switch,” Sturn said. “The mode switches for those older machines are supposed to last three to four years.”

At the beginning of this rash of switch failures, a welding operator was down for two hours during his shift while his machine was pulled off-line and a replacement readied. In addition to the cost of the switch, therefore, was the extra $30/h cost of the operator’s downtime. Mode switch failures became more predictable, however, and the company became adept at limiting downtime during shifts. “It’s a learning curve when a particular problem begins happening, and soon you become expert at a certain repair,” Sturn said. “But these are things you really don’t want to get good at.”

Unfortunately, the fabricator also had to replace fan motors and PC boards as the older welding units began to show their age, at a cost of $125 for a new fan motor and $574 for the associated PC board. “We’re not exactly sure what’s causing these components to fail, but age has something to do with it, because five years ago we weren’t burning up PC boards like we are now with the older machines,” Sturn observed. “Plus, there’s no warning when a fan is about to go. It just goes. That’s another two hours of downtime by the time you shut the operator down, get all the covers off, pull the fan, and put the new fan in.”

Connections had also begun to deteriorate on the 13-year-old machines, which were acquired when they were the first multiprocess machines on the market. “Constant use, heat buildup, and vibration are affecting the connections to switches and tripping thermostats,” Sturn said. “The stress of frequent repairs adds to the problem, so the connection would fail again despite repair work.”

The company’s first 18 inverter units have replaced the older generation machines that had the highest maintenance record and/or those getting the most use.

Welding Quality

Since 1987, Team Industries has provided piping, tank and modular fabrication for the brewery, chemical, pulp and paper, power, refinery, petrochemical, and industrial gas industries, to name a few. In the last 14 years, its manufacturing capabilities have expanded to include pipe spools, skid-mounted equipment modules and manifold assemblies, structural modular framing, rack-mounted process piping, ASME tanks and pressure vessels, and tanks, hoppers, and fittings of all varieties. The company also manufactures its own line of welding positioners and grippers, which it designed specifically for pipe fabrication — Fig. 1.

The fabricator is authorized to use the ASME “PP” and “U” code symbol stamps, and is qualified to perform code fabrication to ASME Section I and VIII Division 1, ASME B31.1 and B31.3, as well as other National Code Standards. Team’s 80 welding operators use the shielded metal arc, gas metal arc, gas tungsten arc, submerged arc, and flux cored arc welding processes. The company works with a wide range of materials, including 304, 316, 321, and duplex stainless, carbon steel, cast alloys, aluminum, nickel-based alloys, titanium, and P91 and P22 chrome-moly steels.

“Basically we sell welding, and welding is our forte,” Panetti said. “We have some of the best operators in the world.
welding here. The systems we build are subject to pressures as high as 2500 lb/in.² at 1500°F. We X-ray approximately 1000 pipe welds per month. We can’t afford not to provide the latest technology to our welding operators.”

Use of advanced technology allows the company to claim a rejection rate of less than one-half of 1% for materials that arrive in the field. Consequently, the company avoids expensive rework. For example, a weld that fails Team’s X-ray or ultrasonic tests can cost $200 to $300 to repair. The loss of the operator’s productivity increases that figure to a $400 to $500 loss.

The new inverter welding power sources have contributed to Team’s quality and manufacturing efforts in a number of ways. User-friendliness was the first benefit the welding operators experienced. Ease in switching from one process to another were other benefits — Fig. 2.

Many of the welders were impressed with the machine’s gas tungsten arc welding capabilities (see lead photo). “It seems to have a nice, stable, smooth arc with (GTA) welding; it’s much nicer than the machines we had,” welding operator Chris Starks said.

In addition, the machines afford more available amperage to handle the company’s higher workloads. “Our operators had become very efficient with the higher amperages, and we were at the top end of what our older machines could put out,” Panetti said. The new machines allow the company to use another 100 A, plus provide 10 A of auxiliary power to run accessories such as water coolers, wire feeders, and high-frequency units.

The second phase of the firm’s welding power source replacement project starts next year.

The increased efficiency the inverter-based units have given the company’s welding operators has had a ripple effect throughout the plant. “Our pipefitters are a little concerned they can’t keep pace with the welders,” Panetti said. “But I think they’ll rise to the challenge and adapt to this new production level.”

---

**Calculating Energy Efficiency**

Inverters provide both good electrical efficiency and a good power factor. In the past, transformer-based welding power sources have done a poor job of converting incoming line power to welding output power. Efficiencies of 60-70% have been typical, with constant current machines being better offenders than constant voltage machines. With inefficient welding machines, most of the “lost” primary power ends up heating the transformer (which is why welding machines have cooling fans). All that hot air results in high utility bills. In fact, if someone gave you a free machine, but it used power inefficiently, you could end up losing money on it.

In 1995, Miller improved the way the copper wire wraps around the iron transformer core for its machines and added a cooling fan that only ran when needed. This boosted power conversion efficiency to approximately 80% for its traditional three-phase input machines and 85% for its inverters. An independent laboratory confirmed the new power sources provided a 10 to nearly 25% energy efficiency advantage over units featuring the old transformer design.

**Power Factor Correction**

Power factor is defined as the ratio of real power (or “working” power, the power that produces useful work, such as creating a welding arc) to apparent power (the total power being provided by the utility). Simply put, the current required to operate a piece of equipment having a low power factor is quite a bit higher than that required for equipment having a high power factor. Many utility companies charge an additional fee if an industrial facility has a low power factor.

A low power factor is caused by inductive loads, such as in the transformer of a welding power source. To overcome a low power factor, manufacturers incorporate a feature called power factor correction (PFC) into a welding power source. Power factor correction is optional on some power sources and a standard function on others. As a result of PFC, the XMT 304 draws 18.9 A on 460-V, three-phase primary service to produce a 300-A/32-V DC welding output. An old CC/CV power source without PFC may draw from 30 up to more than 40 A of primary current, or more than double the load of an inverter.

The following calculations demonstrate the impact of energy efficiency on utility bills.

**Inverter Power Calculations** — Arc-on welding cost: 300 A x 30 V (welding output) x $0.11 (energy cost per kW-hour) x 2400 h (annual arc-on time) ÷ 0.85 (weld efficiency) = $2,795.29.

Unit idle cost: 0.028-kW idle power draw x $0.11 x 1600-h idle time = $4.93.

**Old Welding Unit Calculations** — Arc-on welding cost: 300 A x 30 V (welding output) x $0.11 (energy cost per kW-hour) x 2400 h (annual arc-on time) ÷ 0.71 (weld efficiency) = $3,346.48.

Unit idle cost: 0.411-kW idle power draw x $0.11 x 1600 hours idle time = $72.34.

Power cost to operate old machine: $3,418.82.

Power cost to operate inverter: $2,800.22.

Power savings potential with inverter: $618.60 per year, per machine.

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Welding Offers Utilities Answers about New Chrome-Moly Steel

As power plants strive for increased productivity, designers are specifying higher-alloyed steels for tubing networks.

BY BOB IRVING

Both welding metallurgy and circumferential welding arc being put to the test in hundreds of power plants throughout the world. During shutdowns, pipe and tubing arc being replaced with higher-alloyed steels that enable plants to operate at higher temperatures and pressures, thus increasing operating efficiency. Typically, the old standby 2¼Cr-1Mo steel (P22) is being replaced by a modified 9Cr-1Mo-V steel (P91).

For new plants, the real savings provided by P91 are lighter hangers and support structures, according to David Cable, manager, Welding Operations, Wachs Technical Services Ltd., Charlotte, N.C. In refurbished plants, P91 improves creep resistance.

Over the years it has been in service (more than 300,000 h, in some cases), 2¼Cr-1Mo steel has been a very forgiving material. The area to be welded doesn’t have to be purged and it’s not necessary to postweld heat treat on smaller diameters and thicknesses.

There are, however, questions about P91. Unfortunately, in the few years it has been in service in the United States, failures have occurred because the steel was not properly postweld heat treated.

“P91 is not just another chrome-moly steel,” said R. A. Swain, president of Euroweld, Ltd., Mooresville, N.C. He is in constant contact with engineers directly involved in the design and fabrication of P91 steel in numerous North American power plants. “On 2¼ chrome-1 moly steel, you might be able to get away without postweld heat treatment, but not with P91. With P91, you do it right or you’re in trouble.”

Induction vs. Resistance Heating

J. E. Henry, director of the Materials Technology Center, Alstom Power, Inc., Chattanooga, Tenn., discussed some of the issues involving postweld heat treatment (PWHT) of P91 steel.

“The power industry has been working with chrome-moly steels like P22 for 35 years or more,” Henry said. “It has been found that those steels have high tolerances for variations. If the heat treatment is 150° out of tolerance in the heat treating of P22 steel, it might not affect final properties... But P91 is an entirely different story and should be treated as such. No matter which method is used to perform PWHT on this higher-alloyed chrome-moly steel, there should be no deviation whatsoever in the established procedures.” At Alstom Power, welded P91 piping is postweld heat treated inside carefully calibrated gas or
Typically in the field, however, the choice is either resistance or induction heating. Induction heating is the faster of the two processes, but Mannings USA, Dover, N.J., a major heat treating subcontractor of P91 welds, uses resistance heating equipment exclusively for this type of work. It does so because the company uses its own six-way heat treating console in conjunction with appropriate ceramic pad heaters, thermocouples, plugs, sockets, and other components. Mannings uses its model P256 programmable generator with six channels and either manual or automatic controllers for temperature control when performing PWHT of P91 assemblies. D. J. Ciurlaricillo, manager of technical sales, said resistance heating on P91 tubular welds is the process of choice because it can treat six welds simultaneously.

Miller Electric Mfg. Co., Appleton, Wis., however, uses portable induction heating equipment for this type of application. It has already been used to heat treat orbital welds in cross-country pipelines in the field and is also a candidate process for P91 work.

The Development of P91

Today's P91 steel had its beginning in the late 1960s, developed by the Chestnut Run Laboratories of Combustion Engineering in Chattanooga, Tenn. Metallurgists there modified a version of 9Cr-1Mo steel developed years before by The Timken Co. of Canton, Ohio. The modified grade looked promising, but funding was needed to improve the material. According to C. T. Ward, then a key metallurgist at Combustion Engineering and now a senior consultant at Alstom Power, the search for funding resulted in a proposal submitted to the U.S. Energy Research and Development Administration (later known as the Department of Energy).

The company's customer at the time was Oak Ridge National Laboratory (ORNL) in Oak Ridge, Tenn. The newly modified 9Cr-1Mo alloy was intended for the fast breeder reactor application then under development, and was eventually identified as the reference material for a fast breeder reactor prototype plant, which was to be built on the banks of the Clinch River in Tennessee.

The modified grade was a microalloyed steel that contained controlled trace amounts (less than 1%) of carbon, manganese, phosphorus, sulfur, and silicon. The steel also contained trace amounts of niobium, vanadium, nickel, nitrogen, and aluminum. The presence of niobium and vanadium improved the strength of the steel at elevated temperatures.

"At the time we were working on this effort," recalled Ward, "we saw opportunities for the alloy elsewhere even though our research was not directed toward fossil applications for the alloy."

Unfortunately, plans to build the fast breeder reactor plant in Tennessee were scrapped before the first section of steel was welded, but several European and Japanese steel companies began researching the alloy as a new material for fossil use. As a result of their efforts, the prime suppliers of grade 91 seamless pipe and tubing to American utilities today are Vallourec & Mannesmann Tubes in Europe, and Sumitomo Pipe & Tube Co., Ltd., in Japan.

Lightweight and Strong

Weight reduction is key when evaluating P91. Henry of Alstom Power notes that 16-in.-diameter (406-mm) steam line piping for headers has a wall thickness in conventional installations of 4/8 in. (114 mm). By converting to P91, he said, wall thickness can be reduced to 2/8 in. (63 mm).

In Denmark, a comparison of wall thicknesses for various alloys, including P22, X20, and P91, was developed that found nearly a two-thirds reduction in wall thickness — from 180 mm (5.4 in.) down to 66 mm (2 in.) — was possible when P91 was used in place of P22 steel — Fig. 1. P91 also provided an increase from 44 to 170% in allowable strength in the 950-1100°F (510-593°C) temperature range; an oxidation limit of 100°F (38°C) above typical P22 grade steels; and higher allowable strengths over type 304H stainless steel up to 1130°F (610°C).

The Role of Postweld Heat Treatment

Regardless of thickness or diameter, postweld heat treatment of P91 should be conducted for at least 2 h at temperature to provide appropriate tempering. PWHT temperature ranges between 1375 and 1400°F (745 and 760°C). (The optimum temperature is more likely to be 1400°F.) Post bakes are recommended in instances when the weld cools to room temperature prior to administration of PWHT.

"With P91," said Euroweld's Swain, "the ASME code will actually allow a minimum postweld heat treat of 1300°F. As you go up in temperature, you come down in yield and the steel becomes more ductile and softer. The code goes on to state that you can postweld heat treat P91 steel to 1400°F (760°C) or greater, as long as the lower critical temperature (AC1) is not exceeded.

"If you are not sure of the nickel and manganese content of your filler metal," said Swain, "you could exceed your lower critical temperature, but that is asking for trouble. When a lower Ni+Mn content is present, a higher postweld heat treatment can be used."

Euroweld is including a Certified Material Testing Report (CMTR) of analysis and mechanical properties with its shipments of filler metal to be used for the welding of P91 steel. The CMTR identifies the exact Ni+Mn content in those particular shipments. Only then will a customer know what the range will be for postweld heat treatment.

"We recommend our customers require CMTRs in their purchase orders," said Swain. "Early research showed that even when the composition of the filler metal was within range, coated electrode mechanicals could exhibit nil ductility. Thus, several users also require actual mechanical properties."

P91-Related Consumable Production

Since Europe has had a head start in experience with P91 steel tubulars, it is also well ahead of the United States in the development of consumables needed to weld this alloy steel.

Alloy steel filler metals from overseas differ considerably...
from the specifications developed years ago at Oak Ridge National Laboratory (ORNL) for the welding of the fast breeder reactor. Compared to the ORNL specifications, European consumables feature higher levels of nickel and silicon. Also, there are restrictions in nickel plus manganese content. The higher nickel content improves toughness, while Ni+Mn is limited to 1.5% to make sure the AClβ transformation temperature is maintained at a level that will permit proper tempering.

For several years, ESAB Welding & Cutting Products, Florence, S.C., has produced a flux-cored wire for P91 steel. Most recently, the company introduced two shielded metal arc welding electrodes, one from Sweden and the other manufactured in its plant in Hanover, Pa. The Sweden-produced electrode, said F. B. Lake, senior research engineer in ESAB’s R&D Department in Hanover, meets the AWS E9015-B9 criterion, while the domestically produced electrode is an AWS E9018-B9 filler metal. ESAB also has projects under way to evaluate solid wires for P91 steel.

Bohler Thyssen Welding USA, Houston, Tex., produces solid wire consumables for gas tungsten arc and submerged arc welding. (The company does not produce flux-cored electrodes.) According to its metallurgists, it is essential the critical elements of consumables be maintained within a tightly controlled range in the weld deposit — Ref. 1. The critical elements and their chemical ranges are as follows: carbon (0.08–0.13%); niobium (0.04–0.08%); vanadium (0.15–0.30%); and nitrogen (0.03–0.07%). Adherence to these limits, they claim, ensures creep rupture strength will be adequate to withstand the high temperatures [1040–1122°F (560–600°C)] and 4000 lbf/in² (27,560 Pa) pressures experienced when P91 piping is used in power plants. Bohler Thyssen engineers also agree the sum of Ni+Mn not exceed 1.5% to avoid any undesirable structure changes during PWHT. Two consumables — Thermanit MTS 3 and Thyssen Chromo 9V mod. — capable of obtaining toughness values greater than 30 ft-lb after PWHT at 1382–1400°F (750–760°C) for a minimum of 2 h, are produced.

**Creep Rupture**

Once the operating temperature exceeds 1050°F (566°C), creep rupture becomes a consideration. When niobium levels are reduced to the 0.025 – 0.03% level, encouraging creep rupture results have been observed, said W. F. Newell, Jr., vice president of Eurovecold. This condition is evident in the Supercore 91 flux cored arc welding (FCAW) wire from Metrotec.

“FCAW welds made with Supercore 91 are generally about 5 to 10% stronger at ambient temperature than weld metals produced by shielded metal arc welding (SMAW) and submerged arc welding (SAW),” said Newell, “and are similar to those of gas tungsten arc welding (GTAW) deposits after similar postweld heat treatment, but the corresponding toughness is generally lower. To mitigate the effects of titanium pickup (typically 0.02 – 0.04% Ti), the level of niobium is deliberately controlled to the minimum consistent with meeting weld metal specifications.”

Utilities are attracted to P91 steel because of the opportunity it provides to eliminate weld joints between dissimilar metals. Most of the dissimilar metal joints are presently between type 304H stainless steel and 2%Cr-1Mo steel. In many instances, P91 alone can be used throughout the system.

Dissimilar welds between P91 and either P11, P22, or austenitic stainless steel can be accomplished and are done routinely. In joints between P91 and P22, filler metals of either base metal composition can be used to make the weld. If P22 filler metal is used, the decarburized zone will be in the P22 weld metal. If, on the other hand, a P91 filler metal is used, the carbon-depleted zone will be in the coarse-grained heat-affected zone of the P22 steel. The carburized zone will be in the P91 weld metal.

“The extent of the decarburized zone,” said Newell, “depends on the tempering temperature and the time at temperature. The only way to avoid this condition is to use a nickel-based welding consumable.”

Weld joints between P91 and austenitic stainless steels also require a nickel-based filler metal. “The weld metal can be applied,” said Newell, “or it might involve buttering a P91 ‘pup’ piece that can be heat treated and then field installed.”

**Welding Processes to use with P91**

Welding processes that can be used to weld P91 steel include SMAW, SAW, FCAW, and GTAW — Table 1. The SMAW process was the first method used, and is still the process of choice when skilled welders are available. However, the shortage of skilled welders and the need to increase weld speed and deposition rates have focused greater attention on other processes, especially FCAW. GTA welding is used to some degree because its weld deposits are high quality, but it is also slow. A faster, hot-wire GTA welding process is being used as well as a cold-wire version of GTAW that produces narrow groove welds.

**Flux Cored and Shielded Metal Arc Welding**

Automatic flux cored arc welding is being used in the field by J. A. Jones, Inc., Charlotte, N.C., according to M. D. Scalley, corporate quality assurance manager. At one of four sites, his company is using FCAW for fill passes. Root passes are made using manual GTA welding, followed by two hot passes, both of which are made with manual GTAW. Where bends and turns are encountered, manual welding is still employed, although automatic flux cored arc welding is still most cost effective on long runs of rack pipe installations. At the other three sites, SMAW is used. Most of the postweld heat treating at installations where J. A. Jones works is subcontracted to companies specializing in electric resistance heating.

According to Eurovecold’s Newell, the most widely used process involving P91 is shielded manual arc welding. The procedure involves a gas tungsten arc root pass followed by fill using an AWS E9015-B9 electrode. The second most popular process is FCAW, both in the semiautomatic and automatic modes. An AWS subcommittee is working on a specification for the filler metal. Pending is an E10XT1-B9 filler metal. The recommended shielding gas is either one of the argon/CO₂ mixtures or straight CO₂.

Utilities are primarily interested in weld quality and welding speed. Shielded metal arc welding of P91 is not a fast process, but acceptable weld mechanical properties are easy to obtain as long as the electrode formulation is consistent with B9.
was ill-suited to weld pipes orbitally, EPRI partnered with real time, fuzzy logic voltage, and current control for welding head for welding out of position and a power supply water circulator. The Pipeliner II operates as a system with all automated system developed combined a new generation and nuclear plants. Since conventional flux cored arc welding for instantaneous response to changes in the welding arc.

There is no doubt that utilities prefer flux cored arc welding, but there is a concern about shielding gas. The high content of CO in shielding gas is beneficial but if it is too high, the excessive oxygen in the weld metal can reduce impact toughness. Superecore P91 wires from Metrode have been formulated to operate satisfactorily within either argon-CO₂ mixtures or straight CO₂ shielding gas. The end result is better impact properties with a similar spatter rate. "This is believed to be due to higher penetration and, thus, greater interbead tempering action of previously deposited weld beards," explained Newell.

**Orbital Welding**

Orbital welding equipment for flux cored arc welding of P91 pipe is available from Magnatech Limited Partnership, East Granby, Conn. Known as the Pipeliner II system, this type of equipment has been in use for several years, but has not yet been used on P91 pipe. According to J. G. Emmerson, president of Magnatech, two systems are being used for FCAW of the 2/1Cr-1Mo tubulars for utilities. Emmerson expects a growing need for this type of equipment in the years ahead.

The Pipeliner II is capable of weld deposition rates of 8 lb/h (3.6 kg/h), compared to 4 lb/h (1.8 kg/h) for manual FCAW. The system consists of a weld head, power source, wire feeder, and water circulator. The Pipeliner II operates as a system with all functions controlled from a remote pendant. The inverter power source used with this system uses dynamic process control for instantaneous response to changes in the welding arc.

According to D. W. Gandy, program manager, Materials & Fossil Applications, Repair & Replacement Applications Center, Energy Conversion, Electric Power Research Institute (EPRI), Charlotte, N.C., the power industry began looking in 1995 (Ref. 2) for a way to improve the deposition rates of materials used to weld heavy-walled steam pipes found in fossil and nuclear plants. Since conventional flux cored arc welding was ill-suited to weld pipes orbitally, EPRI partnered with Magnatech Limited Partnership to develop a solution. The automated system developed combined a new generation welding head for welding out of position and a power supply with real time, fuzzy logic voltage, and current control for improved stability. Said Gandy, the resultant system now being used to weld P91 steel has deposition rates three times higher than those achieved with conventional processes.

Liburdi Dimetrics, Charlotte, N.C., has also introduced equipment for operation of hot-wire GTA, cold-wire GTA narrow groove welding, and FCAW called Orbimig 450. According to R. P. Brewer, senior application specialist, units for all three processes have been sold to industry for the welding of P91 steel. As a rule of thumb, Brewer said, the flux cored process seems to work well on 3 in. (76 mm) thicknesses and under. On this process, when 0.045 in. (1.1 mm) diameter is used, welding speed is about 280 m (911 cm) per minute. With hot-wire GTA welding and 0.035 in. (0.89 mm) solid wire as the consumable, welding speeds range from about 200 to 250 in. (508 to 635 cm/min) — see lead photo.

The company also produces systems for hot-wire GTA welding of P91 pipe. This automatic mode of GTA more than triples weld deposition rates of conventional GTA. In this system, the base metal is melted by an oscillating tungsten electrode. Separately, a constant current power source increases the temperature of the alloy steel filler metal through resistance heating. The filler metal reaches its melting point just before entering the weld pool.

A microprocessor controls the settings for current, voltage, travel speed, wire feed speed, and wire feed current. Wire feed rates of up to 400 in. (1016 cm/min) are obtainable. This same system can also be used for conventional cold wire GTA welding in the narrow groove mode. A dual hot wire setup is also available.

### Higher Deposition Rates

In FCAW and with hot-wire GTA, said Cable of Wachs Technical Services, deposition rates are 45 lb (2 kg)/h. On 1.03-in. (2.6-mm) wall Schedule 80 pipe, noted Cable, you can narrow a groove weld with the cold-wire gas tungsten arc process at 6.5 m/h (21.3 ft/h) using 7.7 lb (17 kg) of wire. Using conventional welding, 13 m/h (42.6 ft/h) can be welded, but 16.4 lb (7.4 kg) of filler metal will be consumed. "That's a savings of $191 per joint," he said.

Submerged arc welding is used extensively, especially in semiautomatic mode, for welding P91 steel using both constant current and constant voltage power sources — Fig. 2. One problem when welding semiautomatically involves the feeding of the wire. The stiffness of B9 filler metal precludes ease of feeding through the sharper turn of the standard semiautomatic weld head. This problem can be solved either by reducing wire diameter or by running the rod through a double annealing furnace at the steel mill.

Gas metal arc welding using solid ER905-B9 filler metal under argon shielding has been used sparingly on P91 steel. This is because B9 composition is lean on deoxidizers, which are very important in GMAW. Thus, wetting action is reduced and welds will contain incomplete fusion defects. Oxide inclusions will also be high. GMA welding is very operator specific and, on P91 steel, has not performed with consistency. Warned Newell, "Qualification and use of solid-wire GMAW should be approached with much caution."

### Table 1 — Typical Grade 91 All-Weld-Metal Mechanical Properties at Room Temperature

<table>
<thead>
<tr>
<th>Process</th>
<th>Deposit</th>
<th>Ultimate MPa (ksi)</th>
<th>Yield, 2% MPa (ksi)</th>
<th>Toughness 1-lb (ft-lb)</th>
<th>Hardness HV</th>
</tr>
</thead>
<tbody>
<tr>
<td>SMAW¹</td>
<td>All Weld Metal</td>
<td>820 (120)</td>
<td>700 (102)</td>
<td>65 (47)</td>
<td>240¹</td>
</tr>
<tr>
<td>SMAW¹</td>
<td>Weldment</td>
<td>699 (102)</td>
<td>N/A</td>
<td>54 (39)</td>
<td>N/A</td>
</tr>
<tr>
<td>GTAW²</td>
<td>All Weld Metal</td>
<td>750 (109)</td>
<td>660 (97)</td>
<td>147 (109)</td>
<td>240¹</td>
</tr>
<tr>
<td>GTAW²</td>
<td>Weldment</td>
<td>703 (103)</td>
<td>N/A</td>
<td>199 (144)</td>
<td>N/A</td>
</tr>
<tr>
<td>FCÅW</td>
<td>All Weld Metal</td>
<td>750 (109)</td>
<td>660 (97)</td>
<td>147 (109)</td>
<td>240¹</td>
</tr>
<tr>
<td>FCÅW</td>
<td>Weldment</td>
<td>703 (103)</td>
<td>N/A</td>
<td>199 (144)</td>
<td>N/A</td>
</tr>
<tr>
<td>SAW³</td>
<td>All Weld Metal</td>
<td>720 (105)</td>
<td>610 (89)</td>
<td>60 (44)</td>
<td>240¹</td>
</tr>
<tr>
<td>SAW³</td>
<td>Weldment</td>
<td>657 (96)</td>
<td>N/A</td>
<td>54 (39)</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Notes: 1. PWHT: 760°C/2 h 2. PWHT: 765°C/2 h 3. PWHT: 760°C/4 h

The Future of Alloy Steels

Metallurgists at the National Research Institute for Metals (NRIM), Tsukuba, Japan, predict future ultra-supercritical (USC) boilers will require more highly alloyed steels than P91 — Ref. 3. Steels for this next generation of boiler will require heat-resistant alloys with improved creep rupture strength at elevated temperatures more than 600°C due to increased operating temperature and steam pressure. Prime candidates are in the 9 to 12Cr range. One is P92, a 9Cr-1.5Mo-1.8W-VNb steel made by Sumitomo. Another is P122, a 12Cr-0.4Mo-2W-CuVNb material, also made in Japan. According to NRIM, the USC boilers are more efficient than conventional boilers and release less CO₂ into the atmosphere. Newell noted P92 provides a possible 30% reduction in wall thickness over P91.

Other new steels include E911, made in Europe, which is similar to P91 but has some tungsten; T23, another steel from Japan and Europe, which is like P92 but has only 2%Cr; and T24, also similar to E911 and developed by Mannesmann.

“You think P91 is difficult to weld,” said Cable, “wait until you see Paralloy, a new casting alloy from Europe. It contains high nickel, high chromium, and resembles Inconel®. It is being used in high-temperature ethylene furnaces and exhibits tremendous shrinkage characteristics that are extremely difficult to weld.”

References
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High-Performance Steel Increasingly Used for Bridge Building

BY LON YOST AND SCOTT FUNDERBURK, P. E.

The advantages of HPS 70W, a relatively new material for bridge construction, include corrosion and cracking resistance, high strength, and improved toughness characteristics.

The 995-ft-long Clear Fork River Bridge in Tennessee was built with HPS 70W steel. (Photo courtesy of the Tennessee Department of Transportation [TN-DOT].)

The number of states using high-performance steel (HPS) 70W for bridge construction has steadily increased over the last several years. This is largely due to a law signed in 1998, the Transportation Equity Act for the 21st Century (TEA-21), which authorizes highway and other surface transportation programs for the next six years. Under TEA-21, states receive federal funds to improve highways, opening the door to many new construction projects across the United States. To encourage use of this new metal, the act provides additional funds for bridge projects constructed with HPS 70W. In the three years since the passage of TEA-21, approximately 25 bridges have been built using HPS 70W in eight states.

LON YOST is Senior Application Engineer and SCOTT FUNDERBURK is Welding Design Engineer with The Lincoln Electric Co., Cleveland, Ohio, (216) 481-8100.
The Evolution of HPS 70W for Bridge Construction

The military originally developed high-performance steel for use in submarine construction. In 1994, Congress established a steering committee composed of the U.S. Navy, the Federal Highway Administration (FHWA), and the American Iron and Steel Institute (AISI) to research ways HPS could be transferred from military technology to civilian applications. In particular, the committee was charged with finding new ways to use the steel for bridge construction.

HPS 70W (70,000 lb/in² yield strength steel) was considered for bridge work because it offers the industry many advantages. First and foremost, it has outstanding corrosion-resistance properties. Because of this barrier, painting is not required, meaning less maintenance for state highway crews. In contrast, a non-weathering steel often used in bridge construction requires constant painting and maintenance.

The second advantage of HPS 70W is in the construction process itself. Because of its much greater yield strength, bridge decks that would require, for example, five girders with a 50,000ksi steel may only need three to four with HPS. Fewer girders mean quicker erection and cost savings. The same is also true with bridge piers, which can be spaced farther apart because of the new metal's strength.

Although the cost of HPS 70W and accompanying construction materials is usually more than counterparts of lower yield strength, the fact less has to be erected can offset and even improve the overall cost factor. In addition, many designers are turning to hybrid girders, which use HPS 70W for the flanges and 50W on the web of the girders to keep costs down, yet still maintain high strength levels.

The third advantage offered for bridge building is HPS 70W has a very low carbon equivalent (CE) number, meaning it is resistant to cracking and hardening in the heat-affected zone after welding. For safety reasons, this is important because any cracking can affect the integrity of the bridge. HPS 70W also requires a lower preheat temperature — a plus because of the sheer size of most bridge girders. Reduced preheat saves money and time; it also means less energy is consumed in the preheating process.

Lastly, HPS 70W steel has improved toughness to retard the growth of discontinuities in the metal. Discontinuities can include weld cracking, porosity, undercutting, or poor bead shape. For bridge inspection, the objective is to have discontinuities grow slowly so they can be caught without the bridge's soundness being compromised.

Weld Requirements and Development of Consumables

A subgroup of the Navy, FHWA and AISI steering committee mentioned previously was commissioned in 1996 to study the welding of HPS 70W. This welding advisory group, composed of representatives from all major filler metal manufacturers, academia, and steel producers, was given the task of determining welding guidelines for HPS 70W. The group determined Zone 3 toughness provisions would be required for the welds to match the toughness of the base metal. Weld requirements were thus established as 74 ksi minimum yield strength, 25 ft-lb at -20°F Charpy V-notch impact toughness, and a minimum of 1% nickel for weathering.

Submerged arc welding (SAW) has long been the prevalent welding process in bridge girder fabrication because of its high quality, relatively slow cooling rate, and the ability to weld without requiring a shielding gas. It is also an ideal process for welding the long, straight joints of bridge girders. Although some girders are welded with shielded metal arc welding (SMAW), it is limited to difficult-to-automate welds because SMAW is a much slower process.

As part of its work, the welding advisory group issued a challenge to welding consumables manufacturers to develop a SAW flux/wire combination that could be used effectively with HPS 70W — something that would match the characteristics of HPS 70W and meet the required specifications. Lincoln Electric conducted numerous tests with plates in the lab and girders in actual fabrication shops environments, as well as performing field diffusible hydrogen tests during development of its patented LA-85 wire and MIL100-HPNi flux combination for welding HPS 70W. To date, it is the only flux/electrode combination to be approved by the American Association of State Transportation Officials (AASHTO), which has established the Guide for Highway Bridge Fabrication with HPS 70W. This document is a supplement to AWS D1.5, Bridge Welding Code, detailing how to weld this new metal.

The new flux/electrode combination combines a lower-strength, lower-alloy-content wire with a low-hydrogen flux that contains nickel. This produces the characteristics needed for welding HPS 70W. A moisture-resistant coating on each flux particle seals it from picking up moisture while carbon dioxide generated during welding creates an effervescent effect that encourages hydrogen to diffuse out of the weld pool. As compared to the standard flux for 50W steel, which has a diffusible hydrogen level of approximately 8 mL/100 g of weld metal and can exhibit hydrogen-assisted cracking when welding on HPS 70W, MIL100-HPNi flux typically yields diffusible hydrogen levels of less than 2 mL/100 g of weld metal to prevent cracking.

Welding Guidelines

Although, in general, HPS 70W is easy to weld, a few guidelines must be followed:

- **Turn voltage down.** With typical fluxes, operators turn up the voltage to enhance wetting, but for welding HPS 70W with the approved flux, voltage is reduced to improve wetting action. To maintain the same bead shape as that of conventional flux, voltage should be set 2–3 V lower when using low hydrogen fluxes. On the other hand, current should be increased approximately 50 A to maintain a constant heat input.
- **Do not use electrode negative.** When welding with low-hydrogen fluxes, such as the one for HPS 70W, use direct current electrode positive or AC polarity only. Do not use direct current electrode negative.
- **Use larger-diameter wire.** To produce a good, flat-faced weld profile in a horizontal fillet weld, use a larger-diameter wire such as 3/8 or 5/8 in.
- **Avoid welding in still air.** A chemical-type odor comes off the flux when it is consumed in the arc. A fan or an open door or window is recommended to improve air circulation, and prevent the smell from being noticeable.
- **Look to tandem SAW.** For applications that require high productivity, fabrication shops should consider tandem arc processes — the flux/wire combination will easily lend itself to this type of automated process.
- **Undermatched applications.** If there are instances when a 50W web, for example, will be welded to an HPS 70W flange, fabricators can use the requirements of the 50W set forth by AWS D1.5, Bridge Welding Code, rather than the requirements for the stronger HPS 70W material.
- **Proper Preheat/Interpass Control.** Many girders used for bridge building can be 50 ft or more in length, which presents a preheating challenge. This is especially troublesome when using 50W and multiple passes are required. The minimum interpass...
Temperature must be maintained during all passes. The lower preheat and interpass temperatures required for HPS 70W are easier to maintain.

**Tips for Flux Handling**

Proper flux handling is especially critical with HPS 70W material. Follow these tips:

- **Flux conditioning.** There are two types of ovens needed to properly care for flux. The first, a holding oven, can keep the flux dry, but cannot dry out flux that already contains moisture. The second type is a drying oven to drive moisture out of the flux. For HPS 70W, it is critical a fabrication shop has both types of ovens because when the flux is contaminated with moisture, it will need to be dried at temperatures between 250°F and 400°F (not to exceed 450°F). Once opened, hermetically sealed pails of flux should be put in use or immediately transferred to the holding oven. No conditioning is required of the new flux when it comes out of the pail; welding can be started right after a new pail of MIL800-HPNi is opened.

- **Flux handling.** Eventually, flux particles will break down into fines (or dust). Flux recovery equipment can’t always separate out the fines, so operators should regularly purge the flux recovery equipment of all flux in the system and replace it with new flux. Operators should also take every precaution to ensure moisture doesn’t contaminate flux during the welding process by making sure no moisture is on the steel because of condensation out of a flame used for preheating. Deposit the flux just ahead of the arc on clean, dry steel and recover the unmelted flux right behind the arc. The AASHTO recommends flux be sized for use in pressurized flux feeding systems without the risk of clogging.

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High-performance steel was used to build the 473-ft-long Martin Creek Bridge on State Route 53 in Tennessee. (Photo courtesy of TN-DOT.)

**Future of HPS**

Now that HPS 70W use is growing in the industry, what is next for the new steel?

Currently, both gas metal arc welding and flux cored arc welding consumables are being developed and tested to determine the viability of these processes for use on HPS 70W. Second, fabricators of bridge girders are evolving and becoming more sophisticated in methods for preheating and maintaining interpass temperature, improved flux handling procedures, and implementing alternate welding processes. Third, use of high technology fabrication equipment, such as robotics, is being examined for use in the fabrication of nonconventional and innovative designs.

Use of HPS 70W steel is also being transferred to other applications such as railroad bridges, buildings, and pedestrian walkways.

With the success of HPS 70W, some challenges are being presented for other forms of high-performance steel; for example, developing an HPS 50W steel that can be welded with reduced preheat and finding ways to weld and use HPS 100W in civilian applications.

**Conclusions**

In closing, there are two key points regarding HPS 70W welding in the bridge industry:

- Fabricating HPS 70W is relatively easy when the right consumables, process, and procedures are married.

- With TEA-21 in effect until 2003, the highway and bridge construction industry will stay strong and more HPS 70W bridge projects are expected to be implemented.

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There are many opportunities to learn more about HPS 70W including the World Bridge Symposium, sponsored by the National Steel Bridge Alliance (NSBA), to be held in Chicago, Ill., on October 2-5. For more information, contact Arun Shiroi, NSBA executive director, at (763) 591-9099.
Stress Relief Basics

Structural designers must be aware of residual stress in weldments and common methods used to relieve it

By Andrew Cullison

Stress — the sources are numerous, but fortunately there are a variety of ways to relieve it. No, I'm not talking about the hectic pace of our personal lives, although it certainly can apply, but instead I'm referring to the fabrication of metals.

Residual stress is an internal stress that is not a result of externally applied loads. If stress buildup in the weldment is excessive, the fatigue life of the metal is reduced.

Importance of Stress Relief

Cold working, hot rolling, grinding, quenching treatments, welding, and thermal cutting all can induce residual stress into metal. The nature of residual stress, its distribution, and prediction of the level within a metal is a complex and not completely understood phenomenon, but you can be sure it is present.

Welding, in particular, because of the rapid thermal expansion and contraction created along a very localized area, is a prime source of residual stress. A very high heat source is applied to a small area relative to the cooler surrounding area. That point where the arc is directed is rapidly heated from ambient temperature to temperatures that can be in excess of 3000°F. The metal expands as it is brought to a molten state. As the molten weld pool solidifies along the joint, there is resistance to its shrinkage by the already solidified weld metal and the unmelted base metal adjacent to the weld. This resistance creates a tensile strain in the longitudinal and transverse directions of the weld. Distortion is often the result, and if the stress is excessive, buckling, stress corrosion cracking, and shortened fatigue life are possible.

All welds will have some residual stress, and it will never be totally reduced to zero strain. But the level of stress can be very high depending on certain conditions. Heat input, base metal thickness, cooling rate, restraint of the weldment, and welding process play roles in the level of residual stress induced into a weldment.

Thermal or Nonthermal

There are two major approaches to stress relieving: thermal and mechanical. A major difference between the two is thermal treatment, which in addition to relieving stress, will also affect metallurgical changes in the metal. A postweld heat treatment entails uniform heating of the weldment, holding at temperature, and then a controlled cooling.

As metal becomes hotter, it becomes weaker. Once a certain temperature is reached, there is a reduction in yield strength from the rated property of the steel. The residual stress decreases to that of the lower yield strength, and it is thereby relieved. The effect sometimes visibly manifests itself in the straightening of a distorted material.

For carbon and low-alloy steels, stress relieving is commonly performed in the range of 1100°F to 1350°F. The time at which the weldment is held at temperature is dependent on the thickness of the workpiece and its chemical composition.

The most commonly used method of stress relieving weldments is by postweld heat treatment. Its effectiveness is dependent on the control exercised in bringing the component to temperature and then its subsequent cooling. Therefore, it should be performed by those knowledgeable in its application.

Shot Peening

Shot peening is a cold working method that reduces stress. Small, round metal balls, or shot, are projected onto the surface of the weldment. The shot impacts small indentations into the surface, which induces compressive stress. The tensile residual stresses at the surface of the weldment must "overcome" the compressive stress for a fatigue crack to initiate. If properly applied, the compression works to counteract the tensile stresses. Fatigue cracks have a low probability of developing in the shot-peened area.

Caution must be taken to ensure the shot-peening operation is performed with knowledge of its variables. There are three important variables to control in its application: surface compressive stress, maximum compressive stress, and depth of compressive stress.

The velocity of the shot is another controlling factor. If the impingement of the shot is too deep, detrimental stresses may be induced, negating the desired results.

Vibratory Stress Relief

Another mechanical means of stress relief is by vibration. A mechanical vibrating device is attached to the weldment. The vibration's resonant frequency can be controlled by specially designed machines. The amount of time the weldment is subjected to the vibration is usually dependent on its weight. The vibration can be applied during or immediately after welding.

The vibration seems to even the stress distribution within the weldment by means of plastic deformation of the metal's grains, reducing sharp peaks of stress.

This process is known to be effective in bringing geometric stability to the workpiece. Presently, the process is not endorsed by codes, but neither is it rejected.
AWS Counselor Nominations Invited

Friends and Colleagues:

The American Welding Society established the honor of Counselor to recognize individual members for a career of distinguished organizational leadership that has enhanced the image and impact of the welding industry. Election as a Counselor shall be based on an individual’s career of outstanding accomplishment.

To be eligible for appointment, an individual shall have demonstrated his or her leadership in the welding industry by one or more of the following:

• Leadership of or within an organization that has made a substantial contribution to the welding industry. The individual’s organization shall have shown an ongoing commitment to the industry, as evidenced by support of participation of its employees in industry activities.

• Leadership of or within an organization that has made a substantial contribution to training and vocational education in the welding industry. The individual’s organization shall have shown an ongoing commitment to the industry, as evidenced by support of participation of its employees in industry activities.

For specifics on the nomination requirements, please contact Wendy Sue Reeve at AWS headquarters in Miami, or simply follow the instructions on the Counselor nomination form in this issue of the Welding Journal. The deadline for submission is January 14, 2002. The Committee looks forward to receiving these nominations for 2003 consideration.

Sincerely,

L. W. Myers
Chairman, Counselor Selection Committee

IMPORTANT NOTICE: Please note that the submission deadline of January 14, 2002, is two weeks earlier than in previous notices. The change was necessary because of newly announced dates for the 2002 AWS Convention.
CLASS OF 2003
COUNSELOR NOMINATION FORM

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TITLE/POSITION

BUSINESS ADDRESS

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MAJOR & MINOR

DEGREES OR CERTIFICATES/YEAR

LICENSED PROFESSIONAL ENGINEER: YES NO STATE

SIGNIFICANT WORK EXPERIENCE:

COMPANY/CITY/STATE

POSITION YEARS

COMPANY/CITY/STATE

POSITION YEARS

SUMMARIZE MAJOR CONTRIBUTIONS IN THESE POSITIONS:

SUGGESTED CITATION (50 TO 100 WORDS, USE SEPARATE SHEET) INDICATING WHY THE NOMINEE SHOULD BE SELECTED AS AN AWS COUNSELOR. IF NOMINEE IS SELECTED, THIS STATEMENT MAY BE INCORPORATED WITHIN THE CITATION CERTIFICATE.

**MOST IMPORTANT**
The Counselor Selection Committee criteria are strongly based on and extracted from the categories identified below. All information and support material provided by the candidate's Counselor Proposer, Nominating Members and peers are considered.

SUBMITTED BY:
PROPOSER
AWS Member No.
The proposer will serve as the contact if the Selection Committee requires further information. The proposer is encouraged to include a detailed biography of the candidate and letters of recommendation from individuals describing the specific accomplishments of the candidate. Signatures on this nominating form, or supporting letters from each nominator, are required from four AWS members in addition to the proposer. Signatures may be acquired by photocopying the original and transmitting to each nominating member. Once the signatures are secured, the total package should be submitted.

NOMINATING MEMBER:
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NOMINATING MEMBER:
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SUBMISSION DEADLINE FEBRUARY 1, 2002
Nomination of AWS Counselor

I. HISTORY AND BACKGROUND

In 1999, the American Welding Society established the honor of Counselor to recognize individual members for a career of distinguished organizational leadership that has enhanced the image and impact of the welding industry. Election as a Counselor shall be based on an individual’s career of outstanding accomplishment.

To be eligible for appointment, an individual shall have demonstrated his or her leadership in the welding industry by one or more of the following:

- Leadership of or within an organization that has made a substantial contribution to the welding industry. (The individual’s organization shall have shown an ongoing commitment to the industry, as evidenced by support of participation of its employees in industry activities such as AWS, IIW, WRC, VICA, NEMA, NSRP SP7 or other similar groups.)
- Leadership of or within an organization that has made substantial contribution to training and vocational education in the welding industry. (The individual’s organization shall have shown an ongoing commitment to the industry, as evidenced by support of participation of its employees in industry activities such as AWS, IIW, WRC, VICA, NEMA, NSRP SP7 or other similar groups.)

II. RULES

A. Candidates for Counselor shall have at least 10 years of membership in AWS.
B. Each candidate for Counselor shall be nominated by at least five members of the Society.
C. Nominations shall be submitted on the official form available from AWS headquarters.
D. Nominations must be submitted to AWS headquarters no later than February 1 of the year prior to that in which the award is to be presented.
E. Nominations shall remain valid for three years.
F. All information on nominees will be held in strict confidence.
G. Candidates who have been elected as Fellows of AWS shall not be eligible for election as Counselors. Candidates may not be nominated for both of these awards at the same time.

III. NUMBER OF COUNSELORS TO BE SELECTED

2001 Class of Counselors:
Year one, maximum of 20 Counselors selected, as determined by the committee
2002 Class of Counselors:
Year two, maximum of 20 Counselors selected, as determined by the committee
2003 Class of Counselors:
Year three, maximum of 15 Counselors selected, as determined by the committee
2004 Class of Counselors:
Year four, and thereafter: maximum of 10 Counselors selected, as determined by the committee

Return completed Counselor nomination package to:

Wendy S. Reeve
American Welding Society
550 N.W. LeJeune Road
Miami, FL 33126
Telephone: 800-443-9353, extension 215

SUBMISSION DEADLINE: February 1, 2002
Nooter Subsidiaries Announce Appointments

Nooter Corp., St. Louis, Mo., announced key managers for its newest subsidiary, Nooter Fabrication Services, Inc.

Mark Huck [AWS], formerly vice president-Global Alliances at Nooter Fabricators, Inc., was named president. Michael J. Kelly, formerly director of marketing, Global Alliances for Nooter Fabricators, Inc., was named managing director for Nooter-AMC SDN. Bhd., a joint venture between Nooter Fabrication Services and Amalgamated Metal Corp. in Subang and Kuantan, Malaysia.

Kirk Miller, formerly assistant sales manager at Nooter Fabricators, Inc., will serve as sales manager.

Nooter Construction Company appointed John G. Hagan as controller. Hagan formerly served as chief accountant for the company.

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Circle No. 17 on Reader Info-Card
Jackson Products Hires Managers

Jackson Products, Inc., St. Louis, Mo., announced the hiring of Don Ash [AWS] and Keith Werkley as district managers for its Welding Safety Group.

Ash will manage sales activities for Wisconsin, Minnesota, northern Iowa, northern Illinois, and the eastern sections of North and South Dakota. He brings with him more than 13 years of sales experience in the welding industry, most recently serving as regional manufacturer’s representative at Tregaskiss, Ltd.

Werkley will manage sales activities for Michigan, Indiana, southern Illinois, and Kentucky. Werkley has more than ten years of industrial sales experience, most recently serving as field sales representative at RB&W Logistics.

ESAB Realigns Personnel Responsibilities

ESAB Welding & Cutting Products, Florence, S.C., announced changes in the responsibilities of various management positions.

W. Doug Jones has been named senior vice president of marketing and general manager of ESAB’s Hanover, Pa., plant. He will oversee all facets of the Hanover site, as well as advertising, training, tradeshow, pricing, communications, customer service, and inside sales. He will also handle call sales, consumables, research and development, and reporting product management to site managers.

Mark Elender [AWS] has been named vice president of sales. He will handle regional sales, territory sales management, national accounts, and new sales initiatives including manufacturing and sales representatives.

David Murphy has been appointed senior vice president of finance. He is responsible for corporate finance, tax treasury, and legal.

Richard Powell [AWS] has been named senior vice president of information technology. He will report to ESAB Group president and CEO Ray Hoglund regarding global IT/te-business responsibilities, hardware and network infrastructure, project-based IT software development and implementation, and e-business initiatives.

William Johnson has been appointed senior vice president of operations and general manager of the U.S. Equipment Group. He will oversee the company’s Florence, S.C., site, material and supply chain, including distribution centers, logistics and purchasing, quality, equipment operations, and R&D.

Jill Heiden has been appointed vice president of human resources. She will be responsible for recruitment, hiring, employee policies, benefits, EEOC compliance, salary, and administration.

Obituaries

Warner Simon

Warner Howard Simon died in Dayton, Nev., on May 24, after a bout with cancer. He was the founder and former director of the United States Welding Corp., Carson City, Nev. (previously located in Chatsworth, Calif.).

Simon was a pioneer in the welding industry and a visionary in his field. As director of the U.S. Welding Corp., he brought a new standard of cleanliness and quality to welding wire. His many achievements during his long career as a welding engineer include contributions to upgrading the welding and vacuum melting industries, the development of metallurgically controlled wire reduction process, the invention of special containment systems for housing welding wire spools for maximum protection from the atmosphere, and the development of investment castings repair. Simon developed aerospace materials and wrote specifications for the AMS division of the Society of Automotive Engineers. He served on technical committees, authored numerous technical publications, and received an award from the American Welding Society for a paper on alloy constituents in arc welding.

After retiring when in his 80s, Simon pioneered the weld cladding repair method for steel moment frame buildings, which were unexpectedly found to be damaged following the January 1994 Northridge, Calif., earthquake. He led the DLW Task Group that developed the economic repair method that solved many of the problems and was successfully used to repair several buildings.

Simon was born in Berlin, Germany, on August 7, 1911. Of Jewish heritage, he escaped Nazi Germany in 1938 and fled to England, where he obtained his Ph.D. in welding metallurgy in 1939. After spending time in Canada, he settled in the United States.

He is survived by former wife, Ruth Simon of Dayton, Nev.; sons, Donald of Palmdale, Calif., Edward of Fillmore, Calif., and Mark of Van Nuys, Calif.; daughters, Anita Simonson of St. Paul, Minn., and Vivian Simon-Quirroz of Santa Cruz, Calif.; sister, Kate MacKinnon of Scotland; and 21 grandchildren.

Robert Duncan Alm

Robert Duncan Alm [AWS] died at his home in Vallejo, Calif., on June 20, following a brief illness.

Alm received his engineering degree at California State Polytechnic College and was a registered professional engineer with the state of California. Alm, a U.S. Army veteran of the Korean War, worked at the Mare Island Naval Shipyard for 35 years. He retired in 1988 as head of the Shipyard Welding Engineering Division.

Alm was a Life member of the American Welding Society and active in the San Francisco Section. He served as a consultant for AWS from 1994 through 1998. He was also a member of the Vallejo Elks Lodge and NARFE.

Alm is survived by his wife, Beverly; son, Gregory Dalessi; daughter, Saron Antone; sister, Doris Wohl; three grandchildren; and nephews.

ASM Bestows President’s Award

Elliott Sampson, a lifelong contributor to the development and growth of thermal spray technology, has been awarded the ASM International Thermal Spray Society’s prestigious President’s Award for meritorious service. Elliott, currently the senior marketing manager for Praxair Surface Technologies, Inc., and TAFA Incorporated, has provided more than 35 years of dedicated service and has worked for several of the premier companies that comprise the thermal spray market.

Elliott has served in several different capacities during his career, including running his own thermal spray job shop and holding key marketing and sales positions for the industry’s major suppliers. Among his many accomplishments is the development and acceptance of twin wire arc spray coating for aircraft engine applications.

Al Kay, president of ASM’s Thermal Spray Society, presented the award to Elliott in Singapore at the ITSC 2001 Awards Luncheon held on May 30. Elliott, who was unable to attend the ceremony, prepared a videotaped acceptance speech in which he challenged the thermal spray industry to “continue to search for applications that benefit from the unique advantages thermal spray offers.”
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The AWS Foundation invites you to be a part of its 2002 Silent Auction at the MAX INTERNATIONAL Expo, at Chicago’s McCormick Place, March 4-7.

Proceeds go to help fund welding scholarships and fellowships, and to turn out quality welders, and welding engineers. That way, students win, the industry wins, and you win...

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MAX INTERNATIONAL
March 4-7, 2002
Chicago’s McCormick Place South
Conferences and Exhibitions

15th International Joining, Cutting, and Surfacing Fair “Schweissen & Schneiden.” September 12-18, Essen, Germany. Contact: Claus-Peter Regiani or Christina Kursawe, 49(0)201-7224-227 or 49(0)201-7224-529, FAX: 49(0)201-7244-435, e-mail: regiani@messe-essen.de or kursawe@messe-essen.de; www.messe-essen.de.

International Conference on Advances in Materials and Processing Technologies. September 18-21, Leganés, Madrid, Spain. Contact: AMPT '01 Congress Secretariat, Fundación Universidad Carlos III, Congregación, Avda. de la Universidad, 30, 28911 Leganés, Madrid, Spain, 34 91 624 91 42, FAX: 34 91 624 91 47, e-mail: congrega@fund.uc3m.es.

First Middle East Nondestructive Testing Conference and Exhibition. September 24-26, Gulf International Convention Centre, Bahrain. Cosponsored by the Saudi Arabian Section of the American Society for Nondestructive Testing and the Bahrain Society of Engineers. Contact: The Conference Secretariat, Bahrain Society of Engineers, P.O. Box 835, Manama, Bahrain, 973-727 100, FAX: 973-729 819, e-mail: Mohandis@batelco.com.bh.


Educational Opportunities


Note: A diamond (♦) denotes an AWS-sponsored event.
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Circle No. 12 on Reader Info-Card
Educational Opportunities

**AWS Schedule — CWI/CWE Prep Courses and Exams**

Exam application must be submitted six weeks before exam date. For exam information and application, contact the AWS Certification Dept., (800) 443-9353 ext. 273. For exam prep course information, contact the AWS Education Dept., (800) 443-9353 ext. 229. For AWS Educational Boot Camp information, contact the AWS Education Dept., (800) 443-9353 ext. 477. Dates are subject to change.

<table>
<thead>
<tr>
<th>Cities</th>
<th>Exam Prep Courses</th>
<th>CWI/CWE Exams</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anchorage, Alaska</td>
<td>Sept. 10-14 (API 1104 Clinic also offered)</td>
<td>Sept. 15</td>
</tr>
<tr>
<td>Atlanta, Ga.</td>
<td>Oct. 15-19 (API 1104 Clinic also offered)</td>
<td>Oct. 20</td>
</tr>
<tr>
<td>Baltimore, Md.</td>
<td>Oct. 1-5 (API 1104 Clinic also offered)</td>
<td>Oct. 6</td>
</tr>
<tr>
<td>Beaumont, Tex.</td>
<td>Nov. 9 (API 1104 Clinic &amp; SCW1 also offered)</td>
<td>Nov. 10</td>
</tr>
<tr>
<td>Boston, Mass.</td>
<td>Oct. 8-13, Educational Boot Camp</td>
<td></td>
</tr>
<tr>
<td>Chicago, Ill.</td>
<td>Nov. 12-16 (API 1104 Clinic also offered)</td>
<td>Nov. 17</td>
</tr>
<tr>
<td>Cleveland, Ohio</td>
<td>Dec. 3-7</td>
<td>Dec. 8</td>
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<tr>
<td>Cleveland, Ohio</td>
<td>Jan. 28-Feb. 1, 2002</td>
<td>Feb. 2, 2002</td>
</tr>
<tr>
<td>Columbus, Ohio</td>
<td>Dec. 10-14</td>
<td>Dec. 15</td>
</tr>
<tr>
<td>Dallas, Tex.</td>
<td>Nov. 9 (API 1104 Clinic also offered)</td>
<td>Nov. 10</td>
</tr>
<tr>
<td>Denver, Colo.</td>
<td>Sept. 17-21</td>
<td>Sept. 22</td>
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<tr>
<td>Denver, Colo.</td>
<td>Sept. 24-29, Educational Boot Camp</td>
<td>Sept. 15</td>
</tr>
<tr>
<td>Fresno, Calif.</td>
<td>Sept. 10-14</td>
<td>Sept. 15</td>
</tr>
<tr>
<td>Long Beach, Calif.</td>
<td>Nov. 12-16 (SCW1 also offered)</td>
<td>Nov. 17</td>
</tr>
<tr>
<td>Los Angeles, Calif.</td>
<td>Oct. 8-12</td>
<td>Oct. 13</td>
</tr>
<tr>
<td>Miami, Fla.</td>
<td>Sept. 17-21</td>
<td>Sept. 22</td>
</tr>
<tr>
<td>Miami, Fla.</td>
<td>Oct. 15-19 (API 1104 Clinic also offered)</td>
<td>Oct. 20</td>
</tr>
<tr>
<td>Miami, Fla.</td>
<td>Sept. 10-14 (API 1104 Clinic also offered)</td>
<td></td>
</tr>
</tbody>
</table>

**AWS International Schedule — CWI/CWE Prep Courses and Exams**

**JAPAN**

September 10-14, CWI Training
September 15, CWI Examination
Japan Welding Technology Center
Contact: Makoto Okumura, 44-222-4102,
FAX: 44-233-7976, e-mail: okumura@jwsc.or.jp.

**SAUDI ARABIA**

October 20-24, CWI Training (Bahrain)
October 27, CWI Training (Kuwait)
November 1, CWI Examination (Dammam)
November 3-7, CWI Training (Dammam)
November 8, CWI Examination (Dammam)
Nondestructive Technology Testing Center
Contact: Sodhar Phansalkar, 966-3-882-7522,
FAX: 966-3-882-8417, e-mail: phansalkar@saudi-online.net.

**SHANGHAI, PEOPLE'S REPUBLIC OF CHINA**

September
Int'l Welding Technology Research Laboratory
Contact: Dr. Chon L. Tsai, 866-22-363-3663,
FAX: 886-22-363-6257, e-mail: jwtrl@ms15.hinet.net
or tsai.1@ost.edu

**TAIPEI, TAIWAN**

September
Int'l Welding Technology Research Laboratory
Contact: Dr. Chon L. Tsai, 886-22-363-3663,
FAX: 886-22-363-6257, e-mail: jwtrl@ms15.hinet.net
or tsai.1@ost.edu

**KOREA**

October 29-November 2, CWI Training
November 3, CWI Examination
International Welding Technology Research Lab.
Contact: Dr. Chon L. Tsai, 866-22-363-3663,
FAX: 886-22-363-6257, e-mail: jwtrl@ms15.hinet.net

**SINGAPORE**

December 3-7, CWI Training
December 10, CWI Examination
Seteco Services Pte Ltd.
Contact: 65-566-7777
FAX: 65-566-7718

**INDIA**

December 5-11, SCW1 and CWI Training
December 13 and 14, CWI Examination
Industrial Quality Concepts
Contact: Sundaran Baskaran, 44-499-3826
FAX: 44-499-3826, e-mail: iqec.in.org@vsnl.com
The Navy Joining Center (NJC) is leading a project team in developing adhesive bonding technology for composite-to-steel structures for the Navy's next generation ships. Initially, the focus of this technology will be applications for the USS Zumwalt (DD 21) Class land attack destroyers. The technology developed will also be extended to other surface combatant ships, including aircraft carriers. This development activity is part of the Navy's long-range science and technology program, which is aimed at the advancement and improvement of Navy and Marine Corps operations. Team project members include Bath Iron Works, Ingalls Shipbuilding, The Composites Manufacturing Technology Center of Excellence-South Carolina Research Authority, Pennsylvania State University/ARL, Boeing, and the Edison Welding Institute (EWI).

New material systems are required due to the advanced performance criteria of the DD 21 and other Navy ships. Composites are best-suited for high-performance vessels because they are strong, lightweight, and not susceptible to corrosion.

New joining technologies are also needed for fabrication of large marine composite-to-steel components. Present mechanical fasteners are used to join composite-to-steel and even composite-to-composite joints on current Navy ships. These fasteners are expensive, their installation procedures are labor intensive, and the joints require long-term maintenance.

The technology being developed must be cost effective while meeting the functional requirements of structures, signatures, and longevity. Thus, the focus of this project is to identify and maximize the efficiency of key joint manufacturing details and assess the viability and cost of integrating adhesive bond technology into ship manufacture. Although much work has been done with the design, manufacture, and testing of adhesive bonds in other industries, these advancements may not translate directly to shipbuilding applications due to the large structural components, the manufacturing requirements, and the marine environment.

The project will use a concurrent engineering approach to incrementally demonstrate through analysis and testing that the functional requirements of the adhesive bond joint and manufacturing processes are attainable.

Anticipated results of the project include the following:

- An engineered steel-to-composite joint design(s) that meets functional requirements for Navy surface combatants;
- Comprehensive analysis of composite-to-steel joint design(s);
- Selection of adhesive(s) material that meet functional requirements;
- A robust manufacturing process/procedure usable for shipbuilding;
- Best practice nondestructive inspection method(s) for manufacture and field service use;
- Techniques for field repair;
- Structural integrity demonstration.

The above mentioned items could be used as a template for the implementation of composite structures aboard surface combatants. The rules and tools will set in place so a standard can be established through which current and future hulls will use composites that will support a higher performing weapons platform and more affordable Navy.

For more information, contact George Ritter, EWI, at (614) 688-5199 or via e-mail to george_ritter@ewi.org, or Larry Brown, NJC, at (614) 688-5080 or via e-mail to larry_brown@ewi.org.

Artist concept of DD 21 surface combatant ship.
D1.1 Code Week

D1.1 Structural Code Week

Location       Date
Chicago, Illinois  July 16-29, 2001
Las Vegas, Nevada  September 17-21, 2001
Beaumont, Texas  October 15-19, 2001
Atlanta, Georgia  November 5-9, 2001

Seminar Series
Day 1: (Monday) D1.1 Road Map
Day 2: (Tuesday) Design of Weld Connections
Day 3: (Wednesday) Qualifications
Day 4: (Thursday) Fabrication
Day 5: (Friday) Inspection

D1.5 Road Map

D1.5 Bridge Code Seminar

San Francisco, California  October 2, 2001

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For more information please call 1-800-443-9353 Ext. 449
American Welding Society
The Aluminum Association

Aluminum Welding Seminar & Exhibition

November 7 - 8, 2001
Nashville, TN

AWS and The Aluminum Association have teamed together to explain aluminum welding down to the bare metal. If you are responsible for designing, engineering, or fabricating aluminum structures, you will receive two days of insider hints, tips, advice, and no-nonsense introduction from this seminar offering.

In this fast-paced program these topics will be covered:
Overview of Aluminum Joining; Aluminum Designation System and Characteristics of Aluminum Alloys; Metallurgy; Safety and Health Considerations; Metal Preparation for Welding; Filler Alloy Selection; Gas Metal Arc Welding; GTAW; Variable Polarity Plasma Arc Welding; Resistance Spot Welding; High Energy Beam Welding; Friction Stir Welding of Al Alloys; Robotics Welding; Design and Performance; Weld Discontinuities: Causes and Cures; Application of the AWS D1.2 Structural Welding Code.

Conference Fee:
$550 for AWS members, $625 for nonmembers, exhibitors $750.
Fee includes lunch, refreshment breaks, a reception, presentation handouts and the following publications (nonmember price):
- AA Wrought Alloy Registration Records - (a $10 value)
- AA Casting Alloy Registration Records - (a $8 value)
- AA Welding Aluminum Theory and Practice - (a $35 value)
- AA Aluminum Standards & Data-2000 - (a $40 value)
- AA Aluminum Structural Welding Code- (a $78 value)

Registration fees do not include hotel accommodations. Please make checks payable to the American Welding Society or “AWS.”

For more information please call 1-800-443-9353 Ext. 449 or visit us at www.aws.org
2001 AWS Fellows and Counselors Honored at the Cleveland Exhibition

During the 2001 AWS Welding Show in Cleveland, Ohio, in May, the American Welding Society conferred Fellow or Counselor status on eleven individuals for their continuous and lasting contributions to science and technology in welding.

The honorary title of AWS Fellow was established in 1990 to recognize members who have made distinguished contributions and promoted and sustained professionalism in the field of welding science and technology.

In 1999, the honorary title of AWS Counselor was created to recognize individual members for outstanding organizational leadership that has helped enhance the image and impact of the welding industry.

2001 Class of Fellows

This year, five individuals were named to the 2001 Class of Fellows.

Howard N. Farmer, a retired manager of metallurgical services with Stoody Co., has served the welding industry as a highly respected educator. He has shared his knowledge through instruction, lectures, and publications in many industries including, but not limited to, steel mills, power plants, cement plants, and agriculture.

He helped develop submerged arc welding of rotary rock bits, redesigned a reamer body to prevent breakage, and designed hard metal nozzles to blast mud onto the drilling base. Farmer holds a patent on an invention that makes use of interpass temperature while welding on steel mill rolls to control transformation.

Stanley E. Ferree, a member of AWS for 24 years, is vice president of filler metal technology for ESAB Welding & Cutting Products, Hanover, Pa.

He developed the first 0.035-in.-diameter-gas-shielded flux-cored wire and assisted in the development of the first 0.030-in., self-shielded flux-cored wire in the welding industry. Many of his inventions in gas-shielded flux-cored and metal-cored wires led to the use of the FCAW-G process for applications that previously didn't use cored wires.

Paul A. Kammer, president of Kammer Associates, New Bern, N.C., was instrumental in the development of filler metals for arc welding with specialized high-alloy-covered electrodes for maintenance and repair welding, cored electrodes for joining and surfacing, and metal powders for thermal spraying. He holds four U.S. patents that have resulted in a number of successful commercial products.

Arthur C. Nunes, Jr., an aerospace engineer at Marshall Space Flight Center, was recognized for his...
contributions to the understanding of the variable polarity plasma arc welding process and its application to the welding of aerospace structures. His work in theoretical modeling analysis has led to a more complete physical understanding of welding phenomena encountered in the manufacture of the National Aeronautics and Space Administration Space Transportation System propulsion elements.

- Edmund F. Rybicki is chairman of and a professor in the Mechanical Engineering Department at University of Tulsa, Tulsa, Okla. He was a major contributor to the development and application of methods to evaluate and control residual stresses in welded materials and thermal spray coatings. He has dedicated himself to promoting education on welding and thermal spray coating residual stresses. He holds one U.S. patent and one patent application.

2001 Class of Counselors

Six individuals were named to the 2001 Class of Counselors.

- John Bartley, chairman of John Bartley Consulting Engineering, Galveston, Tex., was recognized for 40 years of distinguished service to the welding community and exceptional leadership through various company and society affiliations. He served as AWS president from 1991 to 1992.

- William E. Berglind, retired director of advertising for Miller Electric Mfg. Co., was honored as a business communications professional with a keen understanding of industry needs. His background and expertise helped guide and encourage various AWS marketing and publishing-related initiatives.

- D. Fred Boyle served as president and chief executive officer of ESAB Group North America prior to his recent retirement. He is currently a director and member of the Board of ESAB Welding & Cutting Products, Florence, S.C. He was named AWS Counselor for his proven leadership and management skills, for mentoring others, and supporting continuing education.

- Donald F. Hastings retired in 1996 as chairman of the board and chief executive officer of The Lincoln Electric Co., Cleveland, Ohio. He was recognized for his distinguished 40-year career at the highest levels of industry and for his leadership, enthusiasm, and guidance of numerous individuals in the field of welding.

- Ralph E. Long, retired in 1992 from Northern States Power Company, remains active in the welding industry as a consultant. He was recognized for taking the lead throughout his career in promoting negotiations between European nations to agree on a homogeneous plan for the education and training of welding personnel. He has provided guidance and development in welding education and has dedicated his professional life to the field in general.

- James H. Walker, now retired, held managerial positions with several companies including Randall Corp., McDermott, Inc., Brown & Root, and Miller Electric Mfg. Co. He was honored for his contributions to the welding community through insightful vision, inventiveness, and creativity. While employed with various manufacturing and engineering companies, he volunteered his time and served on the committees of various associations. He served as AWS president from 1986 to 1987.

Information on Nominating AWS Fellows and Counselors

For information on nominating individuals for AWS Fellow or AWS Counselor Awards, contact Wendy Sue Reeve, Managing Director, Professional Services Division, 550 NW LeJeune Rd., Miami, FL 33126, (800) 443-9553 ext. 215 or, outside the U.S., (305) 443-9553 ext. 215, e-mail: wreeve@aws.org, or visit the American Welding Society's Web site at www.aws.org/awards/awards.html.
AWS Recognizes Achievements in Welding

AWS President Richard Arn Begins Term by Awarding Examples of Extraordinary Welding

American Welding Society President Richard L. Arn presented the AWS Historical Welded Structure Award to the USS Nautilus (SSN 571), the world's first nuclear-powered submarine, on August 11. The ceremony took place at the Submarine Force Museum in Groton, Conn., where the Nautilus is berthed. At the Nautilus's dedication ceremony, Arn honored the Nautilus as a national artifact and for the achievement it represents in the history of welding.

The Nautilus, the world's first nuclear-powered submarine, was named an AWS Historical Welded Structure during a ceremony at the Submarine Force Museum in Groton, Conn., where it is open to the public for tours.

The Nautilus's keel was laid on June 14, 1952, by President Harry S. Truman at the Electric Boat Shipyard in Groton, Conn. She was launched on January 21, 1954, when First Lady Mamie Eisenhower christened her by breaking the traditional bottle of champagne across the bow. Eight months later, on September 30, 1954, the Nautilus became the first commissioned nuclear-powered ship in the U.S. Navy. After an illustrious 25-year career and almost half a million miles steamed, the USS Nautilus was decommissioned on March 30, 1980. On May 20, 1982, in recognition of her uniqueness, the Secretary of the Interior designated the Nautilus a national historic monument. After undergoing an extensive historic ship conversion, the Nautilus opened to the public on April 11, 1986, as the first exhibit of its kind.

At his induction ceremony in June, President Arn expressed his appreciation for the opportunities that were made possible to him "only in America" as a young man entering the field of welding. Throughout his term as president, he vowed to promote welding education in general, while keeping a special focus on the domestic welding community.

AWS's Extraordinary Welding Awards

The technological evolution of this country advanced greatly with the advent of welding. Its introduction spawned the development of welded ships and tanks that served to protect our nation from the threat of military attack. It also enabled the practical use of everyday commodities such as the shower and kitchen sink. In many ways, welding played a vital role in simplifying and enhancing everyday life.

Today, companies are shifting from manual welding processes to newer, automated robotic welding systems. The U.S. Department of Labor reports an overall shortage of skilled welders in the workplace and expects job opportunities to grow well into the year 2008.

The integration of new automated welding systems has created an equal need for skilled machine operators, while the maintenance and repair of existing welding systems and infrastructure building in international markets will continue to require the efforts of traditional welders and allied trades. In a recent AWS survey of producers and providers of welding equipment and design services, 72% of the respondents said there is a critical shortage of skilled workers in the welding arena. Survey respondent John Emmerson, president of Magnatech Ltd. Partnership, noted, "Despite the fact that welding is used in virtually every industry, it seems virtually ignored as a manufacturing science."

For this reason, AWS sponsors the Extraordinary Welding Awards program, recognizing past and present welding achievements and promoting welding of the future. The program includes the Historical Welded Structure Award and the Outstanding Development in Welded Fabrication Award to honor technological advances made in welded construction.
Developed in 1993, the Historical Welded Structure Award is designed to honor structures at least 35 years old that have had a significant impact on history. The award celebrates the advances made in welding and the importance it plays in the development of key products. The Outstanding Development in Welded Fabrication Award acknowledges more recent technological breakthroughs in welding. Past award recipients include the External Tank from the Space Shuttle Main Propulsion Test Article, which is one of the lightest aluminum structures used in space travel; the Eero Saarinen-designed Gateway Arch of St. Louis for its classic weighted catenary curve; and the Tokyo Tower, which was designed to resemble the Eiffel Tower and is one of the world’s tallest free-standing steel structures. These welded structures not only exemplify revolutionary advances in welding but also serve as monuments that have stood the test of time.

Last year alone, AWS selected seventeen recipients for the Historical Welded Structures and Outstanding Development in Welded Fabrication Awards, including the U.S. Pentagon and the battleship USS Missouri.

There are many welded structures left to recognize and many welding opportunities still available today. Through recognition programs like the Extraordinary Welding Award program, the American Welding Society strives to maintain the creative energy that fosters welding achievements.

Earlier this year, four prominent U.S. warships were awarded with Historical Welded Structure plaques by AWS representatives before enthusiastic crowds of welding professionals, guests, and media crews. American Welding Society Vice President and former Navy Technician Ernest Levert presented the award to the USS Becuna, a BALAO-class submarine, which was credited with sinking two Japanese tankers during World War II. The USS Jeremiah O’Brien, one of only two surviving Liberty ships, was recognized by AWS Past President Don Bertossa. While honoring the USS Stewart, former AWS President John Bartley made note of its rescue convoy missions across international waters during the Cold War. Most recently, AWS District 6 Director Gerald Crawford honored the USS Slater, the only destroyer escort still afloat today of the original 565.

Program Information and Nominations

For additional information on the Extraordinary Welding Award program, or to nominate an historical structure for consideration, please contact Nannette Zapata, Corporate Director of Communications, American Welding Society, 550 NW LeJeune Rd., Miami, FL 33126, (800) 443-9353 ext. 308 or, outside the U.S., (305) 443-9353 ext. 308, e-mail: zapata@aws.org.

— by Nydia Zeno, Communications Coordinator, AWS Communications Department.

In front of the USS Stewart in Seawolf Park, Galveston, Tex., are, AWS Past President John Bartley, center in suit, with John McMichael, chief of boat for the Cavalla Historical Foundation, fourth from right wearing white shirt and jeans, and members of the Cavalla/Stewart restoration crew. The USS Cavalla, a World War II Gato-class submarine, is also on display at Seawolf Park and is being restored as well.
Summary of Changes in
ASME Section IX, 2001 Edition

By Walter J. Sperko, P.E.

The following is a summary of the changes that appear in the 2001 edition (which includes the 2001 addenda) of ASME Section IX. These changes and the related discussion are reported by Walter J. Sperko, P.E., vice-chairman of Subcommittee IX; readers are advised the opinions expressed in this article are those of Mr. Sperko and are not the official opinion of Subcommittee IX.

Standard Welding Procedures

It has come to the writer’s attention that contractors using AWS Standard Welding Procedures Specifications (SWPSs) are not complying with the requirements listed in Article V (QW-500). Highlights of those requirements are the following:

- Not all AWS SWPSs are permitted.
- A demonstration test coupon must be welded and tested; QW-520 lists specific information that must be recorded as part of the demonstration.
- SWPSs must be used exactly as they are written; there are no “nonessential variables” when using SWPSs.
- The applicable fabrication document (i.e., construction code, customer specification, etc.) and the demonstration test number must be shown on the SWPS, and it must be signed and dated by the manufacturer or contractor.

Those using SWPSs are advised to read Article V closely — and follow the rules.

Changes in the 2001 Edition

The 2001 edition contains metric units. Readers may recall that ASME published an SI version of the Boiler Code in 1986; when nobody purchased it, ASME stopped publishing it. This edition contains metric units as secondary units (i.e., they are in parentheses and are a conversion of the U.S. Customary Units rather than real metric units). Due to the extra time needed to add the metric units, the 2001 edition was published later than the official July 1 publication date.

In the 2000 addenda, ASME Section 1 specifically permitted use of SWPSs. In the 2001 edition, Section VIII will do the same. Subcommittee III’s position is that specific words are not necessary since Section III’s existing words simply require that one follow Section IX. The B31 Code sections are in the process of adding words to specifically allow use of SWPSs.

Welding Procedure (QW-200) Rule Changes

There has been an historical requirement when qualifying a WPS for welding P-11 base metal (more than 100,000 lb/in² tensile strength, quenched and tempered steel) that a fillet weld test must be conducted in addition to the required groove weld test. This test was originally intended to show that the welding process, materials, and techniques used would not result in underbead cracking. With the advent of low-hydrogen electrodes and a better understanding of the effects of hydrogen during welding, the Subcommittee no longer considered the extra fillet weld test necessary; so QW-202(d) was deleted. It should be noted QW-213 requires that, if thermal cutting and/or backgouging will be used in production welding of P-11 materials, these must be included as part of the procedure qualification test coupon.

When welding dissimilar thickness base metals, QW-202.4(b) permits the use of test coupons as thin as 1/4 in. to be used to support welding on unlimited thickness when welding austenitic stainless steel (P-8), nickel alloys (P-41 through P-47), titanium (P-51 through P-53), and zirconium alloys (P-61 and P-62). This allowance was permitted only when impact testing of these metals was not required. Based on the fact that toughness is degraded more easily when welding thin materials than when welding thick materials, it was agreed the impact testing limit was not necessary, so it was deleted.

For those who weld on impact-tested metals, there is a requirement to qualify using single-pass welds if single-pass welds are going to be made in production (QW-410.9). Its purpose was to address the fact that single-pass welds have not been tempered by subsequent weld passes that would improve the toughness of the previous passes. This has always been a requirement for the other common welding processes, but it was somehow overlooked for shielded metal arc welding (SMAW). That oversight has been corrected in these addenda. Those who have existing SMAW qualifications allowing welding using a single pass per side on impact-tested materials with this qualification do not need to panic and make additional tests since this rule change applies only to new qualifications; see QW-100.3, paragraph five.

A recent development in autogenous GTAW is a flux painted on the outside of a square butt joint after fitup. This flux changes the thermally induced circulation of the weld pool such that the depth of penetration is significantly increased, enabling single-pass welding on ma-
Welder Qualification (QW-300) Changes

For those who do corrosion-resistant and hard-facing weld metal surfacing, QW-381 and QW-382 were clarified to permit welders qualified to deposit surfacing to deposit surfacing of unlimited thickness. In addition, it was clarified the welder had to qualify for welding small-diameter pipe only when the surfacing is applied in the circumferential direction. The latter provision has been deleted from QW-403.16.

A big change was made in the nonmandatory forms. QW-484, which was for documenting welder and welding operator qualifications, was separated into QW-484A for welders and QW-484B for welding operators. Although the old form worked well for welders, it was incomplete and confusing for welding operators. Remember, these forms are nonmandatory so it is not necessary to transfer existing qualification records to these. These new forms are available on the Internet at www.sperkoengineering.com.

Brazing (QB) Changes

Qualification of brazers was made easier. Previously, brazers had to qualify by brazing test coupons with each base metal P-number they would braze in production. When brazing combinations of base metals, brazers had to brazed combination test coupons. This was more restrictive than was required for qualification of procedures. These addenda allow brazers qualified on more than one P-number using a single set of process, filler metal, flux, etc., to braze those P-number base metal in combination without requalification.

Another simplifying change was to allow section tests on pipe between 1 and 3 in. OD to be polished on both halves of one longitudinal section instead of requiring removal of a slice from two locations, as shown in QB-463.2(c). The orientation of the longitudinal cut relative to the testing position was also clarified.

Several years ago, Subcommittee IX adopted AWS A5.31, Specification of Fluxes for Brazing and Brazed Welding, but never incorporated any provision to use the specification under Section IX. QB-406.1 was revised to allow the use of the AWS flux classification as an alternate to specifying the trade name or the nominal chemical composition of the flux.

Coming Attractions

Exciting things in the works by Subcommittee IX include reassignment of nickel alloys into a more useful and rational grouping system, the addition of nonessential variables for corrosion-resistant and hard-facing surfacing and modifications of the new welder and operator qualification forms to address the number of layers of weld metal. Note, the ASME Code Committee meetings are open to the public; the schedule is available on the Internet at www.sperkoengineering.com.

WALTER J. SPERKO is president of Sperko Engineering, a company that provides consulting services in welding, metallurgy, corrosion, and ASME Code issues described at www.sperkoengineering.com. He also teaches how to best use Section IX in publicly offered seminars sponsored by ASME. He can be reached for comment at (336) 674-0600, FAX (336) 674-0202 or by e-mail at sperko@asme.org.
AWS WELCOMES
NEW SUPPORTING COMPANIES

New Educational Institutions

Ashland County West Holmes Career Center
1783 State Rte. 60
Ashland, OH 44805

Associated Builders & Contractors
Construction Training Center
P.O. Box 1566
Nederland, TX 77627

Kent State University
Trumbull Campus
4314 Mahoning Ave. NW
Warren, OH 44805

Kentucky Tech Harrison County Center
551 Webster Ave.
Cynthiana, KY 41031

Lake County High Schools
Technology Campus
19525 West Washington St.
Grayslake, IL 60030

Southside Center for Applied Technology
1781 Harrodsburg Rd.
Lexington, KY 40504

Twin Lakes High School
500 S. Third St.
Monticello, IN 47960

New Supporting Companies

Walla Walla Community College
500 Tanseck Way
Walla Walla, WA 99362

Jack Hicks Steel
405 E. Alabama St.
Plant, FL 32787

New England Bridge Products, Inc.
93-95 Brookline St.
Lynn, MA 01902

Oerlikon Welding Corp.
2700 Post Oak Blvd., Ste. 1800
Houston, TX 77054

Prececco Pelizzari, C.A.
Zona Industrial Villa Rosario
Ave. Principal de Las Lomas, Aptdo. 557
San Cristobal Tachira State
5001 Venezuela

United Steel Fabricators, Inc.
3602 Farnsworth St.
Indianapolis, IN 46241

Welding Mart LLC
401 N. Perkins St.
P.O. Box 1173
Appleton, WI 54914

Hantech Ltd.
190 Yo Chun-Dong
Nam-Ku
Ulsan, Korea

Hantech Ltd designs and fabricates a wide range of pressure vessels, heat exchangers, reactors with agitator, and cryogenic vessels including field double-wall storage tanks and transport tanks for liquid nitrogen, argon, and oxygen, and spherical tanks that deal with carbon steel to high-alloy steel, ferrous and nonferrous.

The company has successfully married several fields of proven technologies to create an innovative and adaptable system, combining the techniques of electropolishing in chemical service and welding of nickel alloys, titanium, and zirconium.

Hantech has grown to become one of the leading engineering and fabricator company's supplying quality chemical equipment through sustained technology development and rigorous quality control since 1973.

AWS Membership

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</tbody>
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Student Chapters, Send Us Your News

Student Chapters are encouraged to send reports of their meetings, activities, and events, along with photographs, for publication in the Welding Journal's Student Activitites department.

Send your meeting/event reports to

Susan Campbell, Assoc. Editor
Welding Journal
550 NW LeJeune Rd.
Miami, FL 33126

Reports can also be faxed to (305) 443-5704 or e-mailed to campbell@aws.org.

District 17 Director Presents Awards

The District Director Award provides a means for District Directors to recognize individuals who have contributed their time and effort to the affairs of their local Section and/or District.

District 17 Director Oren Reich presented the following in his District with this award for 2000-2001.

- William Drake, Ozark
- Eddie Cady, Tulsa
- Dennis Pickering, Central Arkansas
NEW

Gene Sanquini during his presentation to the Long Island Section.

DISTRICT 1

Director: Geoffrey H. Putnam
Phone: (802) 439-5916

DISTRICT 2

Director: Alfred F. Fleury
Phone: (732) 868-0768

♦ LONG ISLAND

May 10
Speaker: Bruce Martin.
Affiliation: PlymoVent.
Topic: Fume extraction.
Activity: District 2 Director Alfred Fleury was on hand to present the Section’s 2001 awards. Sy Becker, Jeff Feiner, and Don Scarcella each received the Past Chairman’s Distinguished Service Award. Brian Cassidy and Eugene Sanquini were each presented with the Section Meritorious Award. Members voted for next year’s officers.

May 17
Activity: Scott Dixon and Roger Bardwell and others from Hudson Scenic Studio, Inc., treated Section members to a look at how magic is made on the Broadway stage through scenery.

JUNE 14

Speaker: Gene Sanquini, CWI.
Affiliation: Retired from Con Edison.
Topic: Welder performance and welder procedure qualifications in accordance with ASME Sect. IX, AWS D1.1 and API-1104 codes and how they apply to the AWS CWI.

DISTRICT 3

Director: Claudia Bottenfield
Phone: (717) 397-1312

♦ YORK-CENTRAL PENNSYLVANIA

May 23
Activity: District 3 Director Claudia Bottenfield presented Section Chairman Mike Bunnell with a Section Chairman Appreciation Award during the Section’s meeting to select District scholarship submissions for the district conference.

DISTRICT 4

Director: Roy C. Lanier
Phone: (252) 321-4611

♦ TRIANGLE

May 22
Activity: The Section held Vendor Appreciation Night and presented Certificates of Appreciation to Sherwin Williams, National Welders, the State Employee Credit Union, and the Titan Atlantic Group. Accepting on behalf
Olean-Bradford Section Chairman Rich DePue, left, with guest speaker Mickey Holmes.

of the companies were Jerry Haines, Spencer Adcock, Joe Johnson, and Russell Wahrman, respectively.

June 9
Activity: The Section held a golf outing at the Brevofield Golf Links. Low net was won by Chuck Owens, low handicap by Eric Umphreville, longest drive by Chuck Owens, and closest to pin by Howard Younginer.

District 5

Director: Wayne J. Engeron
Phone: (770) 939-5563

North Central Florida
May 15
Speakers: Jeffrey Ingraham and Tom Sammon.
Affiliation: Panasonic Automation, Franklin Park, Ill.

District 6

Director: Gerald R. Cramer
Phone: (518) 385-0570

Olean-Buffalo
May 22
Speaker: Mickey Holmes.
Affiliation: The Lincoln Electric Co.
Topic: The latest in welding technology from Lincoln Electric.

District 7

Director: Robert J. Tabernik
Phone: (614) 488-7913

District 8

Director: Wallace E. Honey
Phone: (256) 332-3366

Northeast Mississippi
May 16
Activities: The Section held Ladies' Night. Steve Latham gave a presentation on the history of the American Welding Society and conducted the installation of officers for the 2001-2002 term.

District 9

Director: John Bruskotter
Phone: (504) 367-0603

District 10

Director: Victor Y. Matthews
Phone: (216) 383-2638

District 11

Director: Scott C. Chapple
Phone: (734) 241-7242

Northern Michigan
May 13
Speakers: Bill Neil, chairman; Scott Sinkule, secretary; and Charles Hunt, S.E.N.S.E. and student affairs chairman.
Affiliation: AWS Northern Michigan Section.
Topic: A report of the District 11 Conference and information on how to apply for Section, district and national AWS scholarships.

District 12

Director: Michael D. Kersey
Phone: (262) 650-9364

District 13

Director: J. L. Hunter
(309) 888-8956
Eastern Iowa Section Chairman Mike Myers, left, accepting his Certificate of Appreciation for acting as chairman from District 16 Director Charles Burg.

Sangamon Valley Section’s scholarship winner Amie Wood, center, with Section members at the May meeting. From left to right, back row: are, Brian Huff, Tom Stokes, Tim Neubauer, Tom McGeorge, and Mike Casper; first row, left to right, Chris Laban, Wood, and Mike Hoff.

Race car driver Al Unser, Sr., stopping to sign autographs for Indiana Section members during their tour of the Indianapolis Speedway.

Attending the Kansas City Section’s November meeting are, from left, Dick Blaisdell, Chairman Sam Neubhouse, Secretary Ken Duckworth, guest speaker Rick Hass, Treasurer Doug O’Cobock, Second Vice Chairman Bob Worthington, and First Vice Chairman Dave McKenzie.

DISTRICT 14
Director: Hil Bax
Phone: (314) 644-3500, ext. 105

INDIANA
April 27
Activity: Section members volunteered their time and skill to help the Harrison Parkway Elementary School fabricate an “art tree” from reinforcing bar. The school’s students will construct smaller art projects over the next year and hang them from the tree’s branches. (See story and photo, page 79.)

May 16
Activity: Section members visited the Indianapolis Speedway, where Dennis Klingman, technical training director for The Lincoln Electric Co., met with them to discuss weld repair. Race car driver Al Unser, Sr., spent time with members and signed autographs.

JUNE 9
Speaker: Hil Bax, District 14 director.
Affiliation: AWS District 14.
Topic: Update on the District 14 Conference.

SANGAMON VALLEY
May 8
Speaker: Mike Casper, director of training.
Affiliation: Midwest School of Welding, Lincoln, Ill.
Activities: Members toured the school and its new HVAC addition. Amie Wood was awarded the year’s education scholarship. Chris Laban gave a technical presentation on weld metal microstructures of mild steel.

DISTRICT 16
Director: C. F. Burg
Phone: (515) 294-5428

EASTERN IOWA
May 15
Speaker: Ken Trumbull.
Affiliation: Genesis.
Topic: Welding design and design for robotics.
Activity: District 16 Director Charles Burg presented Section Chairman Mike Myers with a Certificate of Appreciation for his work serving as chairman.

KANSAS CITY
November 9, 2000
Speaker: Rick Hass, president.
Affiliation: R. H. Fastener Supply, Inc.

DISTRICT 15
Director: J. D. Heikkinen
Phone: (218) 741-9693

DISTRICT 14:
- **Director:** Hil Bax
- **Phone:** (314) 644-3500, ext. 105

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  - **Affiliation:** R. H. Fastener Supply, Inc.

**DISTRICT 15**
- **Director:** J. D. Heikkinen
- **Phone:** (218) 741-9693
Kansas City Section incoming Chairman Dave McKenzie, left, presenting outgoing Chairman Sam Newhouse, center, with a Distinguished Service Award as Bob Worthington looks on.


JANUARY 11
Speaker: Gary Storm.
Affiliation: Ellerbee-Beckett.
Topic: Safety in oxyfuel operation.

FEBRUARY 8
Activity: The Section toured the Superior Aluminum Foundry.

MARCH 8
Speakers: Richard Green and Crystal M. Cook.
Affiliation: Conoco and Nuvonyx, respectively.
Topic: Laser gases, gas equipment, and diode lasers.

APRIL 12
Speaker: Tim Long, welding shop supervisor.
Affiliation: Shick Tube Veyor.
Activity: The Section toured the Shick Tube plant and witnessed demonstrations of laser cutting.

DISTRICT 19
Director: Phil Zammit
Phone: (509) 468-2310 ext. 120

ALASKA
April 20
Activities: The Section voted in officers for the 2001-2002 year. The newly elected officers are Bruce Weisman, chairman; Percy Hawes, first vice chairman; Julie Dietz, second vice chairman; Bob McCaulley, secretary; Cregtton Moore, treasurer; Rex Close, Duane Goodrich, and Mark Wood members at large. Justin Hills was announced as the Alaska VICA winner.

MAY 19
Activity: The Section held its annual picnic at Duane and Eleanor Goodrich's ranch in Palmer.

DISTRICT 20
Director: Jesse A. Grantham
Phone: (303) 451-6759

COLORADO
April 12
Speaker: James Corbin, quality control manager, CWI, and CWE.
Affiliation: Big R. Manufacturing LLC, Greeley, Colo.
Topic: How to write a PQR and the ten things managers and inspectors must know to have a PQR accepted.

MAY 10
Speaker: James Corbin, quality control manager, CWI, and CWE.

DISTRICT 21
Director: F. R. Schneider
Phone: (858) 693-1657

SAN DIEGO
May 31
Activity: The Section held an Executive Board Meeting where they reviewed the District 21 Conference and began planning for upcoming meetings and events.

DISTRICT 22
Director: Mark Bell
Phone: (209) 367-1398

INTERNATIONAL SECTIONS

TAIWAN
February 26
Activity: Section Administrator May Chen and Shaun Chou, associate researcher at International Welding Technology Research Laboratory, met with Ta Chlech Hoang of EWI; Charles Concannon of Boeing, international business; Paul Chung, president of
S. Baskaran, chairman of the India Section, welcoming members to the June dinner meeting.

POCWA; Daniel Guerin, Boeing Information Systems; and Thomas Gulledge, director of the Enterprise Engineering Laboratory, George Mason University.

FEBRUARY 26
Speaker: David Ashley, dean of Engineering College.
Affiliation: The Ohio State University.

MAY 24
Speaker: Sindo Kou, chairman, Materials Science and Engineering Department.
Affiliation: University of Wisconsin.
Topic: Welding of aluminum alloys: melting (liquation) outside the weld and its effect.

JUNE 14
Activity: Twenty-eight candidates took the CWI exam. Chon Tsai, and May Chen supervised the exam.

INDIA
MAY 30
Speaker: A. Srinivasulu, managing director.
Affiliation: Germanischer Lloyd Industrial Services India Pvt. Ltd., Chennai.
Topic: The role of the welding engineer.

STUDENT ACTIVITIES

DISTRICT 6

TWIN TIERS STUDENT CHAPTER
May 7, 8, and 9
Activities: Student members went on a trip to the MAX International show in Cleveland. While in the area, members were led on a tour of the GAF shingle facility in Erie, Pa., by Brian Mullen. They also received a tour of the Republic Technologies International plant in Canton, Ohio, from Larry Roberts.

Twin Tiers Student Chapter members break for a photo during their plant tour of Republic Technologies International.

DISTRICT CONFERENCES

DISTRICT 7
May 7, 8, and 9
Activities: District 7 Director Robert J. Tabernik hosted the District 7 Conference at the Edison Welding Institute in Columbus, Ohio. Section scholarships were presented and awards given to officers to commemorate their service to the District. AWS Deputy Executive Director Richard French represented National at the meeting. Attending the conference were representatives from the Wheeling, Pittsburgh, Johnstown-Altoona, Dayton, Columbus, Tri-State, Cincinnati, and Mid-Ohio Valley Sections.

DISTRICT 14
JUNE 9
Activities: District 14 Director Hil Bax hosted the District 14 Conference in Indianapolis, Ind. AWS Section, District and National business was discussed, and scholarship winners were selected. Attending the meeting from AWS headquarters was AWS Past President and Associate Deputy Director Dick Alley.

Attendees at the District 14 Conference pose for a photograph.
Development work has begun on the following new or revised standards. Directly and materially affected individuals are invited to contribute to the development of such standards. Those wanting to participate may contact the Staff Engineer listed with the document.

Participation on AWS Technical Committees and Subcommittees is open to all persons.

AWS D8.9M:200X, Recommended Practices for Test Methods for Evaluating the Resistance Spot Welding Behavior of Automotive Sheet Steel Materials. This document presents recommended practices for evaluating the resistance spot welding behavior of automotive sheet steels. The document contains a number of tests and test methods useful in determining the spot welding performance of coated and uncoated automotive sheet steels of all strength levels and compositions. The test methods are designed to assess current range, electrode endurance, and weld properties of automotive sheet steels. The weld property tests include tests for hold-time sensitivity, weld hardness, shear-tension strength, and cross-tension strength. The document and the test methods, parameters, and test criteria it contains are designed exclusively for laboratory testing and are not intended as recommended practices or standards for manufacturing operations. Engineer: Ed Mitchell. (305) 443-9353 ext. 254.

The American Welding Society (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 all standards be open to public review for comment during the approval process. This column also advises of ANSI approval of documents. The following standards are submitted for public review. A copy may be obtained by sending the amount shown to AWS Technical Dept., 550 NW LeJeune Rd., Miami, FL 33126, or by calling (800) 443-9353 ext. 340.

ISO Draft Standard for Public Review

Copies of the following Draft International Standards are available for review and comment through your national standards body, which in the United States is ANSI, 11 West 42nd St., New York, NY 10036; telephone (212) 642-4900. Any comments regarding ISO documents should be sent to your national standards body.

In the United States, if you wish to participate in the development of International Standards for welding, contact Andrew Davis at AWS, 550 NW LeJeune Rd., Miami, FL, 33126; telephone (800) 443-9353 ext. 466, outside the United States (305) 443-9353 ext. 466, e-mail: adavis@aws.org. Otherwise contact your national standards body.

New Standard Approved by ANSI


Revised Standards Approved by ANSI


D14A Subcommittee Seeks Members

The D14A Subcommittee on Industrial and Mill Canes is seeking new members. The subcommittee is responsible for collecting, reviewing, and promulgating minimum requirements considered necessary for the control of welding in the fabrication of industrial machinery and equipment. This includes weld design, data, welding process selection, materials control, fabrication practices, quality standards inspection, and tests.

For more information on becoming a D14A Subcommittee member, contact D14 Committee Secretary Antony Oseitutu at (800) 443-9353 ext. 314 or outside the U.S. (305) 443-9353 ext. 514 or via e-mail at aos@aws.org.

The following list of errata items apply to the AWS D10.7m/D10.7:2000 standard. The subsection/figure/table/annex number is followed in parentheses by the page number and any other information needed to locate the errata item.


Section 4, Aluminum Pipe Alloys and Their Characteristics, (page 4, paragraph 5) - Change "resistance of corrosion" to "resistance to corrosion."

Table 2, Note B (page 5) - Change "improved color" to "improve color."

Subsection 7.4, Inert Gas (page 16) - Change "(SG-heA-X)" to "(SG-HeA-X)."

Subsection 11.2, Gas Metal Arc Welding (page 23) - Last sentence, take out the word "tungsten."

Subsection 14.5, How to Prevent Fires (page 25) - Change "10 meters (33 feet)" to "11 meters (35 feet)."

Subsection 14.5, How to Prevent Fires (page 26) - Change "*Develop adequate ventilation procedures and use proper equipment used to do the job safely." to "*Develop adequate ventilation procedures and use proper equipment to do the job safely."

TECHNICAL COMMITTEE MEETINGS

All AWS technical committee meetings are open to the public. Persons wishing to attend a meeting should contact the staff secretary of the committee as listed below at AWS, 550 NW LeJeune Rd., Miami, FL 33126; telephone (305) 443-9353.

September 13, G2D Subcommittee on Reactive Alloys, Sunriver, Oreg. Standards preparation meeting. Staff contact: T. R. Potter.

September 14, A5K Subcommittee on Titanium and Zirconium Filler Metals, Sunriver, Oreg. Standards preparation meeting. Staff contact: C. B. Pollock.


September 27-28, C3 Committee on Brazing and Soldering, San Antonio, Tex. Standards preparation meeting. Staff contact: C. B. Pollock.

October 1-5, D14 Committee on Machinry and Equipment, Sunriver, Oreg. Standards preparation and general meeting. Staff contact: A. Y. Oseitutu.

October 4-5, D17 Committee on Welding in the Aircraft and Aerospace Industries, Seattle, Wash. Standards preparation and general meeting. Staff contact: E. F. Mitchell.

October 9, D8 AWS/SAE Joint Committee on Automatic Welding, Detroit, Mich. Standards preparation and general meeting. Staff contact: E. F. Mitchell.

October 16, C7C Subcommittee on Laser Beam Welding and Cutting, Jacksonville, Fla. Standards preparation meeting. Staff contact: E. F. Mitchell.

## 2001–2002 Member-Get-A-Member Campaign

Listed below are the people participating in the 2001–2002 Member-Get-A-Member Campaign. For campaign rules and a prize list, please see page 69 of this Welding Journal. If you have any questions regarding your member proposer points, please call the Membership Department at (800) 443-9353 ext. 480.

### Winner’s Circle
(AWS Members sponsoring 20 or more new Individual Members, per year, since June 1, 1999.)

<table>
<thead>
<tr>
<th>Name</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>J. Compton</td>
<td>San Fernando Valley*</td>
</tr>
<tr>
<td>E. H. Ezell</td>
<td>Mobile**</td>
</tr>
<tr>
<td>J. Merzthal</td>
<td>Peru</td>
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<tr>
<td>B. A. Mikeska</td>
<td>Houston*</td>
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<tr>
<td>W. L. Shreve</td>
<td>Fox Valley*</td>
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<tr>
<td>G. Taylor</td>
<td>Pascagoula*</td>
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<tr>
<td>T. Weaver</td>
<td>Johnstown/Altoona*</td>
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<tr>
<td>W. L. Shreve</td>
<td>Fox Valley*</td>
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<td>B. A. Mikeska</td>
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<tr>
<td>J. Merzthal</td>
<td>Peru</td>
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<tr>
<td>R. L. Peaslee</td>
<td>Detroit — 21</td>
</tr>
<tr>
<td>R. Wray</td>
<td>Nebraska*</td>
</tr>
</tbody>
</table>

*Denotes the number of times an Individual Member has achieved Winner’s Circle status. Status will be awarded at the close of each membership campaign year.

### President’s Guild
(AWS Members sponsoring 20 or more Individual Members between June 1, 2001, and May 31, 2002.)

<table>
<thead>
<tr>
<th>Name</th>
<th>Points</th>
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<tbody>
<tr>
<td>J. Merzthal</td>
<td>22</td>
</tr>
<tr>
<td>R. L. Peaslee</td>
<td>21</td>
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</table>

### President’s Roundtable
(aws Members sponsoring 11–19 new Individual Members between June 1, 2001, and May 31, 2002.)

<table>
<thead>
<tr>
<th>Name</th>
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<tr>
<td>T. A. Ferri</td>
<td>14</td>
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</table>

### President’s Club
(AWS Members sponsoring 6–10 new Individual Members between June 1, 2001, and May 31, 2002.)

<table>
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<tr>
<th>Name</th>
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<tbody>
<tr>
<td>M. Hynoy</td>
<td>6</td>
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</tbody>
</table>

### President’s Honor Roll
(AWS members sponsoring 1–5 new Individual Members between June 1, 2001, and May 31, 2002. Only those sponsoring 2 or more AWS Individual Members are listed.)

<table>
<thead>
<tr>
<th>Name</th>
<th>Points</th>
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</thead>
<tbody>
<tr>
<td>J. Compton, San Fernando Valley</td>
<td>3</td>
</tr>
<tr>
<td>C. Cronin, Jr, Florida West Coast</td>
<td>2</td>
</tr>
<tr>
<td>G. Taylor, Pascagoula</td>
<td>2</td>
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</tbody>
</table>

### Student Sponsors
(AWS members sponsoring 1–5 new Individual Members between June 1, 2001, and May 31, 2002. Only those sponsoring 2 or more AWS Individual Members are listed.)

<table>
<thead>
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<th>Name</th>
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<tr>
<td>J. Compton</td>
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</tr>
<tr>
<td>C. Cronin, Jr, Florida West Coast</td>
<td>2</td>
</tr>
<tr>
<td>R. A. Graf</td>
<td>2</td>
</tr>
<tr>
<td>G. Taylor</td>
<td>2</td>
</tr>
</tbody>
</table>

### Indiana Section Undertakes Welding for Communities Project

For its National Welding Week Project in April, Indiana Section members volunteered their time and skills to make an "tree" from reinforcing bar for the Harrison Parkway Elementary School. The school's plan calls for the students to decorate the tree over the next school year by hanging art projects they make in class from the tree's branches.

![Image of welders working on a welding project](image-url)

Indiana Section members, from left to right, Don Davis, Jim McCaffrey, and Jan Donahue working on the art tree the Section fabricated for Harrison Parkway Elementary School in honor of National Welding Week in April.

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**WELDING JOURNAL | 79**
**GUIDE TO AWS SERVICES**

550 NW Tejene Rd., Miami, FL 33126
Phone: (800) 443-9353; Telex: 51-9245; (888) WELDING
FAX: (305) 443-7559; Internet: www.aws.org
Phone extensions appear in parentheses.

**AWS PRESIDENT**
Richard L. Are
Teletelnet Technologies, Inc.
3701 LaGallia Road
Lisbon, OH 44432

**CONVENTION & EXPOSITIONS**

<table>
<thead>
<tr>
<th>Division Information</th>
<th>Managing Director</th>
<th>(246)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Jeff Weber</td>
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Manages the week-long annual AWS International Welding and Fabricating Exposition and Convention. Regulates space assignments, registration materials, and other Expo activities.

**PUBLICATION SERVICES**

<table>
<thead>
<tr>
<th>Division Information</th>
<th>Managing Director</th>
<th>(246)</th>
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<tbody>
<tr>
<td></td>
<td>Jeff Weber</td>
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</table>

Manages the AWS's monthly magazine, *Welding Journal*, which provides information on the state of the welding industry, its technology, and Society activities. Publishes the *Welding Handbook* and books on general welding subjects.

**WELDING HANDBOOK**

<table>
<thead>
<tr>
<th>Welding Handbook Editor</th>
<th>Annette O'Brien</th>
<th>(303)</th>
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**MEMBER SERVICES**

<table>
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<tr>
<th>Department Information</th>
<th>Associate Executive Director</th>
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<tbody>
<tr>
<td></td>
<td>Gassie R. Barrrell</td>
<td></td>
</tr>
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</table>

Serves as a liaison between Section members and AWS Headquarters. Informs members about AWS benefits and other activities of interest.

**EDUCATION AND CONFERENCE SERVICES**

<table>
<thead>
<tr>
<th>Managing Director</th>
<th>(219)</th>
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<tbody>
<tr>
<td>Debrah C. Weir</td>
<td></td>
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</tbody>
</table>

Information on education programs, projects, and programs, CWI, SCWI, and other seminars designed for preparation for certification. Responsible for the S.E.N.S.E. program for welding education, and dissemination of training and education information on the Web.

**COORDINATOR OF EXPOSITIONS**

<table>
<thead>
<tr>
<th>Exhibiting Information</th>
<th>Managing Director</th>
<th>(246)</th>
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<tbody>
<tr>
<td></td>
<td>Tom L. Davis</td>
<td></td>
</tr>
</tbody>
</table>

Manages the commercial side of the AWS International Welding and Fabricating Exposition and Convention. Regulates space assignments, registration materials, and other Expo activities.

**PRODUCT DEVELOPMENT**

<table>
<thead>
<tr>
<th>Managing Director</th>
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<tbody>
<tr>
<td>Wendy S. Reeve</td>
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**CERTIFICATION OPERATIONS**

<table>
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<tr>
<th>Information and Application Materials on certifying welders, welding inspectors, and educators.</th>
<th>(273)</th>
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<tbody>
<tr>
<td>Managing Director</td>
<td>Wendy S. Reeve</td>
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<tr>
<td>Director</td>
<td>Terry Perez</td>
</tr>
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</table>

**INTERNATIONAL BUSINESS DEVELOPMENT**

| Director of Int'l Business Development | Walter Herrera | (475) |

**TELEWELD**

| FAX: (305) 443-5951 | For information about AWS technical publications, contact the Technical Services personnel listed below. | |

**TECHNICAL SERVICES**

<table>
<thead>
<tr>
<th>Managing Director</th>
<th>Leonard P. Connor</th>
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**ENGINEERS**

<table>
<thead>
<tr>
<th>Hardy H. Campbell III</th>
<th>Structural</th>
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<tr>
<td>Bhalach Gupta</td>
<td>Filler Metal</td>
<td>(301)</td>
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**EXHIBITORS**

<table>
<thead>
<tr>
<th>Christopher J. Pickard</th>
<th>Braising, Soldering, Testing, Railroads, Computerization, Instrumentation</th>
<th>(304)</th>
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<tbody>
<tr>
<td>Tim Potter</td>
<td>Robotics, Joining of Metals and Alloys, Piping and Tubing, Friction Welding</td>
<td>(304)</td>
</tr>
<tr>
<td>John L. Gayler</td>
<td>Metric Practices, Sheet Metal, Plastics and Composites, Personnel Qualification</td>
<td>(304)</td>
</tr>
<tr>
<td>Ed F. Mitchell</td>
<td>Thermal Spray, High-Energy Beam Welding and Cutting, Resistance Welding, Aerospace</td>
<td>(304)</td>
</tr>
</tbody>
</table>

**INFORMATION SERVICES**

| Corporate Director of Administrative Services | Jim Lankford | (211) |

**ADMINISTRATION**

<table>
<thead>
<tr>
<th>Executive Director</th>
<th>Frank G. Delaunay, CAE</th>
<th>(210)</th>
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<tbody>
<tr>
<td>Deputy Executive Directors</td>
<td>Richard D. Branch</td>
<td>(218)</td>
</tr>
<tr>
<td></td>
<td>Jeffrey R. Rubey</td>
<td>(204)</td>
</tr>
<tr>
<td></td>
<td>John J. McCaughlin</td>
<td>(235)</td>
</tr>
<tr>
<td>Assistant Executive Director</td>
<td>Debbie A. Cadavid</td>
<td>(222)</td>
</tr>
<tr>
<td>Corporate Director of Quality Management Systems</td>
<td>Linda K. Williams</td>
<td>(298)</td>
</tr>
<tr>
<td>Chief Financial Officer</td>
<td>Frank R. Tanda</td>
<td>(252)</td>
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**HUMAN RESOURCES**

| Corporate Director and CEO | (258) |
| Joe Gill |       |

**INTERNATIONAL INSTITUTE OF WELDING**

| Information | (294) |

Provides liaison activities involving other professional societies and standards organizations, nationally and internationally.

**GOVERNMENT LIASON SERVICES**

<table>
<thead>
<tr>
<th>Hugh K. Webster</th>
<th>Washington, D.C.</th>
<th>(212) 660-2976</th>
</tr>
</thead>
<tbody>
<tr>
<td>Webster, Chamberlin &amp; Beau</td>
<td>(202) 895-9213</td>
<td></td>
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Identifies sources of funding for welding education and research & development; monitors legislative and regulatory issues important to the industry.

**WELDING EQUIPMENT MANUFACTURERS COMMITTEE**

<table>
<thead>
<tr>
<th>Associate Executive Director</th>
<th>Richard L. Alley</th>
<th>(217)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Welding Industry Network (WIN)</td>
<td>Charles R. Kossinger</td>
<td>(297)</td>
</tr>
</tbody>
</table>

**COMMUNICATIONS**

| Corporate Director, Communications | Nannette M Zapata | (308) |

80 | SEPTEMBER 2001
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 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 District Director.

Interested parties are asked to send a letter stating which particular office they are seeking, including a statement of qualifications, their willingness and ability to serve if nominated and elected, and 20 copies of their biographical sketch.

This material should be sent to J. William Myers, Chairman, National Nominating Committee, American Welding Society, 550 NW LeJeune Rd., Miami, FL 33126.

The next meeting of the National Nominating Committee is currently scheduled for March 2002, in Chicago, III. The terms of office for candidates nominated at this meeting will commence June 1, 2002.

Honorary-Meritorious Awards

The Honorary-Meritorious Awards Committee has the duty to make recommendations regarding nominees presented for Honorary Membership, National Meritorious Certificate, William Irgang Memorial, and the George E. Willis Awards. These awards are presented in conjunction with the AWS Exposition and Convention held each spring. The descriptions of these awards follow, and the submission deadline for consideration is July 1 prior to the year of presentation. All candidate material should be sent to the attention of John J. McLaughlin, Secretary, Honorary-Meritorious Awards Committee, 550 NW LeJeune Rd., Miami, FL 33126.

National Meritorious Certificate Award: This award is given in recognition of the candidate’s counsel, loyalty, and devotion to the affairs of the Society, assistance in promoting cordial relations with industry and other organizations, and for the contribution of time and effort on behalf of the Society.

William Irgang Memorial Award: This award is administered by the American Welding Society and sponsored by The Lincoln Electric Co. to honor the late William Irgang. It is awarded each year to the individual who has done the most to enhance the American Welding Society’s goal of advancing the science and technology of welding over the past five-year period.

George E. Willis Award: This award is administered by the American Welding Society and sponsored by The Lincoln Electric Co. to honor George E. Willis. It is awarded each year to an individual for promoting the advancement of welding internationally by fostering cooperative participation in areas such as technology transfer, standards rationalization, and promotion of industrial goodwill.

International Meritorious Certificate Award: This award is given in recognition of the candidate’s significant contributions to the worldwide welding industry. This award should reflect “service to the International Welding Community” in the broadest terms. The awardee is not required to be a member of the American Welding Society. Multiple awards can be given per year as the situation dictates. The award consists of a certificate to be presented at the award’s luncheon or at another time as appropriate in conjunction with the AWS President’s travel itinerary, and, if appropriate, a one-year membership to AWS.

Honorary Membership Award: An Honorary Member shall be a person of acknowledged eminence in the welding profession, or who is accredited with exceptional accomplishments in the development of the welding art, upon whom the American Welding Society deems it fit to confer an honorary distinction. An Honorary Member shall have full rights of membership.
Q: We are experiencing difficulty brazing 430 (S43000) stainless steel with BNi-9 filler metal at 2000°F (1093°C). We are getting a series of lumps along the edge of the part being brazed instead of the brazing filler metal wetting and flowing as it should. The slots in the heavy section have been laser cut, and a thin plate is being brazed to one side. A part is enclosed so you can see the lumpy braze results.

A: Other than the lumps, the first obvious footprint is the bluish-gray color of the base metal adjacent to the braze joint and on top of the heavier members. This is indicative of nitrogen in either the base metal or atmosphere.

In further discussions, you mentioned the parts have been laser cut using a nitrogen gas to blow the liquid metal out of the laser-cut area. Unfortunately, with boron-containing filler metals such as BNi-2, the boron will nitride and inhibit or prevent the flow of brazing filler metal.

The bluish-gray area indicates the base metal picked up nitrogen and produced a surface not conducive to wetting and flow. This caused the filler metal to ball up in lumps along the edge of the joint. The same effect has been seen in sheets of 347 sprayed with BNi-2 and run through a continuous furnace containing an all-hydrogen atmosphere. Because the curtains on the end of the furnace were nitrogen gas, there was sufficient nitrogen diffusing back into the hot zone to form a nitrogen layer underneath the braze filler metal. Thus, the test plate came out with small lumps of filler metal on the coated surface — Fig. 1.

R. L. PEASLEE is Vice President, Wall Colmonoy Corp., Madison Heights, Mich. This article is based on a column prepared for the AWS Detroit Brazing and Soldering Division's newsletter. Reader may send questions to Mr. Peaslee c/o Welding Journal, 530 NW LeJeune Rd., Miami, FL 33126 or via e-mail to bobpeaslee@wallcolmonoy.com.
BY DAMIAN J. KOTECKI

Q: We need to make transition joints between carbon steel pipe (ASTM A106) and 304H stainless. The carbon steel pipe and transition joints will serve at 700°F (370°C) design temperature. The 304H design temperature, away from the transition joints, will be 1100°F (595°C). The joints will not be postweld heat treated. Type 312 filler metal has been suggested for the transition joints. Is this a good choice?

A: Type 312 filler metal (nominally 29% Cr and 9% Ni) has excellent resistance to hot cracking in such a dissimilar joint because of its high ferrite and tolerance for dilution. From that point of view, it is a good choice, but not from the point of view of design service temperature. Only few people think of 312 as an austenitic stainless steel filler metal, but it is not. It is, in fact, a duplex ferritic-austenitic stainless steel filler metal. It is so high in ferrite content (typically 60 to 90 FN) that it behaves, from a metallurgical viewpoint, very similarly to a duplex stainless steel filler metal such as 2209. These high-chromium, high-ferrite stainless steel filler metals are sensitive to formation of the alpha prime phase during exposure to temperatures of about 550°F (285°C) to 980°F (525°C), which includes the 700°F design temperature.

The alpha prime phase is not an intermetallic compound like sigma phase, which forms at higher temperatures than alpha prime. Alpha prime is a chromium-rich, body-centered cubic (BCC) phase that separates from the iron-rich BCC ferrite phase by diffusion of iron and chromium atoms. On a chromium-iron phase diagram, iron-rich BCC ferrite is symbolized by the Greek letter alpha, and the chromium-rich BCC ferrite is symbolized by the Greek letter alpha followed by a prime symbol. The chemical composition of the alpha prime phase is on the order of 90 to 95% chromium, 20 to 5% iron. The alpha prime phase precipitates within the iron-rich ferrite phase on a very fine scale — an electron microscope is usually necessary to see it clearly. The formation of alpha prime phase severely embrittles both duplex and ferritic stainless steels and their weld metals.

Alpha prime phase forms most rapidly at 885°F (475°C), so the resulting embrittlement is often referred to as “885°F embrittlement.” It is often called “885°F embrittlement” in the United States or “475°C embrittlement” elsewhere in the world. The embrittlement may be severe after exposure of less than an hour at 885°F, for a high-chromium, high-ferrite stainless steel filler metal such as 312. At a temperature of 700°F, perhaps 100 hours, or more, may be necessary to produce the severe embrittlement in 312 filler metal. But embrittlement is inevitable at your design service temperature.

There are several ways embrittlement due to alpha prime phase shows up. The hardness of the ferrite typically increases from less than 200 Vickers without alpha prime to more than 300 Vickers with extensive alpha prime. Tensile elongation of the weld metal typically falls from well above 20% without alpha prime to less than 5% with extensive alpha prime. And the Charpy V-notch impact energy at room temperature falls from more than 20 ft-lb (27 J) without alpha prime to less than 10 ft-lb (14 J) with extensive alpha prime. Corrosion resistance of the weld metal is also damaged by extensive alpha prime precipitation, but this would not be an issue for your dissimilar metal joint since the carbon steel side has little corrosion resistance.

You can find a good review of alpha prime phase and resulting embrittlement in Welding Metallurgy of Stainless Steels by Erich Folkhard (New York, N.Y.: Springer-Verlag).

I suggest you use 309 or 309L filler metal restricted to less than 15 FN instead of 312. While there will be some alpha prime precipitation in the ferrite of this filler metal at your service temperature, because there is limited ferrite, the extent of damage should be comfortably within acceptable limits.

Q: I need to weld 409 stainless pieces for truck exhaust systems. When I tried to weld 409 covered electrodes, he told me they are not available and instead offered me 409 metal cored wire. I don’t have equipment to run the wire and would prefer to use covered electrodes. He suggested 309L electrodes, but I wonder if that is correct. I thought he might have been kidding because he didn’t have 409 covered electrodes in stock and didn’t want to lose a sale. I went to another distributor and was told more or less the same story. Now I’m not sure. What’s the straight scoop?

A: He was not kidding. As far as I know there is no such thing as a 409 covered electrode. The reason for this is that 409 stainless (nominally 17% Cr, 0.5% Ti) is alloyed with titanium, which reacts with the silicate binder in the coating of covered electrodes during welding, as well as with any oxygen available. So, most of the titanium is lost, and the slag tends to become indestructible. As a result, no one makes 409 covered electrodes.

In Japan, there is a ferritic stainless steel electrode known as 410Nb that produces an equivalent weld deposit to the 409 base metal. The niobium (often called “columbium” in the United States) has the same stabilizing effect as the titanium in the 409 base metal, without the tendency to be lost during welding or to produce indestructible slag. However, I doubt you will find a source of 410Nb covered electrodes in this country.

Actually, 309L covered electrodes are probably the best choice. Years ago, using gas metal arc welding, ER309LSi was used extensively in the manufacture of 409 stainless steel automobile exhaust systems. This practice fell out of favor because 409 metal-cored wires became available and were less costly than ER309LSi. But the exhaust systems welded with ER309LSi have performed very well. If you have only a few pieces to weld, I suggest you use 309L covered electrodes. But if you have a lot of these pieces to weld, it might be worth investing in GMAW equipment and going with 409 metal-cored wire.●

DAMIAN J. KOTECKI is the technical director for Stainless and High-Alloy Product Development for The Lincoln Electric Co., Cleveland, Ohio. He is a member of the AWS ASD Subcommittee on Stainless Steel Filler Metals; AWS D1 Structural Welding Committee, Subcommittee on Stainless Steel Welding; and a member and past chair of the Welding Research Council Subcommittee on Welding Stainless Steels and Nickel Base Alloys. Questions may be sent to Mr. Kotecki at WELDING Journal, 550 NW LeJeune Rd., Miami, FL 33126 or via e-mail at Damian.Kotecki@lincolnelectric.com.

Correction: In the August 2001 WELDING Journal’s Stainless Q&A column, the parenthetical remark (e.g., 1500 to 2000 lb/min) on page 103, column 2, should have read (e.g., 1500 to 2000 parts per million).●
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Brochure Highlights Metalworking Solutions

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Catalog Showcases Calibration Products

The company redesigned its calibration catalog showcasing temperature, pressure, and signal calibrators in full color along with details about its expanded services. The 76-page catalog features new laboratory-grade signal calibrators, including the PC6 line of calibrators from SI Pressure, Hathaway's BetaGauge II digital pressure calibrator, and the BetaFlex II modular pressure calibrator.

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Bulletin Describes Oxygen Analyzer

A technical bulletin describing the DF310 process oxygen analyzer is available. The analyzer can be separated into components for mounting throughout an OEM system, or it can be housed in a single, small enclosure. It is not affected by temperature and is available in ranges from 0-500 parts per billion to 0-25%. The analyzer includes the company's nondepleting coulometric sensor that never requires rebuilding or replacing. Calibration is traceable to NIST standards.

Delta F Corp.
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Industrial Catalog Features Grinding Wheels

The company's 2001 industrial catalog features grinding wheels for all MROP applications. Blank stock for fast turnaround on Creepfeed applications, rubber wheels, segments, and superabrasives are listed. The resistance chart and product list are included in the catalog for reference.

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The Robotic Industries Association (RIA) has updated its free video, "Introduction to Successful Robotic Solutions." The video provides a quick overview of the benefits of robotizing and industrial applications. The nine-minute video highlights several companies that have used robotic technology to reduce costs, increase productivity, and improve workplace safety. The video is available from RIA by calling (734) 994-6088.

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Effect of Projection Height on Projection Collapse and Nugget Formation — A Finite Element Study

An incrementally coupled analysis procedure can be used to develop improved procedures for determining weld conditions

BY X. SUN

ABSTRACT. Projection welding is a variation of resistance welding in which current flow is concentrated at the point of contact with a local geometric extension of one (or both) of the parts being welded. These projections are used to concentrate heat generation at the point of contact and, therefore, to generate a weld nugget faster and at a lower current level compared to conventional spot welding. Many factors affect the heat generation and projection collapse of the projection welding process. The effects of some of these factors, such as welding current, electrode force, and sheet material properties, have been studied using the coupled finite element simulation procedures in an earlier study by the author (Ref. 1). This paper is a sequel to the previous effort. It investigates the effect of projection height on projection collapse and nugget formation. Three projection designs with different projection heights were selected for 0.059-in., cold-rolled, low-carbon steel according to Ref. 2. The corresponding heat generation processes using one set of welding parameters were simulated using an incrementally coupled, thermal-electrical-mechanical modeling procedure (Refs. 1, 3). The predicted heating patterns were compared with the weld cross sections obtained from an earlier experimental approach using high-speed motion photography (up to 6000 frames/s). The study offers fundamental understanding of the process physics for different projection designs and demonstrates again the effectiveness of an incrementally coupled modeling procedure.

Introduction

Projection welding is an electrical resistance welding process in which resistance welds are produced at localized points in workpieces held under pressure between suitable electrodes. The projections are usually dome or cone shaped and are made with different designs according to recommendations of some standards. Although tests indicate satisfactory welds can be produced over a wide range of projection shapes, there is some ambiguity concerning optimum designs (Ref. 2). For example, a wide variety of standards are recommended by different technical groups such as the American Welding Society and International Institute of Welding. In addition, different industries tend to establish their own projection design guidelines. It is intuitive that for different projection designs, the current paths will vary and this will, in turn, affect both projection collapse and the pattern of nugget formation. However, due to the complex flow paths for heat and electrical current and variations in material properties with temperature and phase changes, the projection welding process is difficult to analyze. When studying the effect of projection design on weld formation and weld quality, many earlier researchers had to rely on experimental techniques such as consecutive cross sectioning and high-speed motion photography (Refs. 2, 4).

With recent developments in finite element analysis and advances in computer technology, it is now possible to model the projection welding process and study current flow, heat generation, and projection collapse in quantitative detail. For example, the projection welding process was simulated with a coupled electrical-thermal-mechanical analysis procedure in Ref. 1, and the effects of different welding parameters, such as material grade, welding current, and electrode force, were investigated in detail. In this study, the incrementally coupled analysis procedure developed in Refs. 1 and 3 was used to study...
the effect of projection height on heat generation and projection collapse for three different projection designs. A similar modeling procedure was also used to simulate the processes of resistance spot welding; it proved to be an effective tool in analyzing fundamental process physics.

To compare simulation with existing experimental results, the projection designs and sheet material studied in this work are the same as the ones examined in Ref. 2 using high-speed movies. Three projection heights were adopted for the H&R (Harris and Riley) projection in welding of 0.059-in., cold-rolled, low-carbon steel. This study's objective was to examine the current flow and heat generation process for the three projection heights in quantitative detail. This would, in turn, offer some insights on the optimization of projection heights and selection of different welding parameters. Comparison of predicted results with previous experimental measurements using high-speed motion photography (Ref. 2) also served as further validation of the modeling procedure.

**Projection Geometry and Model Description**

Figure 1 shows cross sections of the three projection shapes for 0.059-in., SAE1010 cold-rolled steel as studied in Ref. 2. Projection heights vary from 0.02 to 0.06 in., and they are obtained by using H&R punch and die set T-4 (Refs. 2, 11). Notice the low projection is nearly uniform in thickness throughout, while higher projections showed increasingly thinner necked-down regions.

The sheet material SAE 1010 had a room temperature nominal yield strength of 270 MPa, ultimate strength of 310 MPa, and elongation of 32% (Refs. 10, 14). Its physical (electrical and thermal) and mechanical properties in elevated temperatures were found in Refs. 5–7. A true stress and strain curve was used with no strain rate sensitivity (Ref. 1). It should also be mentioned the analysis did not take into consideration the residual stress states in the projection area due to the punching process, nor did it consider the effect of work hardening on the material 

The electrodes used were flat-faced RWMA Class III electrodes with a face radius of 0.16 in. (4 mm). The same welding parameters were used for the three projection designs: welding current of 9.7 kA with bilinear up-slope control and constant electrode force of 500 lb — Fig. 2. The current is an approximation of the current profile documented in Fig. 2 of Ref. 2. By specifying the constant electrode force, perfect machine follow-up was assumed. Only 8 cycles of weld time were used, as opposed to 30 cycles used in Ref. 2. This was because projection collapse occurred only during the early stage of the welding process. For all three cases, projection collapse was completed by the eighth cycle and nugget growth beyond that point was similar to that of the resistance spot welding process.

The theoretical framework and associated finite element modeling procedure using commercial code [e.g., ABAQUS (Ref. 13)] for the projection welding process are presented in Refs. 1 and 3. A typical finite element mesh is shown in Fig. 3 for the standard projection with three-node linear elements in the projection area and four-node linear elements in the rest of the model. A typical finite element mesh is shown in Fig. 3 for the standard projection.
elements used elsewhere in the model. Only half of the electrode-sheet assembly was modeled with an axisymmetric condition being assumed.

The squeeze cycle was first modeled by mechanical analysis. Uniformly distributed pressure calculated according to the specified electrode force was applied on the top of the upper electrode, and the bottom of the lower electrode was restrained from motion in the vertical direction. Contact surface interactions between the electrode-sheet interfaces and the faying interface were modeled with the concept of contact pair. Contact pair is an option for modeling surface interactions in ABAQUS (Ref. 13). Instead of introducing a fictitious layer of solid interface elements at the contact surface, contact pair is a surface concept in which the master and slave surfaces of the contact are defined. Details of the contact pair formulation can be found in Ref. 13. Results generated from the squeezing cycle mechanical analysis, including deformed shape and coordinates, contact pressure, contact radius, element groups in and not in contact, etc., are extracted and passed into the next-step electrical-thermal analysis in which the welding current is applied.

In the electrical-thermal analysis, the deformed shape of the electrode-sheet assembly calculated from the previous mechanical analysis was used. Zero electrical potential was imposed on the bottom of the lower electrode tip. Distributed current density input calculated from the current input value was applied on the top of the upper electrode. All free surfaces of the electrode and sheet assembly not in contact at that time increment were assumed to have free convection with the surrounding air, and the two electrodes were assumed to be water cooled with a forced-convection coefficient specified on their upper and lower free edges.

The surface electrical resistivity of the faying interface and electrode-sheet interface were calculated using the formulation in Ref. 8 by assuming the maximum temperatures, $T_s$ (Equation 10 in Ref. 3), for the faying interface and the electrode-sheet interface as 1500 and 500°C, respectively (Ref. 1). $T_s$ used at the faying interface was the solidus of bare steel. $T_s$ used at the electrode-sheet interface was lower than the eutectoid temperature of the Fe-Cu alloy (Ref. 8). This is because the cooling water position on the electrodes was not clearly indicated in Ref. 2, and, in the current study, the water-cooling convection coefficient was applied only at the free edges of the electrode ends. By using a lower value of $T_s$ on the electrode-sheet interface, the effect of cooling water was compensated.

The contact radii for the electrode-sheet interfaces and faying interface are extracted from the previous mechanical analysis results to be used in the calculation of electrical contact resistivity. The temperature distribution computed from the above electrical-thermal analysis for
a certain time increment was then imposed as thermal loading conditions for the subsequent thermal-mechanical analysis module. This updating procedure repeated itself for every \( \frac{1}{6} \) cycle (Ref. 1), until the entire welding cycle was totally completed.

**Analysis Results**

**Squeeze Cycle**

At the end of the squeeze cycle, cold collapse of the projection occurred and an area of intimate mechanical contact on the faying interface was established for the subsequent electrical current to pass through. The amount of cold collapse depends on the electrode force and the individual projection design. For example, Fig. 4 shows the contour plots of the stress component on the deformed shapes for the three projection heights after squeeze cycle. As illustrated in Fig. 4, the faying interface contact radius established due to the squeezing force decreases with increasing projection heights. For the lowest projection height, the projection collapsed almost entirely and the contact pressure at the upper electrode-projection interface observed the highest value among the three cases considered.

**Initial Welding Cycles and Projection Collapse**

Because of the differences in the established faying interface contact area for the three projection heights, the corresponding current density distributions, and therefore the rate of heat generation, were also different for the three cases considered in the initial welding cycles. The evolution of the faying interface contact radius during the first two cycles is compared in Fig. 5 for the three cases considered. For all three projection shapes, the contact radius on the faying interface increased monotonically with time during the first two cycles. This was another manifestation of the gradual projection collapse process. The lowest projection consistently had the highest contact radius among the three cases. The contact radius of the standard projection was higher than the highest projection during the squeeze cycle and subsequent first cycle of welding. After the first cycle, the contact radius for the highest projection caught up with the standard projection because of local heating-induced material softening along the periphery of the faying interface.

The change of contact radius during the first two cycles for the lower electrode-sheet interface is shown in Fig. 6 for the three cases considered. The trend was fundamentally different from that of spot welding using flat-faced electrodes (Ref. 8). Before the end of the first welding cycle, the electrode-sheet interface radius increased with time due to the projection collapse process and the corresponding increase of the faying interface contact area.
After the first cycle, the faying interface heating became more intensive. The heat generated at the interface caused thermal expansion in the vicinity of contact interface. The effect of thermal expansion on the faying interface was offset by the projection collapse process; therefore, no decrease in contact radius was observed for the faying interface, as shown in Fig. 5. However, as a result of the faying interface thermal expansion, the contact radii on the lower electrode-sheet interface were reduced.

Among the three cases considered, the lowest projection experienced the slowest heat generation because it had the largest faying interface contact area; the highest projection had the fastest heat generation because of its initial smallest contact area and, therefore, the highest current density distribution along the faying interface. Figure 7 shows, at the end of the second cycle, the temperature distributions and projection collapse patterns for the three projection designs considered. Figure 8 compares the current density distributions for the three projection shapes at the end of the second cycle.

The predicted temperature distributions and projection collapse patterns shown in Fig. 7 compare very well with the experimental results depicted in Fig. 3 of Ref. 2, which were obtained by high-speed movies. For example, at the end of the second cycle, both Figs. 7 and 3 of Ref. 2 show the projection had totally collapsed for the lowest projection and collapsed more than 50% of its original height for the highest projection. The predicted temperature contours are also in good agreement with the contours depicted in Fig. 3 of Ref. 2. Only localized melting occurred for the highest projection, and the peak faying interface temperature increased with increasing projection height, as shown in both studies. The current density concentrated at the outer ring location on the faying interface and, therefore, initial heating was generated primarily at these locations for all three cases — Fig. 8 and Ref. 2. However, the magnitude of the temperature generated was different for the three cases because of the different levels of current density caused by different projection heights. Figure 7B shows greater temperature increase in the thin regions, indicating the standard projection attained substantial heating else-where in addition to just at the interface (Ref. 2). The highest projection design generated the highest interface temperature and the “hot spots” are located around the contact periphery of the faying interface — Fig. 7C. This was an extreme case, as current concentration had become quite high in the thin regions, resulting in much higher temperatures and some premature melting. As will be shown later, these hot spots around the contact periphery became hotter as the welding process continued because of the effect of bulk heating. If the projection had been too high, the rate of projection collapse could not catch up with the rate of excessive local heating and liquid metal expulsion would have occurred.

Subsequent Welding Cycles

Once the projection completely collapsed, the subsequent projection welding process closely resembled the spot welding process. For illustration, Fig. 9 shows, at selective time frames, the molten zone size and projection collapse patterns for the three projection designs during the welding simulation of the first eight welding cycles.

For all three cases considered, melting initiated in the form of a small ring on the faying interface as a result of high current density at these locations. However, the rate of projection collapse and heat generation was considerably different for the three cases considered. From the comparisons shown in Fig. 9, it is clear the lowest projection had the earliest total projection collapse and the highest projection had the fastest rate of heat generation. Initial melting occurred at the end of the second cycle for the highest projection, while no melting was predicted until the end of the sixth cycle for the lowest projection.

For the highest projection, the analysis diverged at the end of the fourth welding cycle because of excessive heating and thermal expansion at the faying interface contact periphery and lack of contact pressure to contain the liquid metal on the interface. This indicated the rate of projection collapse lagged behind the rate of heat generation on the faying interface. From a numerical point of view, analysis would fail if temperature exceeding melting point had been predicted for a point on the contact surface with no contact pressure. In actual welding practice, excess metal expulsion usually resulted in a weaker and inconsistent weld, and was detrimental to the weld's engineering performance (Refs. 2, 9 and 12). Thus, the dynamic balance between the rate of heat generation and projection collapse should be taken into consideration when selecting a projection design and corresponding welding parameters.

The heat generation pattern and nugget formation process after the complete projection collapse were similar to those of the resistance spot welding process with flat-faced electrodes. At the end of the sixth cycle of the standard projection, the molten region spread rapidly toward the weld center, and the molten zone was connected at the center of the weld at the end of the eighth cycle. From that point on, the molten zone became ellipsoidal in shape and grew progressively in size as the welding process continued. The predicted nugget diameter at the end of the eighth cycle for the standard projection was approximately 0.23 in., which compared reasonably well with the experimental measurement documented in Fig. 5 of Ref. 2. A shallower
nugget penetration on the upper sheet was predicted for the lowest projection than the standard projection because of the lower magnitude of current density on the faying interface.

It is interesting to note that, with increasing projection heights, the effects of projection collaring and projection digging (into the lower workpiece) were more prominent. That is, when a high projection was used, some of the material composing the projection at the periphery of the faying interface was squeezed out around the edge of the weld, forming an extruded collar — Figs. 7 and 8. This observation was again consistent with many previous experimental findings (Ref. 10).

Discussion and Conclusions

In this paper, the incrementally coupled finite element analysis procedure is used as a modeling tool to study the effect of projection design on the projection collapse process and heat generation patterns during the early stage of the projection welding process. Three projection designs from an earlier experimental study were adopted, and the predicted results on nugget formation and projection collapse compared reasonably well with the available experimental data obtained through high-speed movies.

This demonstrates again that the incrementally coupled analysis procedure developed in Refs. 1 and 3 can be used as a powerful tool to study the detailed process physics of a highly dynamic, coupled process such as projection welding, and provides some quantitative understanding and guidelines about projection design and welding parameter selection. With this tool, it is possible to develop improved procedures for determining weld conditions, requiring only a nominal amount of experimental work as a means of verification.

It was found that interfacial contact behavior (contact area change due to projection collapse) played a critical role in the initial heating process in projection welding. If an extremely high projection height is used, the rate of localized heating is faster than the rate of projection collapse, causing premature collapse of the projection and heat generation patterns during the early welding cycles. On the other hand, if a low projection height is used, premature collapse of the projection will cause the contact area to be large and, therefore, reduce the current density on the faying interface and delay nugget formation. The dynamic balance between projection collapse and heat generation must therefore be maintained to optimize the projection welding process. To this end, the analysis procedure can be used as a predictive tool to optimize the projection design for a specific sheet material to ensure nugget size and weld quality. Another application area of this tool is in the selection of different welding parameters, such as welding current, electrode force, and sheet material properties. These effects have been discussed in Ref. 1, and will not be repeated here.

It should be mentioned that no material strain rate sensitivity was included in the current simulation results. This was due to the lack of rate data for the elevated temperature under the deformation rate considered. Should such data become available, it could be easily incorporated in the modeling procedure. No work-hardening effect of the projection material due to the punching process was taken into consideration, and the entire projection was considered to be stress and strain free prior to the welding process. Also, the perfect electrode follow-up was assumed for the welding machine, and the magnetic stirring effect, as observed in many earlier high-speed movie studies, was not considered (Ref. 4).

References

Root Weld Formation in Modified Refractory Flux One-Sided Welding: Part 1 — Effect of Welding Variables

A portable, light, and efficient backing system with thermosetting flux offers solid support for root weld formation in field erection

BY V. MALIN

ABSTRACT. Experiments were conducted using modified refractory flux (MRF) welding developed in this program for field application. The effects of welding variables (current, voltage, travel speed, angle of electrode inclination, and amount of iron powder in the groove) on formation of root (backside) welds, including the root bead (deposit inside the groove) and the root reinforcement (deposit outside the groove) were studied. MRF welding is a new, portable, one-sided welding method that utilizes the submerged arc welding process (SAW), thermosetting backing flux, and direct current electrode negative polarity, and features a new, specially designed portable backing system. Modified refractory flux welding produces uniform root welds consistently in steel plate thicknesses ranging from 7.9 to 25.4 mm. It is intended for ship construction where constant welding conditions and groove geometry (especially a 1.6-mm maximum root opening) required for one-sided welding cannot be accurately maintained. The formation of root welds in MRF welding was studied in 17.5-mm-thick, single-V-groove butt joints with a wide (6.4 mm) root opening typical for erection joints. It was found when the root beads had a specific shape, it related to the development of defects in the following fill weld. Also, it was found that welding variables produced profound, and sometimes conflicting, effects on the root weld's shape. For example, increasing the current increased the deposition rate and the depth of joint penetration; however, root bead shape deteriorated and slag pockets formed, which may provoke defects in the following fill weld.

KEY WORDS
One-Sided Welding
Submerged Arc Welding
DCEN
Field Application
Thermosetting Backing
Flux
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Root Weld Geometry
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V. MALIN is with Malin's Welding Consultants, Inc., Highland Park, Ill.

Introduction

Refractory flux (RF) one-sided welding has long been successfully used in Japan (Ref. 1). Nevertheless, there is little known about the RF method in the United States. The distinguishable feature of the RF method is the application of special "thermosetting" (TS) backing fluxes (Ref. 2). Thermosetting flux in powder form is contained in a long trough that is applied to the backside of the plates to be welded, similar to the conventional SAW flux-backing (FB) method. Thermosetting flux contains a small amount of thermosetting resin. During welding, the resin is heated and hardens in front of the arc, turning the molten weld pool. As a result, an acceptable root reinforcement is formed, and there is no need to turn the weldment over and gouge the root weld (as in the conventional SAW FB method). To increase productivity, two electrodes are used simultaneously to complete the weld in one pass, one following the other in a tandem arrangement. The leading arc is fed by direct current electrode negative (DCEN) polarity and forms a root weld. The trailing arc operates on alternating current (AC) and fills the groove. Producing an acceptable root weld is the most difficult task and the key to success in any one-sided welding method, including the RF method. If an acceptable root weld is formed, the rest of the groove may be filled in one pass using one or more additional electrodes and the same or different SAW technique, depending on plate thickness.

The RF method was designed primarily for shop applications. A shop provides favorable conditions, namely sufficient space for large, bulky backing systems and precisely prepared joints characterized by straightness, tight groove tolerances and narrow root openings (1.6 mm max). The RF method provides a good formation of the root weld if both welding variables and groove geometry can be kept fairly constant.

However, the RF method did not find wide application in the field, specifically at the erection stage of ship construction. The reason is that a typical field application is characterized by loose joint tolerances, including large root openings, wide variations in included angle, and significant plate misalignment caused by distortion of previously welded components. Loose joint tolerances present serious difficulties in obtaining adequate root welds. Another reason is imperfection of the backing systems. For field application, a backing system should be portable, light, and efficient. It should tolerate inaccurate joint preparation, intense heat, and adverse flux exposure. Also, very little data exists to establish relationships between root weld formation and varying welding variables or abnormal joint geometry.

Modified refractory flux (MRF) welding is a new, portable, one-sided method developed under the National Shipbuild-
The MRF method consistently obtained uniform root welds under simulated conditions found at the erection stage of ship construction, characterized by wide variations in welding variables and joint geometry. The current laboratory experiments show adequate completed welds can also be produced in the flat position for single-V-groove butt joints in plate thicknesses ranging from 7.9 to 25.4 mm and wide root openings up to 9.5 mm as illustrated in Fig. 1A-C. Although the first implementation of the MRF method was reported to be successful (Ref. 3), further research is needed to provide wider practical application of this promising method to field fabrication of ships, bridges, cranes, and other heavy steel structures where one-sided welding is beneficial.

In a two-electrode, one-pass MRF welding method, the leading electrode is followed by a trailing electrode at some distance. They deposit the root and fill welds at the same time. When the entire weld is completed, the shape of the root bead is not seen in all details because its face is fully remelted by the following weld. However, it is the shape of the root bead that may determine whether the fill weld develops internal defects, as is schematically illustrated in Fig. 2. Under optimal welding conditions, a desirable root weld shape can be obtained. It has a fairly flat top, as shown for root weld R1 in Fig. 2A. However, in reality, the root weld may not be flat. It may have an undesirable buildup or crown, as in root weld R2 shown in Fig. 2B. A crowned root weld may create deep pockets filled with slag on both sides of the groove. If fill weld F1 is deposited over root weld R2, as shown in Fig. 2C, it may not reach the bottom of the slag pockets creating incomplete fusion on both sides of the groove. To avoid these discontinuities, the fill weld must penetrate deeper as shown for weld F2 — Fig. 2C. In fact, penetration should be much deeper than would be necessary for a flat root weld.

In this case, there is a risk that the fill weld may melt through the entire root weld (like weld F3 in Fig. 2C) and impair the appearance of the root reinforcement. A slag pocket may develop in the root weld on one side of the groove due to arc blow even if welding conditions are optimal and produce a flat root weld. It also happens if the electrode is offset about the center of the groove, as shown for root weld R3 in Fig. 2D. Due to some other reasons (to be discussed later), a slag pocket on one side of the groove may be deeper than that on the other side. In this case, the fill weld may not penetrate deeply enough, as shown for weld F2 — Fig. 2C. In fact, penetration should be much deeper than would be necessary for a flat root weld.

The results of the experiments showed that welding variables and groove geometry produced profound, and sometimes conflicting, effects on the shape of the root weld, particularly the root bead (deposit inside the groove) and the root reinforcement (deposit outside the groove). It was found also that the shape of the root bead is crucial for the integrity of an entire weld because it may be related to development of incomplete fusion in the following fill weld. This behavior can be explained as follows.

In a two-electrode, one-pass MRF welding method, the leading electrode is followed by a trailing electrode at some distance. They deposit the root and fill welds at the same time. When the entire weld is completed, the shape of the root bead is not seen in all details because its face is fully remelted by the following weld. However, it is the shape of the root bead that may determine whether the fill weld develops internal defects, as is schematically illustrated in Fig. 2. Under optimal welding conditions, a desirable root weld shape can be obtained. It has a fairly flat top, as shown for root weld R1 in Fig. 2A. However, in reality, the root weld may not be flat. It may have an undesirable buildup or crown, as in root weld R2 shown in Fig. 2B. A crowned root weld may create deep pockets filled with slag on both sides of the groove. If fill weld F1 is deposited over root weld R2, as shown in Fig. 2C, it may not reach the bottom of the slag pockets creating incomplete fusion on both sides of the groove. To avoid these discontinuities, the fill weld must penetrate deeper as shown for weld F2 — Fig. 2C. In fact, penetration should be much deeper than would be necessary for a flat root weld.

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case, incomplete fusion in the fill weld may develop on that side of the groove where the slag pocket is deeper, as illustrated in Fig. 3.

The examples described above show the importance of understanding how variations of welding conditions and joint geometry may affect root weld formation in MRF welding. Due to the complexity of this research, the results are presented in two parts. Part 1 of this investigation describes the effect of welding variables on the shape of the root weld, groove geometry being constant. Part 2 describes the effect of joint geometry (the root opening, included angle, root face, and plate misalignment) on the shape of the root weld, the welding variables being constant. The effects of arc blow and tack welds are also discussed in Part 2.

**Experimental Procedure**

**Equipment and Accessories**

This investigation used a standard two-electrode tractor for SAW selected to provide one-pass capability for plates up to 25.4 mm thick. The leading electrode was followed by the trailing electrode at a distance of about 127 mm in tandem, operating from DC and AC power sources, respectively. Only the leading arc was used during the experiments to deposit the root welds. The leading arc was direct current electrode negative (DCEN) polarity. Advantages of DCEN polarity (as applied to MRF welding) in comparison with direct current electrode positive (DCEP) polarity favored in conventional SAW are 1) higher deposition rate, which helps to deposit a thicker root weld; 2) lower penetration, which results in less risk of melting through a large root opening and damaging the MRF backing; and 3) arc stability at low voltage, which reduces arc blow and heat input.

The backing system was specially designed for multiple applications in MRF welding. It provides sufficient service life and competitive cost per foot of welding in comparison with conventional SAW FB method. If the thermosetting flux is heated to lower temperatures, the strength and heat resistance of the briquette are not sufficient and the molten metal may melt through the flux (a melt through condition). Some melting of the briquette surface always occurs under the weld pool under normal conditions, with maximum melting being in the center of the pool. This assists in creating a root reinforcement. A thin layer of molten slag covers and protects the weld pool from the atmosphere. Also, the slag contains deoxidizers and iron powder. As a result of the interaction between the molten slag and metal, the surface of the root reinforcement has a very smooth, silvery, and shiny appearance. It blends into the base metal very well.

**Materials Welding Conditions and Specimen Preparation**

Two steel plates (17.5 x 305 x 1219 mm) were oxyfuel cut and beveled at...
22.5 or 15 deg and assembled to form a single-V-groove butt joint. The root weld was deposited using the lead electrode only, changing one variable at a time, which included current (I), voltage (U), travel speed (V), angle of inclination of the electrode (α), and height of iron powder (f). Groove geometry was maintained constant with root opening RO = 6.4 mm, included angle 8 = 45 or 30 deg, root face RF = 0, and plate misalignment MA = 0. Basic welding conditions are given in Table 1, unless specified otherwise. Numerous transverse specimens were cut from each weldment. The cross section of each specimen was polished and etched to reveal a weld profile. The profile was reproduced and enlarged. The shape of different root welds, its geometry was defined as a combination of characteristic dimensions and cross-sectional areas determined by measuring the enlarged reproductions taken from the transverse specimens of the root weld, which weren’t always symmetrical — Fig. 4.

Results and Discussion

Effect of Current

Welding current produces a complex, and sometimes conflicting, effect on root weld geometry largely through its effect on deposition rate and arc penetration. Since current has a different effect on the root bead and root reinforcement, that will be discussed separately.

Effect of Current on Shape of Root Bead

The shape of the root bead can be quantitatively characterized by the root fusion characteristics illustrated in Fig. 4. The most important are height of root fusion h_rf and height of root crown (height of slag pockets) h_rc.

Analysis of Root Bead Cross Sections

A number of samples were obtained from the welds performed at currents varying from 500 to 1000 A. Other welding conditions are given in Table 1.

Analysis of the weld cross sections showed the shape of the root bead changed dramatically as the current increased. For example, compare the cross sections of two root welds made at 600 and 1000 A, respectively, as shown in Fig. 5A and B. The transformation of the root weld shape is schematically illustrated in Fig. 6. The most noticeable and largely unfavorable effect is produced on root fusion and the root crown (accentuated by heavy lines and cross-hatched areas, respectively). The size of the root reinforcement is affected to a lesser degree.

At 500 A, root fusion (heavy line) did not reach the bottom of the groove — Fig. 6. At 550 A, root fusion was improved,
Fig. 8 — The current required for adequate root edge penetration at various root openings.

Fig. 9 — Effect of current on geometry of the root reinforcement. \( h_r = \) height of the root reinforcement; \( w_r = \) width of the root.

but no (or inadequate) root reinforcement developed. At 600 A, the arc eventually broke through the root edges and developed a full-sized root reinforcement. The top of the root bead looked fairly flat and no (or negligible) root crown developed. At 700 A, the root fusion decreased and a noticeable crown appeared (cross-hatched area). At 800 and 900 A, root fusion progressively deteriorated and the crown became increasingly taller. It formed deep (and sometimes sharp) pockets filled with slag.

**Effect of Current on Fusion Characteristic of Root Bead**

The effect is quantitatively illustrated in Fig. 7. At 600 A, the height of root fusion was the highest, \( h_r = 9.1 \) mm or 52% of the plate thickness (52% T). As the current increased from 600 to 1000 A, \( h_r \) dropped from 9.1 to 5.5 mm (31% T). This behavior represents almost 40% reduction in root fusion. At the same time, the height of the root crown (height of the resulting slag pockets) \( h_c \) increased dramatically, from 1.1 to 9.8 mm (from 6% T to 36% T). Such a shaped root bead is detrimental because it may cause internal defects in the following fill weld, as discussed earlier.

It was obvious that, at 600 A (and other conditions described in Table 1), the shape of the root bead was most favorable because \( h_r \) was the maximum, while \( h_c \) was almost zero. Such current is called the critical current \( (I_{cr}) \). As the current increased above \( I_{cr} \), the fusion characteristics of the root bead deteriorated, namely \( h_r \) decreased and \( h_c \) grew taller.

**Effect of Current on Shape of Root Reinforcement**

Normally, MRF welding provides a very smooth and shiny root reinforcement. It is uniform along the joint and blends into the base metal well, as shown in Figs. 1, 3, and 5.

**Formation of Root Reinforcement**

Root reinforcement is formed in two steps: 1) the liquid metal penetrates through the root edges and spills out, and 2) the liquid metal melts a groove in the hardened backing flux. The effects of the current on edge penetration and flux melting are rather complex.

Root edge penetration \( (F_{pe}) \) is where the molten metal penetrates through the base metal \( F_{pe} = \) Fig. 4. It is surrounded by the heat-affected zone (HAZ) where the base metal is heated to \( A_{c1} \) temperature (approximately 750°C for steel). As the current increases, the depth of penetration and the depth of the HAZ gradually increase. At some current, the depth of HAZ reaches the bottom of the joint. According to Ref. 4, at this moment, the penetration sharply increased and the molten metal suddenly reached the bottom of the joint. This behavior was confirmed by the experiments in this investigation and illustrated in Fig. 6.

At 500 A, the current was not sufficient, the HAZ did not reach the bottom of the joint, and the weld metal remained inside the groove. At 550 A, the HAZ and the molten metal suddenly reached the bottom of the joint. At 600 A, the weld metal was forced out of the groove by arc forces and the gravity of molten metal, which are great in automatic SAW. This is the first stage of forming the root reinforcement, which is largely determined by the current.

However, if the current increases above 1000 A (in a joint with a wide root opening), \( F_{pe} \) could become so large most of the liquid metal would fall through the entire thickness of the backing flux. This
melt-through situation produced an excessively large and irregular root reinforcement.

Fr depends on other variables and joint geometry. At equal current, root edge penetration may be reduced by placing iron powder into the groove, decreasing the root opening or the included angle, or increasing the root face. For example, the effect of the root opening is illustrated in Fig. 8 (based on welding conditions described in Table 1). The dashed line indicates the recommended minimum current required to adequately penetrate through the edges of the V-groove at various root openings. The area within a narrow (±25 A) band is a scatter of data. The areas above and below the band are the areas of adequate and inadequate root edge penetration, respectively.

Melt-backing situation produced an excessively large and irregular root reinforcement.

Melt-backing situation produced an excessively large and irregular root reinforcement.

Effect of Current on Height and Width of Root Reinforcement

The effect of current is illustrated schematically in Fig. 6 and quantitatively in Fig. 9 (based on conditions in Table 1).

The effect of the current on height of the root reinforcement $h_r$ is complex. At $I < I_{cr}$ (600 A), the arc did not penetrate deep enough and no (or inadequate) root reinforcement was formed. At $I = I_{cr}$, the arc broke through the root edges and a full-height root reinforcement developed. In fact, the maximum $h_r = 1.7$ mm was achieved at $I_{cr}$. Then, $h_r$ decreased as the current increased above $I_{cr}$. For example, at 1000 A, $h_r = 0.8$ mm (drop by about 60%). Such a trend is not favorable because a low-profile root reinforcement is inherent in MRF welding and an increase of $h_r$ is desirable. The minimum
Fig. 12 — Effect of electrode inclination (a) on fusion characteristics of the root bead. \( h_r = \) height of root fusion; \( h_c = \) height of the root crown (slag pocket).

Fig. 13 — Effect of electrode inclination (a) on geometry of the root reinforcement. \( h_r = \) height of the root reinforcement; \( w_r = \) width of the root reinforcement.

The effect of current on the width of root reinforcement \( w_r \) is shown in Fig. 9. At \( I < I_c \) (600 A), no (or inadequate) root reinforcement was formed. At \( I = I_c \) (600 A), the arc broke through the root edges and a full-width root reinforcement developed \( w_r = 14.1 \text{ mm} \). The current increased from 600 to 1000 A, \( w_r \) was practically independent of current and varied very little (within 14.1 - 13.0 mm).

Criteria for Selection of Current

The criteria for selection of current for the root weld in MRF welding differs from other one-sided welding methods. In MRF welding, the requirements should be met for both root bead and root reinforcement as follows:

1) Minimal height of the root crown/slag pockets \( h_c = \text{min.} \)
2) Maximum possible height of root fusion \( h_r = \text{max} \)
3) Maximum possible cross-section area of the root bead \( f_{\text{pb}} = \text{max} \)
4) Minimal asymmetry of root fusion \( A_{\text{f}} = \text{min.} \)
5) Maximum possible root edge penetration \( f_{\text{pe}} = \text{max} \)
6) Maximum possible size of the root reinforcement \( h_r = \text{max} \) and \( w_r = \text{max} \).

It is difficult to find an ideal current to satisfy all requirements for both root bead and root reinforcement under the explored range of welding conditions. The same is true under versatile conditions encountered in production. In this respect, an optimal current may be considered for the root weld that may not satisfy all criteria. This is acceptable if the optimal current is in consideration of the method and welding conditions selected for the fill weld following the root weld. In fact, the fill weld should minimize negative effects and maximize positive effects produced by the optimal current on root weld geometry. Below are some examples.

1) Under the explored conditions (two electrodes arranged in tandem, welding conditions per Table 1, \( RO = 6.4 \text{ mm} \)), the critical current may be considered as an optimal current. However, it may not fully satisfy criterion 3 above because the root weld cross section may not be sufficient. In fact, the remaining (not filled) cross section of the groove \( f_{\text{pl}} \) is quickly filled with the following weld. \( F_{\text{pl}} \) determines the required current for the fill weld. The larger the \( F_{\text{pl}} \), the higher the deposition rate and the current required for the fill weld. If \( F_{\text{pl}} \) is too large, the required current may be too high and the arc may melt through the entire root weld impairing root reinforcement. This can be overcome if the remaining groove is filled in more than one pass. For 17.5-mm-thick plates, a three-electrode arrangement may be a solution.

2) In production, the root opening may vary from 3.2 to 6.4 mm. If \( I_c \) is used as an optimal current, then it will not satisfy criteria 1, 3, 5, and 6. However, some of these drawbacks can be overcome if \( 700 \text{ A} \) is considered as an optimal current. In this case, criteria 3, 5, and 6 will be satisfied. Also, the negative effect of criterion 1 will be neutralized if the slag pockets developed on both sidewalls of the groove (as a result of increasing the current) are remelted by the fill weld. For this purpose, a twin-electrode arrangement may be a better solution than that in example 1. (A twin-electrode arrangement...
ment has two electrodes fed in parallel from a single power source and arranged across the groove).

Effect of Voltage

Effect of voltage was studied by varying it from 20 to 30 V. Acceptable root welds were obtained within the range of 23–25 V. At U < 22 V, the arc became unstable resulting in an unacceptable root weld reinforcement. At U > 26 V, the arc became longer and more sensitive to arc blow. The arc jumped from one side of the groove to another. As a result, voltage and current became erratic. The backing flux did not receive enough heat through radiation and did not harden fast enough in front of the arc. The molten metal melted through the entire flux layer resulting in unacceptable formation of the root reinforcement, frequent melt-through, and damage to the backup unit. Thus, invalid data were obtained beyond the acceptable range because the dimensions of the root bead, or reinforcement, could not be measured or fluctuated erratically.

In contrast to conventional SAW operating at DCEN polarity and other one-sided welding methods, much lower voltage (short arc length) is required for the MRF welding method. Therefore, the voltage was maintained in a very narrow operating range of 23–25 V for all welds tried in this program. Low voltage helps reduce arc blow and heat input to avoid damage to the backing system.

The results of this investigation, although qualitative rather than quantitative, show the MRF method is very sensitive to voltage but is not controlled by this welding process parameter. However, this does not mean the voltage is not an important or essential variable. To obtain acceptable root welds, the voltage is the second most important process parameter after current.

Effect of Travel Speed

In any welding method, travel speed is known to control two important factors: the rate of deposited weld metal and heat input. The lower the travel speed, the greater are both factors. In the two-electrode, one-pass technique used in these experiments, it was important to deposit balanced amounts of metal for the root and the fill welds. However, control over the amount of deposited metal is limited by consideration to provide a favorable shape to the root weld (the bead and reinforcement), which is controlled by the current. Therefore, the effect of the travel speed on the shape of the root weld should be considered in relationship to the current (for a given plate thickness T). On the other hand, a decrease in travel speed increases heat input not only for the root weld, but also for the fill weld. That is why travel speed should be considered with caution in developing MRF welding procedures, especially for heat-sensitive steels.

Effect of Travel Speed on Shape of Root Welds at I = I_{cr}

As discussed previously, the critical current I_{cr} produced a favorably shaped root bead. In fact, it was produced at a certain critical travel speed (V_{cr}). The critical travel speed is the maximum possible speed at which a favorably shaped root weld is still produced. For example, at 600 A and with the welding conditions
described in Table 1, the critical travel speed was 39.6 cm/min.

\[ V > V_{cr} \]

The critical speed \( V_{cr} \) is a function of the travel speed above which the root edge penetration is no longer sufficient. The root edge penetration was not sufficient if the travel speed was above \( V_{cr} \). The root bead shape is not favorable at \( V > V_{cr} \), if the travel speed increases above \( V_{cr} \), the critical travel speed was obtained at 39.6 cm/min. Here, the travel speed can be reduced slightly, up to 10.8 mm (62% T). This resulted in an improvement of the root reinforcement because heat input was still low at \( V = V_{cr} \).

As was previously discussed (Fig. 8), the flow of molten metal increased above 39.6 cm/min. As the travel speed decreased to 28.7 cm/min (by 28%), \( h_{rr} \) increased slightly, up to 10.8 mm (62% T). At this speed, the total heat input may reach very high values. This situation may produce a detrimental effect on weld metal properties, especially toughness. However, for steel not sensitive to heat input, a travel speed below \( V_{cr} \) (down to 28.7 cm/min) may be beneficial.

\[ V = V_{cr} \]

The molten metal flowed in a waving (pulsating) mode causing current and voltage fluctuations. As a result, the height of the root crown fluctuated along the joint in a waving pattern. Thus, a range of 28.7-39.6 cm/min may be considered for these conditions.

The effect of travel speed on root reinforcement shape is illustrated in Fig. 11. If the travel speed decreased from 39.6 to 28.7 cm/min, the height of root reinforcement became unevenly large and flowed under the arc. The molten metal flowed in a waving (pulsating) mode causing current and voltage fluctuations. As a result, the height of the root crown fluctuated along the joint in a waving pattern. Thus, a range of 28.7-39.6 cm/min may be considered for these conditions.

\[ V_{cr} \]

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Effect of Electrode Inclination

The effect of the angle of electrode inclination \( \alpha \) on the shape of the root bead was studied by depositing root welds at \( \alpha = 0 \) and \( \alpha = 15 \) deg. In this study, a unitless criteria \( IR \) was used as a welding variable determined by the formula described in Table 1. For example, assume iron powder height is 11.1 mm in a 17.5-mm-thick single V groove with an included angle of 30 deg and root opening of 3.2 mm. Then, \( IR = 50 \). In other words, iron powder occupies 50% of the groove by volume. If \( IR \) is constant, both \( \beta \) and \( RO \) vary along the joint, \( IR \) varies also. For example, if \( \beta = 30 - 45 \) deg and \( RO = 1.6 - 9.5 \) mm, then \( IR \) varies from 45 to 56%, the error being approximately \( \pm 5.5 \)%. Such wide joint variations are rather extreme and not

One problem in welding heat-sensitive materials is the tendency of the weld pool to be enlarged excessively. So, a root reinforcement shape is illustrated in Fig. 11. Typically, dispensing of iron powder in a groove is carried out by a feeding device or manually. In this program, iron powder was placed manually in the groove prior to welding. Special templates matching the configuration of the groove were used to uniformly level the layer of iron powder to a required height. For example, iron powder was placed manually in the groove prior to welding. Special templates matching the configuration of the groove were used to uniformly level the layer of iron powder to a required height. A criterion for iron powder distribution in a groove is its height \( H \). In this research, a unitless criteria \( IR \) was used as a welding variable determined by the formula described in Table 1. For example, assume iron powder height is 11.1 mm in a 17.5-mm-thick single V groove with an included angle of 30 deg and root opening of 3.2 mm. Then, \( IR = 50 \). In other words, iron powder occupies 50% of the groove by volume. If \( IR \) is constant, both \( \beta \) and \( RO \) vary along the joint, \( IR \) varies also. For example, if \( \beta = 30 - 45 \) deg and \( RO = 1.6 - 9.5 \) mm, then \( IR \) varies from 45 to 56%, the error being approximately \( \pm 5.5 \)%. Such wide joint variations are rather extreme and not
likely to occur along the same joint in production. Therefore, no adjustments in iron powder height was made during the experiments to compensate for root opening or included angle. For example, for $f = 11.1$ mm, IR was considered to be equal to 50% in all 17.5-mm-thick joints explored in this program.

**Effect of Shape of Root Bead and Reinforcement**

Experiments were conducted to determine the effect of iron powder on the shape of the root bead and root reinforcement. Root welds were made at 700 A in a root opening of 6.4 mm with varying amounts of iron powder in the groove. Other welding conditions are given in Table 1, except that $f = 30$ deg. The thicknesses of iron powder were $f = 6.4$ mm (IR = 25%), $f = 11.1$ mm (IR = 50%), $f = 14.3$ mm (IR = 75%), and $f = 17.5$ mm (IR = 100%, full thickness of the plate).

The effects of iron powder on the fusion characteristics of the root bead is illustrated in Fig. 14. At IR = 25% and a root opening of 6.4 mm, iron powder does not protect the joint from melt-through and most of the root bead metal falls under the plate (no data are shown on the graph). As IR increases from 50 to 75%, $h_r$ slightly increased by 16% and then decreased. However, the height of the root crown increases dramatically, at IR = 75% by 26% and at IR = 100% by 45%. Thus, the best combination of fusion characteristics is achieved at IR = 50% because $h_r$ is fairly high, while $h_c$ is at its smallest.

The effect of iron powder on the shape of the root reinforcement is illustrated in Fig. 15. At IR = 25%, unacceptable root reinforcement is obtained due to melt-through. As IR increases from 50 to 100%, both the height and width of the root reinforcement decrease drastically. For example, at IR = 100%, $h_r$ drops to zero, that is, no reinforcement develops. Thus, the best shape of the root reinforcement is achieved at IR = 50%.

**Effect of Iron Powder on Root Weld Shape at Other Welding Conditions**

The effect of iron powder may be different from that described above if welding conditions differ from those in Table 1. At smaller RO and/or $f$ (reduced root edge penetration), IR < 50% may be sufficient to avoid melt-through. In fact, at RO = 0, melt-through can be avoided even without iron powder. On the other hand, IR > 50% may be required under conditions that increase the root edge penetration. For example, acceptable root reinforcements were obtained at RO = 6.4 mm and $f = 900$ A, even at IR = 100%.

**Conclusions**

The results of this study allow the following conclusions to be made:

1) Welding current produces the most favorable effect on root bead shape at a certain magnitude called critical current ($I_{cr} = 600$ A). At $I > I_{cr}$, the shape of the root bead deteriorated; namely, the height of root fusion $h_r$ decreased and the height of the root crown $h_c$ increased. As a result, the risk of internal defects increases. The most desirable size of the root reinforcement is at $I_{cr}$. As current increased, the height of the root reinforcement surprisingly decreased, while the width did not change much. Since low $h_r$ is inherent in the MRF method, such a trend is not favorable. Still, the size of the root reinforcement obtained in the current range of 600-1000 A is considered acceptable.

2) In contrast to conventional SAW and other one-sided welding methods, a very low and narrow operating range of 23-25 V is required for MRF welding. Beyond this range, acceptable root welds are difficult to obtain. The MRF method cannot be controlled by voltage. However, it is the second most important process parameter, alter current, to obtain acceptable root welds.

3) The effect of travel speed $V$ depends on the current. Favorable root fusion characteristics and shape of the root reinforcement are obtained at $I_{cr}$ and at the critical speed $V_{cr} = 39.6$ cm/min. Moderate improvements are observed within a narrow speed range below $V_{cr}$, as $V$ decreases from 39.6 to 28.7 cm/min. However, these benefits are offset by a much higher increase in heat input and may result in deterioration of the weld and HAZ metal properties in heat-sensitive steels.

4) The inclination ($x$) of the leading electrode from the vertical in the direction of welding produced a significant and beneficial effect on the shape of the root weld. At $x = 15$ deg, root fusion characteristics improved in comparison to $x = 0$, most significantly at $I = 500$ A. As the current increased above $I = 500$ A, this effect was gradually reduced to zero at $I = 900$ A. The height and width of the root reinforcement increased also, most noticeably at $I = 600$ A.

5) Iron powder affects the root fusion characteristics and the shape of root reinforcement. The best results were obtained at $F = 100$% and with the amount of iron powder in the groove (by volume) IR = 50%. Increasing IR above 50% led to deterioration of the root fusion characteristics and the shape of the root reinforcement. At IR < 50%, there is a risk of melt-through.

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**References**


Root Weld Formation in Modified Refractory Flux One-Sided Welding: Part 2 — Effect of Joint Geometry

Relationships between the shape of the root weld and variations in joint geometry were established

ABSTRACT. Experiments were conducted using modified refractory flux welding developed for use in the field. The effects of joint geometry (root opening, included angle, root face, and plate misalignment) on root (backside) welds, including the root bead (deposit inside the groove) and the root reinforcement (deposit outside the groove), were studied. The effects of arc blow and tack welds were also studied. Modified refractory flux (MRF) welding is a onesided welding method that utilizes submerged arc welding, thermosetting backing flux, direct current electrode negative polarity, and a specially designed portable backing system (Ref. 1).

Formation of root welds in MRF welding was studied in 17.5-mm-thick, single-V-groove, steel butt joints at wide variation of groove geometry, including 0-9.5-mm root openings, 30-45 deg included angles, 0-4.8-mm root faces and misalignments of 0-4.0 mm. It was found that the root bead shape is crucial to the integrity of the entire groove weld because it may be related to incomplete fusion in the following fill weld. These experiments (Ref. 1) were conducted at constant joint geometry. Indications were strong that variations in joint geometry encountered in the field might have a serious effect on the shape of the root weld. Unfortunately, very little data exists describing this effect. Therefore, the objective of this investigation was to establish the relationships between the shape of the root weld and widely varied (or abnormal) joint geometry typical of the field environment, including root opening (RO), included angle (IA), root face (RF), and plate misalignment (MA). To eliminate the effect of the welding variables, the latter were kept constant. The effects produced by arc blow and tack welds were also studied.

Experimental Procedure

Standard two-electrode SAW equipment and a specially designed backing system used for MRF welding are described in Ref. 1. Two steel plates (17.5 mm x 305 mm x 1219 mm) were oxyfuel cut, beveled at 22.5 or 15 deg, and assembled to form a single-V-groove butt joint. To simulate joint inaccuracy typical in field erection, joint geometry was varied in a controlled setting with 0-9.5-mm root opening, 30-45 deg included angle, 0-4.8-mm root face, and 0-4.0-mm misalignment, welding variables being constant. The root welds were deposited using the leading electrode only. A layer of iron powder was placed into the groove prior to welding. The basic welding conditions are given in Table 1, except those specified otherwise.

A number of transverse specimens were cut from each weldment, including the areas affected by arc blow and tack welds. The cross section of each specimen was polished and etched to reveals the weld profile. The profile was reproduced and enlarged. To characterize quantitatively and compare the shape of different root welds, root weld geometry was defined as a combination of characteristic dimensions and cross-sectional areas, as well as the specific calculated geometric criteria. They were determined by measuring the enlarged reproductions taken from the transverse specimens, as illustrated in Fig. 4 of Ref. 1.

Introduction

Refractory flux one-sided welding is little known in the United States, and is described in Ref. 1. It has long been successful in Japan (Refs. 2, 3).

Modified refractory flux (MRF) welding is a one-sided welding method (Ref. 1) that features a new portable backing system designed to allow application in the field where a wide variation in root openings is typically encountered.

KEY WORDS
One-Sided Welding
Submerged Arc Welding (SAW)
Carbon Steel
Thermosetting Backing Flux
Joint Geometry
Root Weld Geometry
Arc Blow
Tack Welds
### Table 1 — Basic Welding Conditions Used for Root Welds in MRF Welding

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plate thickness $T$ (mm)</td>
<td>17.5</td>
</tr>
<tr>
<td>Joint type</td>
<td>Single-V butt</td>
</tr>
<tr>
<td>Included angle $\beta$ (deg)</td>
<td>45 ± 5</td>
</tr>
<tr>
<td>Root opening $RO$ (mm)</td>
<td>6.4 ± 0.4</td>
</tr>
<tr>
<td>Electrode diameter (mm)</td>
<td>4.0</td>
</tr>
<tr>
<td>Electrode polarity</td>
<td>DCEN</td>
</tr>
<tr>
<td>Inclination $\alpha$ (deg)</td>
<td>15 (drag)</td>
</tr>
<tr>
<td>Backing flux type</td>
<td>Thermoset</td>
</tr>
<tr>
<td>Iron powder height $f$ (mm)</td>
<td>11.1 ± 0.5</td>
</tr>
<tr>
<td>Volume $V$ (%)</td>
<td>50 ± 2.5</td>
</tr>
<tr>
<td>Current $I$ (A)</td>
<td>600 ± 50</td>
</tr>
<tr>
<td>Voltage $U$ (V)</td>
<td>23.5 ± 0.5</td>
</tr>
<tr>
<td>Travel speed $V$ (cm/min)</td>
<td>39.6 ± 2.5</td>
</tr>
</tbody>
</table>

*Experiments were conducted using the leading electrode only. Trailing electrode (if used) operated on AC in tandem with the leading electrode.*

Variations in the root opening changes the groove cross section and, thus, the amounts of filler metal deposited for the root weld and the following fill weld. Root bead geometry may also be affected, as well as root edge penetration. This situation is illustrated in the following examples:

Assume a weld is deposited in a 17.5-mm-thick, single-V-groove butt joint with an included angle of 30 deg. Also, assume the root opening increases along the joint from 1.6 to 6.4 mm. As the $RO$ increases along the joint, groove cross section $F_g$ increases from 109 to 192 mm². In other words, 76% more metal would be needed to fill the groove.

Assume the root bead has no crown. Then, the height of the root bead is equal to the height of root fusion $h_{rf}$. Assume also $h_{rb} = 9.5$ mm and is maintained constant, while $RO$ varies from 1.6 to 6.4 mm. Then, the root bead cross section $F_{rb}$ increases from 39 to 85 mm². This means 115% more metal would be required to keep $h_{rb}$ constant.

Assume that $F_{rb} = 85$ mm², $RO = 6.4$ mm and $h_{rf} = 9.5$ mm. In production, $F_{rb}$ remains the same because welding conditions and deposition rate are practically constant along the joint. If $RO$ decreases to 1.6 mm, then the height of the root bead, $h_{rf}$, increases up to 15 mm (60%). This may have a serious impact on the shape of the root bead and its fusion characteristics.

As discussed in Ref. 1, to obtain an adequate root reinforcement, the arc must first completely penetrate through the root edges. At wider root openings, lower current is needed for adequate penetration and vice versa. For example, 600 A is sufficient at $RO = 6.4$ mm for adequate root edge penetration, while 550 A is not. However, at $RO = 3.2$ mm, 700 A is sufficient, while 600 A is not.

#### Effect of Root Opening on Fusion Characteristics of Root Bead

This complex and current dependent effect was studied by varying the current from 600 to 900 A and the root opening from 0 to 6.4 mm. Other conditions are given in Table 1.

The root fusion height $h_{rf}$ was found by considering the effect of root opening on the root fusion height $h_{rf}$.
(Ref. 1) to be dependent on the current at a constant root opening. The experiments conducted in Ref. 1 at 6.4-mm root opening and 45-deg included angle showed the best root fusion is achieved at critical current \( I_{cr} = 600 \) A. As the current increased above \( I_{cr} \), \( h_{r}\) decreased. A similar trend was observed in this study at \( \beta = 30^\circ \) for both \( RO = 6.4 \) mm and \( RO = 3.2 \) mm, as illustrated in Fig. 3. (No data are shown for \( RO = 6.4 \) mm and \( \beta = 30^\circ \), because the root edges are not completely fused). For example, as current increased from 700 to 900 A at \( RO = 3.2 \) mm, \( h_{r}\) decreased 39% from 10.7 to 6.5 mm.

Comparing the data for \( RO = 3.2 \) mm and \( 6.4 \) mm in Fig. 1, it is obvious that \( h_{r}\) at \( RO = 3.2 \) mm is higher over the entire range of the current explored. For example, at 700 A, \( h_{r}\) is higher by 16% (10.7 vs. 9.2 mm). At 900 A, \( h_{r}\) is higher by 15%. The fact \( h_{r}\) decreased as RO increased is illustrated in Fig. 2 for the root welds made at 900 A. Thus, root fusion deteriorates due to increased current and root opening.

The height of the root crown \( h_{rc}\) was also found to be dependent on the current at a constant root opening (Ref. 1). The experiments conducted in Ref. 1 at \( RO = 6.4 \) mm and \( \beta = 45^\circ \) showed that the lowest root crown and, thus, the slag pockets developed on both sides of the groove are also achieved at 600 A. As the current increased, \( h_{rc}\) also increased. That meant the slag pockets developed on both sides of the groove grew larger. If the slag pockets become too deep, the following fill weld may not remelt them and incomplete fusion may occur. A similar trend is observed in this study at \( \beta = 30^\circ \) for \( RO = 6.4 \) mm and \( 3.2 \) mm, as illustrated in Fig. 1. As the current increased from 700 to 900 A at \( RO = 3.2 \) mm, \( h_{rc}\) increased from 6.8 to 11.0 mm (62%).

Comparing the data in Fig. 1 for \( RO = 3.2 \) mm and \( 6.4 \) mm at 700 A, it is obvious \( h_{rc}\) at \( RO = 3.2 \) mm is much higher than for \( RO = 6.4 \) mm (6.8 vs 2.9 mm). In other words, at 700 A, wider root openings resulted in smaller slag pockets. However, at > 700 A, this favorable trend came into conflict with the opposite trend of increased current. As a result, \( h_{rc}\) is diminished and even reversed at 900 A — Fig. 1. This reverse trend at 900 A is illustrated in Fig. 2, which shows wider root openings result in larger root crowns and deeper slag pockets. In fact, the largest crowns and the deepest slag pockets were observed in root welds deposited at \( RO > 6.4 \) mm and > 900 A. For example, in the completed weld shown in Fig. 3, the root weld was made at \( RO = 9.5 \) mm and 900 A. Very deep slag pockets developed in the root weld, especially on the right side, creating incomplete fusion on the right side. Thus, if welding has to be performed at high currents, root openings less than 6.4 mm are recommended because smaller slag pockets develop. Still, lower currents are preferable because lower \( h_{rc}\) values can be obtained regardless of the root opening. Compare the lowest \( h_{rc}\) value (3.2 mm) obtained at \( RO = 0 \) and 900 A (Fig. 2) with the highest \( h_{rc}\) value (6.8 mm) obtained at \( RO = 3.2 \) mm and 700 A — Fig. 1.

![Fig. 3](image-url) — A cross section of the root weld deposited at \( RO = 9.5 \) mm and 900 A. Notice incomplete fusion on the right sidewall.

![Fig. 4](image-url) — Effect of root opening on the geometry of root reinforcement.

![Fig. 5](image-url) — Effect of included angle at various currents on fusion characteristics of the root bead.
Fig. 6 — Effect of included angle at various currents on the geometry of root reinforcement.

Fig. 7 — Effect of the root face at various currents on fusion characteristics of the root bead.

Effect of Root Opening on Shape of Root Reinforcement

This effect was studied by depositing the root weld in a groove with the root opening varying from 1.6 to 8.0 mm at 700 A. Other conditions are given in Table 1. The samples were cut and measured at locations corresponding to RO = 2.4-7.2 mm at an interval of 1.2 mm. The results are illustrated in Fig. 4.

The height of root reinforcement increased as RO increased — Fig. 4. This increase is beneficial because a low-profile reinforcement is typical for MRF welding. A minimum hrr = 0.8 mm was considered acceptable in this study. At RO < 2.4 mm, the root edges were not sufficiently fused and no root reinforcement developed (no data are shown). A small reinforcement appeared at RO = 2.4 mm. Further increase in root openings from 2.4 to 7.2 mm resulted in hrr increasing from 0.8 to 2.0 mm (133%), a trend opposite the current. As discussed in Ref. 1, hrr did not change much as current increased above Icr.

Effect of Included Angle

In one-sided welding, including the MRF method, plates are typically beveled and assembled to form a single-V-groove butt joint with an included angle. Such joints allow better access to root edges and deeper penetration, which facilitates formation of the root reinforcement.

To study the effect of the included angle on the shape of the root weld, two series of root welds were made at 45- and 30-deg included angles. The root welds were made in V-grooves at 600-900 A, with a root opening of 6.4 mm. All other conditions are given in Table 1.

Effect of Included Angle on Fusion Characteristics of Root Beads

Figure 5 shows the effect of the included angle on the heights of root fusion (hrf) and root crown (hrc). Here, the graphs corresponding to the welds made at 45 and 30 deg are shown in solid and dashed lines, respectively.

The height of root fusion is affected by the included angle, but it depends on the current as well. For example, at Icr = 600 A and 45 deg, hrf = 9.0 mm, while at 30 deg, hrf = 10.4 mm (increase of 16%). At the higher current of 700 A and 45 deg, hrf is reduced from 9.0 to 7.2 mm (20%). This trend is expected at I > Icr, as described in Ref. 1. However, by reducing the angle from 45 to 30 deg, hrf can be restored from 7.2 to 9.2 mm (increase of 27%) even at 700 A. In other words, the reduction in root fusion (due to increase of the current from 600 to 700 A) can be compensated by reducing the included angle from 45 to 30 deg. In this respect, the effect of the reduction of the included angle is similar to that of increasing the inclination (drag) angle of the leading electrode described in Ref. 1. This favorable trend is diminished at a further increase in current. For example, at 800 A, the reduction of the included angle has no effect and at 900 A this trend may even be reversed in favor of the 45-deg angle.

The height of the root crown hrc was reduced as the included angle decreased from 45 to 30 deg at 600-700 A — Fig. 5. This favorable trend diminished and
even reversed in favor of 45 deg at further current increase.

Thus, a 30-deg included angle at lower (700 A) current is recommended because it improves the root fusion characteristics in comparison with that of 45 deg. However, if high (900 A) current has to be used, a 45-deg included angle is more beneficial.

Effect of Included Angle on Shape of Root Reinforcement

This effect is illustrated in Fig. 6. The height of root reinforcement also depends on the current. At 600 A and 45 deg, a higher \( h_r \) was obtained than at 30 deg because a larger angle provides a deeper root edge penetration. However, at 700 A, 30 deg is more beneficial. In fact, the maximum \( h_r \) of 2.2 mm is reached at 700 A and 30 deg. As the current increased, \( h_r \) decreased at both included angles. However, it remained acceptable (> 0.8 mm) within the explored current range (600–900 A).

The width of root reinforcement did not change much as the current increased at both angles of 45 and 30 deg (Fig. 6), although it is slightly wider at 30 deg.

Effect of Root Face

In one-sided welding, plates are typically beveled with a small root face (RF) or without it. Such joints allow closer access to the root edges and deeper root edge penetration facilitates formation of root reinforcement. To study the effect of the root face on the shape of root welds produced by the MRF method, the root welds were deposited at 700 and 800 A in joints with RF = 1.6–4.8 mm. Other welding conditions are given in Table 1, except that RO = 3.2 mm, and cc = 0. The data were compared with those obtained from similar welds with RF = 0.

Effect of Root Face on Fusion Characteristics of Root Beads

This effect is illustrated in Fig. 7. The height of root fusion \( h_r \) increased at both currents as RF increased from 0 to 3.2 mm. However, at RF > 3.2 mm, \( h_r \) sharply decreased. Comparing welds made at 700 and 800 A, it is obvious root fusion was lower at 800 A. Thus, presence of the root face did not change the trend of \( h_r \) decrease as the current increased.

The height of the root crown \( h_c \) remained practically the same at both currents as RF increased from 0 to 3.2 mm. However, at RF > 3.2 mm, \( h_c \) dramatically increased. In fact, at RF = 4.8 mm, the crown became so tall (\( h_c = 60\% \) T) it stood above the plate top surface and became uneven along the joint. Comparing welds made at 700 and 800 A, it was obvious the root crown was taller and slag pockets were deeper at 800 A. This also confirmed the trend that as the current increased, \( h_r \) increased.

Thus, the root face " 3.2 mm offers no advantage at 700 A and results in unfavorable changes in the root fusion characteristics at 800 A, although deterioration is relatively minor. At RF > 3.2 mm, the root fusion characteristics deteriorated at both 700 and 800 A, namely \( h_r \) decreased and \( h_c \) increased.

Effect of Root Face on Shape of Root Reinforcement

It is known that root face reduces penetration through the root edges. This reduction is especially noticeable in the MRF method in which the arc operates using DCEN polarity, which is known for its low penetrating characteristic. As a result, the presence of a root face produces a detrimental effect on the root reinforcement. This effect is illustrated in Fig. 8 for welds made at 700 and 800 A.

The height of root reinforcement \( h_r \) sharply decreased at both currents as RF increased from 0 to 4.8 mm. In fact, at 700 A and RF ≥ 1.6 mm, inadequate or no reinforcement was observed, although the root was completely fused. At 800 A and RF ≥ 3.2 mm, an inadequate reinforcement was formed. Better penetration may be achieved at an increase in current (900 A). However, this result is counterproductive because the crown grows extremely tall and uneven.

The width of root reinforcement sharply decreased at both currents as RF increased from 0 to 4.8 mm. For example, at 700 A, \( w_r \) dropped from 12.9 to 9.0 mm as RF increased from 0 to 4.8 mm.

In conclusion, despite moderate improvements in root fusion characteristics, the overall effect of the root face on root weld geometry cannot be considered favorable. Since considerable cost is involved in preparing a uniform root face in the field, its preparation is not recommended for MRF welding.

Effect of Plate Misalignment

Flux-backing, one-sided welding...
methods are known to be tolerant to misalignment (MA) of plate edges, while copper-backing methods are not. The reason is powder flux under pressure acts similar to liquid and can adjust very well to any surface. This behavior is true for the MRF welding method because the thermosetting backing flux is also powder prior to being heated by the arc.

In fact, MRF welding is very tolerant of misalignment, as illustrated in Fig. 9A. The picture shows a cross section of a completed weld made at 700 A, RO = 6.4 mm, and β = 30 deg. It was cut from a joint that was assembled with a misalignment of 4.8 mm. (Misalignment after welding may differ slightly due to welding distortion.)

For 17.5-mm-thick plates, 4.8 mm represents a fairly large misalignment, 27% of plate thickness. The picture shows an adequate root reinforcement can be obtained in plates even if misalignment is that large. However, an analysis of root weld cross sections shows misalignment distorts the shape of the root weld, as schematically shown in Fig. 10A. Here, the root fusion characteristics on the high and low sides of the groove are identified by letters H and L, respectively.

Effect of Misalignment on Fusion Characteristics of Root Bead

This effect is illustrated on the bar chart shown in Fig. 11. The plates were assembled with misalignment of 2.4 mm (14% T). The root weld (identified as M and shown in Fig. 9B) was deposited at 700 A. Other conditions are given in Table 1. The electrode was set in the center of the groove. The data for weld M (Fig. 11) are compared with those results shown in Fig. 1 (points taken at 700 A and RO = 6.4 mm). The data in Fig. 1 correspond to a symmetrical weld (identified as S), which was made without misalignment using the same welding conditions as those conditions reported for weld M.

The height of root fusion in weld M on both sides of the groove was not even, namely, $h_{rf(H)} < h_{rf(L)}$. In other words, the high side of the groove was fused much less than the low side (7 vs. 11 mm). A comparison of asymmetrical weld M (MA = 2.4 mm) with symmetrical weld S (MA = 0) is demonstrated in Fig. 11. It shows the average heights of root fusion in both welds are almost the same (9.0 vs. 9.2 mm), the difference being only 2%. This indicates misalignment does not change the root fused area much but makes it fairly asymmetric.

The height of the root crown in weld M on both sides of the groove were not even, but the effect was the opposite, $h_{rc(H)} > h_{rc(L)}$. This behavior means the slag pocket on the high side of the groove is deeper (2.0 vs. 1.1 mm). A comparison of asymmetrical weld M with symmetrical weld S (Fig. 11) showed the average $h_{rc}$ in weld M was smaller by 45% (1.6 vs. 2.9 mm). Thus, misalignment reduced the root crown area and the slag pockets.

Effect of Misalignment on Shape of Root Reinforcement

Misalignment distorted the shape of root reinforcement, making it asymmetric, as shown in Fig. 9. To determine the degree of distortion, the pertinent data shown (Fig. 11) for weld M (MA = 2.4 mm) were compared with those in Fig. 4 (points taken at RO = 6.4 mm). The data in Fig. 4 corresponded to the same symmetrical weld S made using the same welding conditions as those for weld M (I = 700 A, RO = 6.4 mm, β = 30 deg, and the rest per Table 1), except that MA = 0.

The height of the root reinforcement in weld M (measured as shown in Fig. 10A) is greater (by 39%) than in weld S (2.5 vs.
Thus, hrr increased as MA increased.

The width of the root reinforcement \( w_r \) in welds M and S are almost the same (15.5 vs. 15.4 mm). In the weld shown in Fig. 9A, \( w_r = 15.5 \) mm, too. Thus, \( w_r \) did not change as MA increased.

**Analysis of Root Weld Geometry**

The data discussed above show plate misalignment produced noticeable changes in geometry of the root weld by 1) causing fusion asymmetry, 2) increasing the size of the reinforcement, and 3) decreasing the size of the crown and the slag pockets. The analysis of these changes, its implications and possible explanations, are discussed below and illustrated in Figs. 10A and B.

Root fusion asymmetry \( A_r_f \) and \( A_r_c \) developed in the root weld as a result of misalignment. (For \( A_r_f \) and \( A_r_c \) definitions, see Fig. 10.) Assume root weld S is made in a joint with constant root opening and no misalignment. It is shown in Fig. 10B by solid lines. The weld is symmetrical, that is

\[
h_{r_{left}} = h_{r_{right}} = h_{r_{left}} = h_{r_{right}}
\]

Assume also a portion of the joint is assembled with misalignment while RO remains the same. The resulting weld M (shown in Fig. 10B by dashed lines) became uneven, that is

\[
h_{r_{left}} < h_{r_{right}} < h_{r_{left}} > h_{r_{right}}
\]

In other words, symmetrical weld S developed asymmetry of root fusion \( A_r_f = 4 \text{ mm} \) (23% T), as illustrated in Fig. 11. The root crown developed much smaller asymmetry, \( A_r_c = 0.9 \text{ mm} \) (5% T). Obviously, the root-fused area in weld M was reshaped at the top, as if the deposited metal flowed toward the low side of the groove. The effect produced by misalignment seems similar to that of electrode offset in the same direction (toward the low side). As a result, the following weld may be susceptible to incomplete fusion on the high side of the groove. For this reason, the electrode should be shifted toward the high side if the plates are assembled with misalignment.

The height of root reinforcement increased due to misalignment, which is a favorable trend for MRF welding. One of the reasons may be the following:

If plates are assembled with a root opening, the actual root opening (\( RO_2 \)) increases due to misalignment \( MA \) — Fig. 10B. For example, if \( MA = 3.2 \text{ mm} \) and \( RO = 6.4 \text{ mm} \), then \( RO_2 = 7.2 \text{ mm} \) (13% increase). Once the root opening increased, \( h_r \) increased, according to Fig. 4.

The size of the root crown and the slag pockets decreases due to misalignment, which is a favorable trend. A possible reason may be that the cross section of the deposited metal (root crown, fused area, and reinforcement) along the same root weld is constant because the deposition rate is constant. Since the root reinforcement becomes larger due to misalignment, this increase may occur at the expense of the root crown (and possibly root-fused area to a lesser degree).

**Effect of Arc Blow**

**Arc Blow Phenomenon in MRF Welding**

Arc blow is expected in MRF welding because the root weld is deposited using DC current. Figure 12A shows a cross section of the root weld affected by arc blow cut from the end portion of the joint. The centerline of the crown and the groove are practically in line in this weld. The effect produced by misalignment seems similar to that of electrode offset in the same direction (toward the low side). As a result, the height of root fusion measured on the left side was higher than that on the right side. The opposite was true for the height of the root crown, which developed a much deeper slag pocket on the right side of the groove. This behavior means arc blow causes asymmetry of the root bead. The asymmetry makes the following weld more susceptible to incomplete fusion because it may not reach the bottom of the deepest slag pocket, as illustrated in Fig. 13.

In contrast, Fig. 12B shows a cross section of the root weld made using the same welding conditions cut from the central portion of the joint and not affected by arc blow. It was evident the root bead was fairly symmetrical in the groove and, thus, less sensitive to incomplete fusion.

The following were noticed during the experiments:

1) Root bead asymmetry was typically greater near tack welds and at the ends of the joint, where arc blow is known to occur most frequently.
2) It was typically greater at higher current and voltage, which are known to intensify arc blow.
3) It was absent when AC was used with the leading arc. Thus, a severe root bead asymmetry may serve as an indirect indication of arc blow during welding.

**Effect of Arc Blow on Fusion Characteristics of Root Weld**

This effect is illustrated on a bar chart shown in Fig. 14. Here a cross section of a root weld affected by a severe arc blow (Fig. 12A, identified as no. 1) was measured. The root weld was made at 900 A and the included angle was 45 deg. Other welding conditions are given in Table 1. Similar data for the root weld made under the same welding conditions, but not affected by arc blow (Fig. 12B, no. 2), are given for comparison.
Weld 2 is slightly asymmetrical due to a normal small offset of the electrode or slight lack of straightness of the root edges along the joint.

The height of root fusion measured on the left and the right sides of the groove in root weld 1 affected by arc blow was extremely uneven (9.8 vs. 2.5 mm). This result is obvious from Fig. 12A. The arc blow caused the arc to favor the left side of the groove in weld 1. As a result, the right sidewall was not fused adequately, in contrast to weld 2, where both sides fused fairly evenly — Fig. 12B. However, according to Fig. 14, the average height of root fusion measured in root welds 1 and 2 was almost the same (4% difference in favor of weld 2).

The height of the root crown, measured on both sides of the groove in root weld 1 was also uneven — Fig. 12A. As a result, an extremely deep slag pocket was formed on the right sidewall. To remelt the slag pocket reliably with the following fill weld may not be possible without melting through the entire root weld. Despite that, the root crown was extremely uneven in weld 1, the average height of the root crown did not differ much from that in weld 2 (10% in favor of weld 1), according to Fig. 12.

Root bead asymmetry developed as a result of arc blow. For example, root fusion asymmetry \( (A_{R}) \) in weld 1 was significant (7.3 mm or 62% T). Such high \( A_{R} \) can be categorized as severe in comparison with that developed as a result of misalignment (23% T) described earlier. Comparing root welds 1 and 2 (Fig. 14), it is obvious \( A_{R} \) differs dramatically (by 300%) in favor of weld 1.

Besides arc blow, other factors may also cause root bead asymmetry, including misalignment, electrode offset, or lack of straightness of the root edges. These factors may reduce or increase the effect of arc blow depending on the direction of each phenomenon. What makes the effect of arc blow different is it develops locally (at tack weld), and it is much more severe. In any case, arc-blow prevention measures, a strict control of electrode offset, and plate edge straightness are required for root welds in MRF welding.

Effect of Tack Welds

All one-sided welding methods are sensitive to tack welds, including MRF welding. Normally, the shape of the root weld along the joint remains uniform, except for small deviations resulting from fluctuations of welding variables and joint geometry. However, this is not true when the arc approaches a tack weld.
Tack weld phenomenon was observed when the arc approached and passed over a tack weld. In MRF welding, the shape of the root weld in areas above and around the tack weld are severely affected and differ from the rest of the weld. These areas will be called the “tack weld affected zone” (TWAZ) to facilitate the discussion below.

A tack weld affects the root weld directly because it is remelted by the leading arc and integrated into the root weld. However, the following fill weld is also affected despite the fact the root weld solidsifies and takes shape before the trailing arc has reached it. This effect is indirect and manifests itself through development of internal defects in the fill weld. Thus, the entire weld may be affected by tack welds. The effect of tack welds on the shape of the root weld was found to be extremely detrimental.

The experimental procedure for studying the TWAZ was as follows:

A root weld was deposited at 600 A to produce the best shape. Other welding conditions are given in Table 1, except the included angle was 45 deg. The plates were assembled with a root opening of 6.4 mm using tack welds deposited by GMAW on a copper bar. The tack weld was 6.4 mm thick and 25 mm in length. The backside of each tack weld was ground flush with the plates. The tack weld started at a distance of 394 mm from the start of the joint and ended at 419 mm. The root weld containing the tack weld was cut out. It was sectioned transversely every 13 mm along the joint and the weld cross sections were measured. The obtained data are plotted on graphs shown in Figs. 15 and 16. A regular root weld not affected by the tack weld was cut for comparison. Its cross section was located at 254 mm or 140 mm ahead of the tack weld relative to the joint.

Effect of Tack Welds on Root
Fusion Characteristics

The effect is shown in Fig. 15. Typically, cross sections of a regular (unaffected) root bead outside of the TWAZ were uniform along the joint. The fusion characteristics of the weld taken at 254 mm are the height of root fusion = 9 mm, the height of the root crown = 1.1 mm, and the asymmetry of root fusion = 0. These characteristics changed dramatically in the TWAZ. The difference in the TWAZ is best characterized at the start, the extreme point, and the end.

The height of root fusion began to decrease suddenly at 368 mm, namely, ahead of the tack weld. The maximum deterioration of root fusion occurred at the end of the tack weld, where \( h_f \) dropped from 9 to 5.5 mm (a decrease of almost 40%). After having reached the minimum, \( h_f \) rose to that of the regular root bead. This behavior happened at some distance behind the tack weld.

The height of the root crown rose suddenly ahead of the tack weld. This was the true beginning of the TWAZ. The highest root crown developed in the middle of the tack weld. Here, \( h_c \) rose dramatically, from 1.1 to 6.5 mm (increased by a factor of six). After that, it decreased to that of the unaffected root bead at some distance behind the tack weld.

The asymmetry of root fusion appeared suddenly at 381 mm, that is, 13 mm ahead of the tack weld. The regular root weld ahead of this point fused evenly on both sides of the groove (\( A_f = 0 \)). Then, a sudden event took place that changed this uniform fusion pattern and caused asymmetry of root fusion. \( A_f \) reached the maximum (2.3 mm) at the end of the tack weld (419 mm). After the arc passed the tack weld, the asymmetry decreased and disappeared. Such an uneven fusion of the sidewalls of the groove within the length of the tack weld can be developed only by a sudden deflection of the arc, caused by a phenomena like arc blow. The implication is the following fill weld could be susceptible to incomplete fusion in the TWAZ.

Effect of Tack Welds on Shape of
Root Reinforcement

This effect was found to be especially detrimental, as illustrated in Fig. 16. Normally, the height and width of root reinforcement outside of the TWAZ were fairly uniform along the joint. In the TWAZ, they changed significantly. Also, sudden zigzags of root reinforcement in the vicinity of the tack weld may be observed due to arc blow provoked by the tack weld.

The height of the root reinforcement was changed in the TWAZ in a peculiar way. At first, it formed a dent at 368 mm and then a bump at 381 mm, both of which looked like a “wave” ahead of the tack weld. In the dent, \( h_{rr} \) suddenly dropped from 1.7 mm (in the regular weld) down to 0.8 mm (50% drop). In the bump, \( h_{rr} \) abruptly rose up to 2.3 mm (increase by 36%). After the bump, \( h_{rr} \) dropped sharply again in the middle of the tack weld, down to 0.3 mm (a huge 84% drop due to lower arc penetration). Then, \( h_{rr} \) gradually increased to the regular height.

The width of the root reinforcement was also affected negatively. When the arc approached the tack weld, \( w_{rr} \) decreased. The minimum was reached in the middle of the tack weld, where \( w_{rr} = 10.4 \) mm (vs. 14.1 mm in the regular weld). Then, \( w_{rr} \) increased gradually to the regular width.

Mechanism of Detrimental Effect of
Tack Welds

As described above, a tack weld produced negative effects on the root weld geometry, namely, it deteriorated the root fusion characteristics, decreased the size of the root reinforcement, and caused...
The amount of iron powder and arc blow. The effect of iron powder was similar to that of a tack weld because each reduced the root edge penetration and, thus, impaired the shape and size of the root reinforcement. In fact, a 6.4-mm-thick tack weld placed in a groove with a 30 deg angle and 6.4-mm root opening occupies the cross-section area of 51 mm². The same amount (by weight) of iron powder would occupy a cross-section area of 132 mm² due to lower density. This situation is equivalent to IR = 68%. (IR is the percentage of the groove cross section occupied by iron powder.) Most of the experiments described above were conducted at optimal IR = 50%, the height of iron powder being 11.1 mm. This means a 4.8-mm layer of iron powder covering a 6.4-mm-thick tack weld is the equivalent of extra IR = 32%. Thus, IR over the tack weld jumps suddenly from 50 to 100%. According to Ref. 1, the height and width of the root reinforcement drop dramatically at IR = 100%. If the 4.8-mm-thick layer of iron powder is removed from only the tack welds, h₉ and w₉ improve, but not much, because IR is still 68%. However, this improvement is not practical and can be risky because a melt-through can occur at the border between iron powder and the tack weld.

The mechanism of the wave (dent and hump) formation in the root reinforcement ahead of the tack weld is not fully understood. Possibly, the stable flow of the weld pool is disturbed when a sizeable amount of extra metal is suddenly thrown into the tail portion of the pool.

Arc blow may be provoked by the tack weld when the arc approaches it. Thus, a tack weld may be responsible for root fusion asymmetry. The reason is, during welding, the current flows through the plates assembled with a root opening (a gap), which creates magnetic fields during welding (Ref. 4). The magnetic lines behind the arc go through solidified weld metal. The magnetic lines ahead of the arc have to cross the air gap. This situation creates a constant imbalance of the magnetic field and a resulting force deflects the arc. Since the deflection is constant, the arc does not deviate from its initially selected path along the joint. However, when the arc approaches a tack weld, more and more lines, which previously crossed the air gap, go through metal. As a result, the new imbalance deflects the arc from its initial path. When the tack weld is consumed, the lines cross the air gap again and the arc returns to its initial path.

**Effect of Other Variables and Factors on TWAZ**

Welding variables and groove geometry may affect the shape of regular root welds for better or worse, as discussed in Ref. 1. In a similar fashion, they may influence the harmful effect produced by tack welds in the TWAZ.

Decreasing the included angle from standard 45 to 30 deg produces a positive effect on fusion characteristics of a regular root bead made at 600 and 700 A, as was shown in Ref. 1. This result is true for the TWAZ, as illustrated in Fig. 15, where the data are presented for welds made at 45 and 600 A. Two extra points are plotted on the graph for comparison. These data were obtained from a weld made at equal welding conditions, except the angle was 30 deg and the current was 700 A. The weld was cut in the middle of a tack weld. These extra points show the root fusion in the TWAZ is improved at 30 deg and 700 A, namely, h₉ is higher while h₉c is lower, despite the increase in the current. Similar improvements are seen in the shape of the root reinforcement — Fig. 16.

Effect of tack weld's size on the TWAZ is direct. The larger the cross section of the tack weld, the more pronounced negative effect it has on the root weld geometry. Thus, the tack weld size should be minimized, depending on the welded structure and its material. In heat-sensitive steel, local preheating would be useful to allow the use of smaller tack welds, while avoiding HAZ cracks, if smaller tack welds would be adequate to support the reinforcement. The shape of the root bead made at 600 and 700 A) or penetrates inadequately (at 800 A).

**Conclusions**

This study makes the following conclusions:

1) The root opening (RO) produces a mixed effect on the shape of the root bead. As the RO increases, the effect is harmful for root fusion regardless of the current because the height of root fusion (h₉) decreases. As far as the height of root crown (h₉c) is concerned, the effect depends on the current. Increasing RO is beneficial at lower currents (I ≤ 700 A) because the root crown and, thus, the slag pockets grow smaller. However, at I > 700 A, this favorable trend comes into conflict with the opposite trend produced by the increase of the current, which prevails. As a result, the slag pockets grow deeper. Still, lower h₉c values are obtained at lower current regardless of RO. An increase in RO produces a beneficial effect on the shape of the root reinforcement because its height (h₉) and the width (w₉) increase.

2) The included angle (β) produces a moderate effect on the shape of the root weld, but this effect depends on the current. A moderate improvement in root head fusion can be obtained by reducing the angle from 45 to 30 deg, but only in a narrow current range (I = 600-700 A). Thus, 30 deg is more beneficial with lower currents, while 45 deg is more beneficial with higher currents. The best root reinforcement is obtained also at 700 A and 30 deg.

3) The effect of the root face (RF) on the root fusion characteristics is marginally favorable until RF reaches 3.2 mm. At a further increase of RF, the root fusion characteristics deteriorate, namely, h₉c decreases and h₉ increases. As RF increases, both the height and the width of the root reinforcement sharply decrease. At RF ≥ 3.2 mm, the arc does not penetrate at all through the root edges (at 700 A) or penetrates inadequately (at 800 A). Since the root face preparation in the field incurs extra costs and is associated with some difficulties, it is not recommended for MRF welding.

4) Plate misalignment (MA) produces noticeable changes in geometry of the root weld by causing fusion asymmetry, decreasing the size of the crown (and the slag pockets) and increasing the size of the reinforcement. The shape of the root bead on the high side of the groove deteriorates in comparison with those in similar welds without misalignment, while that on the low side actually improves. As a result, the high side may be more susceptible to incomplete fusion in the following fill weld. To avoid this situation, the electrode should be offset toward the high side if the plates are assembled with misalignment. The appearance of root reinforcement is not negatively affected, even at 4.8 mm misalignment.

5) Arc blow is especially detrimental in MRF welding. Arc blow affects average fusion characteristics of the root head very little, but causes severe asymmetry of root fusion (A₉). As a result, a very deep slag pocket may be developed locally on one or another side of the groove. Such a weld is more difficult to complete without incomplete fusion or slag inclusions. In this respect, arc blow prevention measures, and stricter control of electrode offset and root edge straightness are required for MRF welding. Surprisingly, arc blow does not negatively affect the shape of the root reinforcement or its appearance.

6) A tack weld produces a highly detrimental effect on the shape and fusion characteristics of the root weld. It represents an abrupt and undesirable change in groove configuration. In the tack weld affected zone (TWAZ), root fu-
sion deteriorates, root crown grows larger, and root fusion asymmetry occurs, making the following fill weld vulnerable to incomplete fusion. The effect of tack welds on the root reinforcement is especially harmful. Its height and width decrease, and its appearance becomes irregular and less attractive in the TWAZ. The larger the thickness and length of the tack weld, the more harmful its effect on root weld geometry.

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References


Appendix

\[ h_{rf} = \text{height of root fusion} \]
\[ h_{rc} = \text{height of the root crown (slag pocket)} \]
\[ w_{rr} = \text{width of root reinforcement} \]
\[ A_{rf} = \text{root fusion asymmetry} \]
\[ A_{rc} = \text{root crown asymmetry} \]
\[ \beta = \text{included angle} \]
\[ I = \text{current} \]
\[ I_{cr} = \text{critical current} \]
\[ MA = \text{misalignment} \]
\[ MRF = \text{modified refractory flux} \]
\[ RO = \text{root opening} \]
\[ RF = \text{root face} \]
\[ TWAZ = \text{tack weld affected zone} \]
\[ IR = \text{percentage of groove cross section occupied by iron powder} \]
\[ T = \text{plate thickness} \]
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