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# WELDING *Journal*

February 2009



## •Welding in the Aerospace Industry

- Guns and Torches Update
- Accurate Fillet Weld Measurements
- Crash Resistance of Aluminum Structures

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

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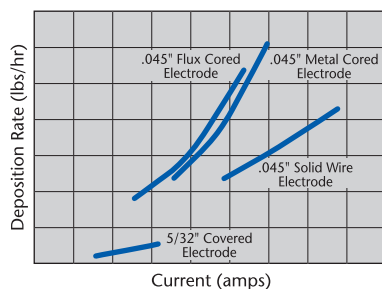
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## WASHINGTON

## WATCHWORD

BY HUGH K. WEBSTER

AWS WASHINGTON GOVERNMENT AFFAIRS OFFICE

## Small Business Administration Cabinet Status May Be Restored

Support is growing in Washington to once again make the administrator of the U.S. Small Business Administration (SBA) a Cabinet-level position. The SBA briefly held Cabinet status under the Clinton administration. The rationale is that the SBA administrator will have greater stature as a Cabinet member and therefore can promote the mission of the SBA more effectively. This move would also emphasize the importance of small business to the U.S. economy. Key members of Congress and President-Elect Barack Obama's transition team have endorsed this action.

## Definition of 'Independent Contractor' May Be Narrowed

A common method of attempting to predict what legislation may be favored by the new administration is by examining bills that President-Elect Barack Obama introduced while serving as a U.S. Senator. One such bill would have made it more difficult for employers to classify workers as independent contractors as opposed to employees. Employers do not have to provide benefits to independent contractors, and therefore many employers prefer that classification.

The legislation advocated by then-Senator Obama would have voided a provision in the law that currently allows employers to designate workers as independent contractors based on long-standing practice in that particular industry. The bill also would have greatly expanded the authority of the Internal Revenue Service in this area, including with respect to issuing regulations on how workers should be classified.

## OSHA Issues Final Personal Protective Equipment Rule Correction

The final Occupational Safety and Health Administration (OSHA) rule on Clarification of Employers' Duty to Provide Personal Protective Equipment and Train Each Employee became effective December 12. The rule revises OSHA standards to clarify that, for employers to be in compliance, they must provide personal protective equipment (PPE) and hazards training for each employee covered by the standards.

The final rule does not impose any new substantive requirements. The duty to provide PPE of all types, including respirators, and training to employees already exists in the law, and this new final rule adds no new compliance burden. Rather, the final rule achieves greater consistency in the applicable OSHA regulations, provides clearer notice of the nature of the employer's duty under existing PPE and training provisions, and clarifies that separate per-employee citations and penalties may be imposed by OSHA.

## Environmental Protection Agency Creates 'Most Wanted' Web Site

The U.S. Environmental Protection Agency has established the first-ever federal database of fugitives accused of violating environmental laws and evading arrest. The Web site, [www.epa.gov/fugitives](http://www.epa.gov/fugitives), includes photos of the accused, summaries of their alleged environmental violations, and information on each fugitive's last known whereabouts. The alleged violations include smuggling of ozone-depleting substances, illegally disposing of hazardous waste, dis-

charging pollutants into the air and water, laundering money, and making criminally false statements.

## Most OSHA Whistleblower Complaints Lack Merit

It is a violation of federal law for an employer to retaliate in any manner against an employee who reports a workplace safety or health violation or otherwise exercises his or her rights under federal occupational safety and health laws. In 2008, of the 1259 retaliation charges investigated by the Occupational Safety and Health Administration (OSHA), 80% were either dismissed or ultimately withdrawn. Only 20% were found have to merit.

## Economic Stimulus to Go beyond Public Works

Most of the attention given to the planned economic stimulus legislation that is expected to be enacted in early 2009 has been on public works infrastructure projects, but there are several other aspects that are relevant to industry. Those identified include the following:

- Provision of a \$3000 refundable tax credit for each additional full-time employee hired by companies in 2009 and 2010;
- Extension of the small business investment expensing limit to \$250,000 through the end of 2009;
- Elimination of all capital gains taxes on investments made in small and startup businesses;
- Making the Research and Development tax credit permanent;
- Creation of a nationwide emergency lending facility for small businesses to be run through the Small Business Administration's Disaster Loan Program;
- Temporary elimination of the fees on the SBA's 7(a) and 504 loan guarantee programs for small businesses;
- Creation of an Advanced Manufacturing Fund to identify and invest in the most compelling advanced manufacturing strategies;
- Doubling of federal funding for the manufacturing extension partnership program that works with manufacturers across the country to improve efficiency, implement new technology, and strengthen company growth;
- Doubling of federal funding for basic research; and
- Creation of a national network of public-private business incubators.

## Federal Web Site Managers Urge President-Elect to Increase Transparency

Government officials in charge of managing federal Web sites are urging the incoming administration to establish Web communications as a core government business function and transform these Web sites into truly helpful sources of information for the U.S. public. There are approximately 24,000 U.S. government Web sites currently in operation, but most tout organizational achievements instead of effectively delivering basic information and services. Legal, security, privacy, and internal policy concerns are partly responsible, according to the Federal Web Managers Council, but in addition many federal agencies tend to focus more on technology and Web site infrastructure than improving content and service delivery. ♦

Contact the AWS Washington Government Affairs Office at 1747 Pennsylvania Ave. NW, Washington, DC 20006; e-mail [hwebster@wc-b.com](mailto:hwebster@wc-b.com); FAX (202) 835-0243.



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## PRESS TIME

### NEWS

## American Welding Society Adds \$1.1 Million to Scholarship Endowments

The American Welding Society (AWS), Miami, Fla., has recently added \$1.1 million to the multimillion-dollar portfolio of scholarship endowments of the AWS Foundation. Funding from the American Welding Society's cash reserves will enable the AWS Foundation to increase its scholarship awards to future welding professionals.

"This major new endowment is specifically targeted to those individuals who are seeking a career in welding," said Sam Gentry, executive director, AWS Foundation. "This will help meet the urgent need for welding personnel in the American workplace."

There is a projected shortage of 200,000 welders in the United States by 2010, and retiring welders are exceeding new welders coming into the field. Also, according to Gentry, the average age of a welder is currently about 54.

Welders are now needed in manufacturing and construction, particularly in major energy and infrastructure projects across the country. Local AWS District volunteers are going to be the primary means of distributing the new scholarship money in accordance with local industry needs.

"Volunteer leaders in AWS Districts know the needs and trends of local industry," said Gentry, "so they can efficiently distribute scholarships to the best candidates, whether they are entering a technical school program or a college."

## Aerospace Welding Minneapolis Achieves EASA Approval

Aerospace Welding Minneapolis, Inc., Eagan, Minn., has gained Part 145 EASA approval from the European Aviation Safety Agency. This certificate has been issued under the terms of the current Bilateral Aviation Safety Agreement and the associated Maintenance Implementation Procedures. It allows the company to export all overhauled and repaired parts to customers in any EASA member country.

Furthermore, AWI's staff includes a FAA designee with Designated Manufacturing Inspection Representative status, allowing for the issuance of Export Certificates of Airworthiness on all of the Aero-Power® brand parts.

## Employers Cautioned against Cutting Back on Workplace Safety in Times of Economic Difficulty

American Society of Safety Engineers' (ASSE) President Warren K. Brown of Fairborn, Ohio, recently referred to reports of some companies cutting safety processes hoping to reduce costs. "Workplace safety processes must be in place at all times," Brown said. "They are even more critical during business downturns."

Laura Comstock, president-elect of the ASSE South Carolina Chapter, also offered input. "Some safety-related purchases and testing can be deferred, but other purchases, such as those for employee personal protective equipment like hardhats, safety glasses, and respirators, are critical to operations," Comstock said.

Plus, the South Carolina ASSE chapter suggests employees can take measures to help companies save money. This can be done by following safe working procedures and practices to prevent injuries, related downtime, and expenses; properly using, cleaning, and caring for protective equipment; reusing gloves whenever possible for as long as possible; and keeping track of safety glasses and reusable hearing protection.

"Money cut from safety processes now could have an enormous cost later; this can be from injury and health care costs, fines, lost production time, employee morale, or worst of all, employee injury or even death. There are better and smarter ways to protect the bottom line," Brown added.

## KUKA Lands Key Aircraft Order

KUKA Robotics, Clinton Township, Mich., has received a blanket order from the European aircraft manufacturer Airbus S.A.S. This is for the delivery of 41 omniMove mobile platforms, which feature a flexible horizontal range of motion in all directions and can rotate on the spot, for assembly of the Airbus A350 XWB. The assembly platforms will be used in the French, British, German, and Spanish Airbus factories to sub-assemble the plane's wings and fuselage sections. The term of the blanket order is five years.

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## EDITORIAL

# AWS Gears New Membership Package to Welders

The Membership Committee and the staff of the AWS Membership Department are always looking for enhancements to our membership benefits. Following two years of concentrated effort to better service the needs of our members who identify themselves as welders, AWS is now ready to introduce the most significant additions to our benefits in many years.

While the overall number of AWS members continues to grow, the number of members identifying themselves as welders remains steady — about 8% of the total. Through a national firm that specializes in large surveys, AWS contacted a large number of welders asking them directly about the present membership package and soliciting their ideas on enhancements that may make a Society membership more attractive to a greater number of welders.

In direct response to their suggestions, the Membership Committee has developed several new member benefits, which include the following:

**1. Discounts on tools/equipment of the trade.** The welders contacted during the survey emphasized that a valuable benefit would be discounts on their needed tools. AWS has worked with GAWDA (Gases and Welding Distributors Association) to provide this benefit. Participating welding distributors will now offer a discount on materials for AWS members. The names and locations on these distributors will be maintained on the AWS Web site ([www.aws.org](http://www.aws.org)). The magnitude of the discount and the materials included as a member benefit will be determined by each individual distributor.

**2. Access to AWS health insurance program.** Many welders identified the need for affordable health insurance as a valuable benefit. AWS has finalized an agreement with a major insurance underwriter to offer not only health insurance but also many other types of insurance coverage for AWS members.

**3. Publications exclusively for welders.** The survey revealed that welders would like information that was specifically directed toward their interests. One item that was identified by a high percentage of the respondents was a package of welding projects that can be used to construct a variety of items. To address this request, AWS and the Lincoln Electric Foundation will make the well-known and respected *Arc Welding Projects*, Volume IV, available as a new publication selection for welders who have just become members of the Society.

**4. Welders Exchange Bulletin Board on the AWS Web site.** A method for the “welder” members to better communicate with other welders was also requested. Through the addition of a new bulletin board feature on the AWS Web site, a welder will be able to ask a question, share a successful project, or seek a solution to a problem. Other welders, then, will be able to easily respond and share their experiences. This bulletin board will be dedicated to allowing welders to communicate with their peers.

**5. Discounts on dental plans, prescriptions, and more.** AWS is providing a comprehensive package of discounts on many things that should add value to a membership. It is anticipated that many of these programs will become a welcome incentive to welders wanting to join AWS.

As you can see, AWS went directly to welders, asked what they would like to have as a member benefit, and as a result, has developed a new plan in response to the interests defined by this vital segment of our industry. The Membership Committee is pleased to offer this new program and anticipates these benefits will be attractive to welders.

On a closing note, I am asking for your help in spreading the news. Share this information with the welders you know and encourage them to take advantage of the opportunity to not only join the premier welding society in the world, but to reap the values provided by these newly added benefits.



Lee G. Kvidahl  
Chair, AWS Membership Committee



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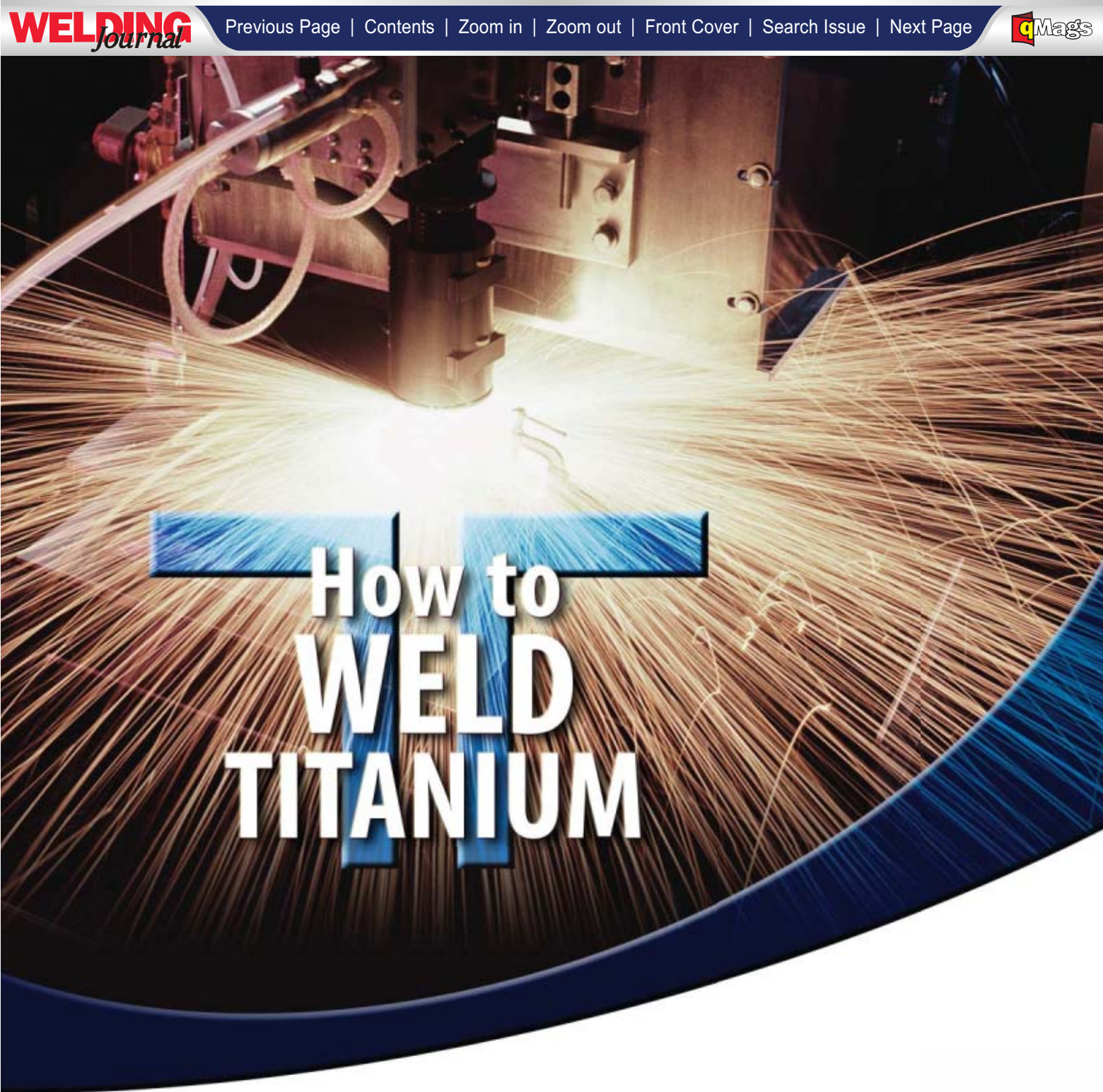
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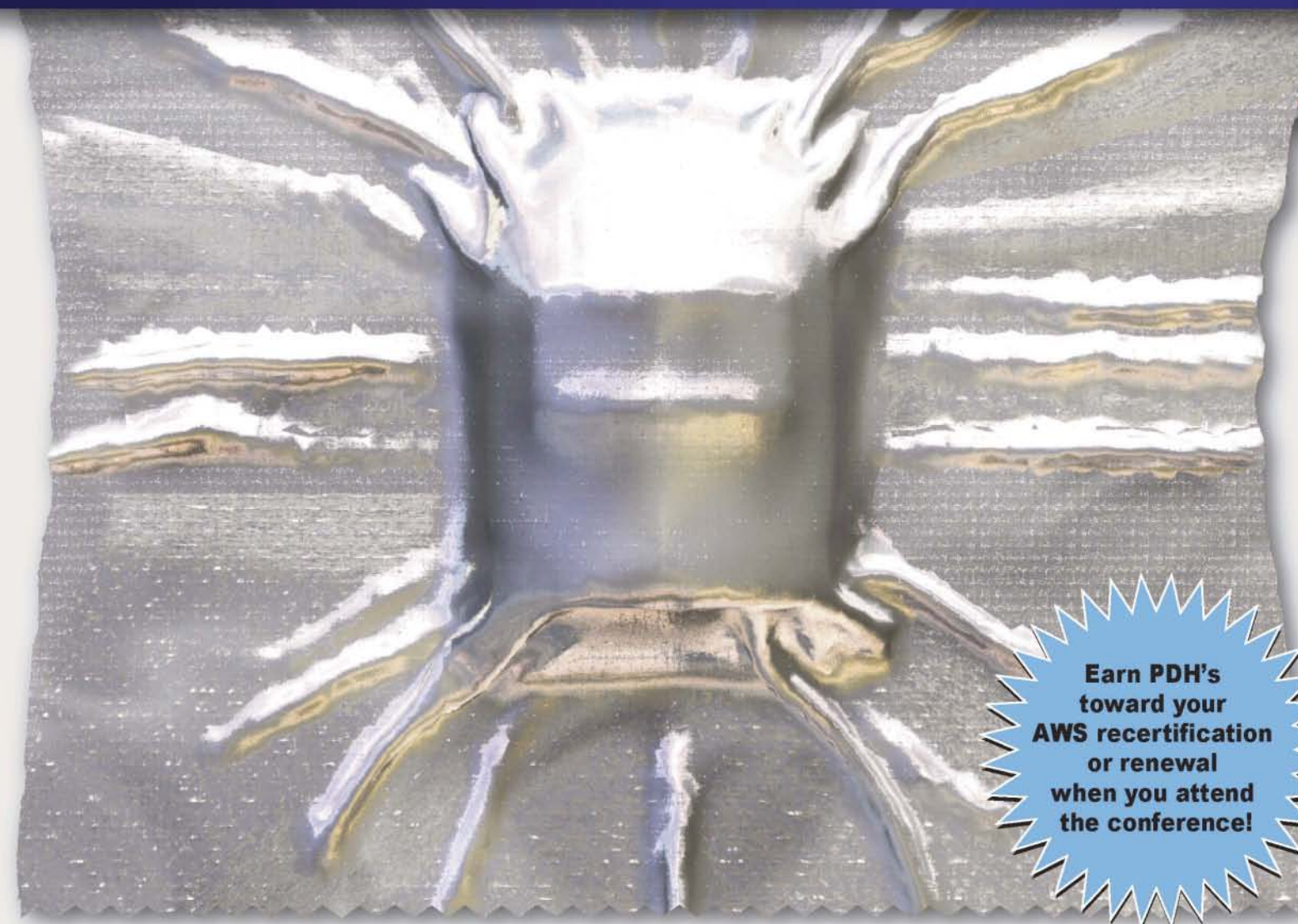


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At this conference, a distinguished panel of aluminum industry experts will survey the state-of-the-art in aluminum welding technology and practice.

The **12<sup>th</sup> Aluminum Welding Conference & Exhibition** will also provide several opportunities for you to network informally with speakers and other participants, as well as to visit an exhibition showcasing products and services available to the aluminum welding industry.

*For the latest conference and exhibitor information or to register for the conference, visit our website at [www.aws.org/conferences](http://www.aws.org/conferences) or call 800-443-9353, ext. 455.*

*To secure tabletop exhibit space or for questions about exhibiting at the conference, please call 800-443-9353, ext. 229.*



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**Toronto**  
**May 5-6, 2009**

## Conference Program

### Overview of Aluminum Welding

*Tony Anderson*  
ESAB Welding & Cutting Products  
Florence, SC

### The Aluminum Designation System & Characteristics of Aluminum Alloys

*Pete Pollak*  
The Aluminum Association, Inc.  
Arlington, VA

### Aluminum Welding Metallurgy

*Tony Anderson*  
ESAB Welding & Cutting Products  
Florence, SC

### Metal Preparation for Aluminum Welding

*William Christy*  
Novelis Inc.  
Kingston, Ontario, Canada

### Filler Alloy Selection Primary Characteristics

*Tony Anderson*  
ESAB Welding & Cutting Products  
Florence, SC

### Gas Metal Arc Welding of Aluminum Alloys

*Mark Burke*  
Indalco  
Mississauga, Ontario, Canada

### Gas Tungsten Arc Welding and Variable Polarity Plasma Arc Welding of Aluminum

*William Christy*  
Novelis Inc.  
Kingston, Ontario, Canada

### Aluminum Weld Discontinuities:

#### Causes and Cures

*Kyle Williams*  
Alcoa Technical Center  
Alcoa Center, PA

### Design and Performance of Aluminum Welds

*Tony Anderson*  
ESAB Welding & Cutting Products  
Florence, SC

### Application of the AWS D1.2 Structural Welding Code—Aluminum

*Kyle Williams*  
Alcoa Technical Center  
Alcoa Center, PA

### Robotic Applications

*Jay Ginder*  
ESAB Welding & Cutting Products  
Florence, SC

### High Energy Density Beam Welding of Aluminum

*William Christy*  
Novelis Inc.  
Kingston, Ontario, Canada

### Cutting Methods for Aluminum Alloys

*Jay Ginder*  
ESAB Welding & Cutting Products  
Florence, SC

### Overview of Solid State Joining Processes for Aluminum

*Donald J. Spinella*  
Alcoa Technical Center  
Alcoa Center, PA

### Friction Stir Welding Aluminum

*Jay Ginder*  
ESAB Welding & Cutting Products  
Florence, SC

### Resistance Spot Welding of Aluminum

*Donald J. Spinella*  
Alcoa Technical Center  
Alcoa Center, PA

### Question and Answer Sessions

*Bernie Altshuller, Moderator*  
Rio Tinto Alcan  
Kingston, Ontario, Canada

## NEWS OF THE INDUSTRY

### Empire Connector Pipeline Project Gets Finished

National Fuel Gas Co.'s wholly owned subsidiary, Empire Pipeline, Inc., Williamsville, N.Y., has placed its Empire Connector Pipeline in service. Construction is now complete, but property restoration will continue into the spring and summer.



*National Fuel Gas Co. recently announced the Empire Connector Pipeline has been completed and is in service. It runs from Victor, N.Y., to near Corning, N.Y., linking the existing Buffalo-to-Syracuse Empire State Pipeline to the Millennium Pipeline project. The pipeline is shown being placed in the trench with care. Expert crews using sidebooms coordinate its installation.*

This project expanded the 157-mile-long Empire State Pipeline by about 77 miles. The Empire Connector, extending from Victor, N.Y., to Corning, N.Y., links the existing Empire State Pipeline that runs from an interconnection with TransCanada Pipeline near Buffalo, N.Y., to Syracuse, N.Y., to the Millennium Pipeline project. Costs are estimated to be approximately \$187 million.

Also, a 20,000-hp compressor station was built as part of the project. Located in Oakfield, N.Y., it increases the pipeline's ability to deliver gas along the expanded pipeline system.

The Empire Connector and Millennium Pipelines are part of an expansion project designed to bring energy supplies to the Northeast. These projects, along with the Algonquin Gas Transmission, LLC, and Iroquois Gas Transmission System, L.P., expansion projects, will provide 525,400 dekatherms per day of new natural gas supply to growing markets.

A positive economic imprint has been left by this project on the communities along the route. More than 800 jobs were created with approximately 420 full-time construction jobs, 70% of which were filled with workers from the region.



*An Empire Connector crew member works on welding together 40- and 80-ft sections of coated pipeline. As many as five welding passes may be necessary to properly join sections of pipe. They must meet high inspection standards required by the contractor, pipeline company, and federal regulators. The welds are 100% visually inspected and X-rayed.*

### Plans Underway for the International Brazing & Soldering Conference

The American Welding Society (AWS) and ASM International have once again joined forces to bring the 4th International Brazing & Soldering Conference (IBSC) to Orlando, Fla., April 26–29. This conference, held every three years, offers pre-conference education sessions as well as three days of technical sessions on the latest developments in the brazing and soldering industries. In addition, top companies in the industry will exhibit their latest brazing and soldering products, giving participants the opportunity to evaluate new products, problem-solve, and network with their peers.

Major players of the world brazing community have committed to participate in the IBSC 2009. Scientists and engineers from

at least 12 countries will present new achievements in more than 80 papers during the eight concurrent sessions. These encompass practically all fields of joining technology including solders and soldering technology; ceramics, composite, and glass joining; filler metals; design, testing, and reliability of joints; brazing fundamentals; brazing processing; light metals joining; and new brazing applications. Also to be presented are plenary sessions titled *Development of New Brazing Filler Metals* and *The Impact of "Green" Legislation Requirements on Soldering Technology Advancement*.

The AWS C3 Brazing Committee members have volunteered their time to participate in organizing the event together with AWS and ASM International staff.

Information regarding the conference can be found at [www.aws.org/education/ibsc](http://www.aws.org/education/ibsc) or by calling (800) 443-9353 (305-443-9353 outside North America), ext. 455.

## Industry Leaders Cosponsor Symposium to Raise Welding Awareness



Miller Electric Mfg. Co. President Mike Weller (center) was impressed by the welding and technical skills of Oshkosh North High School seniors Lucas Dowd (left) and Casey LaMarche for their junior year project — a custom chopper built from the ground up.

At the recent *Career Horizons: Welding* symposium, more than 100 Wisconsin high school counselors, educators, and administrators discovered the bright future welding offers.

Miller Electric Mfg. Co., Airgas, Miron Construction, and AZCO Inc. sponsored the event, which is an initiative of the New North Manufacturing Alliance.

Attendees were informed about the salary potential and wide variety of careers that can originate with an education in welding. Presentations by current welding students, graduates of welding programs, industry experts, and high school administrators were featured. There are 2900 unfilled welding jobs in Wisconsin alone and 360 new openings are created each year.

A goal was to encourage high school personnel to reach out to the industries and businesses in their communities to form partnerships improving the quality of the schools' technical education programs. Another focus was to dispel the myths welding is a low-paying occupation with little potential for advancement.

## EADS Sets up Office at National Research Council Canada's Location

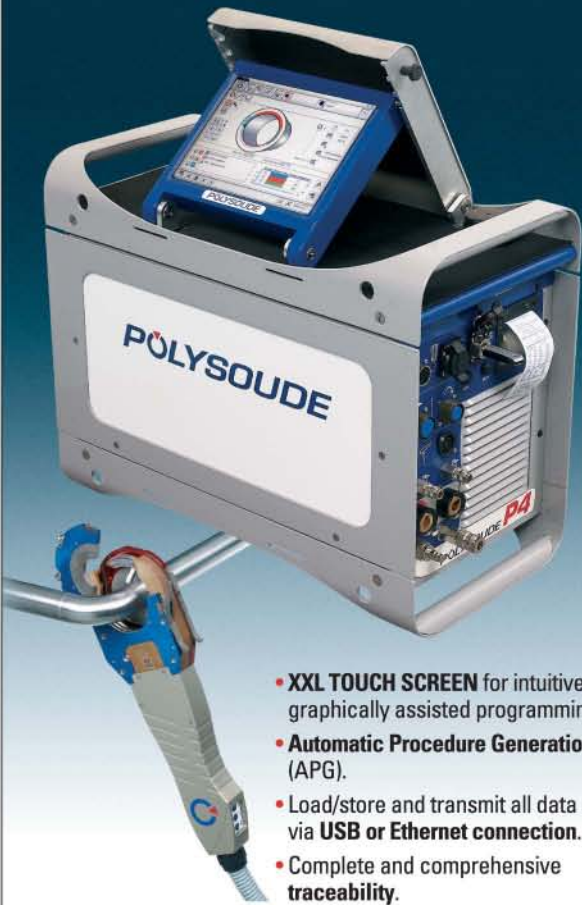
EADS, a provider of aerospace, defense, and related services, has opened an office at the National Research Council Canada's (NRC) site. This will enhance its commitment to aerospace re-



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search and technology development in Canada. Also, opening an office within the NRC's Institute for Aerospace Research (NRC-IAR) facility in Montreal is a step in establishing a long-term closer working relationship between the two organizations.

Currently, they have two joint projects underway, and one is between NRC-IAR Aerospace Manufacturing Technology Centre and EADS Innovation Works that involves friction stir welding. NRC and EADS are considering joint projects that could include the NRC-IAR Structures and Materials Performance Laboratory, and other NRC institutes.

## Southeast Supply Header to Award \$60,000 in Scholarships for Technical Career Fields

Pearl River Community College in Mississippi is one of six community colleges to receive a one-time \$10,000 contribution in scholarship monies from Southeast Supply Header, LLC (SESH), a 50/50 joint venture between Spectra Energy Corp. and CenterPoint Energy, Inc. Additional recipients include Louisiana Technical College – Tallulah Campus, Mississippi Gulf Coast Community College, Jones County Junior College, Copiah-Lincoln Community College, and Bishop State Community College, Mobile, Ala. Scholarships will be awarded to students enrolled in these colleges' technical-vocational programs beginning in summer or fall semesters of 2009.

"Our industry is in real need of workers skilled in industrial and technical trades such as civil engineering technology, surveying, construction management, drafting/design, and welding," said Andrea D. Grover, director, stakeholder outreach, Spectra Energy. This became emphasized as construction was recently completed on the SESH pipeline system, a 274-mile interstate pipeline running from Delhi, La., to Coden, Ala., including 211 miles through Mississippi.

## ESCO Tool Moves to New Building



*ESCO Tool recently acquired and refurbished a 60,000-sq-ft building in Holliston, Mass. Founded as the Evans Supply Co., Winchester, Mass., and purchased by the Brennan family in 1975, this firm has been located in Medfield, Mass., since 1980. It manufactures a range of portable end prep tools and saws for cutting and machining tube and pipe in preparation for welding. "We have been the beneficiary of a growing power industry and are moving into a larger building in response to worldwide demand for our tools, which are used for maintaining and upgrading existing power facilities as well as for new construction," said Matthew Brennan, president.*

## Autumn Career Fair Held at Hobart Institute

The Hobart Institute of Welding Technology, Troy, Ohio, recently hosted a career fair for upcoming and recent graduates. The event allowed students to talk with representatives from

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### About AWS Corporate Memberships:

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

**American Welding Society**

Contact Us:

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

more than a dozen different companies across the country.

Linda Akers, a recruiter for Westech (also known as WOTCO), Casper, Wyo., arrived a day before the fair to make presentations to students. This company produces custom-designed metal fabrications and wear materials for the construction and mining industries. All its welders are qualified to the requirements of AWS D1.1, *Structural Welding Code — Steel*. “Welders must be able to weld with  $\frac{3}{32}$  in. and  $\frac{1}{16}$  in. gas shielded flux cored welding wire,” said Akers. “They must pass a welding test on plate and a written test covering symbols and blueprints...The work is all indoors, and there are no travel requirements for our welders. We currently have both first and second shift openings.”

Janet Piechocki, admissions representative with Hobart Institute, organized the event and explained each company gave the time, effort, and expense to participate and talk with students who had their own individual needs and enticements.

## Macsteel Service Centers USA Increases with New Facility

Macsteel Service Centers USA recently expanded business operations with opening a new 100,000-sq-ft service center in Portland, Ore. A formal plant opening and ribbon-cutting event is planned for this spring.

The Pacific Northwest region including Oregon, Washington, and Idaho will be serviced. Plus, the center will process and stock carbon, stainless, and aluminum flat rolled and wide flange beams. Future plans call for the product line to include channels, angles, tubes, and plates.

James L. Rapae has been named manager of plant operations. The company has also hired six additional employees to fill out the Portland staff.

## VITRONIC Presents the VINTEC Award 2008 to Daimler AG



Dr.-Ing. Norbert Stein (right), president and sole shareholder of VITRONIC GmbH, recently presented the VINTEC Award 2008 to Günter Kasper (left), head of axle production, Daimler AG, at the EuroBLECH trade fair in Hannover, Germany. The award was presented after the joint development and installation of a welding concept at the Daimler plant in Mettingen. Welded joints are automatically inspected and optimized using VIRO<sup>WSI</sup>, a weld joint inspection system from VITRONIC.

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For info go to [www.aws.org/ad-index](http://www.aws.org/ad-index)

**American Welding Society**

Friends and Colleagues:

I want to 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 Fellow 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 July 1, 2009. The Committee looks forward to receiving numerous Fellow nominations for 2010 consideration.

Sincerely,

Nancy C. Cole  
Chair, AWS Fellows Selection Committee



## CLASS OF 2010 FELLOW NOMINATION FORM

*(please type or print in black ink)*

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:

\_\_\_\_\_  
\_\_\_\_\_

IT IS MANDATORY THAT A CITATION (50 TO 100 WORDS, USE SEPARATE SHEET) INDICATING WHY THE NOMINEE SHOULD BE SELECTED AS AN AWS FELLOW ACCOMPANY NOMINATION PACKET. IF NOMINEE IS SELECTED, THIS STATEMENT MAY BE INCORPORATED WITHIN THE CITATION CERTIFICATE.

### SEE GUIDELINES ON REVERSE SIDE

SUBMITTED BY: PROPOSER \_\_\_\_\_ AWS Member No. \_\_\_\_\_  
Print Name \_\_\_\_\_

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: _____ |
| Print Name _____         | Print Name _____         |
| AWS Member No. _____     | AWS Member No. _____     |

|                          |                          |
|--------------------------|--------------------------|
| NOMINATING MEMBER: _____ | NOMINATING MEMBER: _____ |
| Print Name _____         | Print Name _____         |
| AWS Member No. _____     | AWS Member No. _____     |

**SUBMISSION DEADLINE July 1, 2009**



## American Welding Society

### Fellow Description

#### 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 outstanding accomplishments and technical impact of the individual. Such accomplishments will have advanced the science, technology and application of welding, 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
- \* Society and chapter contributions
- \* Professional recognition

#### RULES

1. Candidates shall have 10 years of membership in AWS
2. Candidates shall be nominated by any five members of the Society
3. Nominations shall be submitted on the official form available from AWS Headquarters
4. Nominations must be submitted to AWS Headquarters *no later than July 1 of the year prior to that in which the award is to be presented*
5. Nominations will remain valid for three years
6. All information on nominees will be held in strict confidence
7. No more than two posthumous Fellows may be elected each year

#### NUMBER OF FELLOWS

Maximum of 10 Fellows selected each year.

### AWS Fellow Application Guidelines

Nomination packages for AWS Fellow should clearly demonstrate the candidates outstanding contributions to the advancement of welding science and technology. In order for the Fellows Selection Committee to fairly assess the candidates qualifications, the nomination package must list and clearly describe the candidates specific technical accomplishments, how they contributed to the advancement of welding technology, and that these contributions were sustained. Essential in demonstrating the candidates impact are the following (in approximate order of importance).

1. Description of significant technical advancements. This should be a brief summary of the candidates most significant contributions to the advancement of welding science and technology.
2. Publications of books, papers, articles or other significant scholarly works that demonstrate the contributions cited in (1). Where possible, papers and articles should be designated as to whether they were published in peer-reviewed journals.
3. Inventions and patents.
4. Professional recognition including awards and honors from AWS and other professional societies.
5. Meaningful participation in technical committees. Indicate the number of years served on these committees and any leadership roles (chair, vice-chair, subcommittee responsibilities, etc.).
6. Contributions to handbooks and standards.
7. Presentations made at technical conferences and section meetings.
8. Consultancy — particularly as it impacts technology advancement.
9. Leadership at the technical society or corporate level, particularly as it impacts advancement of welding technology.
10. Participation on organizing committees for technical programming.
11. Advocacy — support of the society and its technical advancement through institutional, political or other means.

Note: Application packages that do not support the candidate using the metrics listed above will have a very low probability of success.

#### Supporting Letters

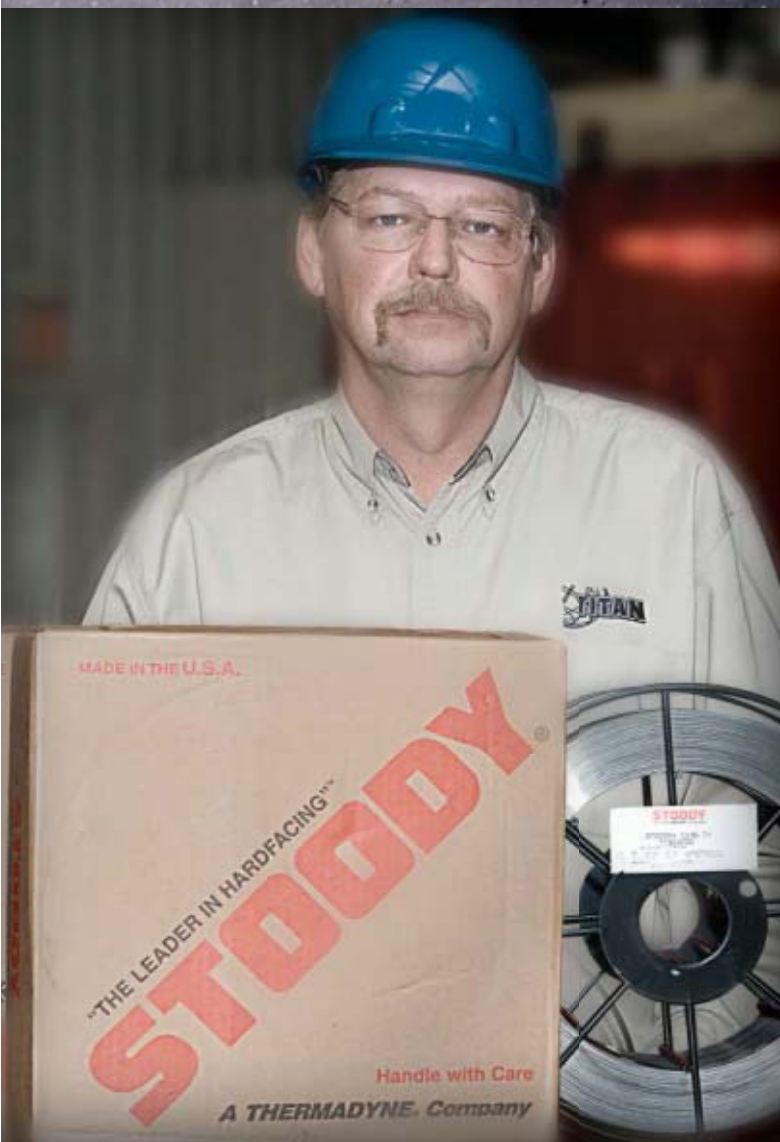
Letters of support from individuals knowledgeable of the candidate and his/her contributions are encouraged. These letters should address the metrics listed above and provide personal insight into the contributions and stature of the candidate. Letters of support that simply endorse the candidate will have little impact on the selection process.

Return completed Fellow nomination package to:

Wendy S. Reeve  
American Welding Society  
Senior Manager  
Award Programs and Administrative Support  
550 N.W. LeJeune Road  
Miami, FL 33126

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SUBMISSION DEADLINE: July 1, 2009



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"Since we've replaced solid MIG wires such as Alloys 625 and C276 with Stooddy's Nickel Flux Cored Wires, productivity and quality improvements have been significant. They advance our ability to automate, eliminating the chance of human error," says Tank Division Manager, Darrell Jones. "It replaces any conventional welding wire because of its 'all position' capabilities."

As one of the leading fabricators and erectors of FGD Scrubber Systems in the nation, Titan has used Stooddy Nickel Flux Cored Wires to tackle tough welds on absorbers and wet electrostatic precipitators (WESPs). "We rely on Stooddy for speed, productivity and quality," says Jones, "and Stooddy's customer support is far superior to any of the other specialty alloy wire companies we have tried in the past."

### DARRELL JONES

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## ALUMINUM

### Q&A

**Q:** I have worked with aluminum and aluminum welding for many years and have often heard many different metallurgical terms — solid-solution hardening, solution heat treatment, precipitation hardening, age hardening, natural aging, artificial aging, annealing, stabilizing, and stress relieving — used for describing the various heat-treating techniques and conditions used for aluminum alloys. Can you explain the different heat treatments and how they can influence manufacturing procedures used for welding, forming, and machining?

**A:** In order to appreciate the effect of thermal treatment on aluminum alloys, we should first understand the principal effects of alloying elements and solid-solution hardening.

Pure aluminum is not heat treatable but it “work hardens” or gains strength when mechanically worked such as bending or stretching. The addition of alloying elements to aluminum does not remove this characteristic; all aluminum alloys gain strength when cold worked. Adding elements to aluminum affect the metal in many respects. One of the most significant effects is that some aluminum alloys can now be made stronger through the use of thermal treatments.

**Solid-Solution Hardening.** Aluminum alloys are made by dissolving other metals in aluminum to form solid solutions. Some atoms of the alloying metals replace certain aluminum atoms in the metallurgical structure; this is called substitutional solid solution.

Other atoms of alloying elements occupy spaces between the base metal atoms in its metallurgical structure (lattice); this is termed interstitial solid solution. In both cases, the metallurgical structure is usually distorted by the new atoms in the structure, thus increasing strength. These alloys may then be further strengthened by heat treating and/or work hardening.

**Precipitation Hardening.** Heat-treatable aluminum alloys contain alloying elements that are more soluble at elevated temperatures than at room temperatures. When these alloys are solution heat treated to put these elements back into solid solution and then rapidly quenched, a supersaturated condition is produced.

The strength of the alloy is developed as the alloying elements precipitate out of the solution during the passage of time. This effect is referred to as precipitation or age hardening. Varying degrees of age hardening occur at room temperature (natural aging), but artificial aging (or

BY TONY ANDERSON



*Fig. 1 — These 600-lb spools of aluminum welding wire are about to undergo an annealing operation to remove the work hardening effect produced by previous wire drawing operations.*

precipitation heat treatment at higher temperatures) usually is employed to develop maximum strengths as quickly as possible. Close control is essential to ensure the correct metallurgical structure that will produce the desired properties.

Solid-solution hardening followed by precipitation hardening is the principal heat-treatment method used for strengthening the heat-treatable aluminum alloys.

Other thermal treatments used to prepare various aluminum alloys for optimum workability and application requirements include annealing, stabilizing, stress relieving, and refrigeration.

**Annealing.** Aluminum and all of its alloys may be annealed to remove the hardening or strengthening effects of cold working or heat treatment described previously. Annealing is accomplished by heating the metal above its recrystallization temperature 650–800°F (345–425°C), depending upon the alloy, and maintaining the required level until recrystallization is complete in work-hardened alloys. For heat-treatable alloys, either a controlled cooling rate or low-temperature soaking treatment is necessary in order to precipitate particles of the alloying elements.

Annealing is used to restore ductility to make the alloy easier to work, both at intermediate stages of fabrication, in which extensive metal deformation (work hardening) has taken place, or whenever

metalworking procedures or end use requirements call for maximum ductility. In Fig. 1, we see spools of aluminum welding wire positioned in a furnace. These spools are about to undergo an annealing operation to remove the work hardening effect of the previous wire drawing operation before subsequent manufacturing operations are carried out. The annealed condition is the material's lowest strength.

**Stabilizing.** Certain nonheat-treatable, work-hardening alloys containing magnesium, such as 5052, gain ductility but lose strength upon room temperature aging. Such age-softening alloys often are stabilized by heating to 225° to 350°F (110° to 180°C) to accelerate the softening to its ultimate limit.

**Stress Relieving.** Internal stresses built up by temperature gradients in aluminum may be caused by many factors: during quenching (rapid cooling), after heat treatment, cooling after welding or casting, from distortion of rolling, forging, extruding, bending, or drawing operations. These internal stresses can be reduced by either thermal or mechanical treatments.

Thermal treatments employing temperatures below those required for annealing often are used for nonheat-treatable wrought alloys with some loss of strength and an increase in ductility.

Where applicable, the metallurgically superior procedure of stressing the metal mechanically is used. This produces a

small, controlled amount of plastic deformation (1–3%) to effect employed stress relief with no resultant loss of strength.

This treatment aligns the residual stress in the direction of working and also reduces the differences between compressive stresses in the outer layer of the metal and the interior tensile stresses within. Mechanical stress relieving is accomplished by stretching or compressing the metal in hydraulic machines.

**Refrigeration.** Hardening of naturally aging heat-treatable alloys can be retarded significantly by refrigeration immediately after solution heat treatment; the lower the temperature the longer the “workable life,” within limits. Some applications of this practice are quite sophisticated, particularly where aerospace components are being fabricated. However, a typical simple use of refrigeration is for storage of Alloy 2024 wire or rod to gain maximum workability when cold-heading rivets are produced from this alloy.

### The Influence of Heat Treatment on Manufacturing Procedures

**Welding.** Typically, the same welding procedures can be used for heat-treatable alloys in various tempers. While the original temper of a base material can have some direct effect on the strength of the completed weld, the predominant effect on the weld strength is from the heat introduced into the base material during welding. Regardless of the heat-treated condition, the heat-affected zone (HAZ) of the base material will determine the welded transverse tensile strength of a groove weld. The design engineer will usually select a specific heat-treated temper based on its physical properties and suitability for the specific application. The welding engineer will then design a welding procedure to best achieve the required mechanical results after welding. Regardless of the heat-treated condition of the base material used, welding procedures should be qualified to establish the suitability of the completed weld for its intended service.

**Forming and Machining.** The heat-treated condition of aluminum alloys can certainly influence the procedures used for forming and machining of these materials. In forming operations, such as bending, using the correct bend radii is essential to prevent fracturing during this manufacturing process. Tables are available that provide the approximate bend radii for various aluminum alloys of different thicknesses and tempers for plate and tubes. These requirements differ depending on the heat-treated condition of the alloy.

The correct tooling for machining of aluminum alloys is dependent on its

machinability rating, designated as A through E. Tables are available that provide this information as well, based on aluminum alloy type and designated heat-treated temper. ♦

#### Acknowledgment

I would like to thank the Aluminum Association for allowing me to use information from its publication, *Forming and Machining Aluminum*. This popular resource for persons interested in forming and machining aluminum is available at [www.aluminum.org](http://www.aluminum.org) in its bookstore.

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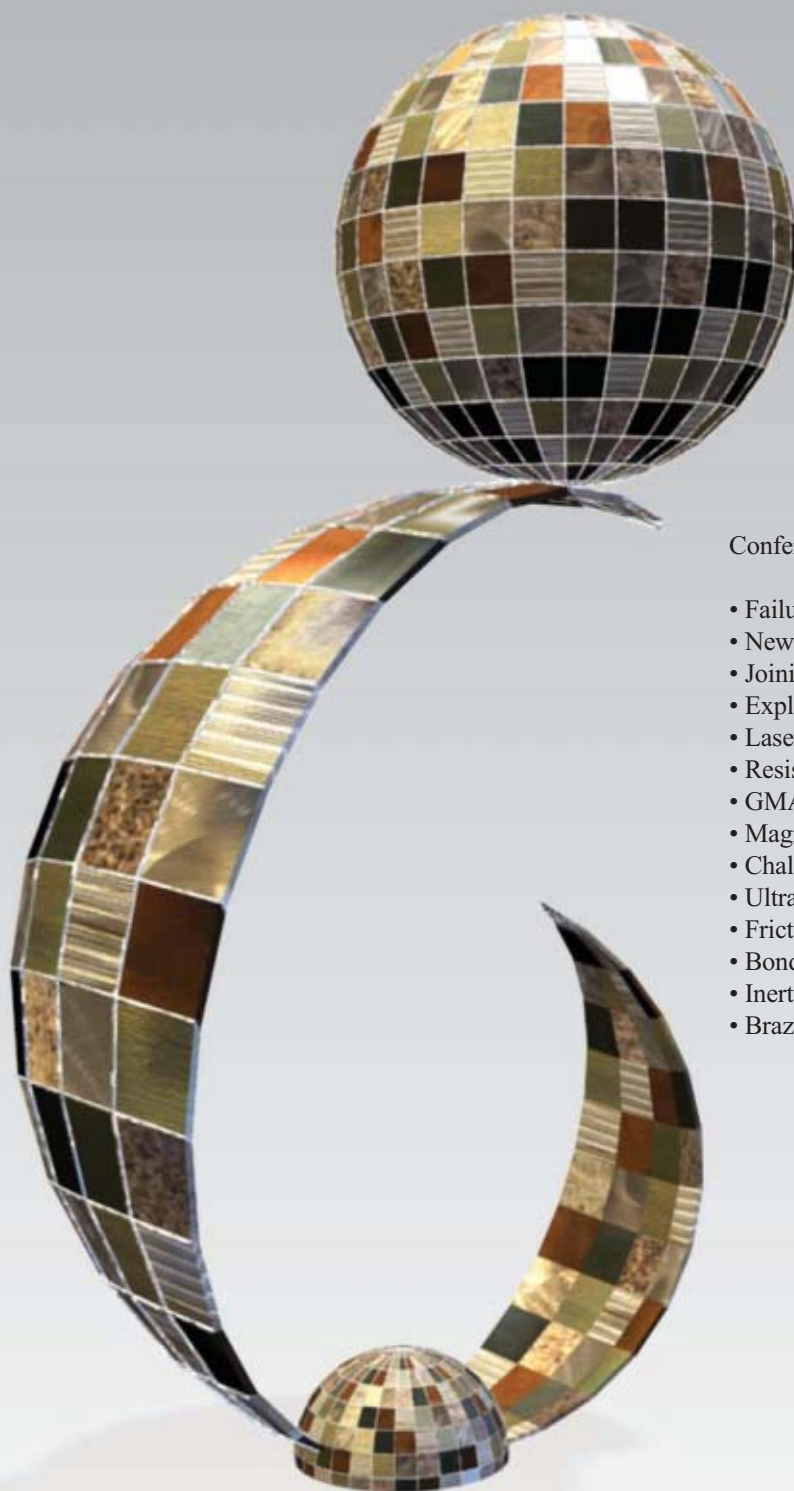
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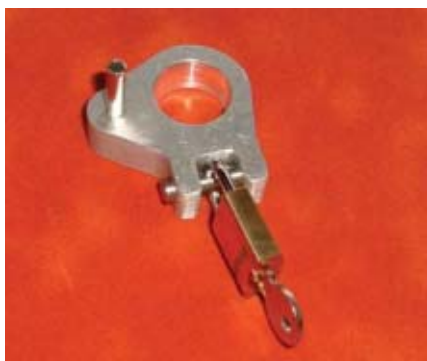
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# In-Process Quality Assurance for Aerospace Welding

*This system is emerging as a new technique for quality assurance for a wide range of processes that will be critical for welding aircraft and aero-structures*

BY VIVEK R. DAVÉ, DANIEL A. HARTMAN, AND MARK J. COLA

In-process quality assurance (IPQA) is an emerging field of enquiry in manufacturing technology originating in the 1980s and recently expanding in several areas of welding for aerospace applications. In this article, we will review the underlying technology for in-process quality assurance as well as recent applications in aerospace and other critical parts manufacturing. The historical context of the concept is traced as applied in particular to the aerospace industry.

In-process quality assurance is the direct interrogation of process physics and dynamics as opposed to exclusive reliance on machine tool monitoring or postprocess inspection. It complements these other technologies and provides valuable process information not available through other means. Applications to real-time closed-loop control are also possible. In-process quality assurance is used to preclude the occurrence of defects altogether.

## Historical Background

### Evolution of the Aerospace Manufacturing Paradigm

In the earliest days of aerospace manufacturing, welding on engine and rocket parts was not uncommon. For example,

Fig. 1 shows a rocket motor case from a captured V-2 in New Mexico. Even after 64 years, the welds in the rocket motor case and the fuel tubing lines are clearly visible.

In terms of airframe construction, riveting has been widely practiced since the 1930s. Early aluminum alloys such as 2017-T4 were weldable, but it was not until the 1940s and later that alloys such as 3003 and 6061 became widely commercially available. Aircraft such as the Martin B-10 shown in Fig. 2, the first all-aluminum monoplane bomber, were riveted. Riveting took hold as the airframe assembly technique of choice, and it has not fundamentally changed conceptually during the nearly 75 years it has been practiced, although significant improvements in alloys and techniques have been made over the decades. By 1950 and onward, a basic pattern for welding in aerospace manufacturing was established, namely that aero-engines contain welded parts, whereas airframes are almost exclusively riveted.

In terms of the larger airframe pieces such as beams, spars, stringers, longerons, frames, formers, etc., these have typically been machined out of monolithic pieces of forged, rolled, or extruded aluminum or titanium. Such construction practices have culminated in modern airliners such as the Boeing 777 and the Airbus A350.

Such aircraft can have millions of individual parts (many of which are rivets) and hundreds of thousands of discrete part numbers.

### New Challenges to the Old Aerospace Manufacturing Paradigm

If we fast-forward to the late 20th and early 21st centuries, we see several influencing factors or trends that will fundamentally change aircraft and aerospace construction irreversibly.

- **Escalating costs of commodity metals.** The cost of raw materials is escalating as global demand outpaces supply, and there does not seem to be a near-term reversal of this trend. With spot commodity prices so high, long-term purchasing agreements will be fundamentally altered in the future.
- **Demise of the primary metalworking industry.** To get large forgings is not a trivial feat, and many of the suppliers that met demand in the past are either out of business or critical skills and know-how have been lost.
- **Escalating cost of energy.** Energy costs are no longer a negligible part of the overall raw material and manufacturing costs.

VIVEK R. DAVÉ (vivek@beyond6-sigma.com), DANIEL A. HARTMAN, and MARK J. COLA are with Beyond6-Sigma Div., Technology Management Co., Inc., Santa Fe, N.Mex.



Fig. 1 — Welds in a 1945 V-2 rocket motor case (original photo by authors).



Fig. 2 — Martin B-10 Bomber, the first all-aluminum riveted monoplane bomber. (Maxwell Air Force Base public domain images.)

- **Escalating cost of labor.** Labor costs at least in North America and Europe remain comparatively high. In still developing economies like India and China, labor rate differentials will shrink over time.
- **Availability of skilled labor.** The historical manufacturing practices that have been prevalent in aerospace manufacturing since WWII have relied on a steady pool of trained technicians and craftsmen, but this supply is in jeopardy in many countries.
- **Drive toward reduced aircraft weight and “greener” aircraft.** Weight savings of just a few hundred pounds in a modern airliner can result in life cycle fuel savings of millions of dollars. Additionally, there will be increasingly stringent regulations worldwide to limit carbon emissions and to make “greener” aircraft.

## Emergence of a New Manufacturing Paradigm

These trends are having and will continue to have a profound influence on aircraft and aerospace design and manufacture. Starting in the 1990s and continuing to this day, there have been various initiatives both in North America and Europe to deal with the consequences of the above-mentioned influencing factors. There seem to be at least two major focus areas of interest and concern right now:

- **More efficient material utilization.** New discrete parts manufacturing techniques are being introduced that greatly reduce the “buy-to-fly” ratio, i.e., the metal that must be bought to make an aircraft. These new technologies focus on welding or additive manufacturing to create parts from raw material feedstock directly or from simpler, less expensive piece parts. The various joining techniques being used include friction welding, arc welding, high-energy-density-beam welding, and material ad-

ditive techniques based on laser or electron beams.

- **More efficient assembly techniques.** There is a movement away from riveting to consider welded fabrication for metal fuselage parts on the one hand, as well as much more extensive use of composite fuselage parts on the other. Laser beam welding, for example, can be up to an order of magnitude faster than riveting as a final assembly technique for aero-structures. The motivating factors for these technological developments are as follows:
  - The need to use less raw material
  - The need to reduce energy use in manufacturing
  - The need to reduce lead time of critical assemblies, thus ensuring on-time delivery
  - The need to reduce part count by eliminating riveting and moving toward unitized fabrications
  - The need to reduce labor costs through greater automation and even autonomous machine tool operation
  - The need to create lighter, more fuel-efficient aircraft with a lower carbon footprint, again enabled by welded fabrication.

## Obstacles to Achieving the New Paradigm

There are significant challenges on this new path of welded aircraft and airframe fabrication. One of the main challenges is quality. The traditional paradigm of using sheet metal skins riveted to structural members that are machined from large starting stock is difficult to overcome and has a 50-plus-year history of successful flight operations. To quote the famous economist John Maynard Keynes, “The difficulty lies not in the new ideas, but in escaping the old ones...”

Additionally, for processes that build up parts layer by layer using a variety of

additive manufacturing processes, there is the danger of burying a defect in lower layers and not being able to detect it later. Lastly, for welded fabrications that eliminate forgings by welding nearer-net shape piece parts, there is the danger that post-process inspection will be time-consuming, expensive, and in some cases inconclusive. This will obviate the gains made by going to all-welded construction in the first place.

Therefore, it is seen that quality assurance and quality control must also evolve to meet the new challenges posed by these historic shifts in aerospace manufacturing practices. IPQA, or in-process quality assurance, represents just such an advance and is a critical enabling technology in the new aircraft and aerospace manufacturing paradigm.

IPQA is not a new idea per se, but only within the last seven years has it become a practical reality. This is due to the confluence of various events:

- Inexpensive computing power of PCs following “Moore’s Law” now into the gigahertz clock speeds for a computer costing \$1400 or less.
- Availability of data storage well into the hundreds of gigabytes
- Commercial availability of a wide array of sensors
- Ready availability of a large data bandwidth
- Significant evolution of the algorithms capable of dealing with large, ill-defined, multidimensional data sets.

When all these elements are put together, it is possible to achieve IPQA, which is simply the on-machine, real-time assessment of part and process quality based on direct observation of process physics, not inspection of physical part attributes.

## Elements of IPQA

The best way to understand IPQA vis-à-vis conventional postprocess inspection

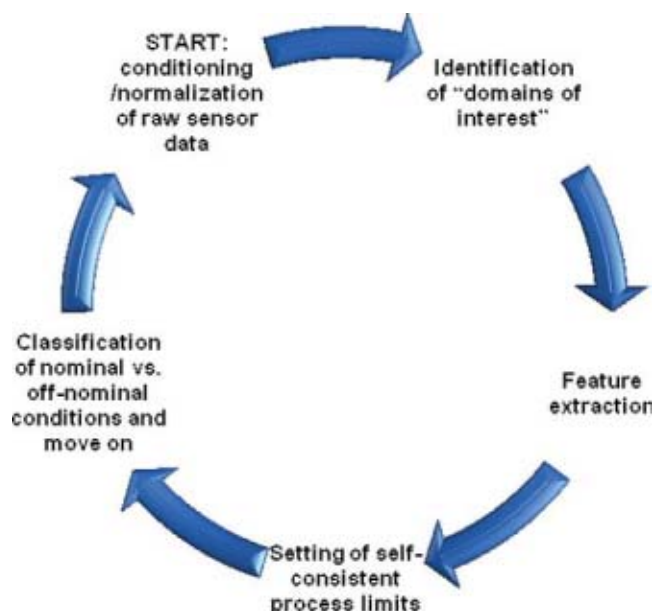


Fig. 3 — Steps in the IPQA process.

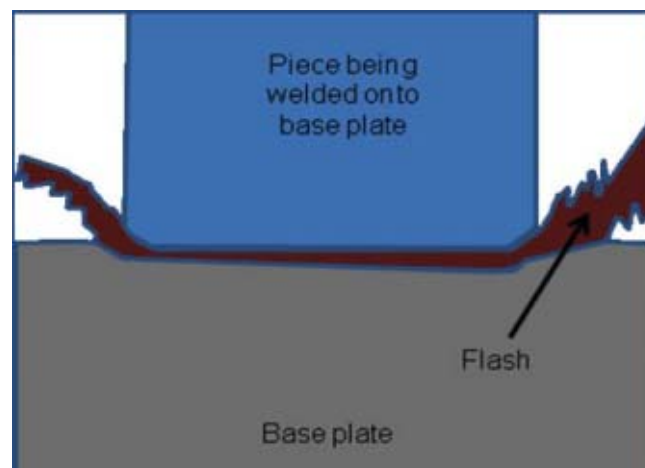


Fig. 4 — Schematic of linear friction weld (LFW) with no undercut.

Table 1 — IPQA as Compared to Conventional Postprocess Inspection

| IPQA                                                                                                                                             | Postprocess Inspection                                                                                              |
|--------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------|
| Prevent Errors – detect and prevent errors, not looking for defects                                                                              | Find Defects – looking for defects, not preventing errors                                                           |
| Process Dynamics – measure and control process dynamics, not inspecting parts                                                                    | Product Attributes – inspect physical attributes, not measurement and control of process dynamics                   |
| Forward-Looking – find and correct errors before defects happen                                                                                  | Backward-looking – finding defects when it is too late to correct underlying errors                                 |
| Constant and Pervasive – looking at the process dynamics for each and every part in sub-millisecond time increments achieving constant vigilance | Discontinuous and Sporadic – inspecting only certain features of certain parts and intermittently at best           |
| Same Timescale as Manufacturing – time scales commensurate with the manufacturing process time                                                   | Slower Timescale than Manufacturing – inspection times up to ten times longer than the manufacturing process itself |

is through the comparisons shown in Table 1. IPQA is not simply machine monitoring. The correct functionality of the machine tool is a necessary, but not sufficient, condition for getting an acceptable part. IPQA goes beyond machine monitoring to look for process conditions that produce low probability of occurrence anomalies. An anomaly is a metallurgical or geometric defect that occurs in a weld despite the fact that all machine monitoring parameters are perfectly normal and the machine tool is putting out the expected process response.

### IPQA in Practice

In order to realize on-machine, real-time assessment of part and process qual-

ity, it is necessary to go through several steps. These steps allow the journey from raw, ill-defined data to concise, actionable quality inference. Figure 3 shows the cycle of events that must take place to successfully execute IPQA.

- **Data collection, filtering, and conditioning.** First, the ill-defined raw data are conditioned, normalized, and aligned spatially with respect to “process start” and “process stop.”
- **Identification of domains of interest.** Then, domains of interest are found within this data set. For example, such domains of interest could be process events such as changes in slope of key control variables such as force or displacement.
- **Feature extraction.** Raw data alone are

ill-defined, large volume, and nearly impossible to interpret. As a result, the feature extraction step of IPQA is perhaps the most important in that it achieves a million-fold reduction in data density while preserving key process physics that allow discrimination between nominal, off-nominal, and anomalous events.

- **Process limits.** Once features have been established, it is now necessary to delineate which features are within expected values for a nominal process, and which are not. This is based on a clear understanding of baseline process performance, i.e., what the end user considers nominal.
- **Classification and notification.** Based on the analysis of limits, it is possible to condense many features into just a single actionable end result. Either the process is behaving in a nominal manner, or it is not. This classification of process behavior can then be used to notify the operator to intervene, or could form the basis for a closed loop adaptive control system to eliminate the underlying cause of error in real time.

### Case Study: IPQA as Applied to Linear Friction Welding

Linear friction welding (LFW) is one of the newer discrete part manufacturing technologies that has been used for compressor parts in aero-engines and is being envisioned for use in aerospace structural component manufacture as well. In LFW, one side of the joint is oscillated, and the two pieces are brought together under a forging pressure. Material then heats up

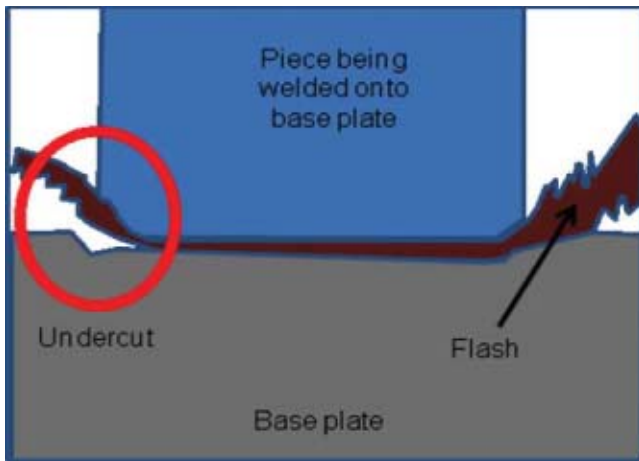


Fig. 5 — Schematic of linear friction weld (LFW) with undercut.



Fig. 6 — Quality metric matrix corresponding to a nominal LFW condition.



Fig. 7 — Quality metric matrix corresponding to a LFW undercut condition.



Fig. 8 — Example of typical GMA weld bead in Ti-6Al-4V without IPQA.



Fig. 9 — Example of typical GMA weld bead in Ti-6Al-4V with IPQA.

and flows out of the joint region so that unaffected base metal comes into contact thus forming a true metallurgical bond.

Although the process is intrinsically reliable, there are possible defect conditions occurring especially at the outer edges of parts that could result in defects being retained in the final part if these conditions are not removed by postweld machining operations. Figures 4 and 5 schematically show one such condition, namely undercut. This is the case where the edge of the weld remains unwelded and there is a notch, or undercut, extending from the edge into the weld region. If this region is too deep, it may not clean up during postweld final machining.

In this study, we collected multiple channels of data including machine tool data and other auxiliary data. The channels collected included oscillation amplitude, forge pressure, joint temperature, acceleration in the moving and stationary jaws, acoustic emission in the moving and stationary jaws, and sound. The resultant raw data files are extremely complex and

ill-defined, but through the feature extraction approach, setting of process limits, and classification scheme, we were able to reduce this large data set to a matrix of numbers known as a Quality Metric Matrix that shows which features are within expected nominal values, and which are not. The result is that a green square in this matrix indicates a feature within expected ranges, and a red square represents an anomalous feature. Figures 6 and 7 show that we can clearly see the difference between welds with undercut and those without undercut based on these multisensor data.

### Case Study: IPQA as Applied to GMAW of Titanium for Repair of Aerospace Parts

Gas metal arc welding (GMAW) is not normally considered for welding of aerospace parts, but it does have significant cost and productivity advantages if the required weld quality can be obtained. There are significant challenges in the use

of GMAW for titanium aerospace applications:

- Sensitivity to contamination
- Spatter
- Instability of arc due to excessive motion of cathode spot
- Shape of weld bead
- Control of heat input, especially on these sections.

The key to overcoming the challenges listed above and achieving process control is to simultaneously track and control three sets of dynamical behaviors — the power supply dynamics, the weld pool dynamics, and the dynamics of droplets melting off of the consumable electrode. Figures 8 and 9 show the typical weld beads made without IPQA and then with IPQA, where all three of these process dynamics were simultaneously monitored and controlled.

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## Other Applications

IPQA is currently being applied to the following proprietary applications:

- Linear friction welding of aero-engine parts
- Linear friction welding of airframe parts
- Rotary friction welding of airframe parts
- Rotary friction welding of automotive parts
- GMAW of titanium aero-engine parts
- Orbital arc welding of tubing for food and drug processing plants
- Hot wire gas tungsten arc welding of power generation components.

## Conclusions

In-process quality assurance is rapidly emerging as a new technique for quality inference and quality assurance for a wide range of manufacturing processes that will be critical for welding aircraft and aero-structures. Many companies are investigating and adopting IPQA since it has the potential to eliminate the bottlenecks at inspection and to automatically flag very subtle process variations before they lead to defects.

In terms of integration into the overall quality system, the best time to incorporate IPQA for any given process is during process development. At this time, the characteristic signatures of normal and abnormal process behavior can be determined, which then in turn determine the ability of the process to make acceptable parts. It has been our experience that even with as few as 12 instances of a baseline configuration (normal process behavior), the IPQA system can "lock onto" the signature of normal, and conversely can start to identify abnormal process behaviors. This is a significantly smaller set of instances or parts than what is required by even so-called small lot SPC techniques.

IPQA does have some imitations however, and the main limitation is that it cannot define quality a priori. IPQA requires expert input from the manufacturing engineer or the quality engineer to ensure that the normal baseline signature established does indeed correspond to process conditions that are capable of making a good part, as independently verified by off-line, postprocess inspection. Thus IPQA once properly calibrated can detect anomalous behavior, but the calibration is critical and requires manufacturing and process expertise. ♦

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# Current Technology in Welding Guns and Torches

*Here's a look at some of the most up-to-date guns and torches for gas metal arc, flux cored arc, and gas tungsten arc welding*

BY ANDREW CULLISON, KRISTIN CAMPBELL, AND MARY RUTH JOHNSEN

The gas metal arc welding gun and gas tungsten arc welding torch are two of the most intimate pieces of equipment welders come into contact with while performing their jobs. During the course of a day they will be holding that gun or torch for hours, so it better perform well and be comfortable to handle. Manufacturers are well aware of this and have been designing to those needs. Below are some of the guns and torches equipment suppliers feel you should be familiar with to help you in your job.

**Welding Guns Handle Heavy Plate.** The new line of Magnum® PRO semiautomatic welding guns are designed for heavy-duty applications, but they are constructed with simplicity in mind. The gun has few parts, and it is easy to disassemble for maintenance and then reassemble. Four models — 250 A, 350 A, 450 A, and 550 A — accommodate welding wires in diameters ranging from 0.035 to  $\frac{5}{64}$  in. — Fig. 1. All the guns are rated at 100% duty cycle, and the capacity goes up to 500 A. Intended for heavy plate applications, an optional locking trigger allows welders to move their hand away from the arc for more comfort. In addition to a heavy-duty nozzle, a compact nozzle is available for maneuvering in tight corners. Lincoln Electric Co., Cleveland, Ohio, (216) 383-2162, [www.lincolnelectric.com](http://www.lincolnelectric.com).



Fig. 1 — The Magnum® PRO welding guns for gas metal arc and flux cored arc welding are brand new to the market.

**Time-Tested in Tough Applications.** The interchangeable drive rolls and pull motor in the handle of PPA26 and PPW401 push-pull gas metal arc welding guns accommodate soft aluminum, as well as hard steel welding wire. The air-cooled PPA26 has a 60% duty cycle rating at 260 A with CO<sub>2</sub> and 220 A with a mixed gas. Model PPW401 (Fig. 2) is water-cooled, and it has a 100% duty cycle with CO<sub>2</sub> rated at 360 A and 320 A with a mixed gas. They both can be used with welding wires ranging in diameter from 0.023 to 0.062 in. (0.6 to 1.6 mm), and both mount on any standard wire feeder. The guns come with standard 15-, 25-, and 36-ft cable lengths and are available with 180-, 30-, and 45-deg goosenecks. CM Industries, Inc., Lake Zurich, Ill., (847) 550-0033, [www.cmindustries.com](http://www.cmindustries.com).



Fig. 2 — The PPW401 push-pull welding gun has proven itself in tough applications.

**Made for Efficient Current Transfer.** The Omega™ 3 semiautomatic welding gun is designed with a direct crimped gun body, a tight interface tolerance, and a neck locking screw to improve current transfer — Fig. 3. The Omega 3 is rated at 350 A, 60% duty cycle with CO<sub>2</sub> gas and 300 A with mixed gas. It accommodates

welding wires ranging from 0.035 to 0.062 in. (0.9 to 1.6 mm) in diameter. The swan neck can be positioned a full 360 deg, and it is covered with a heat-resistant rubber to extend service life. The gun can handle applications from light to heavy duty. The complete series includes Omega 2 rated at 60% duty cycle, 250 A with CO<sub>2</sub> and 200 A with mixed gas; and the Omega 4 at 450 A with CO<sub>2</sub> and 400 A with mixed gas. Alexander Binzel Corp., Frederick, Md., (800) 542-4867, [www.abicorusa.com](http://www.abicorusa.com).



Fig. 3 — The Omega™ 3 is rated at 350 A and can be used for light- to heavy-duty applications.

**GTA Torch Features Soft-Grip Handle.** The LS17 air-cooled torch is a new addition to Weldcraft's Legacy™ Series of GTA torches — Fig. 4. It is rated at 150 A/DC and 125 A/AC, both at 60% duty cycle. Extra highlights are as follows: an interchangeable fingertip switch that provides remote amperage control and can be replaced without any tools; a knuckle joint at the base of the torch handle permitting greater control and easier movement while minimizing stress on the power

ANDREW CULLISON is publisher, KRISTIN CAMPBELL is associate editor, and MARY RUTH JOHNSEN ([mjohnsen@aws.org](mailto:mjohnsen@aws.org)) is editor of the Welding Journal.

cables and back end of the torch body; an air-cooled design that prevents overheating and allows for long-term, welding performance and greater user comfort; and a styled soft-grip handle that prevents slipping to improve overall torch control. The product is available with a 12½- or 25-ft single-piece rubber cable assembly, each of which comes standard with a protective sheath to prolong cable life. Each package comes with a 14-pin connector and control wire for connection to a Miller® power source. Many models are offered with a manual gas control valve allowing the user to adjust shielding gas flow. *Weldcraft, Appleton, Wis., (800) 752-7620, [www.weldcraft.com](http://www.weldcraft.com).*



Fig. 4 — This LS17 air-cooled torch is designed to improve comfort, control, and welding productivity.

**GMA Guns Connect Easily.** ESAB's MXL™ GMA guns offer ergonomic handles that not only reduce fatigue but also promote comfort and easier use — Fig. 5. Optimum cooling is permitted by the swan-neck design for extended life of the neck and wear parts. The guns have a Euro-style central connection. Spring-loaded contact pins in the central connector ensure positive trigger connection. In addition, cable life is improved by molded cable strain reliefs. These guns come in 10- and 13-ft lengths with a choice of standard, straight, or conical gas nozzle styles. In particular, the MXL™ 200 has gun amperage ratings at 35% duty cycle of 200 A for CO<sub>2</sub> and 170 A with Ar/CO<sub>2</sub>; it accommodates wires from 0.023 to 0.040 in. The MXL™ 270 provides gun amperage ratings at 35% duty cycle of 270 A for CO<sub>2</sub> and 260 A with Ar/CO<sub>2</sub>, plus wires 0.030–0.045 in. The MXL™ 340 has gun amperage ratings at 35% duty cycle with CO<sub>2</sub> of 340 A and with Ar/CO<sub>2</sub> of 320 A,

and wires of 0.030–0.045 in. *ESAB Welding & Cutting Equipment, Florence, S.C., (800) 372-2123, [www.esab.com](http://www.esab.com).*



Fig. 5 — Making up the family of convenient and versatile MXL™ GMA guns are (from top) MXL™ 340, MXL™ 270, and MXL™ 200.

**Ergonomically Designed Platform Given by GMA Gun.** The Spray Master™ GMA gun, developed by Tweco, is built on the success of the company's Number 4 GMA gun — Fig. 6. David Wilton, vice president, Tweco Global Welding Products, said, "We felt that welders would be receptive to a more comfortable feel and a higher duty cycle rating from their guns." Smaller and lighter, it features an ergonomically designed platform that is more comfortable to hold. This gun was also designed to improve user comfort by providing a rotatable conductor tube with an articulating head that helps lock the gun angle for certain positions. This makes it easier to reach different joint configurations and tight joints. The series has a high-duty cycle rating of 80% with argon mixed gases, offering good performance in extreme welding applications. Its longer trigger life with its blade-style design creates electrical contact by sliding over each other in a sort of self-cleaning action. Plus, the company's Knuckle-head™ flexible conductor tube — enabling users multiple adjustments and containing a patent-pending mechanical ball and socket design — can be used on a Spray Master™ to increase its range of welding capabilities. Qualities of the 450 model are as follows: 450-A air cooled; comes in 10-, 12-, 15-, 20-, and 25-ft



Fig. 6 — Shown are two GMA guns (from left) Number 4 along with the Spray Master™ 450 model that handles heavy-duty, pulse, and spray applications.

lengths; rear plug connections for Tweco, Miller, Lincoln, and Euro-Kwik; and options/features include metal jacketed and swivel conductor tube, dual schedule, locking trigger, and long tubes. *Tweco, Denton, Tex., (800) 426-1888, [www.tweco.com](http://www.tweco.com).*

**Small GTAW Torches Get to Those Hard-to-Reach Places.** TEC Torch has added a 125-A water-cooled and a 60-A air-cooled model to its line of WeldTec® Micro TIG welding torches — Fig. 7. The torches are designed to perform small, intricate work and to reach into less-accessible areas. Both models share chucks and clear glass nozzles. They come with a straight, pencil-style nozzle, but can be fitted with 45-, 90-, and 180-deg chucks. The standard torch neck length is 3½ in., but special order models are available from 2 to 12 in. They feature a low-maintenance, dual O-ring head design; flexible, soft rubber hose and power cable options; and DX models offer a glove-soft leather protective cable cover. *TEC Torch Co., Inc., San Marcos, Calif., (760) 747-3700, [www.tectorch.com](http://www.tectorch.com).*



Fig. 7 — Standard neck length for the WeldTec® Micro TIG torches is 3½ in., but models with necks from 2 to 12 in. long can be special ordered.

**System Allows Custom Neck Combinations for Most GMAW Applications.** Tregaskiss now offers the QUICK LOAD™ gooseneck system for its curved-handle TOUGH GUN™ hand-held, semi-automatic GMAW guns — Fig. 8. The system allows gooseneck combinations to be changed quickly and easily, minimizing downtime and providing the exact angle for specific welding applications. The system accommodates a variety of gooseneck lengths and styles. A toolless quick-release feature requires the opening and closing of one latch to switch out different gooseneck styles. It also allows the gooseneck to be rotated 360 deg, making it easier to reach awkward joints or to weld in confined areas. In addition, the gooseneck system is combined with the company's QUICK LOAD liner system, which allows a new liner to be installed from the front end of the gun, further minimizing down-

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time. Tregaskiss, Windsor, Ont., Canada, (877) 737-3111, [www.tregaskiss.com](http://www.tregaskiss.com).



Fig. 8 — Various gooseneck styles can be switched out without tools with the QUICK LOAD™ gooseneck system on Tregaskiss's curved-handle TOUGH GUN™ GMAW guns.

**Rubber Grip Handle Makes Guns More Comfortable.** Designed for high-deposition welding that features high current loads over long, continuous joints, Bernard's new HD Q™ and S™ series GMAW guns are available in 300- to 600-A models — Fig. 9. They feature a one-piece straight handle for maneuverability; a rubber overmold provides a better grip for increased operator comfort. It also features an armor-protected locking trigger with an optional dual-schedule switch. Both guns feature the company's Stay-Tite™ technology, which incorporates long-lasting compression fittings and large, tapered neck-to-handle connections to ensure that the gun runs cool and delivers a consistent electrical current to the weld pool. The HD gun is also integrated with Bernard's GMAW gun configurator, which allows users to customize the gun with a variety of cable, neck, consumable, and direct plug options. Bernard Welding Equipment, Beecher, Ill., (800) 946-2281, [www.bernardwelds.com](http://www.bernardwelds.com). ♦



Fig. 9 — The HD Q™ and S™ series guns come in 300- to 600-A models designed for high-deposition GMAW applications.

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*A worker uses the caliper weld inspection method to measure fillet welds in a tubular assembly.*



# How to Accurately Measure Fillet Welds

*A tubular assemblies manufacturer devised a unique method for taking fillet weld readings*

BY JOE PAVILANIS

Woolf Aircraft Products, Inc., got its start in Wayne, Mich., in 1942 fabricating tubular assemblies for B-24 bombers. Today, the company operates out of a 100,000-sq-ft facility in Romulus, Mich., and supplies tubular assemblies for a wide variety of industries, including defense, transportation, power generation, and agriculture. Aircraft and aerospace remain prime segments of the company's business, however. Its 125 employees can fabricate just about any type of tubular assembly.

Woolf Aircraft has the capability of bending tubing from 0.125 through 7 in. in diameter and has a selection of more than 450 radius dies, which gives its customers many options. It also has an extensive material inventory, stocking more than 1400 different sizes and types of material. The company commonly fabricates stainless steel, Inconel™, carbon steel, chrome-moly steel, aluminum, and titanium, and also has experience with magnesium, Hastelloy® X, AL6XN, and other exotic alloys. One of the company's

recent achievements was to become registered to SAE AS9100B, *Quality Management Systems — Aerospace — Requirements*, in 2008. It has 13 welders qualified to the requirements of AWS D17.1, *Specification for Fusion Welding for Aerospace Applications*, in all metals that are fabricated in thickness ranges from 0.020 to 0.250 in. thick, as well as various project-specific certifications to the ASME *Boiler & Pressure Vessel Code*, Section IX, and an array of customer-specific welding specifications.

JOE PAVILANIS ([joep@woolfaircraft.com](mailto:joep@woolfaircraft.com)) is process/quality engineer, Woolf Aircraft Products, Inc., Romulus, Mich.

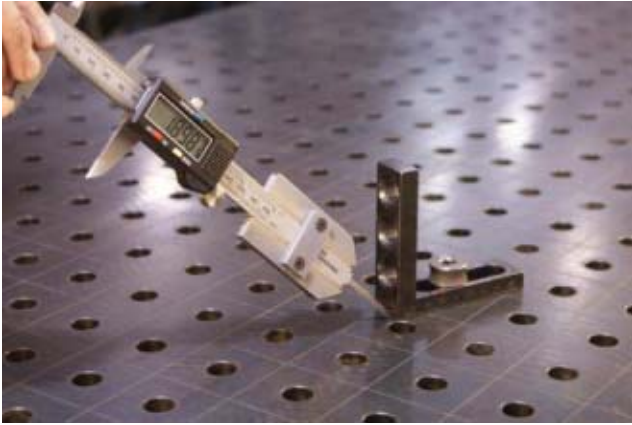


Fig. 1 — The adapter mounts to a digital caliper designed to seat directly onto the corner of a 90-deg angle.

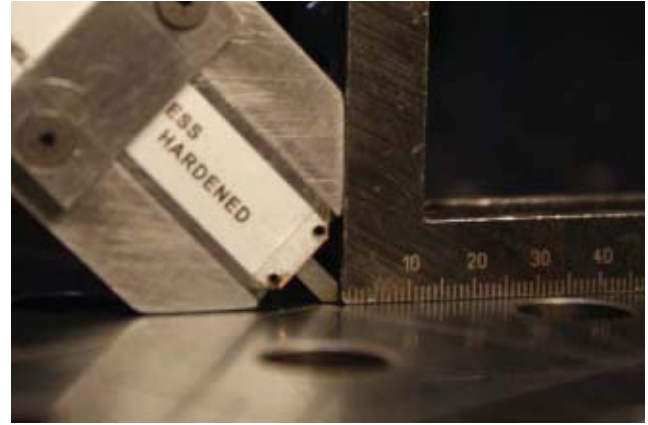


Fig. 2 — The reading gives the distance from the weld root to the weld face, which is the weld throat.



Fig. 3 — A — When touching the weld face, the digital scale shows the actual distance from the root to the face, providing a measurement of the actual weld throat; B — a close-up of the throat measurement.

## Problem/Issue

Many of the weld sizes that Woolf is required to produce are often less than 0.125 in. and as small as 0.040 in. The company has found that traditional fillet weld gauges do not work that well for inspecting and verifying the sizes of welds. Even if you have a custom gauge made as Woolf has done, it is often so small it is difficult to make any sort of determination. This makes the inspection of these welds very slow and difficult. In addition, it is difficult to obtain actual readings when doing dimensional inspection reports.

Currently, most gauges that are used to measure welds are attribute by nature, which means that they only make a comparison to a template rather than an actual reading. There are some gauges that will provide a measurement against an imprinted scale to allow an estimation of the size, but these gauges are not calibrated and do not offer a variable reading that is traceable to the National Institute of Standards and Technology (NIST). As a com-

pany that is registered to the quality management systems of ISO9001:2000 and AS9100B, Woolf must meet the requirement that all measurement systems used to accept product be traceable to NIST.

Woolf Aircraft needed a tool that could provide an actual “variable” reading over a range of fillet weld sizes and be traceable to NIST. Officials there believed that most industries have that same need; therefore, the company developed an inspection tool/system that it can use to measure a leg length, as well as the actual weld throat. With these two known measurements, this information can then be used to determine the actual size as well as the convexity/concavity of a specific fillet weld.

## Caliper Weld Inspection Method

Workers at Woolf Aircraft made an adapter that mounts to a digital caliper that has been designed to seat directly into the corner of a 90-deg angle — Fig. 1. The

digital scale is then set to “zero” and then used in the same manner against the fillet weld. The reading on the caliper gives the distance from the “root” (corner) of the weld to the face of the weld, which is the weld throat — Fig. 2.

When touching the face of the weld, the digital scale will reveal the actual distance from the root of the weld to the face, which is the actual weld throat — Fig. 3.

Using a similar technique to measure the length of a leg, as shown in Fig. 4, the individual leg lengths will be determined. A traditional caliper is used in this measurement.

Now that the two variables are known — leg length and actual throat length — many determinations can be made regarding the weld size. Since the example shown in Fig. 4 is a 45-deg right triangle, then both legs should be equal length — Fig. 5.

## Applicable Industries

Officials at Woolf Aircraft believe this measurement system can be useful to a

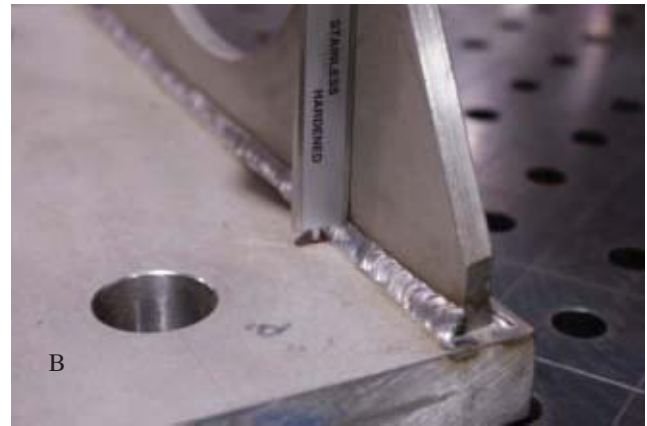


Fig. 4 — A — A similar technique, using a traditional caliper, is used to measure the leg length; B — a close-up of the leg measurement.

wide variety of industries besides aerospace, such as military, automotive, commercial, power generation, etc., and that the entire welding community and every industry it serves is in need of the ability to make variable measurements.

This article provides a basic overview of how the system works. You may have questions as to how useful it is if your fillet weld is not a 90-deg angle, or if it can be used to check for misalignment or to measure weld reinforcement on tube and pipe groove joints. Options are available to handle those situations that are not covered in this discussion. Contact the author for additional information.

## Conclusions

This system allows for variable measurement of the weld legs, actual throat length, calculation of the theoretical throat length, convexity, and concavity. Also, by using calibrated digital instruments during the inspection, the inspection system is then traceable to the National Institute of Standards and Technology, which satisfies the expectations of

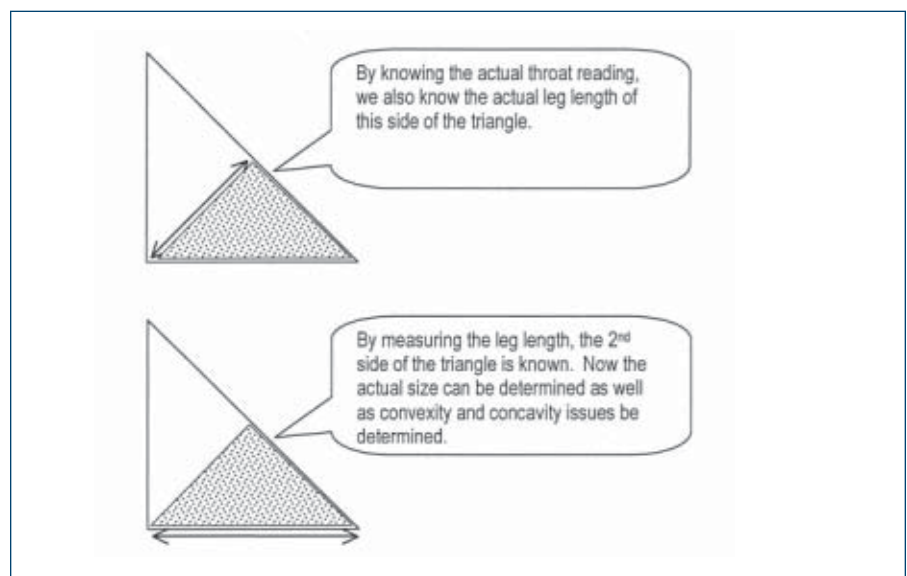


Fig. 5 — Once the two variables are known, other factors are known about the weld size.

quality management systems such as ISO 9001:2000 and SAE AS9100B. These stan-

dards require that anything used to accept product dimensions must be calibrated.

Using this system helps Woolf Aircraft meet the measurement expectations of the various quality system requirements and provide variable measurements without the need for cutting and etching in order to obtain these measurements. ♦

## Acknowledgments

The author would like to thank the following individuals at Woolf Aircraft for their support in this project and with the preparation of this article: Adam Woolf; Al Swistara, vice president, Engineering; Doug Kochan, toolmaker; Dane Borowski, tube fabricator; and Adam Pavilanis, weld engineer intern.

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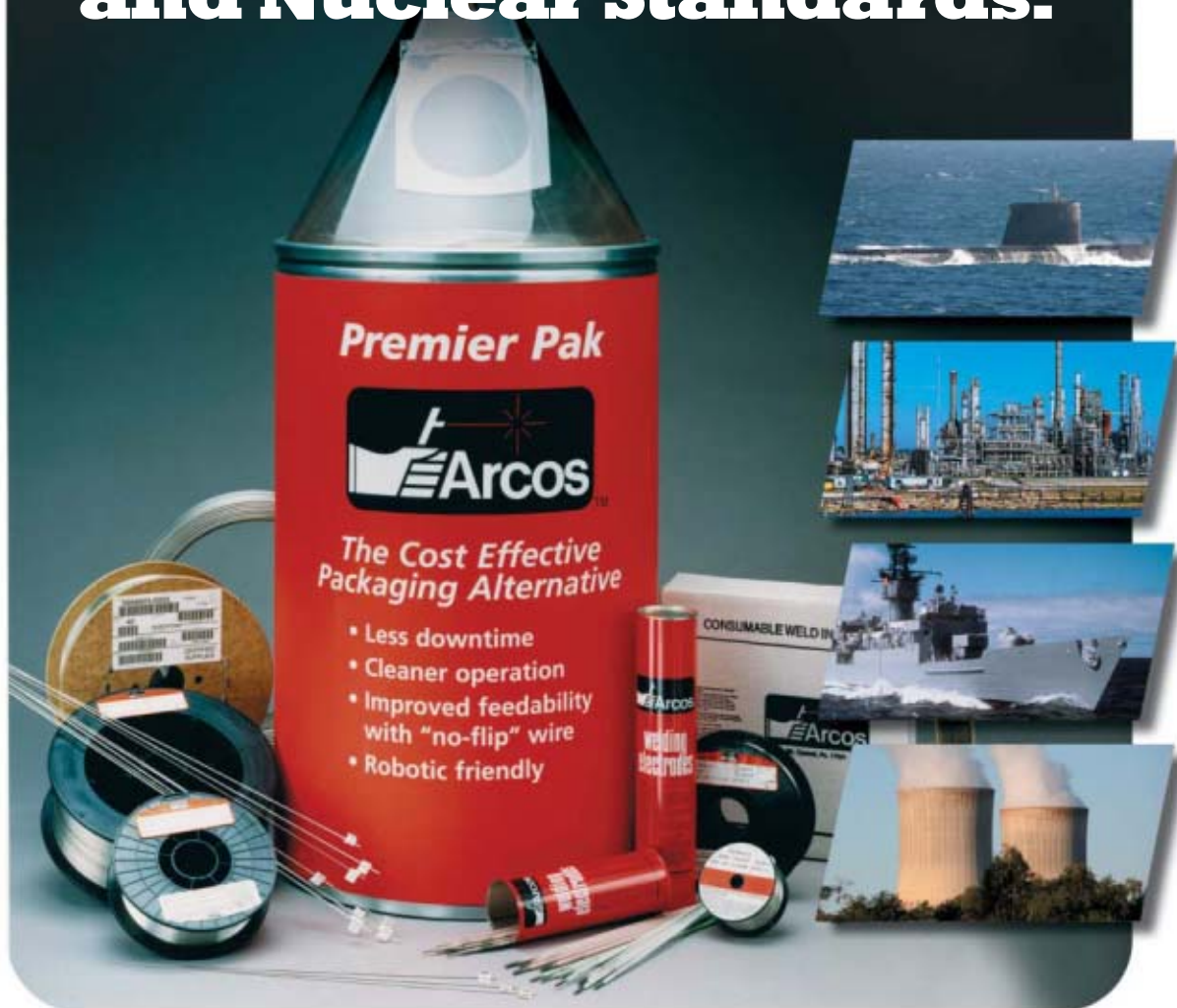
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# Optimizing Crash Resistance of Welded Aluminum Structures

*Combining precipitation, yield strength, work-hardening, and mechanical models has proved useful to optimize the load-bearing capacity of welded automotive components made of age-hardening Al-Mg-Si alloys*

BY O. R. MYHR, Ø. GRONG, O. G. LADEMO, AND T. TRYLAND

Welded components made of age-hardening aluminum alloys are to an increasing extent used within the transport and automotive industries because of their high strength, good formability, low density, and good resistance to general corrosion. However, in certain cases, the application of such alloys is restricted by a low heat-affected zone (HAZ) strength level due to softening reactions occurring during welding, which tend to reduce the overall load-bearing capacity of the component. This represents a major challenge in engineering design.

The manufacturing of welded automotive components from age-hardening aluminum alloys involves a series of thermal and mechanical operations. These alloys have a strong memory of the past process steps due to interactions between different types of particles that form at various temperatures (Refs. 1–3). In particular, the different heat treatment and welding operations that are used toward the end of the process chain (Fig. 1) have a large influence on the resulting structural performance. However, as illustrated in Fig. 2, the selection and optimization of alloy composition, temper, and process conditions cannot readily be based on experimental testing, since the number of possible combinations is too large. Consequently, numerical design tools are desired.

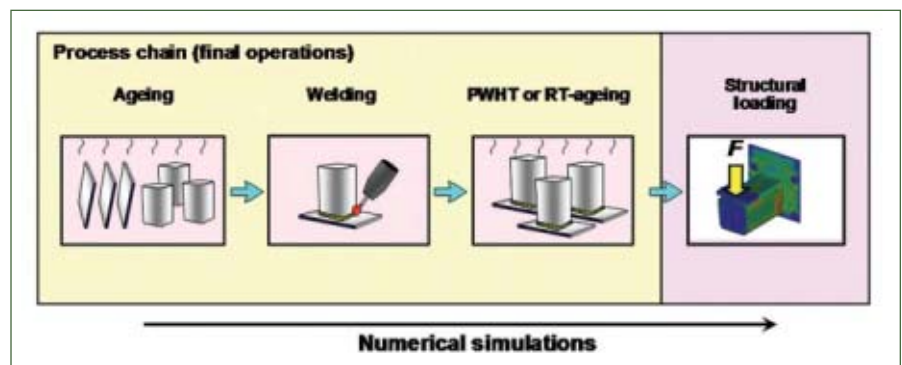


Fig. 1 — Drawings illustrating the different heat treatment and welding operations used in manufacturing crash components made of age-hardening aluminum alloys.

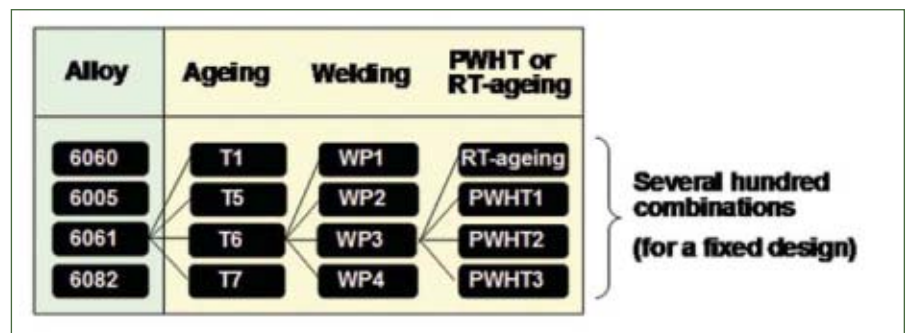


Fig. 2 — Diagram illustrating the number of variables involved in the fabrication of welded crash components made of age-hardening aluminum alloys. The designations T1–T7, WP1–WP4, and PWHT1–PWHT3, refer to different temper, welding, and heat-treatment conditions, respectively.

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Realistic prediction of the mechanical performance of welded components and structures calls for the use of a rather sophisticated numerical simulation technique. In this article a new multiscale modeling approach is presented, where advanced physical-based models for the microstructure and strength evolution during heat treatment and welding of Al-Mg-Si alloys are combined with nonlinear finite element modeling. This multipurpose simulation tool is versatile and applicable for a range of different problems, including the optimization of the crash performance of welded automotive components.

## Case Studies

### Experimental Program

The component consists of a two-chamber extruded profile with 2.2-mm-thick walls and an 8-mm-thick flat extrusion as shown in Fig. 3A. The chemical composition of the AA6060 base metal is given in Table 1. The parts were age-hardened at 185°C before welding and subsequently stored at room temperature for about four weeks before the final structural testing. The tube was welded against the flat extrusion using fully automatic gas metal arc welding (GMAW), four straight weld segments, a welding speed of 14.3 mm/s, and a net arc power of 3.6 kW (assuming an arc efficiency of 0.8). A series of hardness measurements was carried out across the HAZ after about four weeks of full room-temperature aging to check the accuracy of the yield strength model. Finally, the component was subjected to cantilever loading using the setup shown in Fig. 3B, while recording the applied force and the corresponding crosshead displacement.

### Coupling of Microstructure and Mechanical Models

Figure 4 shows the coupling between the different models that are in play, i.e., the weld simulation code *WELDSIM*<sup>™</sup>, the microstructure-based NaMo model, and the mechanical LS-DYNA model. Because their theoretical basis has been documented elsewhere, just a brief description of each submodel is given here.

The thermal module of *WELDSIM*<sup>™</sup> (Refs. 5–8) was used to predict the temperature field resulting from the welding as illustrated by the peak temperature distribution in Fig. 5A. As shown in Fig. 4, the calculated thermal history is input to the microstructure model named NaMo (Nano Structure Module) (Refs. 1–4). This contains a precipitation model that calculates the evolution of the particle size distribution with time, and can be used to

Table 1 — Chemical Composition of Aluminum Alloys Referred to in Text (in wt.-%)

| Alloy  | Si   | Mg   | Fe   | Mn   | Cu   |
|--------|------|------|------|------|------|
| AA6060 | 0.45 | 0.44 | 0.21 | 0.04 | 0.02 |
| AA6082 | 1.04 | 0.67 | 0.20 | 0.54 | 0.03 |

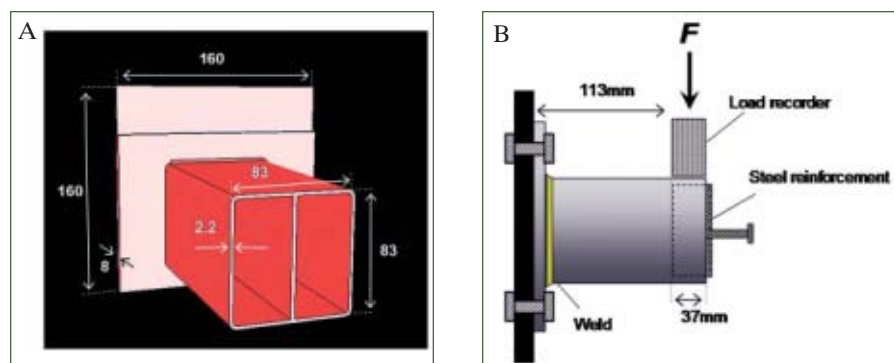


Fig. 3 — Details of the component design and testing conditions. A — Geometry and dimensions of a crash-box; B — experimental setup used for measuring the resulting load-displacement response.

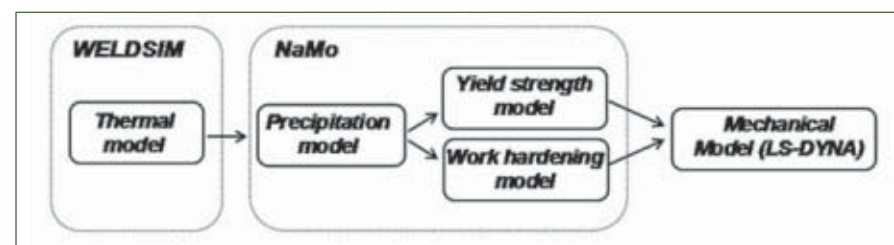


Fig. 4 — Diagram illustrating the coupling between the different models used in the numerical simulations.

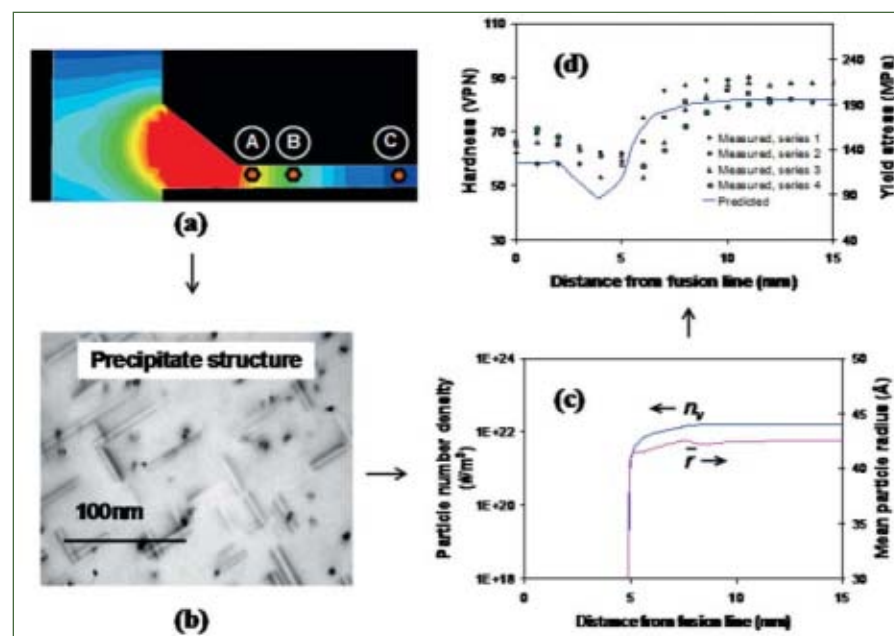


Fig. 5 — Typical outputs from the numerical simulations. A — Predicted peak temperature distribution during welding; B — transmission electron microscope image of the precipitate structure within a specific region of the HAZ; C — predicted variation in particle number density and mean particle radius across the HAZ; D — comparison between predicted and measured hardness profiles across the HAZ.

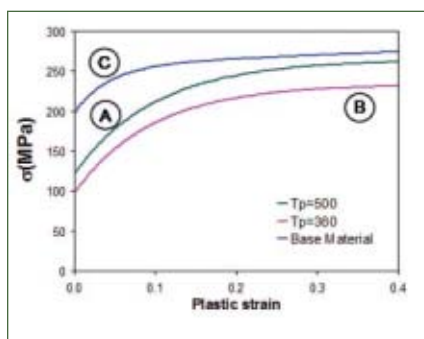


Fig. 6 — Calculated stress-strain curves for the three HAZ positions, A, B, and C, defined in Fig. 5A.

quantify the characteristics of the precipitate structure shown in Fig. 5B. Following complete aging and welding, the precipitate structure varies significantly across the HAZ, as shown in Fig. 5C, which presents plots of the predicted particle number density  $n$  and the mean particle radius  $\bar{r}$  as a function of the distance from the weld interface. Rather complex dislocation-based models are then employed to convert the computed precipitate parameters into an equivalent room-temperature yield strength (or hardness) (Refs. 2–4). Figure 5D shows a comparison between predicted and measured HAZ hardness profiles after complete natural aging, using the yield strength model in NaMo.

The work-hardening behavior of the different peak-temperature regions of the HAZ is then calculated by employing the work-hardening model in NaMo described in Ref. 4, based on inputs from the precipitation model. By combining the results from the yield strength and the work-hardening models, the complete stress-strain curves in any position of the HAZ can be estimated. Examples of calculated stress-strain curves are given in Fig. 6 for the three specific HAZ positions defined in Fig. 5A.

Finally, the commercial FE-code LS-DYNA (Ref. 10) was used to simulate the load-bearing capacity of the welded components using a shell-based modeling approach. This was done by transferring the predicted stress-strain curves for each position of the solution domain to the mechanical model. LS-DYNA is a general-purpose nonlinear finite element code for analyzing large deformation responses of inelastic solids and structures with both implicit and explicit solution capabilities. The full constitutive model includes isotropic linear elasticity, nonlinear isotropic strain hardening, a state-of-the-art anisotropic yield criterion, and the associated flow rule. Further details of the constitutive model, its numerical implementation in LS-DYNA, and previous experience on the use of shell element analyses for the problem at hand are given in Refs. 11–14.

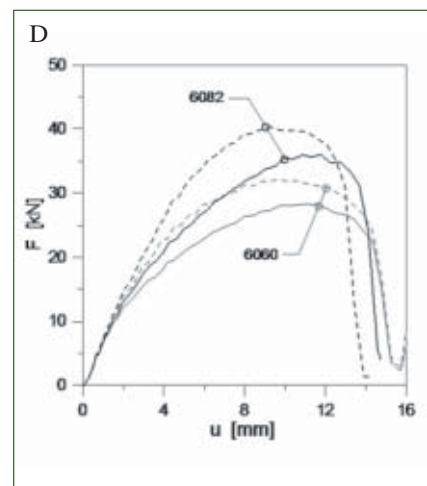
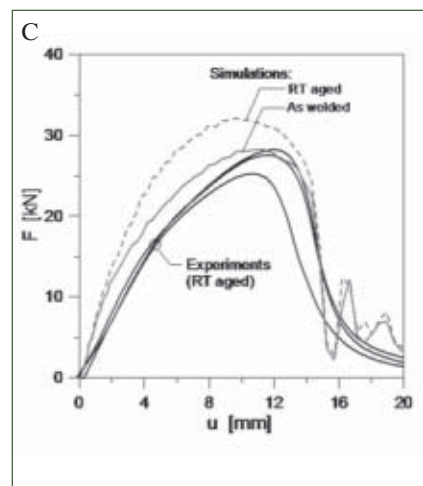
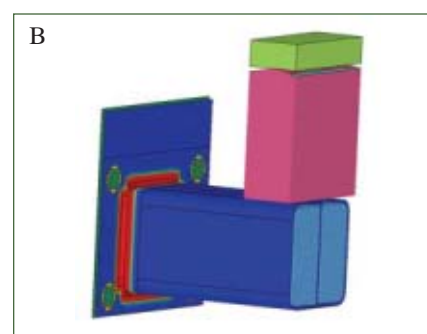


Fig. 7 — Summary of results from the experimental and numerical case study. A — Photograph of the welded component after testing; B — shell model of the component demonstrating the spatial variation of the initial yield stress; C — comparison of predicted and measured load-displacement curves for AA6060; D — summary of predicted load-displacement curves for AA6060 and AA6082.

### Simulation of the Structural Performance

Figure 7A is a photograph of the welded crash component following testing, revealing that failure occurred in the HAZ close to the weld interface. The FE model shown in Fig. 7B consists of shell elements having a characteristic element size of 0.7 mm. Such small elements are required to capture the strong spatial variation in material properties and the corresponding severe strain localization in the HAZ. In addition to simulations of the actual case, i.e., welding of the AA6060 in the initially peak aged (T6) condition followed by complete room-temperature aging, another simulation was performed where testing was assumed to take place immediately after welding.

Figure 7C shows a comparison of predicted and measured load-displacement curves. The simulation of the actual case (i.e., complete room-temperature aging following welding) tend to overestimate the ultimate strength of the component, while the overall agreement is better if the comparison is done on the basis of the simulated load-displacement curves representing the as-welded condition.

The preliminary results obtained for

the AA6060 alloy are encouraging and provide a motivation for extending this modeling concept to other alloy combinations and process routes as well. This is done in Fig. 7D. In the figure, simulation results for a medium-strength AA6082 composition, as shown in Table 1, are compared to corresponding results for AA6060 from Fig. 7C. It follows that a change in the alloy composition from a soft AA6060 to a medium-strength AA6082 alloy results in a significant increase in the predicted ultimate load. These simulation results are interesting, both from an academic and practical point of view, because they illustrate in a quantitative manner how the present modeling approach can be used to optimize the load-bearing capacity and crash performance of welded aluminum structural components simply by manipulating the alloy composition and the applied heat-treatment schedules.

### Concluding Remarks

A new multiscale modeling approach, involving the use of combined precipitation, yield strength, work-hardening, and mechanical models, has been devised that proved useful to optimize the load-bearing

ing capacity of welded crash components made of age-hardening Al-Mg-Si alloys. The main parameters that influence the structural performance are, in addition to geometry and boundary conditions, the following: 1) alloy composition; 2) initial base plate temper condition; 3) applied heat input during welding; and 4) subsequent postweld heat-treatment schedule — all being fully accounted for in the numerical simulations. ♦

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# Real-Time Crack Detection in Aerospace Structures

*Component and tooling damage is detected before failure during low-cycle fatigue testing*

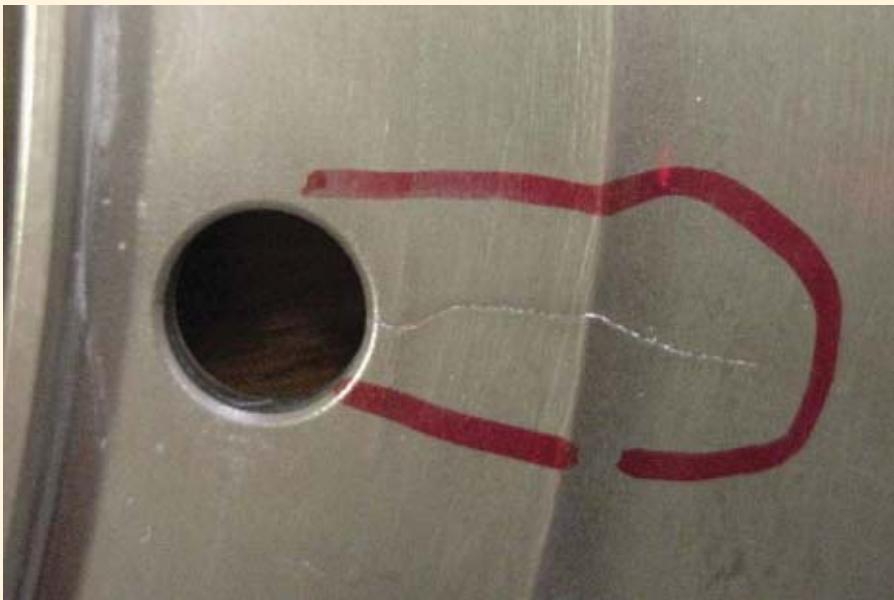


Fig. 1 — Example of a fatigue crack detected before the component failed. The test automatically stopped once the crack was detected.

The development of jet engines and other high-speed machinery requires extensive testing to establish the integrity and useful life of high-speed rotating components. A fundamental evaluation technique for turbine engine rotors is to empirically test and validate the number of cycles the rotors can withstand, either to a predetermined number or all the way to failure. This type of test is typically referred to as a low-cycle fatigue (LCF) test.

During a standard LCF test, an engine rotor component is cycled up and down in speed in a spin rig in order to validate a prescribed number of cycles. Traditionally, these LCF tests end in either successful completion of the full cycle count, or in a complete rotor burst caused by a fatigue-induced crack in the part. This often

results in loss of the component and can also cause damage to tooling and other test facility equipment.

## Preventing Component Destruction

In order to avoid premature component burst, either from crack formation in the component itself or the tooling (the arbor, or spindle, that holds the component in place), Test Devices, Inc. (TDI) developed a patented application known as the real-time crack detection system (RT-CDS), for detecting the initiation of cracks during LCF tests.

The crack detection system automatically detects fatigue-induced cracks during an LCF test with 80 to 90% accuracy

— Fig. 1. When the beginning of a crack is detected, the system automatically stops the LCF test before component failure. This exclusive crack detection interlock capability allows an attended or unattended LCF test to be halted when components or tooling develop cracks — before a damaging rotor burst event.

Conventional LCF procedures require that the testing is stopped periodically in order to inspect for cracks in the component and tooling. This involves removing the test article from the spin rig frequently, thereby greatly extending the cost and schedule of the testing program. The real-time crack detection system can reduce the number of required inspections, thereby enabling more cycles between inspections.

## Real-Time Crack Detection in a Critical Jet Engine Application

A major aerospace jet engine original equipment manufacturer (OEM) recently ran a series of low-cycle fatigue tests on a critical component, which involved the testing of multiple sets of rotors. The company contracted Test Devices, Inc., and another vendor to perform testing on two rotor sets each. The RT-CDS was used for testing and monitoring by TDI, while the other vendor used a conventional LCF testing procedure.

The two companies began their testing at the same time. Early in the testing procedure, one of the rotors at the alternate vendor was destroyed at approximately 80% of its expected life because of a crack rupture in the spin tooling hardware. The spin test equipment incurred substantial damage.

During TDI's testing, a signature in-

Information supplied by Test Devices, Inc., Hudson, Mass., [www.testdevices.com](http://www.testdevices.com); contact: David Woodford, (978) 562-4923.

dicative of a crack was detected, and the crack detection system automatically stopped the test. The customer then performed a component ultrasonic inspection and found two cracks. Early detection by the RT-CDS prevented the destruction of the part, tooling, and equipment. If the cracks had not been discovered, the test article would have been lost without preserving the initiation site and crack face (which are critical for follow-up metallurgical analysis).

A second rotor failed at the alternate vendor after approximately 70% of its expected life as a result of an undetected crack in the OEM tooling. The RT-CDS detected and automatically stopped LCF testing of a second rotor when a crack occurred in the tooling.

The two rotors that were tested using conventional methods were destroyed as a result of fatigue-induced cracks in the tooling. As a result, the engine manufacturer lost two valuable components that could have been saved.

The RT-CDS has also been used during a low-cycle fatigue testing program for evaluating flaw tolerances in the weld plane between air foils and the rotors.

Specifically, the test program was designed to evaluate the fatigue behavior of a blade replacement weld process. Crack growth and propagation of flaws in the weld plane were monitored.

### Benefits of the New System

By detecting cracks in the rotors before they failed, cost savings were substantial and damage to the rotors under test, as well as the test equipment, were prevented. Time can be saved by reducing the number of periodic inspections, the number of interruptions, and avoiding time lost in replacing damaged components and equipment.

The system can also provide initiation and crack growth analysis data that give customers the ability to determine the location, mode, and cause of a crack. The knowledge base of the fatigue life of spinning rotors and other application-critical components can be increased.

The system can be used on a variety of equipment including jet engine rotors, turbochargers, rocket pumps, electric motors, gas turbine rotors, and compressor rotors. ♦



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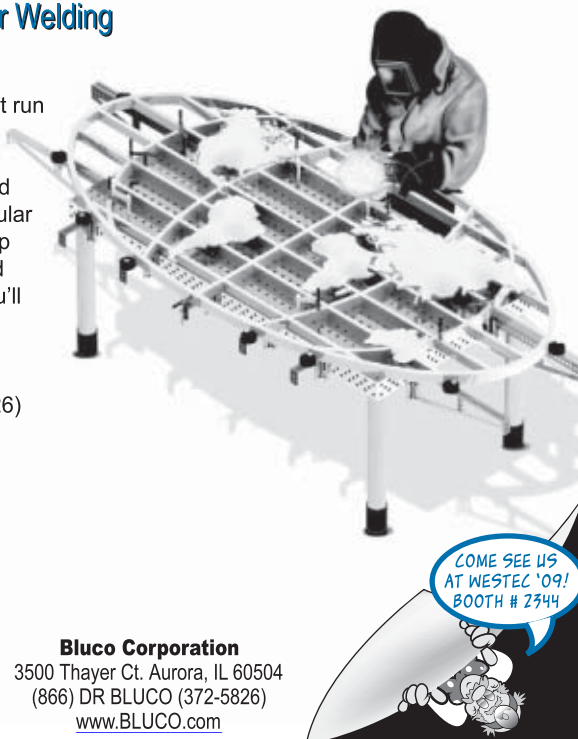
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 Noon – 6:00 PM  
 Lunch: Noon – 1:00 PM  
 Networking Reception: 6:00 PM – 7:00 PM  
  
**Tuesday, April 28**  
 9:30 AM – 3:00 PM  
 Lunch: Noon – 1:00 PM  
  
**Wednesday, April 29**  
 9:30 AM – 3:00 PM  
 Lunch: Noon – 1:00 p.m.

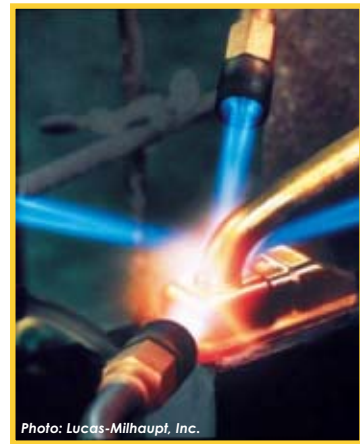


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Photo: Marty Alan McGill



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 employee 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 July 1, 2009. The committee looks forward to receiving these nominations for 2010 consideration.

Sincerely,

Alfred F. Fleury  
Chair, Counselor Selection Committee



## American Welding Society

### 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.

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- 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, SkillsUSA, 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 July 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

Maximum of 10 Counselors selected each year.

Return completed Counselor nomination package to:

Wendy S. Reeve  
American Welding Society  
Senior Manager  
Award Programs and Administrative Support  
550 N.W. LeJeune Road  
Miami, FL 33126

Telephone: 800-443-9353, extension 293

SUBMISSION DEADLINE: July 1, 2009



## American Welding Society

### Nomination of AWS Counselor

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**WELDING**

**WORKBOOK**

**Datasheet 303**

# Fusion Welding for Aerospace Applications

Due to the criticality of many aerospace weldments, the identification, storage, and use of all welding consumables (including wires, rods, inserts, fluxes, gases, etc.) require proper controls. It is important to store fluxes and covered electrodes in a clean, dry environment or in sealed containers. To prevent moisture accumulation, employ heating as necessary. Low-hydrogen shielded metal arc welding (SMAW) and flux cored arc welding (FCAW) electrodes should be handled and stored according to the manufacturer's recommendations or according to AWS A5.1, A5.5, A5.20, or A5.29, as appropriate. Proper identification and storage of consumables will have a positive contribution to the quality of the product.

Filler materials, when used in the welding process, must be specified by the Engineering Authority. Tables 1–3 list the filler materials normally used in welding aerospace base metals. Unless the Engineering Authority allows the use of the table in the

selection of fill material, it is only to be used as a guide by the fabricator. The fabricator is responsible for verifying the correct application of any filler material through the Welding Procedure Specification/Procedure Qualification Record cycle.

Welding fluxes are to be labeled and segregated by type and/or by their particular application. To prevent moisture pickup, store fluxes in sealed containers or keep them in a suitably clean and dry environment. Clean, unfused flux may be reused after reconditioning according to the manufacturer's recommendations.

Consumables used in welding are to be identified using an established standard or specification or by a standard specified in the procurement specification. If the identification marking is destroyed or missing, don't use the consumable. When specified on the engineering drawing or a contract document, traceability of the consumables must be maintained throughout the welding process.

**Table 1 — Filler Metal for Welding Aluminum Alloys Using GMAW, GTAW, and PAW Processes(a)**

| Base Metal | Filler Material Specification | Filler Material |
|------------|-------------------------------|-----------------|
| 1100       | ER1100 or ER4043              | AWS A5.10       |
| 3003       | ER1100 or ER4043              | AWS A5.10       |
| 2219       | ER2319                        | AMS 4191 or AWS |
| A5.10      |                               |                 |
| 5052       | ER5356 or ER4043              | AWS A5.10       |
| 6013       | ER4043                        | AWS A5.10       |
| 6061       | ER4043 or ER5356              | AWS A5.10       |

(a) Refer to C5.12 in the Commentary and 5.12 in the main body of the AWS D17.1 specification.

**Table 2 — Filler Metal for Welding Titanium Alloys Using GMAW, GTAW, and PAW Processes(a)**

| Base Metal                 | Filler Material             | Filler Material Specification |
|----------------------------|-----------------------------|-------------------------------|
| Commercially Pure Titanium | CP<br>ERTi-4                | AMS 4951<br>AWS A5.16         |
| 3Al-2.5V Ti                | ERTi-3Al-2.5V               | AWS A5.16                     |
| 5Al-2.5Sn-Ti               | 5Al-2.5Sn<br>ERTi-5Al-2.5Sn | AMS 4953<br>AWS A5.16         |
| 6Al-4V or<br>6Al-4VELI     | 6-4<br>ERTi-6Al-4V          | AMS 4956<br>AWS A5.16         |

(a) Refer to C5.12 in the Commentary and 5.12 in the main body of the AWS D17.1 specification.

**Table 3 — Filler Metal for Welding Corrosion-Resistant Steels and Heat-Resistant Alloys Using GMAW, GTAW, and PAW Processes(a)**

| Base Metal    | Filler Material                             | Filler Material Specification        |
|---------------|---------------------------------------------|--------------------------------------|
| 304L and 316L | ER308L                                      | AWS A5.9                             |
| 321 and 347   | ER321 or ER347                              | AWS A5.9                             |
| A286          | A286                                        | AMS 5804 or<br>AMS 5805              |
| 21-6-9        | ER219                                       | AWS A5.9                             |
| PH 13-8Mo     | WPH 13-8Mo ELC                              | AMS 5840                             |
| PH 15-7Mo     | WPH 15-7Mo-VM                               | AMS 5812                             |
| PH 15-5       | 15-5PH or ER630                             | AMS 5826 or<br>AWS A5.9              |
| PH 17-4       | WPH 17-4 or<br>ER630                        | AMS 5825 or<br>AWS A5.9              |
| PH 17-7       | PH17-7<br>WPH 15-7Mo-VM                     | AMS 5824<br>AMS 5812                 |
| Inconel® 600  | ERNiCrFe-5                                  | AWS 5.14                             |
| Inconel® 625  | Inconel® 625<br>Hastelloy® W or<br>ERNiMo-3 | AMS 5837<br>AMS 5786 or<br>AWS A5.14 |
| Inconel® 718  | Inconel® 718                                | AMS 5832                             |
| Inconel® X750 | ERNiCrFe-7                                  | AWS A5.14                            |

(a) Refer to C5.12 in the Commentary and 5.12 in the main body of the AWS D17.1 specification.

Excerpted from AWS D17.1: 2001, *Specification for Fusion Welding for Aerospace Applications*.

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## COMING EVENTS

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

**Indian Institute of Welding Nat'l Welding Seminar and Weld India Expo 2009.** Feb. 5-7, Bombay Exhibition Center, Mumbai, India. Visit [www.iiwindia.com/events/current\\_events/weld\\_india\\_expo\\_2009.htm](http://www.iiwindia.com/events/current_events/weld_india_expo_2009.htm).

**PACE 2009, The Power of Paint and Coatings.** Feb. 15-18, New Orleans Convention Center, New Orleans, La. Visit [www.pace2009.com](http://www.pace2009.com).

**HOUSTEX.** Feb. 24-26, George R. Brown Convention Center, Houston, Tex. Contact Society of Mfg. Engineers, (800) 733-4763, [www.sme.org/houstex](http://www.sme.org/houstex).

♦ **Joining Dissimilar Metals Conf.** March 3, 4, Orlando, Fla. Contact American Welding Society, (800/305) 443-9353, ext. 455; visit [www.aws.org](http://www.aws.org).

♦ **Laser Additive Manufacturing Workshop.** March 3, 4, Holiday Inn, Riverwalk, San Antonio, Tex. As a cooperating society, AWS members will receive discounted registration fees. Contact Laser Institute of America, [www.laserinstitute.org](http://www.laserinstitute.org).

**Lean for the Supply Chain.** March 3-5, Crown Plaza Hotel, San Jose, Calif. Contact Society of Mfg. Engineers, (800) 733-4763, [www.sme.org](http://www.sme.org).

♦ **GAWDA, Gases and Welding Distributors Assn., Spring Management Conf.** March 22-24, Sheraton Chicago Hotel & Towers, Chicago, Ill. Visit [www.gawda.org](http://www.gawda.org).

**ILSC® Int'l Laser Safety Conf.** March 23-26, John Ascuaga's Nugget Hotel, Reno, Nev. Sponsored by Laser Institute of America, [www.laserinstitute.org/conferences/ilsc](http://www.laserinstitute.org/conferences/ilsc); or call (407) 380-1553.

**Spring Robot Safety Conf.** March 23-25, Knoxville Marriott, Knoxville, Tenn. Contact Robotic Industries Assn. at [ria@informz.net](mailto:ria@informz.net) or [ria@robotics.org](mailto:ria@robotics.org).

**ABB Automation & Power World 2009.** March 24-26, Orlando World Center Marriott, Orlando, Fla. Visit [www.abb.com/a&pworld](http://www.abb.com/a&pworld).

**Heat Treating of Light Alloys.** March 25, 26, Doubletree Hotel, Anaheim, Calif. Visit [www.asminternational.org](http://www.asminternational.org).

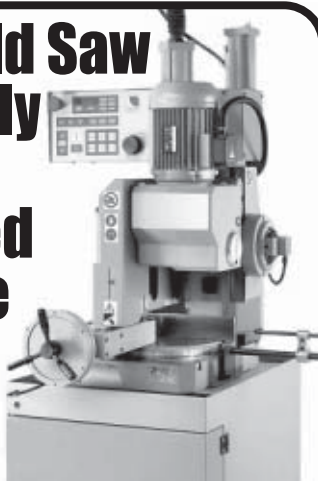
**WESTEC.** March 30-April 2, Los Angeles Convention Center, Los Angeles, Calif. Contact Society of Mfg. Engineers, (800) 733-4763; or visit [www.sme.org/westec](http://www.sme.org/westec).

**MicroMfg. and NanoMfg. Conf. & Exhibits.** March 31-April 1, Sheraton Bloomington Hotel, Minneapolis, Minn. Contact Society of Mfg. Engineers, (800) 733-4763, [www.sme.org/micro](http://www.sme.org/micro), [www.sme.org/nano](http://www.sme.org/nano).

**North American Steel Construction Conf. and AISC Steel Construction Expo.** April 1-4, Phoenix, Ariz. Visit [www.aisc.org](http://www.aisc.org).

**2nd Annual Global Marine Renewable Energy Conf.** April 15, 16, The Carnegie Institution for Science, Washington, D.C. Contacts (877) 463-3846; [info@globalmarinerenewable.com](mailto:info@globalmarinerenewable.com).

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### Visual Inspection

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Apr 27-30 • Jun 22-25 • Aug 17-20 • Oct 12-15

### Arc Welding Inspection & Quality Control

Mar 16-20 • May 4-8 • Jul 27-31 • Oct 19-23

### Weldability of Metals, Ferrous & Nonferrous

Feb 23-27 • Mar 23-27 • Apr 20-24 • May 18-22

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For info go to [www.aws.org/ad-index](http://www.aws.org/ad-index)

**The Aluminum Assn. Spring Meeting.** April 20–22, Omni La Mansion del Rio, San Antonio, Tex. Visit [www.aluminum.org](http://www.aluminum.org).

♦ **GAWDA Spring Management Conf. 2.** April 21–24, Asheville, N.C. Sponsored by Gases and Welding Distributors Assn. Visit [www.gawda.org](http://www.gawda.org).

♦ **IBSC, 4th Int'l Brazing and Soldering Conf.** April 26–29, Hilton Hotel in the Walt Disney World Resort, Orlando, Fla. Cosponsored by AWS and ASM International. Contact American Welding Society, (800/305) 443-9353, ext. 229; visit [www.aws.org](http://www.aws.org).

**JOM-15, 15th Int'l Conf. on the Joining of Materials, and 6th Int'l Conf. on Education in Welding.** May 3–6, Helsingør, Denmark. Contact JOM Institute, [jom\\_aws@post10.tele.dk](mailto:jom_aws@post10.tele.dk).

**AISTech 2009, The Iron & Steel Technology Conf. and Expo and Asia-Pacific Partnership Technology Showcase 2009.** May 4–7, St. Louis, Mo. Contact Association for Iron & Steel Technology [www.iss.org](http://www.iss.org).

**Offshore Technology Conf.** May 4–7, Reliant Center, Houston, Tex. Visit [www.otcnet.org/2009](http://www.otcnet.org/2009).

♦ **12th Aluminum Welding Conf.** May 5, 6, Toronto, Ont., Canada. Contact American Welding Society, (800/305) 443-9353, ext. 229; visit [www.aws.org](http://www.aws.org).

**RAPID 2009.** May 12–14, Renaissance Schaumburg Convention Center, Schaumburg, Ill. Contact Society of Mfg. Engineers, (800) 733-4763, [www.sme.org/rapid](http://www.sme.org/rapid).

**Advanced Manuf. Expo. and Plant Maintenance & Design Engi-**

**neering Show.** May 19–21, Place Bonaventure, Montreal, Que., Canada. Contact Society of Mfg. Engineers, (800) 733-4763, [www.sme.org](http://www.sme.org).

**EASTEC.** May 19–21, Eastern States Exposition Grounds, W. Springfield, Mass. Contact Society of Mfg. Engineers, (800) 733-4763; or visit [www.sme.org/eastec](http://www.sme.org/eastec).

♦ **AWS/Weldmex.** June 2–4, Monterrey, Mexico. Contact American Welding Society, (800/305) 443-9353, ext. 229; or visit [www.aws.org](http://www.aws.org).

**Beijing-Essen Welding & Cutting Fair.** June 2–5, Shanghai, China. Visit [www.beijing-essen-welding.de](http://www.beijing-essen-welding.de).

**AeroMat® 2009 Conf. and Expo.** June 7–11, Dayton Convention Center, Dayton, Ohio. Call ASM customer service (800) 336-5152, ext. 0; e-mail [customerservice@asminternational.org](mailto:customerservice@asminternational.org); or visit <http://asmcommunity.asminternational.org/content/Events/aeromat09/>.

♦ **Weld Cracking VII 'The Heat-Affected Zone' Conf.** June 9, 10, Columbus, Ohio. Contact American Welding Society, (800/305) 443-9353, ext. 229; or visit [www.aws.org](http://www.aws.org).

**First Int'l Conf. on Welding Technologies.** June 11–13, Gazi University, Ankara, Turkey. Visit [www.icwet09.org](http://www.icwet09.org).

♦ **Shipbuilding Conf.** June 16, 17, New Orleans, La. Contact American Welding Society, (800/305) 443-9353, ext. 229; or visit [www.aws.org](http://www.aws.org).

**Western Manufacturing Technology Show.** June 16–18. North-

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lands Park-AgriCom, Edmonton, Alb., Canada. Contact Society of Manufacturing Engineers, (800) 733-4763; or visit [www.sme.org](http://www.sme.org).

♦ **FABTECH International & AWS Welding Show** now including **METALFORM**. Nov. 15–18, McCormick Place, Chicago, Ill. This show is the largest event in North America dedicated to showcasing the full spectrum of metal forming, fabricating, tube and pipe, welding equipment, and technology. Contact American Welding Society, (800/305) 443-9353, ext. 455; or visit [www.aws.org](http://www.aws.org).

## Educational Opportunities

**ASME Section IX Course**. Feb. 10–12, New Orleans, La.; April 6–8, Las Vegas, Nev.; June 1–3, Houston, Tex. Contact Walter J. Sperko, (336) 674-0600; [www.sperkoengineering.com](http://www.sperkoengineering.com).

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

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

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

**CWI/CWE Prep Course and Exam and NDT Inspector Training Courses**. An AWS Accredited Testing Facility. Courses held year-

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

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

**Laser Safety Training Courses**. Courses based on ANSI Z136.1, *Safe Use of Lasers*, presented in Orlando, Fla., or at customer's site. Contact Laser Institute of America, (800) 345-3737, [www.laserinstitute.org](http://www.laserinstitute.org).

**Machine Safeguarding Seminars**. Contact Rockford Systems, Inc., (800) 922-7533, [www.rockfordsystems.com](http://www.rockfordsystems.com).

**Machining and Grinding Courses**. Contact TechSolve, [www.TechSolve.org](http://www.TechSolve.org).

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

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

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# AWS Certification Schedule

## Certification Seminars, Code Clinics and Examinations

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

### Certified Welding Inspector (CWI)

| LOCATION           | SEMINAR DATES  | EXAM DATE |
|--------------------|----------------|-----------|
| Anchorage, AK      | Mar. 22-27     | Mar. 28   |
| Portland, OR       | Mar. 22-27     | Mar. 28   |
| Boston, MA         | Mar. 22-27     | Mar. 28   |
| Phoenix, AZ        | Mar. 22-27     | Mar. 28   |
| York, PA           | EXAM ONLY      | Mar. 28   |
| Miami, FL          | Mar. 29-Apr. 3 | Apr. 4    |
| Chicago, IL        | Mar. 29-Apr. 3 | Apr. 4    |
| Corpus Christi, TX | EXAM ONLY      | Apr. 11   |
| Dallas, TX         | Apr. 19-24     | Apr. 25   |
| Springfield, MO    | Apr. 19-24     | Apr. 25   |
| Baton Rouge, LA    | Apr. 19-24     | Apr. 25   |
| Long Beach, CA     | Apr. 19-24     | Apr. 25   |
| Mobile, AL         | EXAM ONLY      | Apr. 25   |
| San Francisco, CA  | Apr. 26-May 1  | May 2     |
| Portland, ME       | Apr. 26-May 1  | May 2     |
| Las Vegas, NV      | Apr. 26-May 1  | May 2     |
| Waco, TX           | EXAM ONLY      | May 2     |
| Miami, FL          | EXAM ONLY      | May 14    |
| Nashville, TN      | May 10-15      | May 16    |
| Jacksonville, FL   | May 10-15      | May 16    |
| Baltimore, MD      | May 10-15      | May 16    |
| Long Beach, CA     | EXAM ONLY      | May 30    |
| Detroit, MI        | May 31-Jun. 5  | Jun. 6    |
| Miami, FL          | May 31-Jun. 5  | Jun. 6    |
| Albuquerque, NM    | May 31-Jun. 5  | Jun. 6    |
| Spokane, WA        | Jun. 7-12      | Jun. 13   |
| Oklahoma City, OK  | Jun. 7-12      | Jun. 13   |
| Birmingham, AL     | Jun. 7-12      | Jun. 13   |
| Hartford, CT       | Jun. 14-19     | Jun. 20   |
| Pittsburgh, PA     | Jun. 14-19     | Jun. 20   |
| Beaumont, TX       | Jun. 14-19     | Jun. 20   |
| Corpus Christi, TX | EXAM ONLY      | Jun. 20   |
| Miami, FL          | EXAM ONLY      | Jul. 16   |
| Fargo, ND          | Jul. 12-17     | Jul. 18   |
| New Orleans, LA    | Jul. 12-17     | Jul. 18   |
| Sacramento, CA     | Jul. 12-17     | Jul. 18   |
| Kansas City, MO    | Jul. 12-17     | Jul. 18   |
| Phoenix, AZ        | Jul. 19-24     | Jul. 25   |
| Orlando, FL        | Jul. 19-24     | Jul. 25   |
| Milwaukee, WI      | Jul. 19-24     | Jul. 25   |
| Cleveland, OH      | Jul. 26-31     | Aug. 1    |
| Los Angeles, CA    | Jul. 26-31     | Aug. 1    |
| Louisville, KY     | Jul. 26-31     | Aug. 1    |
| Denver, CO         | Aug. 2-7       | Aug. 8    |
| Philadelphia, PA   | Aug. 2-7       | Aug. 8    |
| San Diego, CA      | Aug. 9-14      | Aug. 15   |
| Miami, FL          | Aug. 9-14      | Aug. 15   |
| Charlotte, NC      | Aug. 16-21     | Aug. 22   |
| San Antonio, TX    | Aug. 16-21     | Aug. 22   |
| Bakersfield, CA    | Aug. 16-21     | Aug. 22   |
| Rochester, NY      | EXAM ONLY      | Aug. 22   |
| Portland, ME       | Aug. 23-28     | Aug. 29   |
| Salt Lake City, UT | Aug. 23-28     | Aug. 29   |
| Seattle, WA        | Aug. 23-28     | Aug. 29   |
| Corpus Christi, TX | EXAM ONLY      | Aug. 29   |

### 9-Year Recertification Seminar for CWI/SCWI

| LOCATION       | SEMINAR DATES  | EXAM DATE |
|----------------|----------------|-----------|
| Denver, CO     | Feb. 23-28     | NO EXAM   |
| Dallas, TX     | Mar. 30-Apr. 4 | NO EXAM   |
| Sacramento, CA | May 4-9        | NO EXAM   |
| Pittsburgh, PA | Jun. 1-6       | NO EXAM   |
| San Diego, CA  | Jul. 13-18     | NO EXAM   |
| Orlando, FL    | Aug. 24-29     | NO EXAM   |
| Dallas, TX     | Oct. 5-10      | NO EXAM   |
| Miami, FL      | Nov. 30-Dec. 5 | NO EXAM   |

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

### Certified Welding Supervisor (CWS)

| LOCATION         | SEMINAR DATES   | EXAM DATE |
|------------------|-----------------|-----------|
| Houston, TX.     | Mar. 2-6        | Mar. 7    |
| Baton Rouge, LA  | Apr. 20-24      | Apr. 25   |
| Columbus, OH     | Jun. 1-5        | Jun. 6    |
| Minneapolis, MN  | Jul. 20-24      | Jul. 25   |
| Philadelphia, PA | Aug. 31- Sep. 4 | Sep. 5    |
| Tulsa, OK        | Oct. 5-9        | Oct. 10   |
| Long Beach, CA   | Nov. 30-Dec. 4  | Dec. 5    |

CWS exams are also given at all CWI exam sites.

### Certified Radiographic Interpreter (CRI)

| LOCATION         | SEMINAR DATES | EXAM DATE |
|------------------|---------------|-----------|
| Miami, FL        | Mar. 9-13     | Mar. 14   |
| Indianapolis, IN | Apr. 20-24    | Apr. 25   |
| Miami, FL        | Jun. 22-26    | Jun. 27   |
| Houston, TX      | Jul. 27-31    | Aug. 1    |
| Miami, FL        | Oct. 19-23    | Oct. 24   |

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

### Certified Welding Educator (CWE)

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

### Senior Certified Welding Inspector (SCWI)

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

### Code Clinics & Individual Prep Courses

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

### On-site Training and Examination

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

### International CWI Courses and Exams

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

For information on any of our seminars and certification programs, visit our website at [www.aws.org/certification](http://www.aws.org/certification) or contact AWS at (800/305) 443-9353, Ext. 273 for Certification and Ext. 455 for Seminars. Please apply early to save Fast Track fees. **This schedule is subject to change without notice.** Please verify the dates with the Certification Dept. and confirm your course status before making final travel plans.

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# SOCIETY NEWS

BY HOWARD M. WOODWARD

## Industry Leaders Recognized at the Show



The 2009 AWS board of directors are shown at the FABTECH International & AWS Welding Show.



The four members of the 2008 class of AWS Fellows are (from left) John N. DuPont, Jerry E. Gould, Gerald A. Knorovsky, and Harshad K. D. H. Bhadeshia, pictured below.



The AWS Counselors are (from left) David J. Nangle, Kenneth E. Richter, Richard A. Patterson, Jeffrey S. Noruk, Charles E. Daily, and Matthew J. Lucas Jr. Donald D. Rager was not present for the photo.



The 2008 classes of AWS Fellows and Counselors were inducted October 6 during the FABTECH International & AWS Welding Show held in Las Vegas, Nev.

### 2008 Class of Fellows

**Harshad Kumar Dharamshi Hansraj Bhadeshia** has been a pioneer in modeling microstructure and properties in steel weldments. His main research focus has been the theory of solid-state transformations with emphasis on the prediction of microstructure development in complex metallic alloys. In his capacity as a univer-

sity professor, he has been instrumental in the education of future researchers and leaders in the field of metallurgy. Dr. Bhadeshia has received numerous prestigious awards for his achievements. He is a Fellow of the Royal Society, a Fellow of the Royal Academy of Engineering, and a Foreign Fellow of the Indian Academy of Engineering.

**John N. DuPont** has pioneered new techniques for modeling solidification microstructure under nonequilibrium solidification using liquidus projections from ternary phase diagrams. His efforts brought a better understanding of welding to several commercially important stainless steel and nickel-based alloys. Dr. DuPont is currently a full professor at Lehigh University. He has published more than 150 papers and received numerous prestigious awards. He serves on various AWS and ASM International technical committees, the editorial boards of three scientific journals, and the IIW Committee IX on Welding of Stainless Steel and Nickel-Base Alloys. He is a coorganizer of six international ASM conferences.

**Jerry E. Gould** has been a leader in defining mechanistic interpretations of resistance and solid-state processes. His research includes the first numerical simulations for resistance spot welding to include the effect of contact resistances, and analyses to interpret current ranges, dendrite formation, and the mechanics of electrode wear. Dr. Gould coauthored the first model for prediction of thermal distributions and profiles in friction stir welding. His work has helped promote the understanding of advanced high-strength steels for automotive spot welding applications. He has taken active roles in AWS and other professional organizations, editorial boards, and review panels of a number of welding-related publications. He has been a mentor and educator through his association with The Ohio State University, teaching advanced resistance welding theory and applications.

**Gerald A. Knorovsky** has worked on the selection of materials and processes that optimize joining technology using arc and laser beam welding. Dr. Knorovsky pioneered the use of unique characterization and diagnostic methods for small-scale joining processes to achieve a better understanding of the process physics and of micro and nano joining processes. He is a recognized expert in the many joining processes used by the DOE complex for manufacturing weapons, including solid-state and fusion welding processes as well as brazing and soldering. He has published widely and received numerous awards. He has served as a member of the AWS C6 Committee on Friction Welding since the early 1990s, and served many years as a principal reviewer for the *Welding Journal*.

#### 2008 Class of Counselors

**Charles E. Daily** has served the welding industry for more than 65 years. He served in the military during World War II and the Korean War. After leaving the

military, he worked as a boilermaker welding for Pac-Car, Todds, Lockheed, and J. A. Jones, in addition to working as an inspector and repair welder for other firms. He worked for ten years with Bechtel Corp., and obtained his teaching certificate from Washington State University and taught welding inspection classes at Seattle Central College. Since 1980, Daily has served as president and CEO of Welding and Management Consultants, a business specializing in building management and inspection teams to solve welding and construction problems. He serves on the welding advisory board of Lake Washington Technical College and has served the AWS Puget Sound Section in several leadership capacities. He has personally formed and financially supported many AWS Student Chapters, encouraging young people to continue their educations while promoting the welding industry.

**Matthew J. Lucas Jr.** has specialized in brazing and welding, component design, process development, personnel training, and management. He worked for Union Carbide Corp., Babcock and Wilcox, and General Electric Co. He retired from GE in 2004 after 31 years of service. He worked in the fabrication and repair of aerospace components as a welding and brazing engineer and laboratory manager. He joined the Belcan Corp. in 2005 as senior engineer, providing on-site braze consultations. Lucas currently serves on about 20 AWS technical committees, chairs the Technical Activities Committee, and was an organizer of the AWS D17 Aerospace Welding Committee. He is a Peer Reviewer for *Welding Journal*, and is a reviewer for brazing chapters for *AWS Handbook* and ASM International publications.

**David J. Nangle**, with The Lincoln Electric Co. since 1979, has served as a technical sales representative, district manager, and as distributor sales manager responsible for the company's channels of distribution throughout North America. In 1999, he was named president of Harris Calorific, and in 2005, he additionally became president of J. W. Harris Co. These two companies merged into the Harris Products Group, a Lincoln Electric subsidiary, where he serves as president and CEO. He is vice president and group president for The Lincoln Electric Co. and president of Welding Cutting Tools and Accessories, LLC, the Cleveland-based retail division of Lincoln Electric. Nangle served on the AWS board of directors from 1992 to 1996, was a member of the Finance Committee from 1996 to 2004, and served on several committees for the Gases and Welding Distribution Association.

**Jeffrey Scott Noruk** is a research leader, welding engineer, and mentor. His areas of expertise include welding process development, robotic automation, laser-based vision for weld tracking, welding inspection, process monitoring, and control. He worked on a project that launched the first friction stir welded component for the North American automotive market. The project helped to introduce friction stir welding into a high-volume production application. Noruk has mentored graduate students at the University of Wisconsin and The Ohio State University, is a member of several advisory boards in the welding field, and has been involved with various AWS technical committees on robotic and automotive welding for more than 20 years.

**Richard Alan Patterson** has been with the Los Alamos National Laboratory for most of his career, working on the *Polaris*, *Trident*, and cruise missile systems as well as the Strategic Defense Initiatives (Star Wars). He served on the DOE Blue Ribbon Panel on Accident Survivability and Security Control of Nuclear Weapons, held key roles with the Anti-Submarine Warfare Team, the Interagency Task Force on Uranium Melting and Casting, and the DOE Interlaboratory Strategic Plan for Materials. Patterson is a distinguished welding researcher, program manager, mentor, conference organizer, and developer of specialty welding equipment for manufacturing weapons.

**Donald D. Rager**, an AWS Life Member, has served in the metals-fabrication industry for more than 37 years. He is president of Rager Consulting, Inc., Coles Point, Va., a licensed professional engineer in Virginia and Ohio, and a recognized expert in the field of joining aluminum and structural steel. He has served on the Aluminum Association Welding Committee, presented seminars, and published papers in the *Welding Journal*, and holds a U.S. patent for *Apparatus for and Method of Joining Stranded Cable*. A welding engineering graduate of The Ohio State University, Rager has contributed his skills to many AWS technical committees, chairing the D1.1 Structural Welding Committee, and serving on the Technical Activities Committee, D1C Subcommittee 3 on Fabrication (22 years), D1G Subcommittee 7 on Aluminum Structures (28 years), D1B Subcommittee 2 on Qualification (25 years), ex-officio member of the B2 Committee on Procedure and Performance Qualification, and is a past member of the Welding Handbook Committee.

**Kenneth E. Richter Sr.**, an AWS Life Member, is a past chairman of the AWS San Francisco Section, AWS Educational



Stephen Liu



Peng-Sheng Wei



William L. Harris



Dale H. Lange



Todd A. Palmer



John W. Elmer

Activities Committee, and an ASM International committee, and is a Paul Harris Fellow of Rotary International. He began his career as a high school welding instructor, then worked 28 years as a product and process development engineer for the Linde division of Union Carbide Corp. Later, at NuWeld and the MCI division of Diametrics, he made major innovative contributions to the development of welding automation. As president of Kemppi Inc., he introduced inverter power supplies for GTA and GMA welding to the U.S. market, and at Aztec International Engineering Technology he was instrumental in the design and manufacture of an automatic GTA welding system. Currently, Richter is president of Richter Industries, Inc., in Scottsdale, Ariz.

#### Comfort A. Adams Lecture Award

*Welding in the Deep Oceans:  
Conquest of the Other Frontier!*

**Stephen K. C. Liu**, an AWS Fellow and a Distinguished Member, is a professor of metallurgical and materials engineering at Colorado School of Mines where he received his PhD in metallurgical engineering. Before joining the faculty in 1987, Liu was a research metallurgist at ACESITA steel mill in Brazil and an assistant professor in industrial and manufacturing engineering at Pennsylvania State University. He has received AWS citations including the Adams Memorial Membership Award, McKay-Helm Award, Robert L. Peaslee Brazing Award, Honorary Membership Award, and Plummer Education Lecture Award. He is a Fellow of ASME and ASM International and chosen for the SAE Teetor Educational Award in 1986. Currently, Liu chairs the AWS Technical Papers Committee and is a member of the Chapter Council of ASM International.

#### Adams Memorial Membership Award

**Peng-Sheng Wei**, an AWS Fellow and a Fellow of ASME, is a full professor at the University of California at Davis where he received his PhD in mechanical engineering. He taught engineering courses at National Sun Yat-Sen Univer-

sity in Taiwan before taking his present position. His graduate students specialize in the advancement of electron beam, laser beam, and resistance welding projects. He has published more than 50 papers on welding-related topics.

#### Howard E. Adkins Memorial Instructor Membership Award

**William L. Harris**, senior welding instructor at Mississippi Gulf Coast Community College, has taught welding for more than 31 years. He established the college's AWS Student Chapter where he has served as faculty advisor for the past 28 years. An AWS member for 30 years, he currently serves as chair of the AWS Pascagoula Section, is an AWS Certified Welding Inspector (CWI), and has been a Certified Welding Educator. He received his associate degree in welding technology and master instructor certification at the college. Harris was part of the Mississippi State Department of Education welding team that developed the first model curriculum for postsecondary welding in the state. He was a consultant for the Mississippi State Research and Curriculum Unit that produced a manual used to train students in the gas tungsten arc welding process, and is involved with Web-enhanced welding education utilizing Blackboard and D2L platforms for posting assignments, welding instruction, and online exams. The students need only attend the lab for hands-on skills training. He also developed a two-day Certified Welding Inspector training seminar and a CWI training manual with instruction provided in the CD format. Harris has received several citations, including Section Educator, Section Meritorious, and CWI of the Year Awards.

**Dale H. Lange** joined the Northeast Wisconsin Technical College in Marinette, Wis., as a full-time welding instructor in 1980, and received his MS in vocational education in 1984 from the University of Wisconsin — Stout. He works with local industries setting up special courses and updating the college curriculum to meet their needs. Lange is a qualified structural and pipe welder who has worked for a variety of industrial manufacturers in the pressure vessel and ship-

building industries. He is an AWS Certified Welding Inspector and an AWS Certified Welding Educator. He is the owner of D. L. Welding Consultant Firm where he works on welding procedures, production process analysis, troubleshooting, and materials testing. His recognitions include the NWTTC Outstanding Teacher Award, NWTTC Faculty Association Teaching Award, the Marinette Area Chamber of Commerce Educator of the Year Award, and the Catholic Central High School Foundation Touchey Award.

#### Robert J. Conkling Memorial Award

**2008 SkillsUSA Championships Gold Medalist Schools**

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**Niagara Public Schools, Niagara, Wis.**  
First Place — Postsecondary  
**College of Eastern Utah, Price, Utah**

#### A. F. Davis Silver Medal Award Machine Design

*Transferring Electron Beam Welding  
Parameters Using the Enhanced Modified  
Faraday Cup*

**Todd A. Palmer** earned his PhD in materials science and engineering (1999) from Pennsylvania State University. Since 2007, he has been at the Applied Research Laboratory at Pennsylvania State University where he is a research associate and an assistant professor in the Department of Materials Science and Engineering. For the previous seven years, he was at Lawrence Livermore National Laboratory, Livermore, Calif., where he was a metallurgist with the Materials Science and Technology division in the Chemistry, Materials, and Life Sciences Directorate. He is currently chair of the C7B Subcommittee on Electron Beam Welding and Cutting, vice chair of the C7 Committee on High Energy Beam Welding and Cutting, and is a member of the Welding Research and Development Committee. He is also a member of the peer review panel for the *Welding Journal*, the editorial board for *Science and Technology of Welding and Joining*, and a key reader for *Metallurgical and Materials Transactions*. Palmer has received the A. F. Davis Silver Medal Award, Koichi



Kenneth D. Nicklas



T. M. Mustaleski Jr.



Michael H. Tosten



Scott L. West



William R. Kanne Jr.



Benjamin J. Cross

Masubuchi Award, and William Spraragen Memorial Award from the American Welding Society, the Geoffrey Belton Award of The Iron and Steel Society, and the ASM International Graduate Student Paper Competition. From June 1995 to June 1998, he received an American Welding Society Graduate Research Fellowship. He has authored more than 40 articles and reports. His current research interests involve the characterization of phase transformations in structural materials using synchrotron-based in situ X-ray diffraction techniques, and high-energy-density electron and laser beam welding and joining processes.

**John W. Elmer**, an AWS Fellow, joined Lawrence Livermore National Laboratory (LLNL) in 1982 where he is currently the group leader for materials and joining. He received his ScD in metallurgy from Massachusetts Institute of Technology in 1989. Elmer is primarily concerned with joining using electron and laser beams, arc welding, vacuum brazing, soldering, and diffusion bonding. He has authored more than 120 technical papers on topics relating to in-situ observations of welds using synchrotron radiation, materials joining, metallurgy, rapid solidification, high-energy-density beam-material interactions, electron beam diagnostics, explosive welding, and the kinetics of phase transformations. He is a Fellow of ASM International, a registered Professional Engineer, and holds ten U.S. patents. His awards include the Comfort A. Adam's Lecture, William Spraragen Award, Prof. Masubuchi-Shinsho Corporation Award, A. F. Davis Silver Medal Award, Warren F. Savage Memorial Award, and Samuel Wylie Miller Memorial Medal Award. He currently serves on many committees for AWS and ASM International, and is an adjunct professor at the Pennsylvania State University.

**Kenneth D. Nicklas** received his BS degree in metallurgical and materials engineering from the University of Pittsburgh, followed by graduate studies at the University of Tennessee. Since 1980, he has been employed at the Y-12 National Security Complex of Babcock and Wilcox

Technical Services, Y-12 LLC, where he currently is a research staff member in the Applied Technologies Division. Nicklas works in the areas of welding metallurgy and process and procedure development. He has received several DOE Awards of Excellence for quality improvements and technical achievements. He served two terms as chairman of the AWS Northeast Tennessee Section, and has been the Section's treasurer since 1994.

**Thomas M. Mustaleski Jr.**, an AWS Fellow and Life Member, received his metallurgical engineering degree from Rensselaer Polytechnic Institute with graduate work at the University of Wisconsin and the University of Tennessee. Currently, he is chairman of the American Council of the International Institute of Welding (IIW). He also chairs the IIW Select Committee on Welding for Aircraft and Aerospace Applications. He has served as the U.S. delegate to IIW Commission V, vice delegate to Commission IV, and as lead U.S. representative to SC AIR. He also serves as a representative to SC QUAL. Mustaleski served two terms as an AWS director-at-large, three terms as a vice president, AWS president (2003–2004), and various officer posts for the Milwaukee and Northeast Tennessee Sections. He recently retired from BWSXT Y12, Oak Ridge, Tenn., where he worked since 1974. There, he was involved in welding metallurgy and process and procedure development.

#### **Maintenance and Surfacing** *Repair Techniques for Fusion Reactor Applications*

**Michael H. Tosten** received his PhD in metals science and engineering from Pennsylvania State University in 1988. He has been with the Savannah River Site for more than 20 years where he is a principal scientist in the Materials Science and Technology Directorate at the Savannah River National Laboratory. Tosten has more than 27 years of experience with transmission electron microscopy. He has published papers regarding phase transformations, hydrogen and helium effects in stainless steels, phase separation and radiolysis of nuclear waste glass formula-

tions, and solid-state and fusion welding of tritium-containment materials.

**Scott L. West** is a senior fellow engineer in the Defense Programs Technology Section of the Savannah River National Laboratory, with responsibility for evaluating the service behavior of weldments used for storage and transport of nuclear materials. For 21 years, he has worked on welding process applications and equipment development, welding metallurgy, weld simulation, failure analysis of welded components, residual stresses in weldments, with responsibility for developing procedures and specifications for control of welding. Earlier, he worked for Westinghouse Electric Corp. involved in the development of tube-to-tubesheet welds for breeder reactor steam generators, working mainly with chromium-molybdenum steels. He received his PhD from The Ohio State University where his graduate work focused on monitoring and control of resistance spot welding and weldability of cast nickel-based superalloys. He has received the AWS Charles H. Jennings Memorial Award.

**William R. Kanne Jr.**, recently retired, worked 36 years at the Savannah River National Laboratory where he held leadership roles in the technology areas of solid-state resistance welding, and welding irradiated stainless steel and iridium alloys. His earlier work concerned physical metallurgy, compatibility of radioisotopes with high-temperature alloys, liquid metal corrosion, and creep and dislocation structures in intermetallic compounds. Kanne received his PhD in metallurgy from the University of Wisconsin. A Fellow of ASM International, he has filled leadership roles locally and nationally. He was a vice president and board member of the International Metallographic Society (IMS), and a member of the American Welding Society for more than 30 years where he served as a Principal Reviewer on the Technical Papers Committee. He has been awarded one patent, published 30 papers, and received best paper awards from AWS and IMS. Twice he was cited to receive the Westinghouse Signature Award of Excellence.



Stephen W. Banovic



Thomas A. Siewert



Dongcheol Kim



Tae Hyung Kim



Young Whan Park



Kieun Sung

**Benjamin J. Cross** holds a PhD in international business administration. He is a registered Professional Engineer in the state of Colorado, and he has 26 years of experience, including nuclear propulsion for the U.S. Navy, commercial nuclear power generation, nuclear weapons materials production, fission and fusion research and development, and international nuclear nonproliferation. Currently, Cross is the manager of the nuclear energy programs at Savannah River National Laboratory, where he is concerned with fission and fusion research and development, and nuclear energy-related technical support activities. He has published several technical and managerial articles in peer-reviewed journals. He is actively involved in the American Nuclear Society, and is a member of the American Society of Mechanical Engineers, Institute of Nuclear Materials Management, Fusion Power Associates, and Citizens for Nuclear Technology Awareness.

#### Structure Design

##### *Failure of Welded Floor Truss*

##### *Connections from the Exterior Wall during Collapse of the World Trade Center Towers*

**Stephen W. Banovic** received his PhD in materials science and engineering from Lehigh University in 1999. His dissertation focused on the weldability and high-temperature corrosion resistance of iron-aluminum weld overlay coatings. In 2000, he was awarded a National Research Council Postdoctoral Fellowship at National Institute of Standards and Technology (NIST) to study the influence of microstructural variables on sheet metal formability. In 2002, he became a full-time materials research scientist in the Metallurgy Division. His current research focuses on the fundamental linkages between microstructure and the mechanical response of advanced lightweight materials for automotive applications and innovative ballistic materials. His other interests include microstructural characterization, measurement of crystallographic texture of thin film and bulk materials, and failure analysis. He has published more than 40 papers. For his role in the NIST World Trade Center investi-

gation, Banovic was awarded the Department of Commerce Gold Medal for Scientific/Engineering Achievement in 2005.

**Thomas A. Siewert**, an AWS Distinguished Member and a Life Member, leads the Structural Materials Group of the Materials Reliability Div. at the National Institute of Standards and Technology (NIST), Boulder, Colo. For 25 years, his group has studied reliability issues in the national infrastructure, pipelines, and buildings, including the collapse of the World Trade Center towers. Currently, his group is studying safety issues affecting steel bridges and pipelines carrying gas, oil, ethanol, and hydrogen. After receiving his PhD from the University of Wisconsin in 1976, he worked at Alloy Rods as a researcher until joining NIST in 1984. He has chaired the American Council of the IIW, is a Peer Reviewer for *Welding Journal*, and contributed to *Welding Handbook*. In the early 1980s, he served as chairman of the AWS York-Central Pennsylvania Section, and currently is an AWS director-at-large.

#### Dalton E. Hamilton Memorial CWI of the Year Award

**Joseph Kane**, an AWS Distinguished Member active in the Long Island Section, has worked for more than 30 years in the welding industry. As an AWS Senior CWI, Kane has worked as a QC and QA inspector, and welding consultant. He has inspected bridge fabrications, gas pipelines, structural steel projects, highway and indoor signage, aircraft components, floating boom structures, and boiler installations. Most recently, Kane served as a QA inspector for the Freedom Tower in the new World Trade Center construction project in New York City. A member of the AWS Certification Committee since 1977, he is chairman of the Structural Inspector Subcommittee, and the Dalton E. Hamilton CWI of the Year Selection Subcommittee. He also serves on the Ethics Subcommittee, CWI Plus Subcommittee, Welding Engineer Subcommittee, QC-1 Subcommittee, and other certification task groups. He served on the AWS board of directors as District 2 director from 1992 to 1998.

#### W. H. Hobart Memorial Award

##### *Estimation of Weld Quality in High-Frequency Electric Resistance Welding with Image Processing*

**Dongcheol Kim** received his PhD degree in welding engineering from the Hanyang University, Seoul, Korea, in 2000. From 2000 to 2002, he worked for Research Institute of Industrial Science & Technology, Pohang, Korea, as a welding researcher for weld quality monitoring and optimization of flash butt, high-frequency resistance, and gas metal arc welding processes. From 2002 to 2007, he worked for Shipbuilding & Plant R & D Institute, Samsung Heavy Industries Company, Geoje, Korea. As a welding engineer he was involved in many welding projects including shipbuilding, construction of bridges, and offshore structures. His welding research includes the development and application of tandem electrogas welding systems and the development of automatic welding systems for the New Tacoma Narrows Bridge project. In 2007, Kim joined the Korean Institute of Industrial Technology (KITECH) as a senior researcher. His work focuses on the monitoring and the control of resistance spot, resistance lap seam, high-frequency resistance, flash butt, and arc welding processes. He has published numerous papers on welding parameter optimization and weld quality monitoring and control. Two papers have appeared in the *Welding Journal*.

**Tae Hyung Kim** received his PhD degree in mechanical engineering from Hanyang University, Seoul, Korea, in 2006. From 2006 to 2007, he conducted his postdoctoral research at the university in spot welding, and machine and quality monitoring. Kim has published several papers on the subjects of spot welding, quality monitoring, and control using artificial intelligence.

**Young Whan Park** received his PhD degree in welding and artificial intelligence from Hanyang University, Seoul, Korea, in 2006. Currently, he is a researcher with the Pohang Iron & Steel Co., Pohang, South Korea. His research



Munjin Kang



Choong-Myeong Kim



Chul-Ku Lee



Sehun Rhee



Cipriani Davis



Chon-Liang Tsai

includes welding process simulation and optimization for automotive steel applications in resistance spot welding, and laser welding using artificial intelligence algorithms. He has published papers on the subject in various scientific journals.

**Kieun Sung** received his PhD in mechanical engineering from Hanyang University, Seoul, Korea, in 2008. Currently, he is with the university's Research Institute of Industrial Science. His research interests include microfabrication joining applications and its processes. From 2002 to 2005, he was a military researcher at the university where he carried out many projects for the development of welding automation systems using laser vision sensors. Sung has developed special laser vision sensors for nuclear reactor repair systems and published several papers in various research and scientific journals.

**Munjin Kang** has more than 20 years of experience in welding engineering, welding system development, weld quality monitoring, and automation practice and research. He received his PhD in welding engineering from the Hanyang University, Seoul, Korea, in 2000. Currently, Kang is a director of the Industrial Technology Center at the Korean Institute of Industrial Technology (KITECH). His research focuses on arc and resistance spot welding system developments, monitoring and control of high-frequency resistance welding processes, and flash butt welding processes. Prior to joining KITECH in 2003, he worked for the Research Institute of Industrial Science & Technology (1986–2003), Pohang, Korea, as a welding researcher for the development of mesh seam welding systems, development of flash butt welding systems, weld quality monitoring of high-frequency resistance welding, and the development of inverter arc welding systems. Many of his papers have been published in various research journals, including the *Welding Journal*.

**Choong-Myeong Kim** is a principal researcher with the Joining Research Group, Technical Research Laboratories of the Pohang Iron and Steel Co., Pohang, South Korea. He has been active in weld-

ing engineering research for 23 years and is currently taking doctoral studies at Hanyang University, Seoul, Korea. His career has been devoted to the field of arc welding and electric resistance welding of carbon steels for shipbuilding, pipeline, and steel structures. He also specializes in fracture analysis of welded joints.

**Chul-Ku Lee** received his PhD in mechanical engineering from Hanyang University, Seoul, Korea. For more than 30 years, he has been in welding engineering research and education and is currently teaching at Seoul National University of Technology. He is also a visiting professor at the The Ohio State University and the University of Central Florida. His research areas include welding process development, nondestructive testing, solid-state welding, and laser beam welding. Lee is an active member of the Korean Welding Society and has served on its board of directors.

**Sehun Rhee** received his PhD in mechanical engineering from the University of Michigan in 1990. Since 1994, he has served as a professor at Hanyang University. His research focus has been on welding monitoring systems using neural networks, fuzzy logic, and spot and laser welding for automotive applications. Rhee's recent research projects have involved adhesive bonding, microjoining for MEMS, and electronic and macroscale joining processes. His publications have appeared in a number of research journals.

#### Honorary Membership Award

**Cipriani Davis** received his MS in training and performance management from Leicester University, UK, in 2008. In 1973, he worked with the Caribbean Industrial Research Institute as a senior machinist, and in 1978, served as a technical vocational teacher at John S. Donaldson Technical Institute in Port of Spain, Trinidad. In 1986, he taught at San Fernando Technical Institute in California. Davis returned to Trinidad where, from 1987 to 1989, he was with Damus Williams Aimes, Ltd. At Caribbean Tyre Co. he served as senior extrusion technician, and at Caribbean Research Institute he was

site engineer. Since 1990, he has been with the Metal Industries Co. Ltd., Trinidad and Tabago, West Indies. In 2005, he became CEO and continues to serve as an instructor, training coordinator, and general manager of the Training Division. Davis, a Certified Welding Inspector, is chairman of the AWS Trinidad and Tobago International Section.

**John W. Elmer.** See biography under A. F. Davis Silver Medal Award.

#### International Meritorious Certificate Award

**Cipriani Davis.** His biography appears under Honorary Membership Award.

**Chon-Liang Tsai**, an AWS Fellow, is a full professor in the welding engineering program at The Ohio State University. He holds a PhD from Massachusetts Institute of Technology. He has worked in welding engineering research and education for about 30 years, and has published more than 150 technical papers in various peer-reviewed journals and conference proceedings. He is best known for his accomplishments in applying advanced computer technologies to develop solutions for structural applications, and his innovative modeling techniques for the analysis of welding-induced residual stresses and distortion. Tsai founded the Welding Society of the Republic of China (Taiwan) in 1987, the International Welding Technology Research Laboratory in Taiwan in 1994, and the AWS Taiwan Section in 1995. Recently, he helped to establish the AWS Korean International Section.

#### William Irrgang Memorial Award

**John W. Elmer.** See biography under A. F. Davis Silver Medal Award.

#### Charles H. Jennings Memorial Award

*The Discontinuous Weld Bead Defect in High-Speed Gas Metal Arc Welds*

**Tam C. Nguyen** is a member of the welding, joining, and engineering faculty at Conestoga Polytechnic. He received his PhD in mechanical engineering from the University of Waterloo in 2005. Prior to his PhD work, he served as a product de-



Tam C. Nguyen



David C. Weckman



David A. Johnson



Muralidhar Tumuluru



Min Hyun Cho



David F. Farson

velopment and welding engineer at Centerline (Windsor) Ltd. Nguyen's research focuses on welding process optimization to provide higher welding speeds. Nguyen has been awarded one patent, coauthored five peer-reviewed papers, and made several technical presentations. During his studies, he received numerous awards and scholarships including Natural Science and Engineering Research Council Postgraduate Scholarships, Paul Niessen-Cominco Medal for Excellence in Materials Experimentation, Alumni Outstanding Academic Achievement Award, and the Sandford Fleming Foundation Silver Medal.

**David C. Weckman** received his PhD in mechanical engineering from the University of Waterloo, Canada. He joined the university's Materials Engineering and Processing group faculty where he teaches materials science and engineering, solid body mechanics, welding processes, and welding design. He has conducted research on the joining of a wide range of alloys using laser welding, friction welding, and various arc welding processes employing thermomechanical and thermofluids numerical modeling and experimental techniques. His current research includes high-speed welding of aluminum alloys using lasers and various arc welding processes, and gas metal arc welding of advanced high-strength steels. He has received the Charles H. Jennings Memorial Award and the A. F. Davis Silver Medal Award. He currently serves on the editorial board of *Science and Technology of Welding and Joining* and is a member of the AWS Welding Research and Development Committee.

**David A. Johnson** received his PhD degree in mechanical engineering from McMaster University, Canada, in 1994. In 1997, he joined the Fluid Mechanics group faculty within the Department of Mechanical Engineering at the University of Waterloo. Johnson teaches fluid mechanics, experimental design and measurements, and rotating machinery. He has conducted research on the fluid mechanic aspects of gas metal arc welding processes, turbulent jet studies, and numerous studies of turbomachinery

using experimental and numerical modeling approaches.

#### James F. Lincoln Gold Medal Award

*The Effect of Coatings on the Resistance Spot Welding Behavior of 780 MPa Dual-Phase Steel*

**Muralidhar Tumuluru** received his degrees in materials and welding engineering from Rensselaer Polytechnic Institute and The Ohio State University. He has 27 years of experience in welding, of which he has worked the last 11 years at the U.S. Steel Research and Technology Center. The main focus of his research has been to characterize the joining behavior of advanced high-strength steels developed for automotive applications. He has lectured widely and authored numerous publications on the subject. He teaches welding technology for U.S. Steel's internal training program and has conducted presentations for welding personnel at various automotive companies on the joining aspects of advanced high-strength steels. Prior to joining U.S. Steel, he worked for Westinghouse Electric Corp. and Spang & Co. Tumuluru has been an AWS member since 1980. He is a member of the AWS A5 Committee on Filler Metals and Allied Materials, AC02 Commission II on Arc Welding, and D14H Subcommittee on the Surfacing of Industrial Rolls. He serves as vice chair of the D8 Committee on Automotive Welding, and chairs the task group updating D8.9, *Recommended Practices for Test Methods for Evaluating the Resistance Spot Welding Behavior of Automotive Sheet Steel Materials*.

#### McKay-Helm Award

*Simulation Study of a Hybrid Process for the Prevention of Weld Bead Hump Formation*

**Min Hyun Cho** received his PhD degree in welding engineering from The Ohio State University in 2006. His postdoctoral research work focuses on laser conduction mode welding simulation sponsored by Los Alamos National Laboratory. He studies welding processes and the analysis of welding defects, such as hump formation, incomplete fusion, etc.,

using numerical simulation as a tool for welding process optimization.

**David F. Farson** has more than 30 years of experience in the welding engineering and laser materials processing field. He received his PhD in electrical engineering from The Ohio State University where he currently is a faculty member in the Industrial and Systems Engineering Dept. teaching laser materials processing and manufacturing process automation and control. He worked at Westinghouse Electric R&D Center and Penn State University Applied Research Laboratory where he served as deputy head of the Laser Processing Dept. and a graduate faculty member. He has authored more than 115 papers, and is a recognized expert in his field. Farson has served as president of Laser Institute of America where he was elected a Fellow in 1997. He coedited the *Handbook of Laser Materials Processing* reference book, and serves as associate editor of the *LIA Journal of Laser Applications*. Additionally, he serves on the AWS Awards, Technical Papers, Research, and Conference Committees.

#### Prof. Koichi Masubuchi Award

**Manabu Tanaka** received his PhD degree in welding engineering from Osaka University, Osaka, Japan, in 2000. Since 1992, he has been with the university as a research associate in the Joining and Welding Research Institute, and currently is teaching as a professor. His major focuses of study have been in the physics of welding, including plasma diagnostics, electrode phenomena, and numerical modeling. His current research concerns the evolution of the unified numerical simulations from gas tungsten arc to gas metal arc in order to clearly understand the physical behavior of the gas metal arc welding process. Tanaka has authored more than 80 publications. He is the recipient of many citations from the Japan Welding Society including the Best Paper Award for Encouragement, the Best Presentation Award, Physics of Welding Award, the Best Author Award, and the Kihara Prize from the Association for Weld Joining Technology Promotion.



Manabu Tanaka



Omer W. Blodgett



Claudia B. Bottenfield



Phillip D. Winslow



David R. Sigler



James G. Schroth

### Samuel Wylie Miller Memorial Medal Award

**Omer W. Blodgett**, an AWS Fellow, received his ME degree from the University of Minnesota, and an honorary Doctor of Science degree from LeTourneau University where the Omer Blodgett Endowed Chair of Welding and Materials Joining Engineering has been established in his honor. He was welding superintendent with the Globe Shipbuilding Co. in Superior, Wis., from 1941 to 1945. Since 1945, he has served as senior design consultant at The Lincoln Electric Co. He has been a lecturer at Lincoln Electric's machine and structural design seminars and has frequently spoken on welded design at AWS Sections and national meetings. Blodgett has conducted his structural design seminars all over the world. He is an advisory member of the AWS Structural Welding Committee, and was active on the AISC Committee on Specifications and the Welding Research Council's Task Group on Beam to Column Connections. Blodgett received the AWS A. F. Davis Silver Medal Award for his work in structural design. In 1968, he was the lecturer for the Educational Lecture Series at the AWS Annual Meeting. He received the AWS Honorary Membership Award, Silver Quill Editorial Achievement Award, and the T. R. Higgins Lectureship Award from AISC. Blodgett has authored numerous articles and handbooks including *Design of Weldments* and *Design of Welded Structures*. He is a licensed Professional Engineer in the state of Ohio and named a Fellow of ASCE, and ASME.

### National Meritorious Award

**Claudia B. Bottenfield** is sales and marketing manager with Dressel Welding Supply, Inc. in Lancaster, Pa. Prior to joining the company, she was with Arc Welder Group, Baltimore, Md., for 28 years. A graduate of the Business College of Maryland, she has taken many courses offered by United Abrasive, Lincoln Electric, Victor, Harris Calorific, Arcair, and others. Bottenfield has been an active member of AWS since 1983. She has held various officer positions in the Maryland, Lancaster, and York-Central Pennsylvania Sections, and has served as District 3 director for

two terms. Currently, she is an associate trustee for the AWS Foundation, Inc., where she has cochaired the silent auctions held during the FABTECH International & AWS Welding Shows. Bottenfield is also involved in SkillsUSA, the Occupation Advisory Committee, York County School of Technology, the Weld Shop Annual Car Show Committee, Women in Construction, and various educational career advisory boards.

**Phillip D. Winslow** has worked for more than 40 years in the sales and marketing management areas of the welding industry. He received his degree in business management from the University of New Hampshire in 1964, and continued advanced studies in marketing at Dartmouth College and the University of Southern New Hampshire. From 1964 to 1968, he served as a captain in the United States Air Force. In 1968, he joined Uniroyal, Inc., first as a sales representative then regional sales manager, and a product manager. In 1974, he joined the Nashua Corp. in managerial positions. In 1988, he joined Markem Corp. as a division manager. In 1991, he left to work for Aavid Thermal Technology, a supplier of thermal management components, serving as vice president of worldwide sales and marketing. He joined Hypertherm, Inc., in 1992, where he worked until his retirement in 2007. During this time, he served variously as vice president of its North American, European, and Asian marketing and sales divisions. Throughout his career, Winslow has served as chair of the Welding Equipment Manufacturers Committee and a consultant to the U.S. Department of Commerce on exporting of capital goods.

### Robert L. Peaslee Brazing Award

*Sulfide-Induced Corrosion of Copper-Silver-Phosphorus Brazed Joints in Welding Transformers*

**David R. Sigler** joined General Motors Research Laboratory in 1982 after receiving his PhD in metallurgical engineering from Wayne State University. As a National Science Foundation Fellow at WSU, his research focused on under-



Yar-Ming Wang



Dusanka Radovic

standing the fatigue behavior of high-strength aluminum alloys and nondestructively evaluating fatigue damage using laser interferometry. At GM, he has been a member of the R&D Center for 26 years. His major research activities have included the development of stainless steel materials for catalytic converters, joining of advanced lightweight materials for body structures, and development of manufacturing processes for fuel cells. He currently holds nine patents and has authored 23 publications.

**James G. Schroth** received his PhD in metallurgical engineering from The Ohio State University. Joining General Motors in 1985, he currently is a Technical Fellow and lab group manager in the Materials and Processes Lab of General Motors R & D Center, where he oversees technology innovations in sheet metal forming and interfacial phenomena. His research interests include physical and mechanical metallurgy of advanced high-strength steels and frictional aspects of aluminum sheet forming at elevated temperatures. He has extensive experience with automotive applications of steels, stainless steels, aluminum, and copper alloys in various forms. Schroth, who holds 18 patents, is an expert on sheet steels for both body and power-train applications, and for hot aluminum-forming and brazing technology. He has developed a family of microalloyed steels specifically for copper-brazed power-train applications.

**Yar-Ming Wang** received his PhD in metallurgical engineering from the Missouri University of Science and Technology. In 1977, he worked as a research assistant professor at the university and as



# AWS IS ON A MISSION

## Win Great Prizes in the **2007-2008 AWS Member-Get-A-Member Campaign\***

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

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\*The 2007-2008 MGM Campaign runs from June 1, 2007 to May 31, 2008. Prizes are awarded at the close of the campaign.



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- 03 ☐ Sales
- 04 ☐ Purchasing
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- 20 ☐ Engineer — design
- 21 ☐ Engineer — manufacturing
- 06 ☐ Engineer — other
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- 12 ☐ Metallurgist
- 13 ☐ Research & development
- 22 ☐ Quality control
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- 08 ☐ Supervisor, foreman
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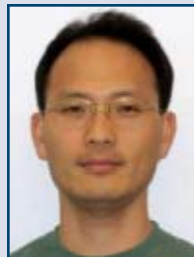
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- W ☐ Sheet metal
- X ☐ Structures
- Y ☐ Other
- Z ☐ Automation
- 1 ☐ Robotics
- 2 ☐ Computerization of Welding



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Gloria Morris



Timothy Anderson

a research scientist at Sprague Electric Co. For more than 29 years he has been with General Motors where he is currently a staff researcher in the Materials and Processes Laboratory at the R&D Center. His areas of research include battery development for electric and hybrid vehicles, coating technology (anodization, conversion coatings, plasma CVD, and plating), automotive corrosion protection, and corrosion testing methods. Wang, who holds ten U.S. patents, has authored more than 30 technical papers. In 2004, he received the Abner Brenner Award from The American Electroplaters and Surface Finishers Society.

**Dusanka Radovic** received her master's in chemical engineering from Wayne State University. Radovic has worked 30 years in the General Motors R&D Department. Her studies focus on electrochemical research and corrosion.

#### Plummer Memorial Education Lecture Award

##### *Why Is Welding Important?*

**Thomas W. Eagar**, an AWS Fellow, received his ScD from Massachusetts Institute of Technology (MIT) in 1975. Following graduation, he worked for Bethlehem Steel Corp. Homer Research Laboratories briefly, then returned to MIT as a faculty member where he currently is professor of materials engineering and engineering systems. In 1995, he was appointed and served for five years as head of the Department of Materials Science and Engineering. Among his numerous citations, Eagar received the Adams Memorial Membership Award, Comfort A. Adams Lecture Award, Charles H. Jennings Memorial Medal Award, Champion H. Mathewson Gold Medal of AIME, Warren F. Savage Award, William Spraragen Memorial Award, William Irgang Award, Silver Quill Award, and the Henry Marion Howe Medal of ASM International. Eagar was elected an ASM Fellow and an AAAS Fellow. In 1997, he was elected a member of the National Academy of Engineering. In June 2003, he testified before Congress on manufacturing employment in the United States. He is on the editorial board of *Science*

and *Technology of Welding and Joining* and is a Principal Reviewer for the *Welding Journal*. He has published more than 200 papers and holds 13 patents.

#### Safety and Health Award

**Susan R. Fiore** received her M.S. degree in materials engineering from Rensselaer Polytechnic Institute. She began her career in welding consumable development at The Lincoln Electric Co. In 1988, she joined L-TEC Welding and Cutting Products, which later became part of the ESAB Group. At ESAB, she was responsible for consumable development, hazard communication, and technical service. She specialized in developing high-strength steel alloys. In 2000, she joined Edison Welding Institute. As a senior engineer in the Engineering and Materials Group, she worked on weldability studies, failure analyses, and consumables optimization programs. She recently joined EWI's Program Management Office as a project manager. In her current position, Fiore manages a wide range of research and development projects for both commercial and government entities. Fiore has been an AWS member for more than 25 years. She is a member of the AWS Safety and Health Committee, where she served as chair from 1999 to 2005. She has also served on the SH-1 and SH-4 subcommittees as well as the ANSI Z49 committee. She has presented talks on the OSHA hexavalent chromium standard at numerous venues. Her articles, "Reducing Exposure to Hexavalent Chromium in Welding Fumes," and "Choosing the Proper Self-Shielded FCAW Wire," were published in the *Welding Journal*.

#### Warren F. Savage Memorial Award

##### *Weld-Bottom Macroseggregation Caused by Dissimilar Filler Metals*

**Youngki Yang** received his MS degree in metallurgical engineering from Seoul National University in 1997. In 1999, he entered the University of Wisconsin materials science and engineering PhD program. From 2003 to 2004, he took part in an educational program on international businesses sponsored and organized by

the Korean government. In 2005, he returned to the university where he currently is completing work on his PhD. Yang's current research interests include macrosegregation during arc welding, friction stir welding of aluminum and magnesium alloys, and hot tearing of creep-resistant magnesium-alloy castings. His thesis will focus on macrosegregation in arc welding caused by dissimilar filler metals. He has contributed to numerous papers on topics relating to macrosegregation in arc welding and friction stir welding of magnesium and aluminum alloys.

**Sindo Kou**, an AWS Fellow, received his PhD in materials science and engineering from the Massachusetts Institute of Technology. He worked at General Motors Research Laboratory in 1978, and as an associate professor at Carnegie-Mellon University from 1979 to 1983. In 1983, Kou joined the University of Wisconsin-Madison where he became a full professor in 1985. He is currently chair of the Department of Materials Science and Engineering. He has authored two texts, *Welding Metallurgy* and *Transport Phenomena and Materials Processing*. Kou has received numerous honors including the John Chipman Award from Iron and Steel Society of AIME, Adams Memorial Membership Award, ASM International Fellow status (1998), Chancellors' Award for Distinguished Teaching from the University of Wisconsin, Benjamin Smith Reynolds Award for Excellence in Teaching from the College of Engineering, University of Wisconsin, Charles H. Jennings Memorial Award, Warren F. Savage Memorial Award, and William Spraragen Memorial Award.

#### Silver Quill

##### **Editorial Achievement Award**

##### *Welding — Binding Ancient Technology to Modern Life* on The History Channel

**Gloria Morris** and **Philip Kruener** have written and produced more than 80 hours of award-winning television, documentary, and corporate programming. Their documentary work can be seen regularly on The History Channel and the Discovery Channel.



Matthew J. Perricone



John N. DuPont



Arnold R. Marder



Ernest D. Levert Sr.



Robert White Sr.

### William Spraragen Memorial Award

*The Influence of Molybdenum on  
Stainless Steel Weld Microstructures*

**Timothy Anderson** received his PhD in materials science and engineering from Lehigh University in 2008. His graduate research, conducted under the guidance of John DuPont, focused on the weld repair of single-crystal nickel-based superalloys. His other research interests focused on solidification processes, including microstructural development of Mo-bearing filler metals, solidification cracking studies, and thermodynamic modeling of complex alloy systems. He has made numerous conference presentations and published a number of papers on his projects. Anderson received graduate research fellowships from AWS and the Navy Joining Center. In 2006, he was awarded the IIW Granjon Prize in the Materials Behavior category. Anderson is currently employed as a research engineer at ExxonMobil Upstream Research Co.

**Matthew J. Perricone** is a senior scientist and project manager in the Technical Consulting Services division at RJ Lee Group (RJLG) in Monroeville, Pa. Prior to joining RJLG, he worked as a senior member of the technical staff in the Joining and Coatings division of Sandia National Laboratories, where he received a 2007 Employee Recognition Award as team leader of a project focused on laser welding. He has worked as a materials scientist in governmental, academic, and industrial sectors with much of his technical focus on physical metallurgy and the joining processes of welding, brazing, and soldering. Perricone received an AWS graduate research fellowship. At Lehigh University, where he studied the physical metallurgy of welding under the guidance of John N. DuPont, he earned his PhD in 2005. At ASM International, he served as a member of the 2008 Nominating Committee, is the immediate past chair of the Emerging Professionals Program, and serves on Chapter Council as the Representative for District X. His research interests include the physical metallurgy of welding and joining processes, as well as microstructural development in multi-

component alloys. He has authored a number of papers that have been published in peer-reviewed journals.

**John N. DuPont.** See the biography under the incoming class of Fellows.

**Arnold R. Marder** received his PhD in metallurgy and materials science from Lehigh University. Marder worked for Curtiss-Wright Corp. from 1962 to 1965, then served more than 20 years at the Homer Research Laboratories of Bethlehem Steel Corp. In 1986, he joined the Lehigh University faculty. Retired in 2007, he is currently an emeritus professor in the Department of Materials Science and Engineering. Marder's research interests include processing-structure-property relationships of materials. In particular, his research involved coatings and alloys for ambient and high-temperature environments, including erosion, oxidation, and sulfidation. He has an ongoing interest in the physical metallurgy of steel and is still active in research on weld overlay coating of superalloys and iron aluminide intermetallics, and weldability studies of Cr-Mo steels.

### R. D. Thomas Memorial Award

**Ernest D. Levert Sr.**, an AWS past president, is an AWS Counselor, a Life Member, and Distinguished Member of the Society. He received his welding engineering degree from The Ohio State University (OSU). He joined Lockheed Martin Missiles and Fire Control in Dallas, Tex., in 1986, where he currently works in the Production Engineering Department as the senior staff manufacturing engineer. Some of his projects include the International Space Station Thermal Control Units Program, Patriot Advanced Capability, Army Tactical Missile System, Line-of-Sight Missile Program, Joint Strike Fighter Program, Advanced Missile Programs, Terminal High-Altitude Area Defense Project, and the Multiple-Launch Rocket System. He is a Registered Professional Engineer in the state of Texas. Previously, Levert worked for General Dynamics, Convair Div., San Diego, as a welding engineer. The programs he sup-

ported included the Atlas Space Vehicle, Tomahawk Cruise Missile, Ground Launched Cruise Missile, and the Space Shuttle. Levert is president of the Federation of Materials Societies, chairman of the IIW Commission IV, Power Beam Processes, and serves as the U.S. Delegate at the IIW annual assemblies. He served as president of the American Welding Society (2002–2003). Levert's many awards include the Lockheed Martin MFC Production Technical Excellence Staff: Welding Engineering and Materials Joining, Lockheed Martin NOVA Award for Outstanding Leadership, The OSU College of Engineering Distinguished Alumnus Award, The OSU Minority Engineering Program Excellence Award, NTA Technical Achiever Award, and was nominated for the National Black Engineer of the Year for Professional Achievements in Industry.

### Elihu Thomson Resistance Welding Award

**Robert White Sr.** (awarded posthumously) dedicated more than 50 years to developing and building custom-made resistance welding machines. In 1960, he established the Janda Company where he designed and built more than 3000 machines for the U.S. government and the aerospace, building, wire products, and sheet metal industries. He also designed an array of resistance welding machines for manufacturing products as diverse as multihead missile fins, meshes, floor panels, elevators, wire baskets, shelves, racks, shopping carts, cabinets, office furniture, televisions, dishwashers, oven chassis, slot machines, seat frames, brake shoes, truck frames, concrete cages, and solar panels. Some of his designs include fully automated welding, loading, unloading, and stacking stations. White was recognized as a leading authority in the field of resistance welding. Lockheed Martin acknowledged his achievements with an award for his "dedication and significant contributions to a program of great national importance."

### George E. Willis Award

**Chon-Liang Tsai.** See bio under International Meritorious Certificate Award. ♦

## Tech Topics

### Standards for ANSI Public Review

A3.0M/A3.0:200X, *Standard Welding Terms and Definitions*. Revised — \$102. Review expires 2/2/09.

B5.14:200X, *Specification for the Qualification of Welding Sales Representatives*. Revised — \$102. Review expires 1/19/08.

D1.8/D1.8M:200X, *Structural Welding Code — Seismic Supplement*. Revised — \$57. Review expires 1/19/08.

AWS was approved as an accredited standards-preparing organization by the American National Standards Institute (ANSI) in 1979. AWS rules, as approved by ANSI, require that all standards be open to public review for comment during the approval process. The above three standards were open for public review until the dates shown. Draft copies may be obtained from Rosalinda O'Neill, ext. 451, [roneill@aws.org](mailto:roneill@aws.org).

### New Standards Projects

Work has begun on revising the following six standards. Directly and materially affected individuals are invited to contribute to their development. Contact the staff engineer listed with the document for more information. Participation on AWS Technical Committees and Subcommittees is open to all persons.

C4.2/C4.2M:200X, *Recommended Practices for Safe Oxyfuel Gas Cutting Torch Operation*. This document contains the procedures to be used in conjunction with oxyfuel gas cutting equipment and the latest safety requirements. Complete lists of equipment are available from individual manufacturers. Stakeholders: This document will be used by oxyfuel gas cutters (operators) involved with steel plate cutting, tooling fabrication, manufacturers of equipment, and building construction. Annette Alonso, ext. 299.

C7.1M/C7.1:200X, *Recommended Practices for Electron Beam Welding (and Allied/Related Processes)*. This document presents recommended practices for electron beam welding. It is intended to cover common applications of the process. Processes definitions, safe practices, general process requirements, and inspection criteria are provided. Stakeholders: Laser welders, welders, and anyone interested in high-tech welding processes. Reino Starks, ext. 304.

D1.1/D1.1M:2010, *Structural Welding Code — Steel*. This code covers the welding requirements for any type of welded structure made from the commonly used carbon and low-alloy steels. Clauses 1–8 constitute a body of rules for the regulation of welding in steel construction. The code includes eight normative and 12 informative annexes and a code commentary. Stakeholders: Structural engineers working with steel, designers, manufacturers, welders, qualifiers, inspectors, and fabricators. Selvis Morales, ext. 313.

D1.2/D1.2M:200X, *Structural Welding Code — Aluminum*. This code covers the welding requirements for any type structure made from aluminum structural alloys, except for aluminum pressure vessels and pressure piping. Clauses 1–7 constitute a body of rules for the regulation of welding in aluminum construction. A commentary on the code is included with the document. Stakeholders: Structural engineers working with aluminum, designers, manufacturers, welders, qualifiers, inspectors, and fabricators. Selvis Morales, ext. 313.

D1.5M/D1.5:200X, *Bridge Welding Code*. This code covers the welding requirements for AASHTO highway bridges made from carbon and low-alloy steels. The 2008 edition contains dimen-

sions in metric SI Units and U.S. Customary Units. Clauses 1–7 constitute a body of rules for the regulation of welding in steel construction. The provisions for Clause 9 have been distributed throughout the D1.5 code. Clauses 8, 10, and 11 do not contain provisions, as their analogue D1.1 sections are not applicable to the D1.5 code. Clause 12 contains the requirements for fabricating fracture critical members. Stakeholders: Structural engineers, designers, manufacturers, welders, qualifiers, inspectors, and fabricators involved in welding bridges. Selvis Morales, ext. 313.

D1.6/D1.6M:2007-AMD 1, *Structural Welding Code — Stainless Steel*. This code covers the requirements for welding stainless steel structural assemblies. Stakeholders: Structural engineers working with stainless steel, manufacturers, welders, qualifiers, and inspectors. Selvis Morales, ext. 313.

### Standards Approved by ANSI

D14.8M:2009 (ISO/TR 17844:2004 IDT), *Standard Methods for the Avoidance of Cold Cracks*. New standard approved 11/11/08.

D16.3M/D16.3:2009, *Risk Assessment Guide for Robotic Arc Welding*. Revision approved 11/13/08.

A5.26/A5.26M-97 (R2009), *Specification for Carbon and Low-Alloy Steel Electrodes for Electrode Gas Welding*. Reaffirmed 11/20/08.

### Technical Committee Meetings

March 17–20, D1 Committee on Structural Welding. Tucson, Ariz. Call Selvis Morales, ext. 313.

March 30, 31, A5 Committee on Filler Metals and Allied Materials. Orlando, Fla. Call Rakesh Gupta, ext. 301.

## Member-Get-A-Member Campaign

Listed are the Dec. 16 standings for the current campaign. See page 69 of this *Welding Journal* or visit [www.aws.org/mgm](http://www.aws.org/mgm) for rules and prize list. Call the Membership Dept., (800) 443-9353, ext. 480, regarding your member proposer point status.

### Winner's Circle

Sponsored 20+ new members.

The superscript indicates the number of times the member has achieved Winner's Circle status since June 1, 1999.

J. Compton, San Fernando Valley<sup>7</sup>  
E. Ezell, Mobile<sup>6</sup>  
J. Merzthal, Peru<sup>2</sup>  
G. Taylor, Pascagoula<sup>2</sup>  
L. Taylor, Pascagoula<sup>2</sup>

B. Mikeska, Houston<sup>1</sup>  
R. Peaslee, Detroit<sup>1</sup>  
W. Shreve, Fox Valley<sup>1</sup>  
M. Karagoulis, Detroit<sup>1</sup>  
S. McGill, NE Tennessee<sup>1</sup>  
T. Weaver, Johnstown/Altoona<sup>1</sup>  
G. Woormer, Johnstown/Altoona<sup>1</sup>  
R. Wray, Nebraska<sup>1</sup>  
M. Haggard, Inland Empire<sup>1</sup>

### President's Roundtable

Sponsored 9–19 new members.

P. Betts, Mobile — 12

### President's Club

Sponsored 3–8 new members.

L. Contreras, South Florida — 8  
J. Compton, San Fernando Valley — 5  
C. Daon, Israel — 5  
W. Rice, Tri-State — 5  
E. Ezell, Mobile — 4  
R. Newman, Maine — 4  
B. Vernyi, Cleveland — 4  
C. Becker, Northwest — 3  
R. Ellenbecker, Fox Valley — 3  
B. Franklin, Mobile — 3  
L. Moss, Sangamon Valley — 3  
M. Rahn, Iowa — 3  
M. Wheat, Western Carolina — 3  
D. Wright, Kansas City — 3

— MGM continued on next page

— *MGM continued from previous page*

### President's Honor Roll

C. Alfaro, San Diego — 2  
M. Boggs, Stark Central — 2  
M. Boyer, Detroit — 2  
B. Donaldson, British Columbia — 2  
E. Dupree, Tidewater — 2  
F. Hendrix, New Jersey — 2  
R. Johnson, Detroit — 2  
J. Padilla, Cuautitlan Izcalli — 2  
J. Polson, L.A./Inland Empire — 2  
J. Sisson, Niagara Frontier — 2  
K. Smith, North Texas — 2  
A. Stute, Madison-Beloit — 2  
D. Thomason, Chicago — 2  
B. Whatley, Albuquerque — 2  
M. Yung, Portland — 2  
P. Zammit, Spokane — 2

### Student Member Sponsors

*Sponsored 4 or more students.*

D. Berger, New Orleans — 110  
B. Benyon, Pittsburgh — 41

A. Baughman, Stark Central — 36  
A. Rowe, Philadelphia — 36  
A. Zinn, Eastern Iowa — 34  
T. Moore, New Orleans — 32  
J. Carney, Western Michigan — 26  
E. Norman, Ozark — 26  
S. Siviski, Maine — 26  
R. Newman, Maine — 24  
R. Cook, Utah — 23  
D. Schnalzer, Lehigh Valley — 22  
H. Hughes, Mahoning Valley — 20  
R. Munns, Utah — 20  
D. Pickering, Central Arkansas — 18  
T. Strickland, Arizona — 17  
J. Boyer, Lancaster — 15  
C. Donnell, Northwest Ohio — 15  
W. Harris, Pascagoula — 14  
J. Roberts, Sacramento — 14  
R. Hutchinson, Long Bch./Or. Cty. — 13  
A. Mattox, Lexington — 13  
R. Rummel, Central Texas — 13  
D. Saunders, Lakeshore — 13  
A. Stute, Madison-Beloit — 13  
D. Taylor, Kern — 13

R. Evans, Siouxland — 11  
C. Kipp, Lehigh Valley — 10  
D. Vranich, North Florida — 10  
C. Abram, Columbus — 9  
A. Badeaux, Washington, D.C. — 9  
S. Colton, San Diego — 9  
R. Ledford Jr., Birmingham — 9  
R. Norris, Maine — 9  
V. Facchiano, Lehigh Valley — 9  
D. Kowalski, Pittsburgh — 8  
M. Rabo, Sacramento — 8  
N. Carlson, Idaho/Montana — 7  
W. Galvery Jr., Long Bch./Or. Cty. — 7  
B. Hallila, New Orleans — 7  
D. Howard, Johnstown/Altoona — 7  
S. MacKenzie, Northern Michigan — 7  
D. Zabel, Southeast Nebraska — 7  
J. Geesey, Pittsburgh — 6  
C. Schiner, Wyoming — 6  
D. Kearns, Northern Michigan — 5  
R. Olesky, Pittsburgh — 5  
J. Reed, Ozark — 5  
C. Hobson, Olympic Section — 4  
S. Robeson, Cumberland Valley — 4

## New AWS Supporters

### Sustaining Companies

#### Classic Protective Coatings, Inc.

N7670 State Hwy. 25  
Menomonie, WI 54751-5928  
(715) 233-6267; FAX (715) 233-6268  
[www.classicprotectivecoatings.com](http://www.classicprotectivecoatings.com)  
Representative: **John Newkirk**

Classic Protective Coatings, Inc., is a nationwide industrial contractor specializing in tank rehabilitation. It provides the largest high-production welding, sandblasting, waterblasting, industrial coatings, and containment equipment at locations nationwide. Accomplishments include roof and rafter replacement, seismic upgrades, safety and security upgrades, and elevation and location changes.

#### Ironwood Industries, Inc.

18249 U.S. Hwy. 41 S.  
Spring Hill, FL 34610  
Phones: (800) 647-6113; (352) 754-8512  
Representative: **Brian J. Fiegel**

Ironwood Industries, Inc., is a diversified steel services company. It specializes in the fabrication and erection of structural and miscellaneous steel products. Based in Florida, it serves the southeast.

#### Precision Certified Welding, Inc.

203 N. Jersey St.  
Dayton, OH 45403  
(937) 781-9353; FAX (937) 781-9665  
[www.precisioncertifiedwelding.com](http://www.precisioncertifiedwelding.com)  
Representative: **Brad A. Verburg**

Precision Certified Welding, established in 1989, is a full-service welding and fabrication company committed to

quality and quick turnarounds. Its lasers and micro gas tungsten arc welding processes are housed in a clean room suitable for medical, aerospace, and mold repair operations. Other services include fabrications up to five tons, CNC machining, and production sawing.

### Supporting Companies

#### Econospan Structures Corp.

R. R. 2 Site 26, Comp 24  
Chase, BC V0E 1M0, Canada

#### Paidar Quality Structure Eng. Pr. Co.

PO Box 1431745657  
Tehran 0098, Iran

#### Portagas, Inc. DBA Cyltex, LLC

6717B Polk St.  
Houston, TX 77011

### Affiliate Companies

#### BSM Consulting Engineers, Inc.

801 Commercial St., PO Box 502  
Astoria, OR 97103

#### Caviness Welding Inc.

1004 River Ave.  
Roanoke, VA 24013

#### Certified Inspection Services Ltd.

941 Thomas  
Winnipeg, MB R2L 2C6, Canada

#### Eco-Tec Inc.

1145 Squires Beach Rd.  
Pickering, ON L1W 3T9, Canada

#### Elite Structures, Inc.

303 Old Quitman Rd., Box 207  
Adel, GA 31639

#### Engineered Building Products, Inc.

18 Southwood Dr.  
Bloomfield, CT 06002

#### ICM Georgia Inc.

6795 Oak Ridge Commerce Way SW  
Austelle, GA 30168

#### TesTex Canada

555 Edinburgh Dr., Ste. 9  
Moncton, NB E1E 4E3, Canada

#### The Steel Construction Group Inc.

7035 Bee Caves Rd., Ste. 206  
Austin, TX 78746

### Educational Institutions

#### Allegan County Area

#### Technical & Education Center

2891 116th Ave.  
Allegan, MI 49010

#### Idesh Azma Iranian

14155-5634  
Tehran 15949-45911, Iran

#### Jefferson College

1000 Viking Dr.  
Hillsboro, MO 63050

#### Joliet Junior College

1215 Houbolt Rd.  
Joliet, IL 60431

# SECTION NEWS

## District 1

**Russ Norris, director**  
(207) 283-1861  
[rnorris@maine.rr.com](mailto:rnorris@maine.rr.com)

## CENTRAL MASS./RHODE ISLAND

NOVEMBER 20

Activity: The Section members participated in a six-hour-long training program presented at Old Colony Regional Vo-Tech High School in Rochester, Mass. The event allowed one-on-one training for each of the school's junior class. The presenters were **Al Caron** and **Jon Marland** of Local 51 United Associations of Plumbers, Pipefitters, and Refrigeration, based in East Providence, R.I.



*Student welders learned a lot during the training program hosted by the Central Massachusetts/Rhode Island Section.*

## District 2

**Kenneth R. Stockton, director**  
(908) 412-7099  
[kenneth.stockton@pseg.com](mailto:kenneth.stockton@pseg.com)

## NEW JERSEY

MAY 20

Activity: The Section members participated in a vendors' day event held at L'Af-faire Restaurant in Mountainside, N.J.

SEPTEMBER 16

Speakers: **Denis Hache**, senior technical sales engineer; and **Kristy Wielkiewicz**, innovator business unit manager  
Affiliation: Western Enterprises  
Topic: Gas manifold systems

Activity: The program was held at Snuffy's Pantagis Renaissance in Scotch Plains, N.J.

NOVEMBER 18

Speakers: **Richard Senna** and **Ronald Zakarzewski**, welding instructors  
Affiliation: United Association of Journeymen and Apprentices of the Plumbing and Pipe Fitting Industry  
Topic: Accelerated welder training at UA  
Activity: The meeting was held at Snuffy's Clambar in Scotch Plains, N.J.

## PHILADELPHIA

NOVEMBER 12

Speaker: **Frank Srogota**, regional sales manager



*Shown at the Central Massachusetts/Rhode Island Section training program are (from left) Chairman Douglas Desrochers, presenters Al Caron and Jon Marland, and Michael Richard.*



*Shown at the September New Jersey Section program are (from left) speakers Denis Hache and Kristy Wielkiewicz with Chairman Seann Bradley.*



New Jersey Section Chair Seann Bradley (far right) presents speaker gifts to welding instructors Ronald Zakarzewski (left) and Richard Senna.



Speaker Frank Srogota (left) shares a hearty handshake with Gary Atherton, Philadelphia Section chair.

Affiliation: Kriebel Engineered Equipment Ltd.  
Topic: Fume collection  
Activity: This Philadelphia Section program was held in Essington, Pa.

## District 3

Michael Wiswesser, director  
(610) 820-9551  
[mike@welderinstitute.com](mailto:mike@welderinstitute.com)

NOVEMBER 10-14

Activity: **Claudia Bottenfield** joined other District 3 members to facilitate a week-long training program for Certified Welding Inspectors in State College, Pa. **John Bailey** of General Electric presented the course in ultrasonic testing Level 1. Attendees included **Fran Brieden, Mike Mehan, Kurt LaLonde, Troy Rider, Eric Roberts, Larry Dudek, Adam Morrison, David Puccio, Tom Hoskin, and Claude Stimpson.**

## LANCASTER

DECEMBER 10

Activity: The Section hosted an AWS information table and participated at the Lancaster County Career and Technology Center's open house in Mount Joy, Pa. Section board member **John Boyer**, a welding instructor at the center, presented hands-on welding activities for the students. Working the AWS table were Chairman **Mike Sebergandio**, Technical Representative **Justin Heistand**, Secretary **Trina Siegrist**, and **Tim Siegrist**, communications chairman.

## District 4

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



Lancaster Section board members manning the AWS information table in December included (from left) Chairman Mike Sebergandio, Justin Heistand, Trina Siegrist, and Tim Siegrist.



Shown at the District 3 CWI training program are (from left) Fran Brieden, Mike Mehan, Kurt LaLonde, instructor John Bailey, Troy Rider, Eric Roberts, Larry Dudek, Adam Morrison, David Puccio, Tom Hoskin, and Claude Stimpson.

## District 5

**Steve Mattson**, director  
(904) 260-6040  
[steve.mattson@yahoo.com](mailto:steve.mattson@yahoo.com)

### ATLANTA

NOVEMBER 12

Speakers: **Leroy Bundrage**, Georgia Power Co.; and **Cajun Seeger**, Mechanical Trades Institute, Local 72

Topic: The shortage of qualified welders and the importance of technical colleges  
Activity: District 5 Director **Steve Mattson** reviewed the Section's scholarship program. **John Scott** discussed how the SkillsUSA and VICA programs have helped to increase the number of students entering the workforce. **Kevin Ward** commented on how NCCER and the training program can help move trainees into the workforce faster.



Shown at the Atlanta Section program are (from left) District 5 Director Steve Mattson, speakers Cajun Seeger and Leroy Bundrage, and Chair Robbie Zappa.

### SOUTH CAROLINA

NOVEMBER 20

Speaker: **Bill Masten**, quality assurance  
Affiliation: Nucor Steel Co.  
Topic: Metallurgy and quality control

## District 6

**Kenneth Phy**, director  
(315) 218-5297  
[kphy@gmail.com](mailto:kphy@gmail.com)

## District 7

**Don Howard**, director  
(814) 269-2895  
[howard@ctc.com](mailto:howard@ctc.com)

### CINCINNATI/DAYTON

DECEMBER 9

Speaker: **Candice Mehmetli**, development manager for clean energy  
Affiliation: Edison Welding Institute  
Topic: Opportunities in the wind power industry

Activity: The Dayton Section announced its activities page is now available on the AWS Web site. This joint meeting of the Cincinnati and Dayton Sections was held at Bullwinkle's in Miamisburg, Ohio.

### JOHNNY APPLESEED

NOVEMBER 22

Activity: The Section hosted a welding competition at Ivy Tech Community College in Fort Wayne, Ind., for 29 contestants. **William R. Richman**, owner of Richman Welding Works, Defiance, Ohio, received his AWS Life Member Award for 35 years of service to the So-



Shown at the South Carolina Section program are (from left) Vice Chair Ben Magrone, speaker Bill Masten, and Odell Haselden, treasurer.



Bill Richman (left) receives his AWS Life Membership Award from Eric Tart, secretary, Johnny Appleseed Section.



Candice Mehmetli accepts a speaker gift from Steve Whitney, Dayton Section chair.

ciety. The top welders in the Johnny Appleseed Section contest were **Gary Cearns, Joe Payne, and Zach Straw**. The judges for the event, all AWS CWIs, were **Dan Nichter, Kevin Langdon, and Wayne Porter**.

## District 8

**Joe Livesay, director**  
(931) 484-7502, ext. 143  
[joe.livesay@ttcc.edu](mailto:joe.livesay@ttcc.edu)

### CHATTANOOGA

OCTOBER 21

Speaker: **Jim Hurley**, southeast regional sales manager

Affiliation: Triumph Inc.

Topic: The current state of the art in laser material processing

Activity: **Bill Brooks** received an appreciation award for serving as Section chair. The meeting was held at Komatsu Restaurant in Chattanooga, Tenn.

### HOLSTON VALLEY

NOVEMBER 18

Activity: The Section members toured the Edwards & Associates — Custom Helicopters facility in Piney Flats, Tenn. Following the tour, the members had dinner at Pardner's Barbecue Restaurant where **Gary Killebrew** of Airgas, Inc., spoke on gas metal arc welding machines.

## District 9

**George D. Fairbanks Jr., director**  
(225) 473-6362  
[fits@bellsouth.net](mailto:fits@bellsouth.net)

### MOBILE

NOVEMBER 13

Speaker: **Connie Bowling**, director

Affiliation: AWS Foundation, Solutions Opportunity Squad

Topic: Workforce development

Activity: The Section will present a Certified Welding Supervisor preparatory course in March. For information, call Secretary **Eleanor Ezell** at (251) 457-8681. The meeting was held at Saucy-Q Bar B Que in Mobile Ala.

### NEW ORLEANS

NOVEMBER 15

Activity: The Section hosted its 2008 student welding competition at New Orleans Pipe Trades Local 60 in Metairie, La. The judges were CWIs **Paul C. Hebert, Tony Demarco, John Pajak, Cris Gotangco, and Travis Moore**. The students represented New Orleans Pipe Trades Local



*Shown judging at the Johnny Appleseed Section welding competition are (from left) CWIs Dan Nichter, Kevin Langdon, and Wayne Porter.*



*Bill Brooks (left) receives his chairman's appreciation certificate from Don Russell, Chattanooga Section treasurer.*



*Jim Hurley (right) receives a speaker gift from Chattanooga Section Chair Bill Brooks.*



*Speaker Connie Bowling is welcomed to the lectern by Josh Sanders, Mobile Section chair.*



*Chris Fernandez (left) is shown with Matthew Howerton, New Orleans Section chairman, at the Nov. 15 program.*



*Shown at the New Orleans Section Nov. 18 program are (from left) speaker **Gurdon Camus**, **Aldo Duron**, and Chair **Matthew Howerton**.*

60, Ironworkers Local 58, and several Louisiana Technical College campuses. **Chris Fernandez**, New Orleans Pipe Trades Local 60, was named the 2008 instructor winner.

NOVEMBER 18

Speaker: **Gurdon Camus**

Affiliation: Capital Safety Group of Red Wing

Topic: Fall protection techniques

Activity: This New Orleans Section meeting was sponsored by Ironworkers Local 58. **Aldo Duron**, with Local 58, organized the program.

## PASCAGOULA

NOVEMBER 18

Activity: The Section held its annual student night for 115 attendees. Speakers included **Connie Bowling**, AWS Foundation director Solutions Opportunity Squad; and **Charles Bennett**, CEO of Advance Technology, Inc. Bowling informed the students about the scholarship opportunities available through AWS and distributed literature to assist them in making career choices. Bennett discussed the local need for welders and the need for good welder training. Other speakers included AWS Vice President **John Bruskotter** and **James McNulty**, training manager at Signal International. District 9 Director **George Fairbanks** presented the AWS District and Section awards. The members of the Mississippi Gulf Coast C. C. Jackson County Student Chapter hosted the event. The meeting was held on the campus.

## District 10

**Richard A. Harris**, director  
(440) 338-5921  
[richaharris@alltel.net](mailto:richaharris@alltel.net)



*Beginning welder winners in the New Orleans Section contest on Nov. 15 are (from left) **Israel Velazquez**, **Jontell Jeffrey**, **Jodi Clelland**, **Aaron Lee Lukinvich**, **Titus Turner**, with Chair **Matthew Howerton**.*



*The advanced welder winners in the New Orleans Section contest on Nov. 15 are (from left) **Troy West**, **Warren Andy**, **Gary Campbell Jr.**, **Leroy Bell**, and **Brian Addison**, shown with Chairman **Matthew Howerton**.*



*Speaker **Connie Bowling** is shown with **William Harris**, Pascagoula Section chair.*



***Charles Bennett** (left) receives a speaker gift from **William Harris**, Pascagoula Section chairman.*



*Student Chapter members learned about welding scholarships at the Pascagoula Section program held Nov. 18.*



*Bernie Durkin shows Shane Steele, a promising young stud welder, the tricks of the trade at the CCCTC Student Chapter event.*



*Kia McDevitt presents Bernie Durkin a speaker gift at the CCCTC program.*



*John Bohr, Detroit Section vice chair, chats with Santa (a.k.a. Don Czerniewski), social chairman, at the recent holiday party.*



*Everyone tried their hand at stud welding at the CCCTC Student Chapter event.*

## CCCTC Student Chapter

NOVEMBER 20

Activity: The Columbiana County Career & Technical Center Student Chapter studied stud welding at the school welding lab. **Bernie Durkin** of Nelson Stud Welding conducted the program with assistance from **Huck Hughes**, Student Chapter advisor.

## MAHONING VALLEY

OCTOBER 23

Activity: The Section members joined members of the Warren, Ohio, ASM International Chapter to tour CMI-EFCO, formerly Electric Furnace Co., in Salem, Ohio. They had the opportunity to study the manufacture of industrial heat treating furnaces for galvanizing, annealing, and other applications.

## District 11

**Eftihios Siradakis**, director  
(989) 894-4101  
[ft.siradakis@airgas.com](mailto:ft.siradakis@airgas.com)

### DETROIT

DECEMBER 11

Activity: The Section hosted its annual holiday party at Ukrainian Cultural Center in Warren, Mich. **Don Czerniewski**, who donned a Santa Claus costume, was the MC. The event featured a silent auction and other contests that raised more than \$1000 for the Section's scholarship fund.

## District 12

**Sean P. Moran**, director  
(920) 954-3828  
[sean.moran@hobartbrothers.com](mailto:sean.moran@hobartbrothers.com)

### LAKESHORE

DECEMBER 11

Speaker: **Thomas Proft**, president  
Affiliation: T. L. Proft and Associates  
Topic: Designing to prevent fastener and weld failures  
Activity: The meeting was held at Mackinaws Grill & Spirits in Green Bay, Wis.



*Shown at the Madison-Beloit Section program are (from left) Frank Juckem, Jim Smith, Gary Bergstrom, Jim Pfeil, Chair Ben Newcomb, Bill Dawson, speaker Scott Raether, Burt Wheeler, Terry Schindler, and Jim Harrison.*



*Speaker Thomas Proft (right), an AWS Life Member, is shown with Nick Freiberg, Lakeshore Section chair.*



*Shown at the Detroit Section's holiday party are long-time AWS members (from left) Chuck Padden, Bernie Bastian, Carl Hildebrand, and Amos Winsand.*



*The students had a great time working with the latest equipment at the Madison-Beloit Section students' night program.*

## MADISON-BELOIT

OCTOBER 15

Activity: The Section members toured the Overture Center for the Arts guided by **Scott Raether**, director of operations at Novum Structures. The tour pointed out the use of architectural design and how welding is involved to facilitate the unique design of the building. The meeting continued at the Coliseum Bar and Grill in Madison, Wis., where Raether presented a talk on the center.



*Shown at the November Chicago Section board meeting are (back, from left) Anghelina Ifitimie, Marty Vondra, Craig Tichelar, and Pete Host; seated are Chairman Hank Sima and Vicky Landorf.*



Shown at the December Chicago Section program are (from left) Eric Krauss, speakers Bill Miller and Steven Kocheny, and Chairman Hank Sima.



Steve Roth (left) and Gary Ward demonstrated forge welding techniques for members of the Indiana and Dayton Sections.



Students participating in the Sangamon Valley welding contest are (from left) Cy Sills, Dalton Wagner, Cody Swisher, Michael Creek, Brett Ellis, Thomas Rigdon, Kevin Smith, Austin Buhlig, and John Behner.

NOVEMBER 12

Activity: The Madison-Beloit Section hosted its annual students' night program at Madison Area Technical College in Madison, Wis. On hand were representatives from Lincoln Electric, Miller Electric, ESAB, and 3M to demonstrate their wares and show the students how to operate the equipment. Fifty-two students participated in the event.

## District 13

**W. Richard Polanin, director**  
(309) 694-5404  
[rpolanin@icc.edu](mailto:rpolanin@icc.edu)

### CHICAGO

NOVEMBER 12

Activity: The Section members toured LB Steel in Harvey, Ill., to study operations in its heavy metal fabrication shop. About 50 attendees participated in the program.

NOVEMBER 19

Activity: The Section held its board meeting at Bohemian Crystal Restaurant in Chicago, Ill.

DECEMBER 10

Speakers: **Bill Miller**, sales manager, and **Steven A. Kocheny**, applications engineer, laser technology  
Affiliation: Leister Technologies, LLC  
Topic: Laser welding of plastics  
Activity: The program was held at Bohemian Crystal Restaurant.

## District 14

**Tully C. Parker, director**  
(618) 667-7795  
[tparke@millerwelds.com](mailto:tparke@millerwelds.com)

### INDIANA/DAYTON

NOVEMBER 11

Activity: The Indiana Section members traveled to the Miami County Fair Grounds in Troy, Ohio, for a joint meeting with the Dayton Section. **Steve Roth** and **Gary Ward** of the Southern Ohio Forge and Anvil Association demonstrated forge welding. The featured project was making an ax head from a flat piece of steel then forge welding a high-carbon steel tip onto the part.

### LEXINGTON

NOVEMBER 20

Activity: **Jeff Staton**, a division manager for Hypertherm, presented a demonstration of the latest plasma arc cutting equipment for the Section members and local welding students.

## SANGAMON VALLEY

NOVEMBER 20

Activity: The Section members held their students' night program during the Decatur Area Technical Academy's open house and parents' night program in Decatur, Ill. Nine students competed in the Section-sponsored welding demonstration contest. **Kevin Smith** received the first place prize. The other welders included **Cy Sills**, **Dalton Wagner**, **Cody Swisher**, **Michael Creek**, **Brett Ellis**, **Thomas Rigdon**, **Austin Buhlig**, and **John Behner**. The competition prizes were donated by Ilmo Products and S. J. Smith Welding Supply.



*Oren Reich (left) receives his silver membership certificate from Ryan Rummel, Central Texas Section chairman.*

stitute, Hot Springs, Ark.

Topic: The image of welding

Activity: The meeting was held at the Arkansas Career Training Institute.



*Jeff Staton discussed plasma arc cutting techniques at the Lexington Section's program in November.*



*Shown at the Northwest Section's open forum are moderator Bob Sands (left) and Chairman Todd Bridgum.*

## District 15

**Mace V. Harris**, director

(612) 861-3870

[macevh@aol.com](mailto:macevh@aol.com)

## District 15 NORTHWEST

DECEMBER 10

Activity: The Section hosted its annual certification open forum moderated by Vice Chair **Bob Sands**, a welding engineer and supervisor at Production Engineering Corp. The topic was "Why Do We Need Welding Procedures?" The event was held in Shoreview, Minn.

## District 16

**David Landon**, director

(641) 621-7476

[dlandon@vermeermfg.com](mailto:dlandon@vermeermfg.com)

## SIOUXLAND

DECEMBER 9

Activity: The Section members toured AKG Midwest, Inc., in Mitchell, S.Dak., to study the manufacture of coolers and heat exchangers for construction and agriculture equipment. Following the tour and a question and answer session, the members visited the Mitchell Technical Institute Technology Center for a tour of the facility. The presenter was **Doug Greenway**, director of business and industrial training.

## District 17

**J. J. Jones**, director

(940) 368-3130

[jjones@thermadyne.com](mailto:jjones@thermadyne.com)

## CENTRAL ARKANSAS

SEPTEMBER 25

Speaker: **Dennis Pickering**, Section chairman and welding instructor

Affiliation: Arkansas Career Training In-

## CENTRAL TEXAS

OCTOBER 28

Speaker: **Frank Wilkins**, chairman

Affiliation: Texas State Technical College (TSTC) welding department

Topic: The future of the welding industry and the growing need for welders

Activity: The program was held at TSTC in Waco, Tex.

Activity: **Oren Reich** received his silver membership certificate for 25 years of service to the Society.

## NORTH TEXAS

NOVEMBER 18

Speaker: **Robert Steinbock**

Affiliation: Superbolt Inc.

Topic: Gaining the advantage with multi-jackbolt tensioners

Activity: This was a joint meeting with members of the local chapter of ASME. About 65 people attended the program, held at the University of Texas at Arlington, Tex. The Section is collecting canned foods in support of the North Texas Food Bank.

DECEMBER 9

Activity: The North Texas Section hosted its annual silent auction at Humperdinks Restaurant in Arlington, Tex. The event raised \$1080 for the Section's scholarship program.

## District 18

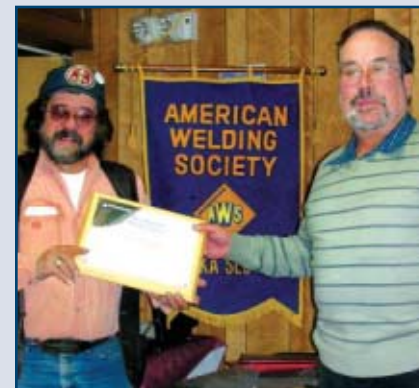
**John Bray**, director

(281) 997-7273

[sales@affiliatedmachinery.com](mailto:sales@affiliatedmachinery.com)



*Speaker Frank Wilkins (right) is shown with Ryan Rummel, Central Texas Section chair.*



*Bruce Weisman (left) receives the District Director Certificate Award from Neil Shannon, District 19 director, at the Alaska Section program in September.*



Peter Macksey (left) receives the District Director Certificate Award from Neil Shannon, District 19 director, at the Alaska Section program in September.



Albuquerque Section awardees include (from left) Pat Baumann, Wade Florence, Jim Kunz, Richard Moku, Charlie Robino, and Phil Fuerschbach.



Speaker Carl Heinrich (right) is shown with John Little at the British Columbia Section program.



Speaker Mike Hosking (left) is shown with Tom Lienert, Albuquerque Section chair.



Don McLeod receives his Life Membership Certificate from Pat Newhouse, British Columbia Section chair.



Colorado Section Chair James Corbin (left) is shown with speaker Dave Bennett.

## District 19

Neil Shannon, director  
(503) 419-4546  
[neilshnn@msn.com](mailto:neilshnn@msn.com)

### ALASKA

SEPTEMBER 26

Speaker: **Neil Shannon**, District 19 director  
Affiliation: Carlson Testing, project manager  
Topic: Electroslag surfacing of naval propulsion shafting  
Activity: **Bruce Weisman** and **Peter Macksey** received District Director Certificate Awards. The meeting was held at Peggy's Restaurant in Anchorage, Alaska.

NOVEMBER 21

Speaker: **Scott Sheaffer**, advanced technical sales specialist  
Affiliation: Olympus NDT  
Topic: Multitechnology flaw detectors  
Activity: **Bruce Weisman**, certification chair, announced the 2009 CWI seminar and examinations schedule. The Alaska Section will host a CWI seminar followed by the exam in late March, plus an examination (no seminar) in September. For more information on these events, contact **Peter Macksey** at (907) 264-2804; [pmacksey@steelfabak.com](mailto:pmacksey@steelfabak.com).

### BRITISH COLUMBIA

NOVEMBER 13

Speaker: **Carl Heinrich**, CEO  
Affiliation: Roboweld  
Topic: Robotic welding of heavy-thickness mining truck wheels  
Activity: **Don McLeod** received his Life Membership Award for 35 years of service to the Society. The meeting was held



Utah Section members celebrated their annual turkey shoot event at Impact Guns.

at Roboweld in Coquitlam, B.C., Canada. Following the talk, the members toured the facility.

## District 20

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

### ALBUQUERQUE

NOVEMBER 20

Speaker: **Mike Hosking**, manager, joining and coating department  
Affiliation: Sandia National Laboratories

Topic: Comparison of soldering, brazing, and welding technologies

Activity: **Phil Fuerschbach** and **Charlie Robino** received their Silver Membership Certificates and pins for 25 years of service to the Society. Awards were presented to **Pat Baumann**: District CWI of the Year; **Mike Thomas**: Section CWI of the Year; **Wade Florence** and **Richard Moku**: Section Meritorious; **Jim Kunz**: Section Appreciation; and **Jameson Butler**: Student Member Award. The program was held at Central New Mexico Community College in Albuquerque, N.Mex.

### COLORADO

NOVEMBER 13

Speaker: **Dave Bennett**, VP of sales  
Affiliation: Eaton Metal

Topic: Fabrication of large pressure vessels

Activity: Awards were presented to **Marjorie Oliver**: Section CWI of the Year; **Bob Teuscher**: District Director; and **Fred Schaefer**: Section Meritorious.



Eighty-one Sacramento Valley section members attended the November program.

### SOUTHERN COLORADO

NOVEMBER 17

Activity: The Section members toured Springs Fabrication in Colorado Springs, Colo., to study its new high bay tank facility. Participating in the tour were **Tom Neppi**, president, **Steve Bixler**, and **Belinda Popovich**.

### UTAH

NOVEMBER 18

Activity: The Section held its annual turkey shoot at Impact Guns in Roy, Utah. Wayne Western coordinated the event.

## District 21

Nanette Samanich, director  
(702) 429-5017  
[weldor07@aol.com](mailto:weldor07@aol.com)



Speaker **Regis Geisler** (right) is shown with **Don Robinson**, Sacramento Valley Section chair.

## District 22

Dale Flood, director  
(916) 288-6100, ext. 172  
[flashflood@email.com](mailto:flashflood@email.com)



Colorado Section Chair James Corbin (left) is shown with award winners (from left) Marjorie Oliver, Bob Teuscher, and Fred Schaefer.



Shown during the Southern Colorado Section tour of Springs Fabrication are (from left) Belinda Popovich, Tom Neppi, and Steve Bixler.



Shown at the San Francisco holiday program are (from left) Caroline Miller, Section Chair Liisa Pine, Rebecca Anders, and Jessica Hobbs.

## SACRAMENTO VALLEY

NOVEMBER 19

Speakers: **Regis Geisler**, welding sales engineer; and **Mark Ehrlich**

Affiliation: The Lincoln Electric Co.

Topic: Proper welding techniques using NR 232 flux core wire

Activity: Following Geisler's talk, he and Ehrlich demonstrated the welding procedures in the American River College welding lab, managed by instructors **Mark Reese** and **Melvin Johnson**.

## SAN FRANCISCO

DECEMBER 3

Activity: Sixty-five Section members and guests attended a special holiday presentation of the Flaming Lotus Girls and their pyrotechnic artworks. The program was held at Spenger's Restaurant in Berkeley, Calif.

## Director Awards Announced

District 9 Director George Fairbanks has nominated the following members for this award:

**Charlie Lewis** — Acadiana Section

**Marcie Jacquet** — Acadiana Section

**Leslie Bertrand** — Acadiana Section

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.

## Membership Counts

| Member Grades                       | As of 1/01/09 |
|-------------------------------------|---------------|
| Sustaining.....                     | 516           |
| Supporting.....                     | 315           |
| Educational.....                    | 488           |
| Affiliate.....                      | 467           |
| Welding distributor.....            | 49            |
| <b>Total corporate members.....</b> | <b>1,835</b>  |
| Individual members.....             | 49,666        |
| Student + transitional members..... | 5,406         |
| <b>Total members.....</b>           | <b>55,072</b> |

## Guide to AWS Services

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

### AWS PRESIDENT

**Victor Y. Matthews**  
[vic\\_matthews@lincolnelectric.com](mailto:vic_matthews@lincolnelectric.com)  
The Lincoln Electric Co.  
7955 Dines Rd.  
Novelty, OH 44072

### ADMINISTRATION

**Ray W. Shook**.. [rshook@aws.org](mailto:rshook@aws.org) .....(210)  
Executive Director

**Frank R. Tarafa**.. [tarafa@aws.org](mailto:tarafa@aws.org) .....(252)  
CFO/Deputy Executive Director

**Cassie R. Burrell**.. [cburrell@aws.org](mailto:cburrell@aws.org) .....(253)  
Deputy Executive Director

**Jeff Weber**.. [jweber@aws.org](mailto:jweber@aws.org) .....(246)  
Senior Associate Executive Director

**Gricelda Manalich**.. [gricelda@aws.org](mailto:gricelda@aws.org) .....(294)  
Executive Assistant for Board Services

### Administrative Services

**Jim Lankford**.. [jiml@aws.org](mailto:jiml@aws.org) .....(214)  
Managing Director

**Armando Campana**.. [acampana@aws.org](mailto:acampana@aws.org) .....(296)  
IT Network Director

**Hidail Nuñez**.. [hidail@aws.org](mailto:hidail@aws.org) .....(287)  
Director

**Natalia Swain**.. [nswain@aws.org](mailto:nswain@aws.org) .....(245)  
Database Administrator

### Human Resources

**Luisa Hernandez**.. [luisa@aws.org](mailto:luisa@aws.org) .....(266)  
Director, Compensation and Benefits

**Dora A. Shade**.. [dshade@aws.org](mailto:dshade@aws.org) .....(235)  
Manager, Human Resources

### INT'L INSTITUTE of WELDING

**Sissibeth Lopez**.. [sissi@aws.org](mailto:sissi@aws.org) .....(319)  
Senior Coordinator  
Provides liaison services with other national and international professional societies and standards organizations.

### GOVERNMENT LIAISON SERVICES

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

### CONVENTION and EXPOSITIONS

**Jeff Weber**.. [jweber@aws.org](mailto:jweber@aws.org) .....(246)  
Senior Associate Executive Director

**Joe Krall**.. [jkrall@aws.org](mailto:jkrall@aws.org) .....(297)  
Corporate Director, Exhibition Sales  
Organizes the annual AWS Welding Show and  
Convention, regulates space assignments, regis-  
tration items, and other Expo activities.

### Brazing and Soldering Manufacturers' Committee

**Jeff Weber**.. [jweber@aws.org](mailto:jweber@aws.org) .....(246)

### RWMA — Resistance Welding Manufacturing Alliance

**Susan Hopkins**.. [susan@aws.org](mailto:susan@aws.org) .....(295)  
Manager

### WEMCO — Welding Equipment Manufacturers' Committee

**Natalie Tapley**.. [tapley@aws.org](mailto:tapley@aws.org) .....(444)  
Manager

### PUBLICATION SERVICES

Department Information .....(275)

**Andrew Cullison**.. [cullison@aws.org](mailto:cullison@aws.org) .....(249)  
Managing Director

### Welding Journal

**Andrew Cullison**.. [cullison@aws.org](mailto:cullison@aws.org) .....(249)  
Publisher

### Editor

**Mary Ruth Johnsen**.. [mjohnsen@aws.org](mailto:mjohnsen@aws.org) .....(238)

### National Sales Director

**Rob Saltzstein**.. [salty@aws.org](mailto:salty@aws.org) .....(243)

### Society and Section News Editor

**Howard Woodward**.. [woodward@aws.org](mailto:woodward@aws.org) .....(244)

### Welding Handbook

**Annette O'Brien**.. [aobrien@aws.org](mailto:aobrien@aws.org) .....(303)  
Welding Handbook Editor  
Publishes the Society's monthly magazine, *Weld-  
ing Journal*, which provides information on the  
state of the welding industry, its technology, and  
Society activities. Publishes *Inspection Trends*, the  
*Welding Handbook*, and books on general welding  
subjects.

### MARKETING COMMUNICATIONS

#### Director

**Ross Hancock**.. [rhancock@aws.org](mailto:rhancock@aws.org) .....(226)

#### Webmaster

**Angela Miller**.. [amiller@aws.org](mailto:amiller@aws.org) .....(456)

### MEMBER SERVICES

Department Information .....(480)

#### Deputy Executive Director

**Cassie R. Burrell**.. [cburrell@aws.org](mailto:cburrell@aws.org) .....(253)

#### Director

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

### CERTIFICATION SERVICES

Department Information .....(273)

#### Managing Director, Certification Operations

**John Filippi**.. [jfilippi@aws.org](mailto:jfilippi@aws.org) .....(222)

#### Managing Director, Technical Operations

**Peter Howe**.. [phowe@aws.org](mailto:phowe@aws.org) .....(309)  
Manages and oversees the development, in-  
tegrity, and technical content of all certification  
programs.

#### Director, Int'l Business & Certification Programs

**Priti Jain**.. [pjain@aws.org](mailto:pjain@aws.org) .....(258)  
Directs all int'l business and certification pro-  
grams. Is responsible for oversight of all agencies  
handling AWS certification programs.

### EDUCATION SERVICES

#### Managing Director

**Dennis Marks**.. [dmarks@aws.org](mailto:dmarks@aws.org) .....(449)

Director, Education Services Administration  
and Convention Operations

**John Ospina**.. [jospina@aws.org](mailto:jospina@aws.org) .....(462)

### AWS AWARDS, FELLOWS, COUNSELORS

#### Senior Manager

**Wendy S. Reeve**.. [wreeve@aws.org](mailto:wreeve@aws.org) .....(293)  
Coordinates AWS awards and AWS Fellow and  
Counselor nominees.

### TECHNICAL SERVICES

Department Information .....(340)

#### Managing Director

**Andrew R. Davis**.. [adavis@aws.org](mailto:adavis@aws.org) .....(466)  
Int'l Standards Activities, American Council of  
the Int'l Institute of Welding (IIW)

#### Director, National Standards Activities

**John L. Gayler**.. [gayler@aws.org](mailto:gayler@aws.org) .....(472)  
Personnel and Facilities Qualification, Comput-  
erization of Welding Information

#### Manager, Safety and Health

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

#### Technical Publications

AWS publishes about 200 documents widely used  
throughout the welding industry.

#### Senior Manager

**Rosalinda O'Neill**.. [roneill@aws.org](mailto:roneill@aws.org) .....(451)

#### Staff Engineers/Standards Program Managers

**Annette Alonso**.. [aalonso@aws.org](mailto:aalonso@aws.org) .....(299)  
Automotive Welding, Resistance Welding, Oxy-  
fuel Gas Welding and Cutting, Definitions and  
Symbols, Sheet Metal Welding

**Stephen Borrero**.. [sborrero@aws.org](mailto:sborrero@aws.org) .....(334)

Joining of Metals and Alloys, Brazing and Sol-  
dering, Brazing Filler Metals and Fluxes, Brazing  
Handbook, Soldering Handbook

**Rakesh Gupta**.. [gupta@aws.org](mailto:gupta@aws.org) .....(301)

Filler Metals and Allied Materials, Int'l Filler  
Metals, Instrumentation for Welding, UNS Num-  
bers Assignment

**Brian McGrath**.. [bmcgrath@aws.org](mailto:bmcgrath@aws.org) .....(311)

Methods of Inspection, Mechanical Testing of  
Welds, Welding in Marine Construction, Piping  
and Tubing

**Selvis Morales**.. [smorales@aws.org](mailto:smorales@aws.org) .....(313)

Welding Qualification, Structural Welding

**Matthew Rubin**.. [mrubin@aws.org](mailto:mrubin@aws.org) .....(215)

Machinery and Equipment, Robotics Welding,  
Arc Welding and Cutting Processes

**Reino Starks**.. [rstarks@aws.org](mailto:rstarks@aws.org) .....(304)

Welding in Sanitary Applications, High-Energy  
Beam Welding, Aircraft and Aerospace, Friction  
Welding, Railroad Welding, Thermal Spray

**Note:** Official interpretations of AWS standards  
may be obtained only by sending a request in writ-  
ing to the Managing Director, Technical Services.  
Oral opinions on AWS standards may be ren-  
dered. However, such opinions represent only the  
personal opinions of the particular individuals  
giving them. These individuals do not speak on  
behalf of AWS, nor do these oral opinions con-  
stitute official or unofficial opinions or inter-  
pretations of AWS. In addition, oral opinions are in-  
formal and should not be used as a substitute for  
an official interpretation.

## Nominees for National Office

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

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

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

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

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

**Treasurer:** To be eligible to hold the

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

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

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

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

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

## Honorary Meritorious Awards

The Honorary Meritorious Awards Committee makes recommendations for the nominees presented to receive the Honorary Membership, National Meritorious Certificate, William Irrgang Memorial, and the George E. Willis Awards. These honors are presented during the FABTECH International & AWS

Welding Show held each fall. The deadline for submissions is December 31 prior to the year of the awards presentations. Send candidate materials to Wendy Sue Reeve, secretary, Honorary Meritorious Awards Committee, [wreeve@aws.org](mailto:wreeve@aws.org); 550 NW LeJeune Rd., Miami, FL 33126. Descriptions of these awards follow.

### William Irrgang Memorial Award

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

### George E. Willis Award

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

### Honorary Membership Award

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

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

### National Meritorious Certificate Award

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

### International Meritorious Certificate Award

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

## AWS Publications Sales

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

### Welding Journal Reprints

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

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

### FosteReprints

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Reprint Marketing Manager  
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## AWS Foundation

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

Chairman, Board of Trustees  
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Executive Director, AWS  
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Director, Solutions Opportunity Squad  
**Connie Bowling**, ext. 308, [cbowling@aws.org](mailto:cbowling@aws.org)

550 NW LeJeune Rd., Miami, FL 33126  
(305) 445-6628; (800) 443-9353, ext. 293  
General Information:  
(800) 443-9353, ext. 689; [vpinsky@aws.org](mailto:vpinsky@aws.org)

## AWS Mission Statement

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

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

# **NASCC** **THE STEEL CONFERENCE**

Incorporating the  
2009 Annual Stability Conference

**PHOENIX, ARIZONA**

**Phoenix Civic Plaza Convention Center**

**Conference:** April 1–4, 2009

**Exhibits:** April 1–3, 2009

**Technical Seminars ♦ Networking ♦ Product Showcase**  
for Structural Engineers, Detailers, Erectors, and Fabricators

## Who attends?

More than 3,700 structural engineers, steel fabricators, erectors, detailers, educators, and others involved in the design and construction of fabricated steel attend the conference each year. In addition to conference seminars, attendees have many networking opportunities, including the annual Fabricator Workshops, where fabricators can exchange ideas in a non-competitive environment.

## What about the exhibit hall?

More than 3,700 structural engineers, steel fabricators, erectors, detailers, educators, and others involved in the design and construction of fabricated steel attend the conference each year. In addition to conference seminars, attendees have many networking opportunities, including the annual Fabricator Workshops, where fabricators can exchange ideas in a non-competitive environment.

## What will I learn?

Learn about topics ranging from gusset plates for seismic construction to structural integrity in buildings to HSS design. Some sessions focus on technical issues while other focus on fabrication, erection, or detailing. But all attendees are welcome to attend any of the sessions, regardless of track. In addition to our regular technical sessions, we've also invited some of the industry's top professors and some of the leading experts to give their "best lecture." Speakers include Shankar Nair, Bill Thornton, Jim Malley, Tom Ferrell, Abbas Aminmansour, Peter Birkemoe, Chia-Ming Uang, and Duane Ellifrit. And new this year, we're offering a two-day "how to design" program from one of the nation's top structural engineering firms (this is a more formal version of the program Computerized Structural Design uses to train its new employees).

**For more information, visit**

**[www.aisc.org/nascc](http://www.aisc.org/nascc)**

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For Info go to [www.aws.org/ad-index](http://www.aws.org/ad-index)

**THE STEEL CONFERENCE** is a premier education event aimed at providing structural engineers, steel fabricators, erectors, and detailers with practical information and the latest design and construction techniques. More than 60 technical sessions offer a variety of educational opportunities:

- |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
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| <ul style="list-style-type: none"> <li>Creating the Desirable Workplace</li> <li>The Wal-Mart Effect and Your Business</li> <li>Gusset Plates for Seismic Construction</li> <li>Structural Integrity in Buildings</li> <li>Steel Interchange LIVE!</li> <li>Who's Financially Responsible When a Job Goes Bad?</li> <li>Delegating Connection Responsibility to the Fabricator—What Is the EOR's Legal Responsibility?</li> <li>Rules of Thumb for Steel Design</li> <li>Design of Frames Using Web-Tapered Members</li> <li>Staggered Truss Systems: Lessons Learned</li> <li>HSS Design</li> <li>Specifying Camber—Rules of Thumb for Designers</li> <li>The Process of Renovation—Concept to Completion!</li> <li>Safety by Design</li> <li>Better Base Plate Designs</li> <li>Connection Design: Dealing with Load Paths, Transfer Forces, and the Apparent Lack of Joint Equilibrium</li> <li>Cold-Formed and Hot-Rolled: The Best of Both Worlds</li> <li>What Fabricator Certification Means to the EOR</li> <li>Wind Design Considerations for Steel Joists and Joist Girders</li> <li>Trends in Offshoring/Outsourcing and How Advances in Software Address the Migration</li> <li>An Introduction to Earthquake Engineering and Seismic Codes—Part I: Ductility</li> <li>An Introduction to Earthquake Engineering and Seismic Codes—Part II: Seismic Provisions</li> </ul> | <ul style="list-style-type: none"> <li>An Introduction to Earthquake Engineering and Seismic Codes—Part III: Design Examples</li> <li>BIM: "Cradle to Grave"—From the Structural Engineer's Perspective</li> <li>How Does Parking Play with Mixed-Use?</li> <li>Ethics and Accountability</li> <li>Improving Shop Safety</li> <li>Estimating Rules of Thumb</li> <li>QMC's Top 10 CARs: Part I</li> <li>QMC's Top 10 CARs: Part II</li> <li>Current Sales Forecasts and Outlook</li> <li>Contract Language and Risk Management—Understanding Basic Contract Language</li> <li>Employee Retention (What's New? What Can We Do?)</li> <li>Trucking: Lease vs. Buy vs. Contract</li> <li>Fabricator Roundtable</li> <li>Connections: The Good, the Bad, and the Ugly</li> <li>RFIs: Use and Abuse (Do you Know the Difference?)</li> <li>Document Control Management</li> <li>How to Get Rich in Detailing</li> <li>Value-Added Selling: Competing Against Overseas Detailers</li> <li>OSHA Revisited</li> <li>Fire Protection, Painting and Galvanizing (What the Detailer Should Know)</li> <li>Communicating and Coordinating Between Detailers</li> <li>Stair and Miscellaneous Steel Detailing in 3D</li> <li>High Seismic—An Erector's Guide</li> <li>Safety First</li> <li>Moving Steel to Make Iron</li> <li>Preparing a Site-Specific Erection Plan</li> </ul> |
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**and much more!**

# PROFESSIONAL PROGRAM ABSTRACT SUBMITTAL

## Annual FABTECH International & AWS Welding Show

### Chicago, IL – November 15-18, 2009

**Submission Deadline: March 13, 2009**

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

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| <b>Primary Author (Full Name):</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |                       |                                                                                                                                                                                                                                                                                                                                                                                                     |                 |
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| <b>Co-Author(s):</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                              |                       |                                                                                                                                                                                                                                                                                                                                                                                                     |                 |
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| <b>Answer the following about this paper</b><br>Original submittal? Yes <input type="checkbox"/> No <input type="checkbox"/> Progress report? Yes <input type="checkbox"/> No <input type="checkbox"/> Review paper? Yes <input type="checkbox"/> No <input type="checkbox"/> Tutorial? Yes <input type="checkbox"/> No <input type="checkbox"/><br>What are the welding/Joining processes used?<br>What are the materials used?<br>What is the main emphasis of this paper? Process Oriented <input type="checkbox"/> Materials Oriented <input type="checkbox"/> Modeling <input type="checkbox"/><br>To what industry segments is this paper most applicable?<br>Has material in this paper ever been published or presented previously? Yes <input type="checkbox"/> No <input type="checkbox"/><br>If "Yes", when and where?<br>Is this a graduate study related research? Yes <input type="checkbox"/> No <input type="checkbox"/><br>If accepted, will the author(s) present this paper in person? Yes <input type="checkbox"/> Maybe <input type="checkbox"/> No <input type="checkbox"/> |                       |                                                                                                                                                                                                                                                                                                                                                                                                     |                 |
| <b>Keywords: Please indicate the top four keywords associated with your research below</b><br><div style="border-bottom: 1px solid black; width: 100%; margin-bottom: 5px;"></div> <div style="border-bottom: 1px solid black; width: 100%; margin-bottom: 5px;"></div> <div style="border-bottom: 1px solid black; width: 100%; margin-bottom: 5px;"></div> <div style="border-bottom: 1px solid black; width: 100%; margin-bottom: 5px;"></div>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                       |                                                                                                                                                                                                                                                                                                                                                                                                     |                 |
| <b>Guidelines for abstract submittal and selection criteria:</b> <ul style="list-style-type: none"> <li>Only those abstracts submitted on this form will be considered. Follow the guidelines and word limits indicated.</li> <li>Complete this form using MSWord. Submit electronically via email to <a href="mailto:techpapers@aws.org">techpapers@aws.org</a></li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |                       |                                                                                                                                                                                                                                                                                                                                                                                                     |                 |
| <b>Technical/Research Oriented</b> <ul style="list-style-type: none"> <li>New science or research.</li> <li>Selection based on technical merit.</li> <li>Emphasis is on previously unpublished work in science or engineering relevant to welding, joining and allied processes.</li> <li>Preference will be given to submittals with clearly communicated benefit to the welding industry.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |                       | <b>Applied Technology</b> <ul style="list-style-type: none"> <li>New or unique applications.</li> <li>Selection based on technical merit.</li> <li>Emphasis is on previously unpublished work that applies known principles of joining science or engineering in unique ways.</li> <li>Preference will be given to submittals with clearly communicated benefit to the welding industry.</li> </ul> |                 |
| <b>Education</b> <ul style="list-style-type: none"> <li>Innovation in welding education at all levels.</li> <li>Emphasis is on education/training methods and their successes.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                       | Papers should address overall relevance to the welding industry.                                                                                                                                                                                                                                                                                                                                    |                 |
| <input checked="" type="checkbox"/> Check the category that best applies:                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         |                       |                                                                                                                                                                                                                                                                                                                                                                                                     |                 |
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**Proposed Title (max. 50 characters):**

**Proposed Subtitle (max. 50 characters):**

**Abstract:**

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

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

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

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

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

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

Return this form, completed on both sides, to

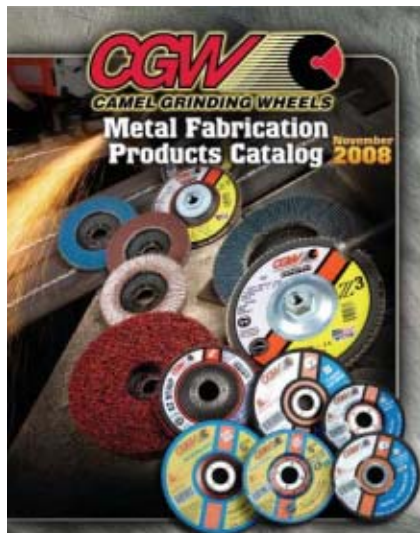
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**NEW**

**LITERATURE**

**Metal Fabrication Products Pictured in Catalog**



More than 1600 products, including 200 new surface-finishing products, are displayed in the company's latest catalog that is divided into three main color-coded categories. Featured are flap discs, semi-flex discs, resin fiber discs, quick-change discs, flap wheels, hook and loop surface-conditioning discs, Quickie Cut™ cut-off wheels, depressed-center wheels, and stationary saw wheels. The catalog can be viewed online in the USA section of the Web site.

**CGW-Camel Grinding Wheels, USA**  
[www.cgwheels.com](http://www.cgwheels.com)  
(800) 447-4248

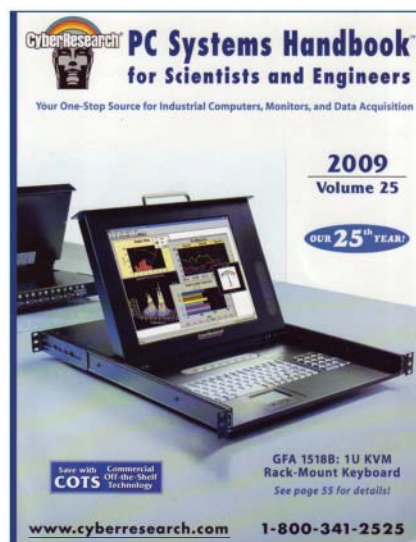
**Casting Handbook Issued**

The revised *ASM Handbook*, Vol. 15, *Casting*, updates and expands coverage on the principles and practices of casting in several ways. Melt processing methods and equipment are described for iron, steel, and aluminum in terms of fluxing, degassing, molten metal filtration, refinement, and modification. Solidification, process modeling, and filling and feeding concepts are updated to reflect the continuing improvements in casting methods and processing. The major methods of green-sand, no-bake, and shell molding are described further in individual articles. Additional articles are devoted to the foundry practice of cast irons, steels, aluminum, copper alloys, and zinc. Expert updates are also provided on many other significant casting methods such as high-pressure die casting, lost-foam, squeeze casting, semisolid methods, spray casting,

rapid solidification, and low-pressure die casting of high-integrity product. Automation technology is addressed with expanded coverage on continuous casting of aluminum and copper, specifications, selection, and properties of gray iron, ductile irons, malleable irons, compacted graphite irons, high-alloy irons, cast steels, aluminum, copper, zinc, magnesium, cobalt, nickel, titanium, zirconium, and cast metal matrix composites. The text lists for \$264, \$212 to ASM members. Sample articles can be downloaded free at the Web site.

**ASM International**  
[www.asminternational.org](http://www.asminternational.org)  
(440) 338-5151

**Industrial PCs Handbook Updated for 2009**



The 220-page, full-color, 2009 *PC Systems Handbook for Scientists and Engineers* features an expanded line of industrial PCs and monitors including peripherals, accessories, data acquisition, and communications. Covered also are extensive lines of workstations, chassis with front and rear slot access, motherboards, SBCs, and accessories such as pointing devices, KVMs, hard drives, removable drives, video cards, and signal extenders and amplifiers. Featured are new models in the FoldAway™ series employing 1U rack-mount monitor/key-board combinations, and the CYRAQ® series with NEMA 4X PCs and monitors in sizes from 6½ to 24 in.

**CyberResearch, Inc.**  
[www.cyberresearch.com](http://www.cyberresearch.com)  
(800) 341-2525 or (203) 643-5000

**Pocket Welding Guide Released in 30th Edition**

The 30th edition of the popular *Pocket Welding Guide* has been completely revised and updated with the addition of the latest filler metals, new photos of good and bad welds, preheat temperatures for metals, and the AISI designation system for carbon and low-alloy steels. It includes troubleshooting guides, essentials for good welding, welding symbols, joints, and positions, causes and cures for common welding problems, etc. The toolbox size guide is \$4.95. Order online or by phone.

**Hobart Institute of Welding Technology**  
[www.welding.org](http://www.welding.org)  
(800) 332-9448, ext. 5433; (937) 332-5433

**Updated Abrasive Products Catalog Offered**

A new abrasive products catalog illustrates and describes various size aluminum oxide, zirconia, alumina, and ceramic abrasive belts for use with Dynafile, Dynaflex II, Dynabelter, and various other tools. Included are a wide selection of aluminum oxide and silicon carbide sanding discs for use with the palm-style and two-handed random orbital sanders. Other products pictured are scalloped-edge abrasive discs, locking-type discs, flap wheels, fiber discs, microfinishing rolls, sanding stars, abrasive bands, cut-off wheels, and Type 27 depressed-center grinding wheels.

**Dynabrade, Inc.**  
[www.dynabrade.com](http://www.dynabrade.com)  
(716) 631-0100

**Consumables Guide for Wind Towers Published**

The *Wind Tower Fabrication Consumable Selection Guide* is offered to assist fabricators in determining critical welding process factors, including consumable selection and welding procedures for wind tower welding. Included is an optimized welding procedure to help fabricators increase productivity and reduce costs using submerged arc wire and fluxes that meet the critical weld chemistry restrictions for wind tower fabrication. The ten products detailed are Lincolnweld® L-61 (AWS EM12K), general-purpose electrode for a wide range of applications with single or multipass submerged arc welding; L-S3 (AWS EH12K) produces low-temperature impact properties ideal for the most

demanding offshore applications; LA-85 (AWS ENi5) for use on weathering steels and applications requiring excellent low-temperature impact properties; L-70 (AWS EA1) for single- or multipass welds on pipe and other limited pass applications where impact properties are required; LA-90 (AWS EA3K) special-purpose wire; LA-81 (AWS EG) for extremely high toughness, often used for arctic-grade line pipe or as a back bead on multipass welds, and for welding up to API X90 grade pipe; and three fluxes for specific applications. Obtain Bulletin GSM08-01 online or call.

**The Lincoln Electric Co.**  
[www.lincolnelectric.com](http://www.lincolnelectric.com)  
(888) 355-3213

## Laser Fabricating Systems Pictured in Catalog

A 36-page, well-illustrated, full-color catalog depicts the company's complete lines of profiling and processing systems. The five sections include laser cutting, precision plasma cutting, plasma and oxy-fuel cutting, plate working systems, and waterjet cutting. Twelve different machines are described with their technical specifications presented in a user-friendly



table format. Other sections detail control systems and application software for part programming, nesting, and production management.

**Farley Laserlab Cutting Systems**  
[www.farleylaserlab.com](http://www.farleylaserlab.com)  
(815) 874-1400

## CD Offers QC Air Gauging Solutions

The company's newest CD provides full product specifications and pricing on its lines of air gauging, tool taper cleaners, force check gauges, and test equipment for quality control for use in the au-



tomotive, aerospace, medical, and other precision metalworking industries. Highlighted in the new CD is the MSK multifunctional measurement and control device, which combines pneumatic and tactile touching for both in-process and post-process component inspection. The products feature high accuracy and resolution repeatability, down to 0.1 micron, capable of air gauging small-diameter holes. The air gauging stations are designed for use in machine tool spindle and tool manufacturers, as well as end user shops, for gauging HSK and CAT tooling, power drawbars, and other spindle interface components. Free copies of the CD are available on request.

**Stotz Gaging Co.**  
[www.stotz-usa.com](http://www.stotz-usa.com)  
(815) 297-1805



## → HELP FOUND

### BETTER CANDIDATES, BETTER RESULTS

AWS JobFind works better than other job sites because it specializes in the materials joining industry. Hire those hard-to-find Certified Welding Inspectors (CWIs), Welders, Engineers, Welding Managers, Consultants and more at [www.awsjobfind.com](http://www.awsjobfind.com). You'll find more than 2,000 résumés of top job seekers in the industry!

### THE TOOLS TO DO MORE

AWS JobFind provides companies with the tools to post, edit and manage their job listings easily and effectively, any day or time, have immediate access to an entire résumé database of qualified candidates, look for candidates who match their employment needs: full-time, part-time or contract employees, receive and respond to résumés, cover letters, etc. via e-mail.

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**VISIT [WWW.AWSJOBFIND.COM](http://WWW.AWSJOBFIND.COM)**

## PERSONNEL

### Lincoln Expands Marketing Capabilities



Lisa Byall



Bruce Chantry

The Lincoln Electric Co., Cleveland, Ohio, has promoted **Lisa Byall** and **Bruce Chantry** to the newly created position of portfolio manager. Byall, with the company for 16 years, most recently served as product manager, flux cored wires, and worked in the distributor training department and as a technical sales representative. She will be responsible for overseeing the welding consumable portfolio. Chantry, with the company for 13 years, most recently was product manager, advanced welding equipment. He will be responsible for overseeing the welding equipment portfolio.

### Altra Names VP



Mark Klossner

Altra Industrial Motion, Braintree, Mass., a producer of mechanical power transmission products, has appointed **Mark Klossner** vice president and general manager of the Altra Engineered Couplings Group. Klossner, with the company since 2004, most recently served as managing director for the company's business unit Matrix International, based in Brechin, Scotland.

### Genesis Appoints Director

Genesis Systems Group, LLC, Davenport, Iowa, has appointed **Makoto Matsuoka** senior director of new domestic business development, based at the company's Rochester Hills, Mich., facility. Prior to joining the company, Matsuoka was a contract employee for Genesis as

## MEMBER MILESTONE

### Feldstein Awarded ASME's J. Hall Taylor Medal



Joel Feldstein

**Joel G. Feldstein**, an AWS Life Member, has been awarded the J. Hall Taylor Medal from the American Society of Mechanical Engineers (ASME). Feldstein was cited for his "professionalism and leadership in consensus building for pressure equipment codes and standards, and for technical excellence in the advancement of standards for welding in pressure vessel and piping construction." He has played a key role in the *Boiler and Pressure Vessel Code* process for more than 20 years. As chair of the BPVC Standards Committee, he has worked to produce a new structure for the committee that facilitates and increases global participation. He also chairs the ASME Subcommittee on Welding. Feldstein has been an active member of the AWS A5 Committee on Filler Metals and Allied Materials and the A5D Subcommittee on Stainless Steel Filler Metals.

sales support for the Asian automotive market segment.

### Applied Robotics Names Applications Engineer

Applied Robotics Inc., Glenville, N.Y., has appointed **Jim Crowder** an applications engineer. Crowder, with ten years of engineering experience, previously worked for Precision Valve Automation, Halfmoon, N.Y., where he served as a product manager.

### Aluminum Association Appoints Chairmen

The Aluminum Association, Arlington, Va., has announced appointments within its Associate Member Committee. Named were **David Pownall** as chairman, and **Jeff Lawrence** as vice chairman. Pownall is sales director for J. McIntyre Machinery Ltd., based in Nottingham, UK. Lawrence is the North American sales manager for Houghton International Inc., headquartered in Valley Forge, Pa.

**Joseph Zuclich** the 2009 George M. Wilkening Award for "brilliant contributions in bioeffects research." Barat, a certified laser safety officer, is with National Ignition Facility at Lawrence Berkeley National Laboratory. He has published several textbooks, including *Laser Safety Management*, and contributed to *Medical Applications of Lasers*, and the LIA's *Laser Safety Guide*, tenth edition. He also serves on the ANSI Z136 Standards Committee and LBNL Laser Safety Committee. Zuclich, a research laser biophysicist retired from Northrop Grumman, has investigated a broad field of laser exposure parameters, specifically laser-human tissue interactions and ocular hazards to define laser safety limits.

### PMA Elects Board Chairman

Precision Metalforming Association, Cleveland, Ohio, has elected **Wayne Boeckman** chairman of the board of directors for 2009. Boeckman is president and CEO of Quick-Way Stampings, Inc., in Euless, Tex.

### Orbitform Group Names Brazil Representative

The Orbitform Group, a manufacturer of riveting machines and assembly automation equipment, has named **Alceu Natali** its representative in Brazil. Natali has more than 30 years of experience in industrial sales in the Brazilian market.

## Empire Industries Names Manager

Empire Industries Ltd., Fort McMurray, AB, Canada, a supplier of steel fabrication and installation services, has named **Vince Tidder** projects and maintenance manager for Sorge's Welding Ltd., and its wholly owned subsidiary, Lemax Machine & Welding Inc. Tidder, a certified inter-provincial steam pipefitter, most recently served as site manager for Jacobs Industrial Services.

## Obituaries

### Charles R. Fassinger



*Charles Fassinger*

**Charles R. Fassinger**, 79, died November 22 at his home in Nashville, Tenn. He served AWS as its treasurer (1987–1991), and from 1991 to 2003 he held various staff positions, including education director, assistant executive director, managing director of technical services, and associate executive director of the Industry Action Committee. He served as District 10 director, was a member of the National Nominating Committee, chaired the National Show Committee in 1970 and 1974, and chaired the Cleveland Section (1971–1972), where he was named Man of the Year for 1980. He wrote articles on welding steel for ASM International *Metals Handbook*, a paper, *10 Criteria for Welding Automation*, and operation manuals for training and qualifying workers for welding aluminum LNG ships. Fassinger worked on the design of GMA welding equipment and lectured nationally on

welding automation. He also presented courses in welding processes for AWS groups, the Cleveland Engineering Society, and Cleveland State University. In 1948, Fassinger became vice president of plant manufacturing at Universal Welder Corp. From 1957 to 1960, he was assistant chief engineer for Auto Arc Weld Manufacturing, a producer of wire feeders and special welding systems, and in 1975, he became president of Techniweld, Inc., a Cleveland, Ohio, welding, fabricating, and heavy machinery job shop. He later served as vice president of Manager Systems Div., Scott-Tarbell Inc., a welding distributor (1960–1971), and as marketing manager for Cecil Equipment Co., a supplier of welding guidance systems (1971–1972). From 1972 to 1974, Fassinger worked as a consultant for automatic welding applications. He served in the Army National Guard 1947 to 1973, and in the Vietnam war as a lieutenant colonel. He was active in the Army Reserve until 1982, and served the state deputy commander for the Ohio Military Reserve. He was very active in Rotary International in Miami, Fla., and was a past president of the Cleveland, Ohio, club. He is survived by his wife, Janet, daughters Susan Crawford and Jill Williams, a son Glen, five grandchildren, and a sister, Carol Fedak.

### William Bennett Bunn

**William (Bill) Bennett Bunn**, 100, died November 15. Bunn, an AWS Life Member, joined the Society in 1937. He was with the Florida West Coast Section. A longtime Bradenton, Fla., resident, his career spanned more than 50 years as a consultant inspecting and certifying the safety of nuclear reactor components manufactured in the United States and overseas. He was an authority on containment vessels for securing radioactive materials. He was working for the New Jersey-based M. W. Kellogg Co., a manufacturer of power plant components, when his firm was hired to work on the first nuclear-powered submarine, the USS *Nautilus*, that was commissioned in 1955. Bunn developed an early fascination for welding and working with machinery along side of his father, a machine shop supervisor for a railroad. He studied civil and mechanical engineering at the University of Tennessee before graduating with a degree in chemical engineering in 1932. He worked at the Navy Yard in Washington, D.C., for four years before beginning work for Kellogg in 1939. He also worked for Combustion Engineering in Chattanooga, Tenn., for nearly 20 years before retiring in 1975 to Bradenton, Fla. During retirement, he continued to work as a consultant for the American Society of Mechanical Engi-

neers (ASME) nuclear certification program. He was a Fellow of ASME, and a collector of jazz music and sports cars. He gave up driving when he was 98. Bunn spent the last few years living with his family in St. Petersburg, Fla., and Washington, D.C. He is survived by his daughters Libby Bunn, Joanna George, and Karen Hill, and several grandchildren and great-grandchildren.

## NEW PRODUCTS

— continued from page 27

### Welding Clamps, Magnetic Tools Allow Fast Setup



A series of heavy-duty clamps and fitup magnets is offered. The F-clamps, built with the strength of drop forged, heat-treated, nickel/chrome plated bar stock, feature a screw with copper-coating to protect against weld spatter. They come in light duty (500 lb), 8 in.; heavy duty (1000 lb), 8, 12, and 16 in.; and super duty (1250 lb), 8, 12, and 16 in. The 2-axis clamp is a solution for a 90-deg fitup. Useful for welding square and round tubes, angle, and channel iron, it contains a floating head and rotating spindle screw. Four locking pliers and welding clamps have a heavy-duty gnarled head and nickel-chrome plated handles. These are available in 4, 6, and 11 in. along with a long neck version. The swivel magnet adjusts to almost any angle to hold metal objects in place while welding; both 3-in. magnets swivel 360 deg and pull with 50 lb of strength. The magnetic ground clamp, rated at 500 A, can stick to any weldable ferrous metal and has an orange rubberized release lever. A twist of the knob release on the quick release magnet engages or disengages a firm hold on thick steel.

**Hobart Welding Products**  
[www.HobartWelders.com](http://www.HobartWelders.com)  
(877) 462-2781

**POSTER ABSTRACT SUBMITTAL**  
**Annual FABTECH International & AWS Welding Show**  
 Chicago, IL – November 15-18, 2009  
*(Complete a separate submittal for each poster.)*

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| <b>Poster Requirements and Selection Criteria:</b> <ul style="list-style-type: none"> <li>Only those abstracts submitted on this form will be considered. Follow the guidelines and word limits indicated. Complete this form using MSWord. Submit electronically via email to <a href="mailto:techpapers@aws.org">techpapers@aws.org</a> or print and mail.</li> <li>Maximum size – 44 inches tall x 30 inches wide. (Vertical format, please).</li> <li>Must be legible from a distance of 6 feet. A minimum font size of 14 pt. is suggested.</li> <li>Posters must be submitted to AWS as a single flat printed medium (e.g. laminated print or foam core board mount).</li> <li>Any technical topic relevant to the welding industry is acceptable (e.g. welding processes &amp; controls, welding procedures, welding design, structural integrity related to welding, weld inspection, welding metallurgy, etc.).</li> <li>Submittals that are incomplete and that do not satisfy these basic guidelines will not be considered for competition.</li> </ul> <p>Posters accepted for competition will be judged based on technical content, clarity of communication, novelty/relevance of the subject &amp; ideas conveyed and overall aesthetic impression.</p> <p>Criteria by category as follows:</p>                                                                                                                                                                                                                               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| <b>(A) Student</b> <ul style="list-style-type: none"> <li>Students enrolled in 2 yr. college and/or certificate programs at time of submittal.</li> <li>Presentation need not represent actual experimental work. Rather, emphasis is placed on demonstrating a clear understanding of technical concepts and subject matter.</li> <li>Practical application is important and should be demonstrated.</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | <b>(B) Student</b> <ul style="list-style-type: none"> <li>For students enrolled in baccalaureate engineering or engineering technology programs at the time of submittal.</li> <li>Poster should represent the student's own experimental work. 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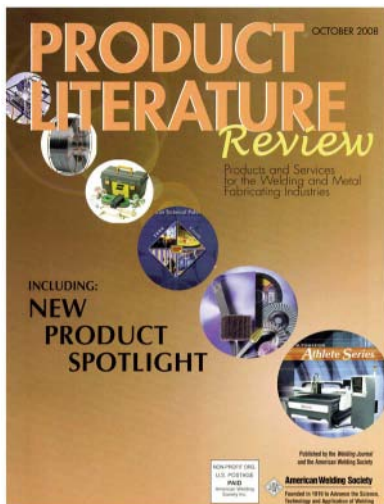
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SUPPLEMENT TO THE WELDING JOURNAL, FEBRUARY 2009  
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# Hyperbaric GMA Welding of Duplex Stainless Steel at 12 and 35 Bar

*Underwater welds show excellent mechanical properties when made under dry hyperbaric conditions*

BY O. M. AKSELSEN, H. FOSTERVOLL, AND C. H. AHLEN

## ABSTRACT

**ABSTRACT.** The present work was conducted to assess the weldability of duplex stainless steel under hyperbaric conditions relevant for future remote-controlled hot tap welding. This was achieved by horizontal welding with Inconel® 625 wire in V-grooves on plates in 2205 duplex steel in chamber pressures of 12 and 35 bar. The highest maximum hardness occurred in the heat-affected zone (HAZ) of the root bead, where HV<sub>10</sub> values in the range from 260 to slightly above 280 were measured. The results showed that there is weld metal undermatch with respect to the yield strength (~ 460–490 MPa), while the tensile strength (~ 740 MPa) was at the same level as that of the base plate. The notch toughness at –30°C was excellent for all positions tested (weld metal, weld interface, and weld interface +2 mm), and is far beyond current offshore requirements. The HAZ and weld metal were also characterized with respect to their microstructures. Although the welds were quite similar, the 35 bar weld appeared to have a thin zone (0–40 µm thickness) of ferrite in the HAZ close to the weld interface. The weld metal microstructure consisted of primary and secondary dendrite arms, which are the first to solidify. During this part of the solidification, solute elements are enriched in the liquid. With falling temperature, the solubility is probably exceeded with subsequent formation of intermetallic phases, as well as nitrides/carbides. Finally, the base metal dilution was subjected to microprobe analysis, showing large variations in weld metal chemical composition between different passes. The implications of the results with respect to corrosion and fracture toughness are discussed.

## Introduction

Hot-tapping is now a well-established technology both onshore and offshore subsea in connection of branch pipelines to production pipeline systems without stopping production. The majority of the onshore hot taps is based on welding the branch pipe to the pipeline with subsequent tapping by using hydraulic drilling. So far, the subsea hot taps have been made by divers using welded branch pipe connections, preinstalled hot tap tees, or by using retrofitted hot tap clamps with elastomer seals between the clamp and the main pipe. However, elastomer seals used as a single barrier are often regarded as a risk with reduced reliability and safety. The reason is that the elastomer can deteriorate mainly due to swelling in hydrocarbon service with a subsequent extrusion in the gap between the clamp and the main pipe. To use welded seals is regarded as a method to improve the lifetime, reliability, and safety. So far, less than ten hot-taps have been carried out on subsea pipelines in the North Sea. These hot-taps have provided very cost-effective solutions, but are based on an approach using divers and it is thus limited to water depths where diving may be applied. On the Norwegian continental shelf this limitation is 180 m maximum. Accordingly, there is a need for diverless and fully remote-controlled technology for future hot tapping. This new remote system will also represent a substantial

cost reduction since the offshore vessel alone used for the remote equipment is approximately half the daily cost of an offshore vessel with diver support, without including the additional cost of diver qualification (Ref. 1).

The fully remote hot tapping will be done using gas metal arc welding (GMAW), which represents a new situation in the Norwegian oil and gas industry. Up to now, all diver-assisted remotely controlled welding has been done by gas tungsten arc welding (GTAW) through the Pipeline Repair System (PRS) pool. Here, the research and development leading to this technology were launched in the middle of the 1970s (Refs. 2–7), with studies on how the weld metal chemical composition and moisture pickup were affected by pressure (water depth) in welding of low-alloy steels. More recently, the effects of hydrogen and oxygen have also been evaluated for higher-alloyed steels, such as duplex stainless steels (Ref. 8) and supermartensitic 13% Cr stainless steels (Ref. 9). However, since the remotely controlled GTAW has been developed for industrial use offshore in pipeline tie-ins and repair, the development of reliable equipment (Refs. 10–12) has been a major issue. All this is now available under the PRS pool, and has been overviewed in a recent paper (Ref. 13), showing that more than 70 offshore pipeline tie-ins have been completed so far.

Hyperbaric GMA welding has been developed over the past decades at Cranfield University, and is fully demonstrated for orbital V-groove welding (Refs. 14, 15) with successful process operation at up to 2500-m water depth. It has already been selected as the process method for a sleeve repair technique for pipelines for operation at up to 1000 m in

## KEYWORDS

Hyperbaric Welding  
Gas Metal Arc Welding  
GMAW  
Duplex Stainless Steel  
Inconel® 625 Weld Metal  
Mechanical Properties  
Microstructures

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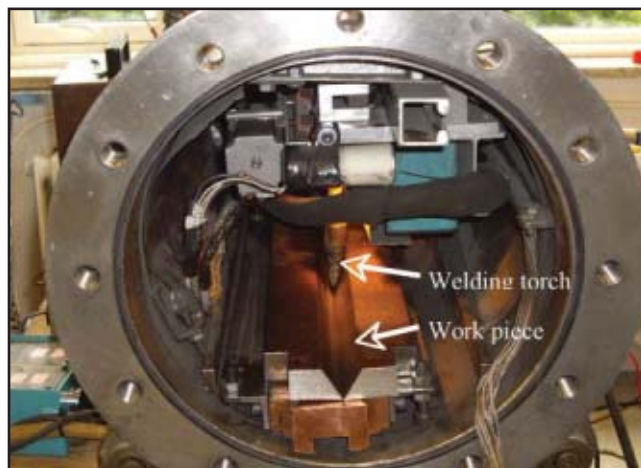


Fig. 1 — Hyperbaric welding chamber.

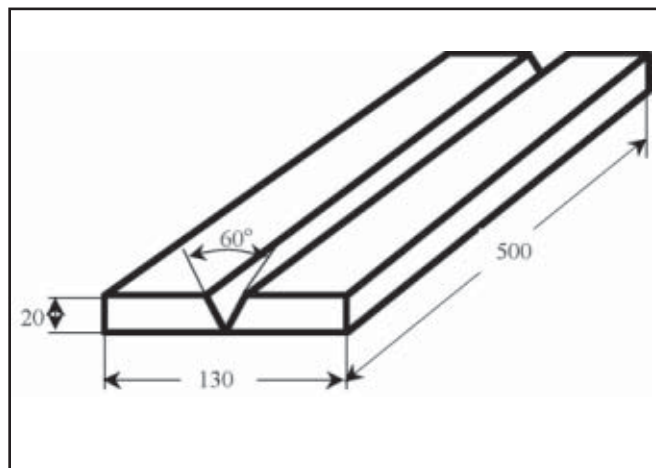


Fig. 2 — Dimensions of workpiece (in mm).

the first instance. More information about equipment, including details on the structural design and installation of the hot tap tee can be found elsewhere (Ref. 16). However, the present investigation is part of the development of robust GMA welding technology to be used in future diverless, remote-controlled tie-in and hot tap welding. Welding tests were carried out in a small chamber pressurized to 12 and 35 bar, corresponding to 110- and 340-m water depth. A conventional (22% Cr, 5% Ni) duplex stainless steel was selected as plate material since it may be an alternative for hot tap branch pipes. It was intended to identify a robust welding wire which gives excellent resistance against corrosion and hydrogen-induced cracking, and a strength level similar to that of the base metal. For this purpose, a solid Inconel® 625 Ni-based superalloy wire was selected. It was shown that excellent mechanical properties are achievable.

## Materials and Experimental Procedure

### Materials

The chemical compositions of the base metal and the welding wire are outlined in Table 1. The base metal is a 20-mm-thick plate of classical 2205 duplex stainless steel (UNS S31803, 22% Cr-5% Ni) with 3% Mo and 0.18% N. Its room-temperature yield and tensile strengths are 518 and 744 MPa, respectively. The selected wire is Inconel® 625, which is a nickel-based (~66%) superalloy sup-

plied with 0.9 mm diameter. The major alloying elements are Cr (~21%), Mo (~9%), Nb (3.3%), and Fe (~1%).

### Welding

Welding tests at 12 bar (Weld 1) and 35 bar (Weld 2) were carried out in a cylindrical chamber with volume of 100 L and internal diameter of 350 mm — Fig.1. The chamber was equipped with a conventional wire feeder and GMA welding gun rigged up for V-groove welding of plates in the flat position. The length of the workpieces were 500 mm with total width of 130 mm and thickness of 20 mm. A 60-deg V-groove was machined for welding — Fig.2. The power source comprised three modified Fronius Transpocket TP450s in series. The chamber was pressurized with 99.996% pure argon, and no separate shielding gas through the welding gun was used. Prior to pressurizing, the chamber was evacuated to 0.1 bar. The oxygen content in the chamber was below 200 ppm when the welding started. The welding parameters used for both welds are shown in Table 2. The interpass temperature was maximum 50°C. Welding was done without stiffeners, and the plates were thus free to deform. As expected, substantial angular distortion was found.

### Chemical Analysis

Samples were cut for full chemical analysis for both Welds 1 and 2. These were taken in the weld center (mid thickness). Sulfur and carbon were analyzed by

infrared combustion, while oxygen and nitrogen contents were found by inert gas fusion analysis. An optical emission spectrometer was used to determine the content of all other elements.

### Mechanical Testing

Mechanical testing included both all-weld-metal tensile testing and Charpy V-notch toughness testing at -30°C, and was carried out in agreement with the DnV offshore standard (Ref. 17). Tensile bars were cut from the weld metal with length axis parallel to the welding direction. The specimens were 48 mm long with a 24-mm gauge length of 4-mm diameter, while the 12-mm-long sample heads were M8 threads. Two parallels were included. Charpy V samples of 10- × 10-mm cross sections and 55-mm lengths were cut transverse to the welding direction. These were taken out from the welds at a distance of 2 mm below the plate surface. The notch was positioned to provide fracture along the welding direction. A total number of 3 parallels were tested at -30°C. Three different notch positions were included, i.e., the weld metal center, the weld interface, and the weld interface + 2 mm. These are shown schematically in Fig. 3. For all positions, macro-etching was done to locate the notch. For the weld interface position, the intention was to achieve roughly 50% weld metal and 50% HAZ along the notch.

### Metallography

One macro specimen was cut as cross

Table 1 — Chemical Composition of Wires and Base Material (elements in wt-%)

| Material                        | C     | Si    | Mn   | P      | S      | Cr    | Ni    | Mo   | Al   | Ti    | N    |
|---------------------------------|-------|-------|------|--------|--------|-------|-------|------|------|-------|------|
| 2205 duplex steel               | 0.016 | 0.4   | 1.4  | 0.023  | 0.001  | 22.3  | 5.7   | 3.1  | —    | —     | 0.18 |
| Inconel 625 wire <sup>(a)</sup> | 0.015 | <0.05 | 0.03 | <0.005 | 0.0006 | 20.68 | 65.74 | 8.81 | 0.24 | 0.063 | -    |

(a) With 3.23% Nb, <0.05% Co, 1.09% Fe.

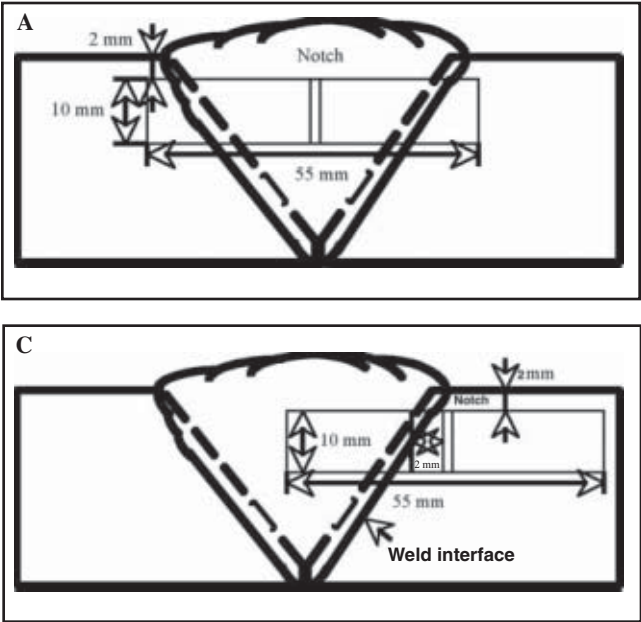


Fig. 3 — Schematic illustration of Charpy V-notch location. A — Weld metal center; B — weld interface; C — weld interface + 2 mm.

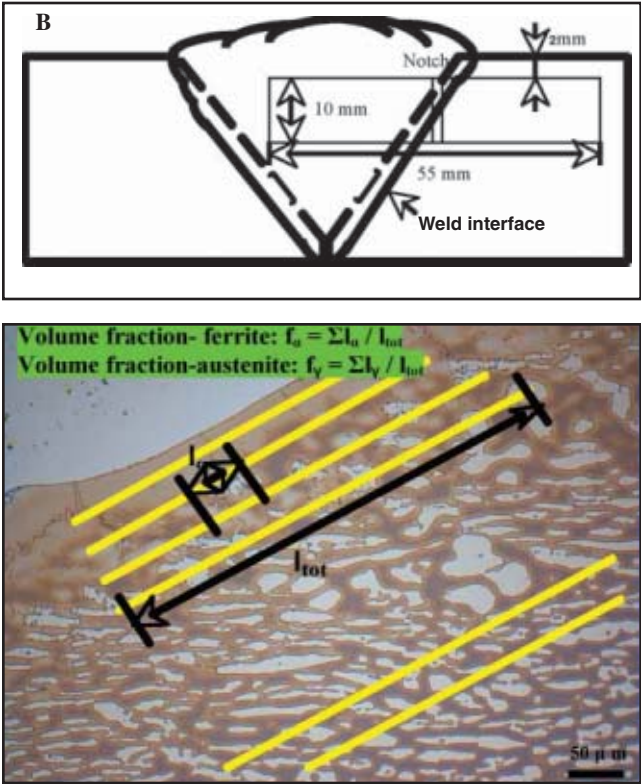


Fig. 4 — Schematic illustration of measurements (rough estimates) of ferrite volume fractions in the HAZ.

sections from each plate weld and prepared using standard metallographic techniques. Vickers hardness traverses with 10-kg load ( $HV_{10}$ ) were run across the entire weld and the base metals both in the cap and root positions. After macro photos were taken, the specimens were examined in more detail for microstructure characterization. For HAZ examination, the specimens were etched in NaOH solution. The austenite-ferrite contents were estimated based on the mean linear interception length concept, as briefly defined in Ref. 18. This was done on micrographs taken at a magnification of 200 $\times$ , and is schematically illustrated in Fig. 4. Subsequently, the Inconel 625 weld metal was examined based on electrolytical etching of specimens in 10% oxalic acid (aqueous solution) for 20–30 s, operating at room temperature with 6 V and 1 A.

## Results and Discussion

### Weld Defects

Both Welds 1 and 2 were completed with 14 individual stringer beads. Due to

the one-sided welding without the use of stiffeners, substantial angular distortion took place. Thorough examination in un-etched and etched macro specimens in an optical microscope did not reveal any critical weld defects.

### Weld Metal Chemical Composition

The weld metal chemical composition is outlined in Table 3. It is seen that some Ni is “lost” due to pickup of iron through base metal dilution (6.7 wt-% Fe for both welds). The Ni content is slightly above 60 wt-%, while the Inconel wire had almost 66 wt-%. Molybdenum is also somewhat lower in the weld than in the wire. The nitrogen concentration was found to be 220–230 ppm, which is much lower than

the level in the base metal (0.18 wt-% N). The weld metal oxygen content is low (120 ppm). The carbon content was also low (0.01 wt-%). Finally, there is a slight pickup of Mn due to base metal dilution, i.e., from 0.03 wt-% in the wire to 0.18–0.19 wt-% in the welds.

### Hardness Profiles

Hardness traverses were performed on both the root and the cap side of the macro specimens. The maximum individual hardness values found in the base metal, HAZ, and weld metal are plotted in Fig. 5 and listed in Table 4, where minimum, maximum, and average values are summarized. The highest individual level was found in the HAZ of the root bead,

Table 2 — Welding Parameters

| Parameter                 | 12 bar (Weld No.1) | 35 bar (Weld No. 2) |
|---------------------------|--------------------|---------------------|
| Welding current (average) | 170 A              | 166 A               |
| Arc voltage (average)     | 28.8 V             | 29.8 V              |
| Welding speed             | 6 mm/s             |                     |
| Wire feed rate            | 10 m/min           |                     |
| Interpass                 | Maximum 50°C       |                     |

Table 3 — Weld Metal Chemical Composition (elements in wt-%)

| Weld No.                  | C    | Si   | Mn   | S     | Cr   | Ni   | Mo  | Nb  | Fe  | Al   | Ti   | N     | O     |
|---------------------------|------|------|------|-------|------|------|-----|-----|-----|------|------|-------|-------|
| 1 (12 bar) <sup>(a)</sup> | 0.01 | <0.1 | 0.18 | 0.002 | 21.1 | 60.4 | 7.9 | 3.2 | 6.7 | 0.17 | 0.09 | 0.022 | 0.012 |
| 2 (35 bar) <sup>(a)</sup> | 0.01 | <0.1 | 0.19 | 0.002 | 20.9 | 60.8 | 7.7 | 3.2 | 6.7 | 0.17 | 0.09 | 0.023 | 0.012 |

(a) With 0.08% Cu.

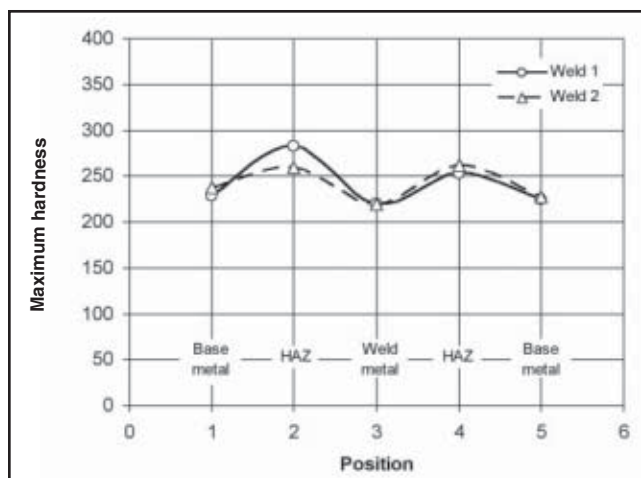


Fig. 5 — Hardness distribution in Welds 1 and 2.

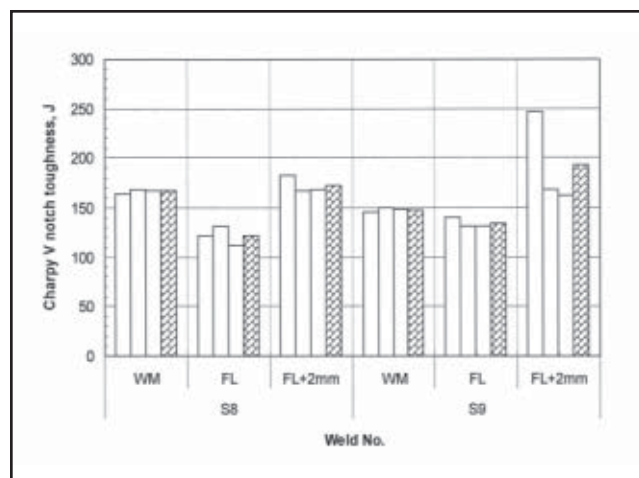


Fig. 6 — Charpy V-notch toughness at  $-30^{\circ}\text{C}$  (open rectangles: individual values, filled rectangles: average value).

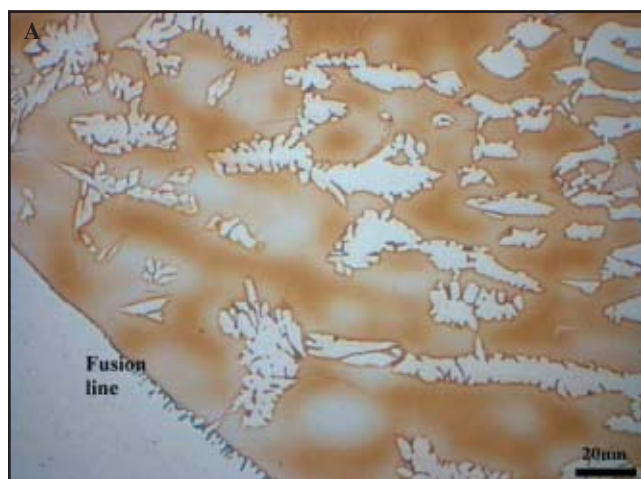


Fig. 7 — HAZ microstructure of cap bead. A — Weld 1; B — Weld 2.

Table 4 — Hardness Distribution in the Welds

| Weld No. | Base Metal |     |                       | HAZ |     |                       | Weld Metal |     |                      |
|----------|------------|-----|-----------------------|-----|-----|-----------------------|------------|-----|----------------------|
|          | Min        | Max | Mean                  | Min | Max | Mean                  | Min        | Max | Mean                 |
| S8       | 217        | 222 | 229 (12 indentations) | 229 | 283 | 246 (17 indentations) | 193        | 220 | 204 (6 indentations) |
| S9       | 214        | 225 | 238 (10 indentations) | 239 | 284 | 249 (9 indentations)  | 201        | 220 | 208 (7 indentations) |

Table 5 — Results from All Weld Metal Tensile Testing

| Weld No.   | Yield Strength $R_{p0.2}$ , MPa | Tensile Strength $R_m$ , MPa | Elongation at Fracture $A_5$ , % | Yield to Tensile Ratio $R_{p0.2}/R_m$ |
|------------|---------------------------------|------------------------------|----------------------------------|---------------------------------------|
| Base metal | 518                             | 744                          | —                                | 0.70                                  |
| 1 (12 bar) | 491                             | 739                          | 67                               | 0.66                                  |
| 2 (35 bar) | 468                             | 735                          | 70                               | 0.64                                  |

i.e., 283–284  $\text{HV}_{10}$  for both welds, both with average close to 250. The maximum weld metal hardness was relatively low, 220  $\text{HV}_{10}$  with mean values of 204 and 208 for Welds 1 and 2, respectively. The base metal hardness varied between 220

and 240  $\text{HV}_{10}$ . These hardness values are similar to previously reported results (Refs. 1, 19) using the Inconel wire in welding of low-alloy API X65 steels for a wide range in water depths (pressures between 12 and 100 bar).

#### Tensile Properties

The results from all-weld-metal tensile testing are summarized in Table 5. The average yield strengths were 491 and 468 MPa for Welds 1 and 2, respectively, with

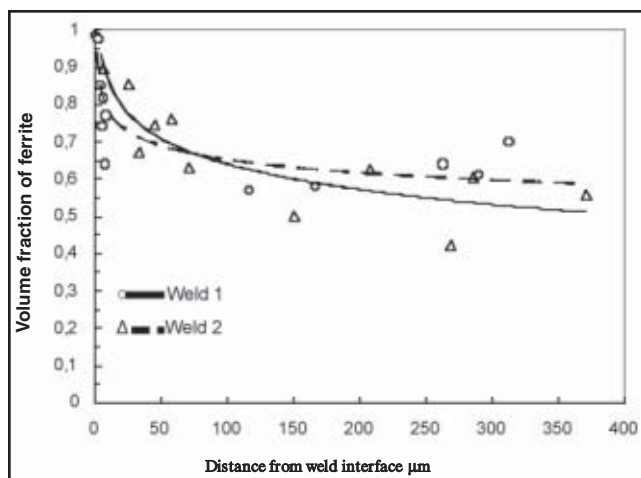


Fig. 8 — Variation in HAZ volume-fraction of ferrite as function of distance from the weld interface (the lines are "trend lines").

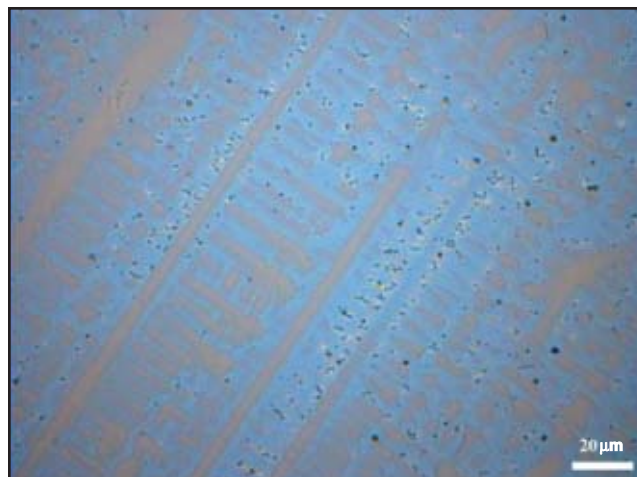


Fig. 9 — Microstructure in primary weld metal, Weld 1.

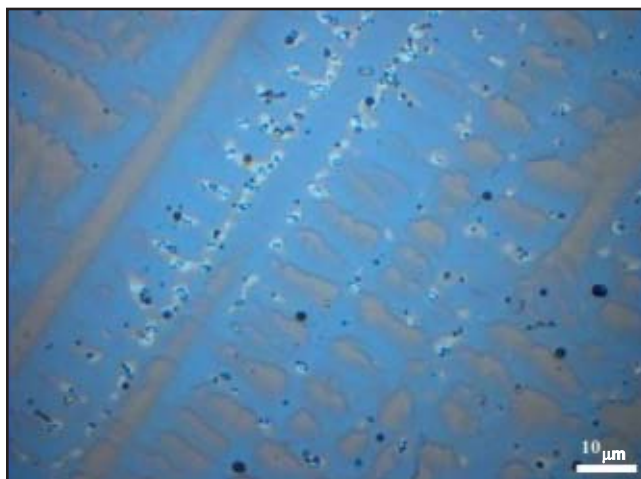


Fig. 10 — Close-up of area in Fig. 6, Weld 1.

corresponding tensile strengths of 739 and 735 MPa. This means that both welds represent an undermatch situation, i.e., weld metal yield strength is lower than that of the base metal (518 MPa). However, the yield strengths of both welds are higher than the minimum specified yield strength for the base metal, satisfying current requirements set to X65 pipe (65,000 lb/in<sup>2</sup> or 450 MPa in yield strength). The tensile strength is similar to that of the base metal.

#### Notch Toughness

The results from impact testing are illustrated in Fig. 6. Three positions were tested; 1) weld metal, 2) weld interface, and 3) weld interface + 2 mm. It is seen that all positions possessed excellent toughness (> 100 J) at -30°C. Moreover, the scatter is quite low between the different parallels. For Weld 1, the weld metal toughness exceeded 150 J, while Weld 2 had values slightly below 150 J. However, this toughness is still a bit lower

than earlier reported values for X65 welds, where the Inconel 625 weld metal had toughness values beyond 200 J (Ref. 19). High toughness of Inconel 625 weld metals are expected since there is no transition temperature from ductile to brittle fracture for nickel alloys. The weld interface toughness was also very good with individual values in the range 112–132 and 132–141 J for Welds 1 and 2, respectively. Thus, the two welds are quite similar. In addition, the scatter in toughness is quite low in spite of the fact that the impact value represents a mixture between the duplex HAZ and the Inconel 625 weld metal. Moreover, the weld interface is expected to fluctuate along

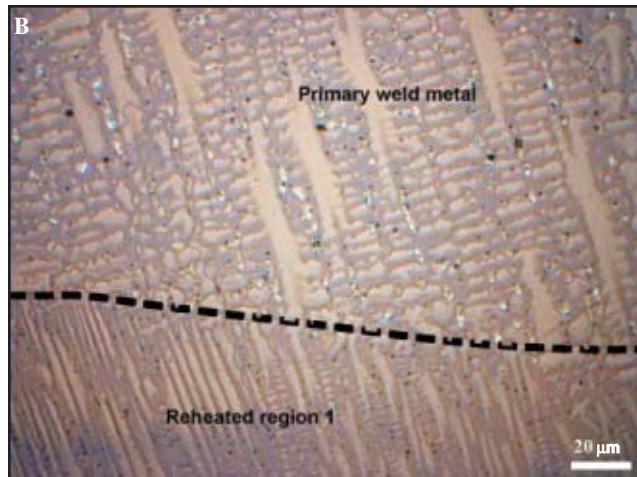
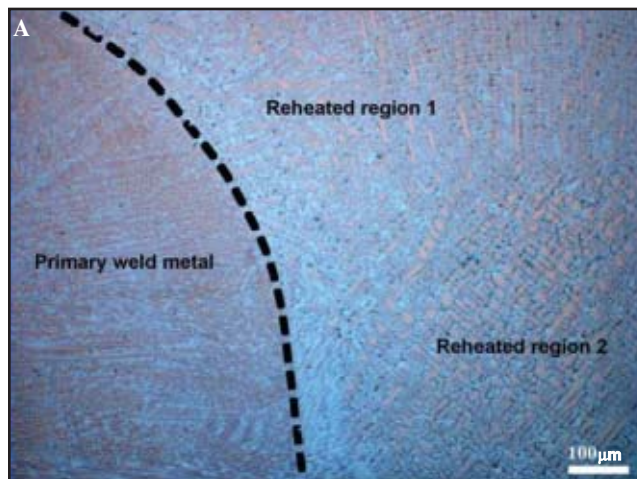


Fig. 11 — Overview of reheated weld metal. A — Weld 1; B — Weld 2.

the weld, which may imply that the ratio between the HAZ and the weld metal distributed along the notch in the Charpy specimen will vary almost from 0 to 1.0. The Charpy specimens have not been examined after the completion of testing, so this ratio is not yet known. Therefore, it is difficult to assess the present results in a

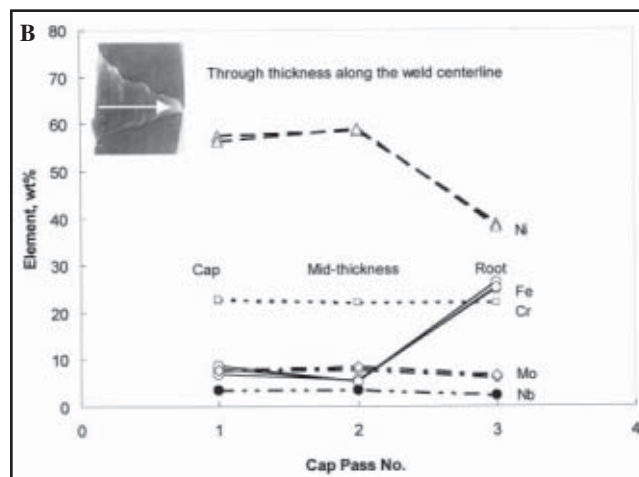
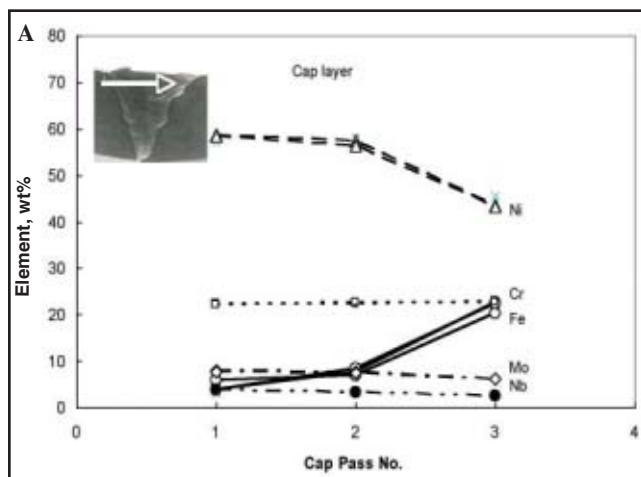


Fig. 12 — Variation in element concentration in Weld 2. A — Cap layer; B — through plate thickness.

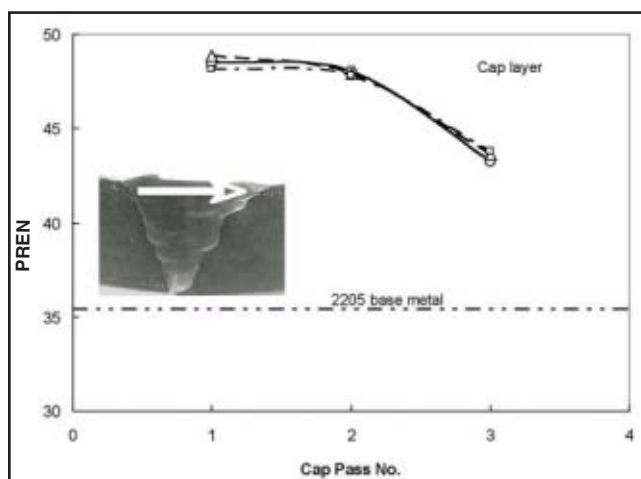


Fig. 13 — Pitting resistance equivalent (PREN) values across the cap layer of Weld 2. The nitrogen contents are 0.18% in the 2205 base metal, 220 ppm in Weld 1, and 230 ppm in Weld 2. The content in the Inconel 625 wire is not known.

consumables will obviously be very important, and the Inconel 625 appears to give satisfactory robustness.

#### Microstructure Examination

The HAZ microstructure of Weld 1 consists of ferrite and austenite (Fig. 7A), but with more ferrite than in the base metal. Weld 2 also had similar microstructure in the HAZ, but here there was found a 40–80  $\mu\text{m}$  narrow layer at the weld interface with only ferrite —

both Welds 1 and 2 for comparison of the nitrogen distribution.

A high-volume fraction of ferrite in the high-temperature region of HAZ in duplex stainless steels is not surprising, but rather usual. This is due to the grain coarsening of the ferrite taking place during the heating cycle followed by rapid cooling, which together with the grain coarsening may prevent austenite formation. Such high amount of ferrite is considered detrimental to notch toughness and also the corrosion resistance through possible precipitation of chromium nitrides ( $\text{Cr}_2\text{N}$  or  $\text{CrN}$ ) in the ferrite which may take place due to limited solubility of nitrogen in ferrite. The Cr nitrides will then reduce the PREN value of the matrix with a possible rise in the pitting corrosion susceptibility. In addition, an eventual diffusion of nitrogen into the weld metal due to the large concentration gradient may cause a further reduction of the local pitting corrosion resistance. Therefore, it is usual to specify a certain range in the ferrite content to satisfy offshore requirements in welding of duplex stainless steels. One example is discussed later in this paper.

The ferrite and austenite volume fractions were estimated using mean linear intercept technique to quantify the microstructure in different distances from the weld interface. It should be noticed that the distance from the weld interface is roughly approximated due its bowing nature. The results are shown in Fig. 8. This plot confirms the high-volume fraction of ferrite in the HAZ of both welds close to the weld interface, and that Weld 2 contains almost ferrite only in a narrow region, as already noticed in the micrograph in Fig. 7B. The statistics are quite poor here, and there is certainly also a large scatter. The results must therefore be treated with some care. It should be kept in mind that the DnV offshore standard prescribes the volume-fraction of

statistical manner, but there is no reason to believe that the toughness should suddenly drop to levels below the minimum requirements set in current offshore specifications. For X65 type of quality, the Charpy requirements are minimum single and average values of 38 J and 45 J, respectively (Ref. 17). For an X70 pipe, the corresponding values are raised to 40 and 50 J. With these requirements in mind, the welds are clearly acceptable in terms of mechanical properties.

However, the impact values are much lower than that previously reported for weld interface notched specimens when welding low-alloy X65 steel with Inconel 625 wire (Ref. 19). On the other hand, the toughness level is beyond that reported in conventional (at 1 bar) flux cored arc and submerged arc welding, which was in the range of 63–76 and 100–141 for the weld interface and HAZ, respectively (quoted in Ref. 20). For the weld interface toughness, the welding

Fig.7B. This observation is probably linked to the welding arc restriction with increasing chamber pressure (water depth), as the case when going from weld deposition of Weld 1 at 12 bar to Weld 2 at 35 bar. The smaller arc area may thus, in turn, cause more rapid cooling, which may be sufficient to prevent austenite nucleation within a narrow band close to the weld interface. An additional cause may be diffusion of nitrogen from the HAZ to the weld metal due to the large concentration gradient in nitrogen, i.e., from 0.18% N in the base metal to 220–230 ppm in the weld metal. This diffusion may take place when the region close to the weld interface is brought up to the temperature of partially melting or when it is fully ferritic where the diffusion is more rapid than in austenite. An eventual verification of this phenomenon would be possible through more detailed microprobe analyses performing several line scans across the narrow ferrite band and the weld interface in

ferrite to be within the range from 0.35 to 0.55 for the base metal, and between 0.35 and 0.65 for the HAZ and the weld metal in welding of duplex stainless steel with matching consumables (Ref. 17). Therefore, a part of the HAZ in both welds, representing a distance from the weld interface of 60  $\mu\text{m}$  is clearly outside the specified range. In a welding procedure qualification situation, this fact would have to be dealt with through verification of sufficient mechanical and corrosion properties through testing.

The weld metal microstructure of Weld 1 is shown in Fig. 9 and reveals dendritic solidification. Similar features were found in the study of Weld 2 microstructures. The primary dendrite arms (gray-brown) solidify first, followed by secondary dendrite arms, and finally, the interdendritic regions (blue) where enrichment in solute elements takes place, primarily Nb and Mo. With falling temperature during cooling, the solubility of these solutes decreases with subsequent formation of intermetallic phases and precipitation of particles. This point is shown in Fig. 10, where particles are entirely present in the interdendritic regions, further underlining the microscopic segregation of solutes. These particles may be carbides (e.g., NbC, black spots in the figures) or intermetallic particles (e.g., Laves phase, blue particles in the figures). Due to the thermodynamics with mutual full solid solubility between Nb and Mo, and between Cr and Mo, there are several possible stoichiometries of the intermetallic phases. In the Ni-Nb binary system,  $\text{Ni}_3\text{Nb}$  and  $\text{Ni}_2\text{Nb}$  may form on the Ni-rich side. For binary Cr-Nb mixture, the  $\text{Cr}_2\text{Nb}$  may exist. In binary Ni-Mo alloys, several phases are possible, both stable and metastable phases may form. Previous microprobe analyses of similar Inconel 625 weld metals (Ref. 19) have confirmed the presence of Nb-rich particles present, often with Ti, N, O, and C, indicating that the analysis volume comprises of NbN (or NbCN), together with Ti-containing non-metallic inclusions. The intermetallic particles seemed to be consistent with a  $(\text{Me}_1)_2(\text{Me}_2)$  kind of phase, suggesting them to be Laves phase of the form  $(\text{Ni,Cr,Fe})_2(\text{Nb,Mo})$ . Nb and Mo have large atomic radii, while Ni, Cr, and Fe have smaller, but similar-sized radii. Due to their presence, questions can be raised concerning their effects on mechanical properties and corrosion resistance. However, intermetallic precipitates represent the major strengthening mechanism in higher-alloyed Ni-based superalloys like Inconel 718.

The reheated weld metal microstructure is shown in Fig. 11. Due to the absence of solid-state phase transformations, the microstructure of the reheated

region is very similar to that of the primary weld metal. Still, redistribution of alloying elements may take place, depending on the temperature and time available for diffusion.

### Base Metal Dilution

Base metal dilution may change the chemical composition locally, and may thus be important to corrosion resistance and local fracture toughness. Such dilution was examined in different beads and in the HAZ to obtain information on the local variations in chemical composition. The chemical analyses were performed with JEOL JXA-8500F instrument equipped with a wavelength dispersive spectrometer (WDS). Three individual analyses were performed per location, and large variations were found for certain beads. The results are plotted in Fig. 12 in terms of element concentration (wt-%) for Fe, Ni, Cr, Mo, and Nb. For the cap layer data plotted in Fig. 12A, it is seen that the base metal dilution is fairly high for sidewall beads, with more than 20 wt-% Fe in one of these beads. Here, the Ni content was reduced from about 66 wt-% in the welding wire to approximately 44 wt-%, which confirms a base metal dilution of about 20%. The Cr content in the weld metals (22–23 wt-%) were similar as their origins, namely the welding wire and the base metal. The Mo and Nb concentrations are slightly lower in the cap layer than in the wire due to base metal dilution. In the central bead of the cap layer, there is as expected much lower base metal dilution with 7–9 wt-% Fe, indicating a dilution of 6–8%. As expected, the vertical (through thickness) element distribution plotted in Fig. 12B demonstrates that the highest base metal dilution is found in the root pass. Here, the Fe concentration is about 26 wt-%, with Ni content of 56–58 wt-%. By contrast, the mid-thickness central weld pass revealed low dilution with 5–6 wt-% Fe and 58–59 wt-% Ni. As with the horizontal cap layer analyses, the Cr, Mo, and Nb contents were fairly constant throughout the plate thickness along the weld centerline. The vertical analyses along the sidewall of the groove showed large scatter in the Ni content, i.e., 41–55 and 39–58 wt-% for Welds 1 and 2, respectively. These variations are also associated with similar variation in the Fe content, which is due to pertinent variations in positioning (welding gun) of the individual stringer beads in the groove.

It should be noticed that the volume of analysis is only in the order of 1  $\mu\text{m}^3$ , by contrast to the large volume involved in base metal and weld metal chemical analyses (typically 1 in. in diameter). Microprobe analysis may detect eventual macro/micro segregations, and the po-

tent differences in composition between ferrite and austenite. This may explain the small deviations between the data in Fig. 12 for the base metal and the chemical composition data in Tables 1 (base metal) and 3 (weld metal).

### Practical Implications

The quantitative effects of the variations in chemical composition and base metal dilution are not possible to assess from the present investigation. There are numerous corrosion types that may take place, including general corrosion, pitting corrosion, crevice corrosion, stress corrosion cracking, sulfide stress corrosion cracking, intergranular corrosion, galvanic corrosion, contact corrosion, and the subject in focus over the past decade, hydrogen-induced cracking (HIC).

Under certain conditions, particularly involving high concentrations of chlorides (such as sodium chloride in seawater), moderately high temperatures and exacerbated by low pH (i.e., acidic conditions), very localized corrosion can occur leading to perforation of pipes and fittings, etc. Grades high in chromium, and particularly molybdenum and nitrogen, are more resistant to pitting corrosion. The Pitting Resistance Equivalent Number (PREN) has been found to give a good indication of the pitting resistance of stainless steels. The PREN can be calculated as (in wt-%):

$$\text{PREN} = \text{Cr} + 3.3 \text{ Mo} + 16 \text{ N}$$

The PREN values for the base metal and the weld metal are 35.4 and 50.1, respectively. Since the weld metal represents a mixture between these two extremes, the PREN would be expected to fall between them. This is further evidenced by the plots in Fig. 13 illustrating the PREN value distribution in the cap layer of Weld 2. Similar results were found for Weld 1. Therefore, the welds should have sufficient resistance to pitting with all PREN values above 43. However, as previously noticed, high ferrite content in the HAZ may cause precipitation of Cr nitrides, which again may change the resistance against localized corrosion attacks.

Hydrogen-induced cracking may take place under cathodic protection where the potential provides hydrogen generation. Hydrogen atoms may enter the material with subsequent degradation of material toughness as a consequence. Alternatively, hydrogen may enter the material by a corrosion process by sour service (sulfide stress corrosion cracking). In order to resist sour service, a maximum hardness level of 22 Rockwell C (= 248 Vickers hardness) is required (Ref.

21). However, this is valid for carbon steel only. For wrought and cast duplex stainless steels in the solution-annealed and liquid-quenched condition, hardness requirement is set to 28 HRC (= 286 HV) maximum (Ref. 21). Heat treatments to increase strength or hardness are not allowed. For welds in duplex stainless steels (Ref. 22), the hardness may not exceed an average value of 310 HV<sub>10</sub>, and no individual reading may exceed 320 HV<sub>10</sub>. In addition, the measured weld metal and HAZ ferrite volume fraction must be between 0.35 and 0.65 (Ref. 17). In the present investigation, the highest HV value in the HAZ was found to be 283 in the HAZ of the root pass in Weld 1. It should therefore satisfy current requirements set to maximum hardness. The same is the case for Weld 2, but here the ferrite volume fraction is almost 1.0 in a narrow region (0–40 µm thickness) at the weld interface. The implication of this finding is not clear since all toughness values were very high, including those of the weld interface. However, it may influence the resistance against localized corrosion attacks such as pitting. Such testing was outside the scope of the present investigation.

## Conclusions

The present work was carried out as part of the development of hyperbaric gas metal arc (GMA) welding for future remote-controlled hot tap welding. The welding trials for mechanical testing and metallographic inspection were performed at 12 and 35 bar with 2205 duplex stainless steel base metal and Inconel 625 solid wire. The following main conclusions can be drawn:

- The highest single hardness value was 283 HV<sub>10</sub>, found in the HAZ of the 2205 duplex steel. All other values were below about 250. However, it should be noticed that these welds were allowed to freely distort since no stiffeners were used.
- Both welds represent a strength undermatch situation where weld metal yield strength is lower than that of the base metal (518 MPa). The yield strengths were 491 and 468 MPa for Welds 1 and 2, respectively, with corresponding tensile strengths of 739 and 735 MPa. The tensile strength is similar to that of the base metal.
- Three positions were tested with respect to notch toughness; 1) weld metal, 2) weld interface, and 3) weld interface + 2 mm. As shown, all positions possessed excellent toughness (> 100 J) at –30°C.
- Some concern may be raised with respect to the high ferrite volume fraction (~ 1.0) in a narrow (up to 40 µm) region at the weld interface, although the implication of this finding is not clear since all

toughness values were very high, including those of the weld interface.

- The weld metal microstructure study revealed dendrite solidification with primary and secondary dendrite arms, and interdendritic regions with enrichment in solute elements, primarily Nb and Mo. The decreasing solubility of these solutes during cooling resulted in formation of intermetallic phases. Along with this, precipitation of particles took place.

- Base metal dilution resulted in large local variations in the weld metal chemical composition. The quantitative effects of these variations in chemical composition cannot be assessed from the present investigation, but the low hardness level should satisfy requirements set for sour (or at least mildly sour) service.

## Acknowledgments

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# Control of Longitudinal Bending Distortion of Built-Up Beams by High-Frequency Induction Heating

*A new practical method was proposed to mitigate longitudinal bending distortion of built-up beams during fabrication processes*

BY J. U. PARK, S. C. PARK, AND C. H. LEE

## ABSTRACT

Longitudinal bending distortion is induced by fillet welding during the build-up process of T-section beams. This distortion decreases productivity and the quality of welded structures because it requires additional correction work in the assembly stages of ship construction. Longitudinal bending distortion is caused by the welding moment, which is calculated by multiplying the shrinkage force due to welding by the distance between the welding heat source and a neutral axis on the cross section of built-up beams. However, this distortion can be mitigated by induction heating on the web plate of built-up beams, generating a reverse moment of the same magnitude as the bending moment due to fillet welding. In this study, location and intensity of induction heat input were determined based on experiments and simple equations. The mechanism of longitudinal bending distortion in the build-up process was investigated using three-dimensional thermal elastic-plastic analysis. A new control method of longitudinal bending distortion was proposed using high-frequency induction heating with verification of its validity.

## Introduction

Built-up beams are widely used to improve the longitudinal strength of ship structures. In general, four Very Large Crude-oil Carriers (VLCCs) are built in a year. In this case, about 1050 pieces of

built-up beams are to be made in a month. Fillet welding is employed to produce built-up beams, connecting web plates to flange plates. During manufacturing, fillet welding induces built-up beams to deform longitudinally (Ref. 1) because the weld length is relatively long (5~22 m) and weld metals deposited on the joint are located lower than the neutral axis of the built-up beam. Accordingly, various methods have been used to prevent or correct the longitudinal bending distortion in shipyards. The first one is triangular heating on the web plate using a gas burner after welding; the second one is to produce plastic deformation using mechanical presses after welding. But these methods have disadvantages in that distortion has to be corrected in a separate stage of the manufacturing process, which decreases productivity and the quality of hull assembly.

As a result, these problems brought up the necessity of research to estimate and prevent the longitudinal bending distortion, and a series of studies was done by Sasayama (Ref. 2). He estimated the amount of longitudinal bending distortion with a change of leg length of welding using simple beam theory. Okerblom (Ref. 3) presented simple equations to estimate the amount of longitudinal bending distortion through thermal elastic-plastic analysis and verified his theoretical results by comparing against experimental results. Tsuji (Ref. 4) also performed a thermal elastic-plastic analysis to estimate the amount of weld-

ing distortion on the cross-sectional part of a strip plate and verified the validity of his results by comparing them with ones obtained from experiments. Masubuchi (Ref. 5) estimated the residual distortion of an aluminum plate with a T-section using one-dimensional thermal elastic-plastic analysis and compared it with results obtained from experiments. Aoki (Ref. 6) classified the factors affecting distortion via numerical analysis and experiments by using the results of the study by Tsuji (Ref. 4) and proposed simple equations. Jang (Refs. 7, 8) estimated the magnitude of longitudinal distortion due to welding and the amount of triangular heating needed to correct the distortion. By the way, all these studies focus on the estimation of the amount of longitudinal bending distortion, except Jang's (Refs. 7, 8). However, his method has the disadvantage that the distortion must be corrected in a separate stage of the manufacturing process after welding.

Therefore, this study focuses on explaining the mechanism of the longitudinal bending distortion in built-up beams using three-dimensional thermal elastic-plastic analysis, and proposing a new control method of this distortion by using induction heating with verification of its validity by comparing the results of numerical analysis and experiments for the large T-section structures.

## Longitudinal Bending Distortion and Its Control Method

During a manufacturing process for built-up beams, fillet welding causes transient and residual longitudinal bending distortion in the built-up beam. The mechanism of the distortion can be explained through three-dimensional thermal elastic-plastic analysis using the finite element method. Major parameters known to have influences on inducing and mitigating longitudinal bending distortion are evaluated by investigating the numerical analysis results.

## KEYWORDS

Distortion Control  
Built-Up Beams  
Finite Element Analysis  
Induction Heating  
Distortion  
Longitudinal Bending

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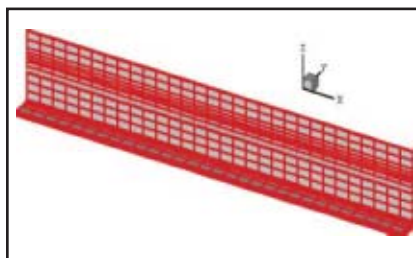


Fig. 1 — Finite element analysis model for the built-up beam.

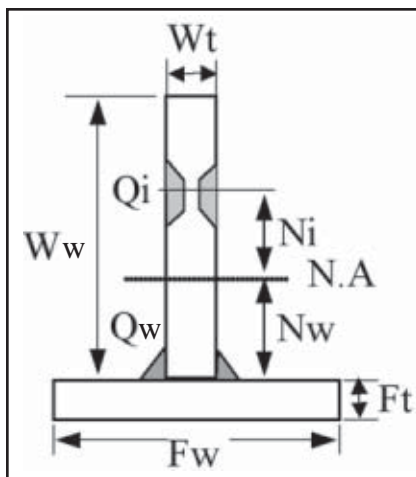


Fig. 2 — Cross section of the built-up beam with induction heating.

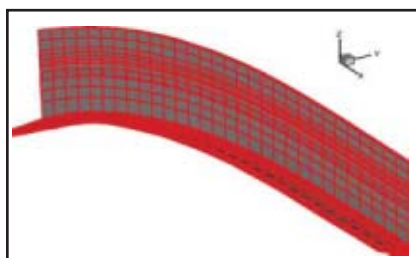


Fig. 3 — Shape of longitudinal bending distortion of the built-up beam.

## Numerical Modeling and Analysis

Figure 1 shows the finite element analysis model for the built-up beam. A 1:4 model was employed considering the symmetry of the built-up beam with two fillet welds deposited simultaneously on each side of the joint and the huge computational time consumed in analyzing the distortion behavior of T-section joint of 3000 mm in weld length using a moving heat source model. The boundary conditions for the numerical analysis were taken considering the symmetric condition of built-up beams and the prevention of rigid body motion. Under these conditions, welding distortion was generated freely without additional restraints. The verified in-house finite ele-

Table 1 — Dimensions and Heat Input for Finite Element Analysis

| Model Type | Flange Plate (mm) |           | Web Plate (mm) |           | Length L (mm) | Heat Input of Ind. Heating (cal/mm <sup>3</sup> ·s) | Ni (mm) |
|------------|-------------------|-----------|----------------|-----------|---------------|-----------------------------------------------------|---------|
|            | Width             | Thickness | Width          | Thickness |               |                                                     |         |
| A1         | 150               | 18        | 250            | 11.5      | 3000          | —                                                   | —       |
| A2         | 150               | 18        | 250            | 11.5      | 3000          | 0.640                                               | 95      |
| A3         | 150               | 18        | 250            | 11.5      | 3000          | 0.932                                               | 95      |
| A4         | 150               | 18        | 250            | 11.5      | 3000          | 0.448                                               | 95      |
| A5         | 150               | 22        | 300            | 11.5      | 3000          | 0.640                                               | 122.6   |

ment analysis program was employed and the total numbers of elements and nodes used were 1440 and 2232, respectively. Eight-node isoparametric solid elements and body heat flux model with Gaussian heat distribution were used for numerical analysis.

Also, three-dimensional transient heat transfer analysis was performed for fillet welding with a moving heat source and subsequently three-dimensional thermal elastic-plastic stress analysis was carried out with previously calculated thermal loads, considering temperature-dependent thermal and mechanical properties of the material.

A cross section of fillet welded T-joint with induction heating on both sides of web plate is shown in Fig. 2; Nw is the distance from the neutral axis to the welding heat source, and Ni is the distance from the neutral axis to the induction heat source. Table 1 shows the specimen dimensions and induction heat input conditions used for the finite element analysis.

All the specimens were made of 11.5, 18, and 22 mm thicknesses of AH32 (315 MPa yield strength) steel plates. The submerged arc welding process was used for fillet welding with 720 A, 26 V, 1004 mm/min welding speed, AWS-A5.17 EM13K/L-50 welding wire of 2 mm in diameter, and two fillet welds of leg length of 5 mm were made simultaneously on each side of the web and flange joint. The welding heat input, in the analysis, is 1118 J/mm and the arc efficiency is determined to be 0.9 from a previous study.

## Mechanism and Control Method of Longitudinal Bending Distortion

Figure 3 shows the shape of magnified residual bending distortion obtained from the results of the three-dimensional thermal elastic-plastic stress analysis for Model A1, while Fig. 4 shows the transient and residual longitudinal bending distortion behavior for Model A1 with elapsed times at the top edge of the web plate. During welding, Model A1 deformed downward (–z direction) due to the expansion of the welded joint, but finally deformed upward (+z direction) due to the shrinkage of the welded joint after cooling down to room temperature. For Model

A1, the amount of final longitudinal bending distortion was found to be 3.5 mm at the middle of beam length, but a distortion of about 100 mm was observed in a large T-section structure with a length of 20,000 mm of the built-up beam.

The upward convex longitudinal bending distortion is produced by the welding moment (Mw), because the welded joint is located lower than the neutral axis of the cross section of the built-up beam as shown in Fig. 5. The welding moment is represented by multiplying the shrinkage force P(Qw) of the welded joint by the distance (Nw) from the neutral axis of the cross section of the built-up beam to the welding heating source (Qw). The magnitude of longitudinal bending distortion increases with the increase of the shrinkage force and the distance from the neutral axis to the welding heat input (Qw).

The longitudinal bending distortion produced by the welding moment can be mitigated by generating an induction heating moment (Mi ≅ Qi × Ni) with the same magnitude of the welding moment and orientating it in the direction opposite to the welding moment. In large T-section structures, the welding moment can be obtained with the neutral axis of the cross section of the built-up beam, the location of the welding heating source, and the amount of welding heat input. Also, the induction heating moment can be generated by controlling the amount of induction heat input (Qi) and the distance (Ni) from the neutral axis to the induction heating source. Assuming that the amount of the induction heat input is constant, the distance from the neutral axis to the induction heating source is obtained by Ni ≅ Qw × Nw/Qi. As a result, the longitudinal bending distortion can be controlled by heating the determined location with the induction heating, simultaneously operating with the welding process.

## Characteristics of Longitudinal Bending Distortion by Induction Heating

The control method of longitudinal bending distortion in the above section is verified by varying the induction heating

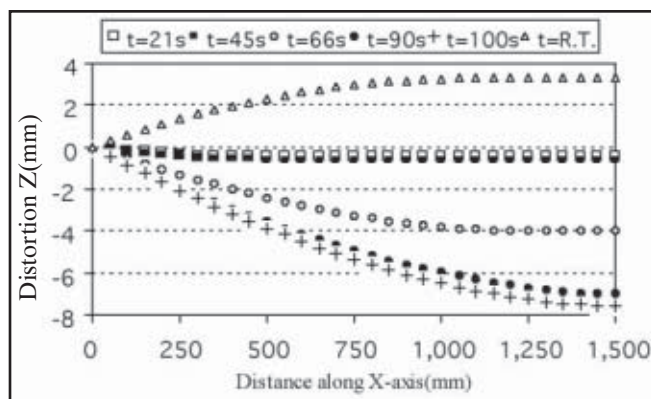


Fig. 4 — Distribution of longitudinal bending distortion (Model A1).

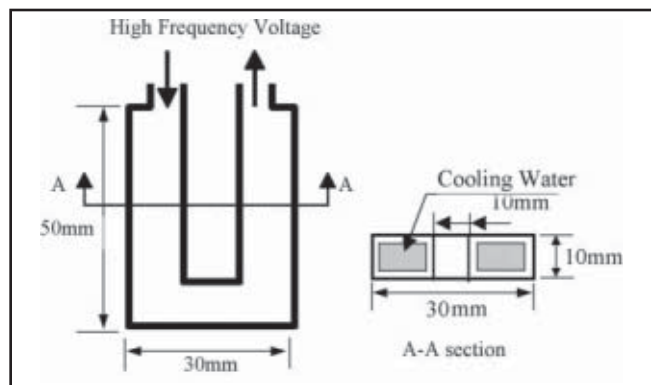


Fig. 6 — Shape of the induction heating coil.

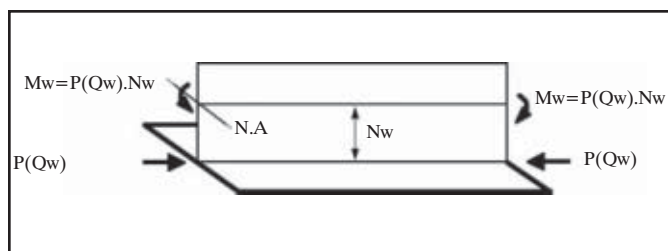


Fig. 5 — Welding moment for longitudinal bending distortion of the T-joint.

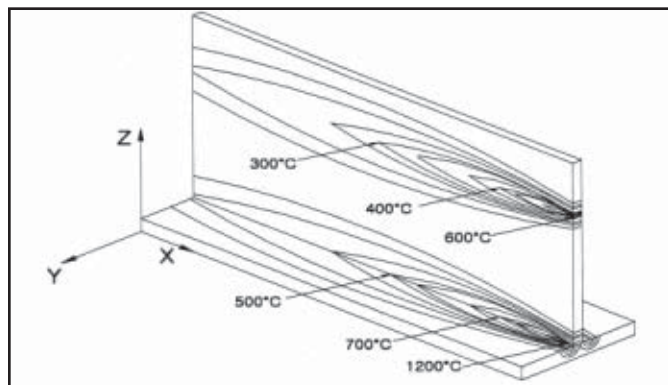


Fig. 7 — Temperature distribution due to fillet welding and induction heating (Model A2).

conditions using the three-dimensional thermal elastic-plastic finite element analysis. At first, the effects of intensity of induction heat input on the longitudinal bending distortion are evaluated and subsequently the analysis results are applied to Model A5.

#### Numerical Analysis Model

Models A2~A4 in Table 1 were numerically analyzed. The welding conditions were the same as those in the above section. The shape of the induction heating coil is shown in Fig. 6 and two heating coils were placed on each side of the web plates. Induction heating coils were designed to be stationary and built-up beams were forced to move on to the direction of heating coils on the rails with a welding speed. The induction heating rate was equal to the welding speed and the maximum depth of the heat-affected zone (HAZ) by induction heating was about 3 mm with a semielliptical cross section. Though the amount of induction heating has to be calculated by electric and magnetic field analyses for three-dimensional transient heat transfer, the amount of induction heat input was set to  $0.64 \text{ cal/mm}^3 \cdot \text{s}$  by performing the three-dimensional transient heat transfer analysis through an iterative process. Also, the location of the induction heat-

ing is set to be 95 mm away from the top edge of the web plate.

#### Longitudinal Bending Distortion by Induction Heating

Figure 7 shows the temperature distribution (at time = 90 s) produced by induction heating and fillet welding for Model A2. Also, Fig. 8 indicates the transient and residual longitudinal bending distortion based on numerical analysis results. From the analysis results, the maximum transient longitudinal bending distortion by induction heating is reduced to 50% as compared with the one by fillet welding only. From the temperature distribution and thermal history around induction HAZ and weld metal, it was noticed that the transient bending distortion was largely influenced by induction heating, and the residual bending distortion can be controlled by maintaining a balance of shrinkage forces.

The effects of intensity of induction heat input on longitudinal bending distortion were investigated and the analysis results are shown in Fig. 9. In Model A3, the amount of induction heat input was increased by 30% compared to Model A2 and in Model A4, reduced by 30%. From the results of the analysis, the amount of longitudinal bending distortion can be controlled by changing the amount of in-

duction heat input because the magnitude of the longitudinal bending distortion is proportional to the intensity of heat input.

#### Investigation of the Validity of Distortion Control Method by Induction Heating

In order to investigate the validity of the control method of longitudinal bending distortion by induction heating, Model A5 was numerically analyzed. The welding and induction heating conditions for finite element analysis were the same as those in Model A2.

The longitudinal bending distortion is generated by the bending moment due to welding, which is the value of the heat input of welding ( $Q_w = 1118 \text{ J/mm}$ ) multiplied by the distance ( $N_w = 55 \text{ mm}$ ) from the neutral axis of the built-up beam to the welded joint. To balance the welding moment, the induction moment must be calculated and applied to in the direction opposite of the welding moment. The amount of induction heat input is calculated as follows:

$$Q_w \times N_w \approx Q_i \times N_i \therefore Q_i \approx (Q_w \times N_w) / N_i \quad (1)$$

Because the distance from the neutral axis to the induction heating source was 95 mm, as shown in Table 1, the amount of induction heat input was calculated as

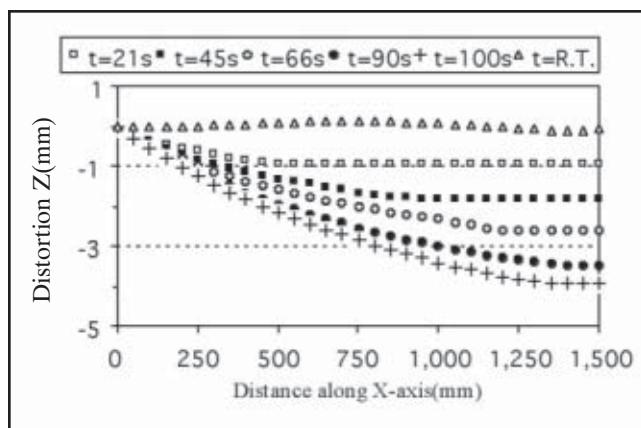


Fig. 8 — Longitudinal bending distortion by fillet welding and induction heating (Model A2).

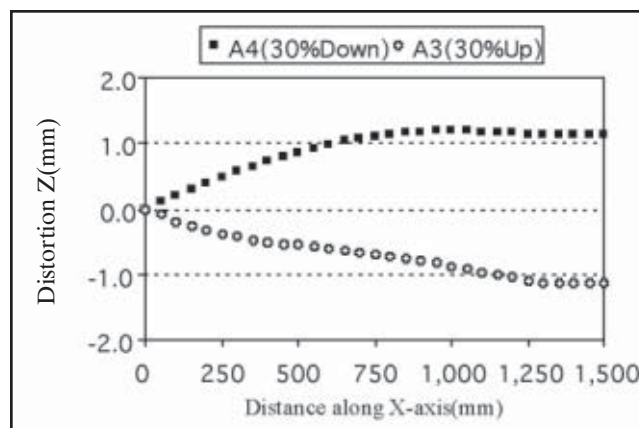


Fig. 9 — Longitudinal bending distortion by fillet welding and induction heating (Models A3 and A4).

Table 2 — Dimensions and Heat Input for Experimental Validation

| Model Type | Flange Plate (mm) |           | Web Plate (mm) |           | Length L (mm) | Temperature (°C) | Ni (mm) |
|------------|-------------------|-----------|----------------|-----------|---------------|------------------|---------|
|            | Width             | Thickness | Width          | Thickness |               |                  |         |
| E1         | 150               | 18        | 450            | 11.5      | 20,600        | 390              | 200     |
| E2         | 150               | 18        | 450            | 11.5      | 20,600        | 430              | 200     |
| E3         | 150               | 18        | 450            | 11.5      | 20,600        | 470              | 200     |
| E4         | 150               | 18        | 450            | 11.5      | 20,600        | 430              | 145     |
| E5         | 150               | 18        | 300            | 11.5      | 20,600        | 430              | 165     |
| E6         | 150               | 18        | 300            | 11.5      | 20,600        | 430              | 205     |
| E7         | 150               | 18        | 300            | 11.5      | 20,600        | 430              | 225     |
| E8         | 150               | 22        | 500            | 11.5      | 20,200        | 430              | 240     |
| E9         | 150               | 18        | 450            | 11.5      | 20,600        | 430              | 225     |

647 J/mm by Equation 1. The amount of induction heat input and location (Ni) calculated by Equation 1 can be applied to determine the output power of the induction heating instrument with various induction coil shapes. In the case of Model A5, the location (Ni) of induction heating was calculated as 122.6 mm by Equation 1 because the distance (Nw) from the neutral axis of the cross section of the built-up beam to the welded joint was 71 mm, and this value was used in this analysis.

Figure 10 shows the behavior of the transient and residual longitudinal bending distortion by fillet welding only, while Fig. 11 indicates the transient and residual longitudinal bending distortion by induction heating and fillet welding. From the analysis results, the longitudinal bending distortion was measured as about 2.5 mm at the middle of web plate of the built-up beam length by welding only, while the longitudinal bending distortion was produced as almost zero at the middle of length of T-joint by induction heating and fillet welding. Consequently, the validity of distortion control method by induction heating was verified by numerical analysis.

## Experiments for Large T-Section Structures

The control method of longitudinal bending distortion, which was verified by the numerical analysis in the above section, was verified by experiment. In this, effects of the induction heat input and location of induction heating on the longitudinal bending distortion were examined, and finally the control method of longitudinal bending distortion by induction heating was applied to large T-section structures.

### Specimen Dimensions and Experimental Conditions

Table 2 presents the specimen dimensions and heat input for experimental validation. The welding conditions and induction heating coil used for the experiments were the same as those in the above section. However, the conditions of induction heating changed with the experimental conditions. The amount of longitudinal bending distortion was measured, using string and caliper, at the top edge of the web plate when the temperature of both the welded part and

the induction-heated part reached room temperature.

### Effects of the Temperature of Induction Heating

To examine the effects of temperature variations due to induction heating on the longitudinal bending distortion, the induction heating coil was set to be located 200 mm upward from the neutral axis throughout the experiment, and the temperature of induction heating changed from 390°C (Model E1) to 470°C (Model E3). These induction temperatures were measured, using an infrared temperature measurement instrument, at a location 100 mm away from the heating coil after induction heating.

Figure 12 shows the longitudinal bending distortion after fillet welding with a change of temperature of induction heating. As the temperature of induction heating becomes higher, longitudinal bending distortion increased in a downward direction (–z direction) because of the increase of the moment by induction heating ( $M_i \approx Q_i \times Ni$ ). For Model E3 (470°C), it produced about 50 mm longitudinal bending distortion at the middle of the built-up beam length.

### Effects of Location of Induction Heating

To examine the effects of induction heating location on longitudinal bending distortion, the temperature of induction heating was set to 430°C (the temperature at 100 mm away from heating coil in welding direction) throughout the experiment, and the distance (Ni) from the neutral axis to the induction heating source changed from 145 mm (Model E4) to 225 mm (Model E7).

The amount of longitudinal bending distortion with a change of location of induction heating is shown in Fig. 13, and

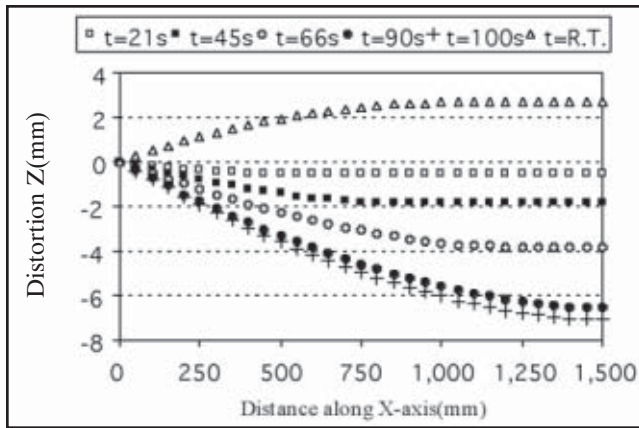


Fig. 10 — Longitudinal bending distortion by fillet welding (Model A5).

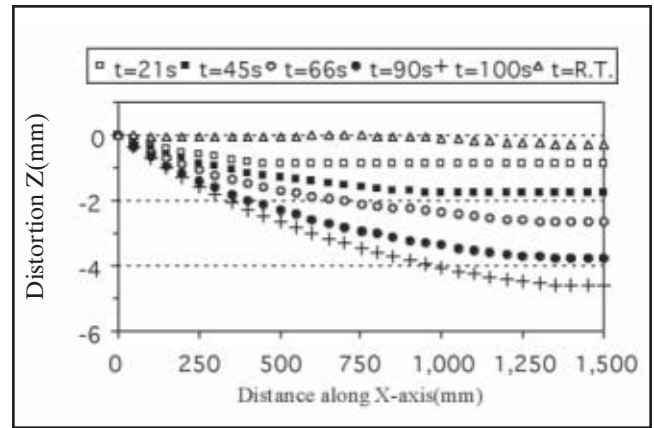


Fig. 11 — Longitudinal bending distortion by welding and induction heating (Model A5).

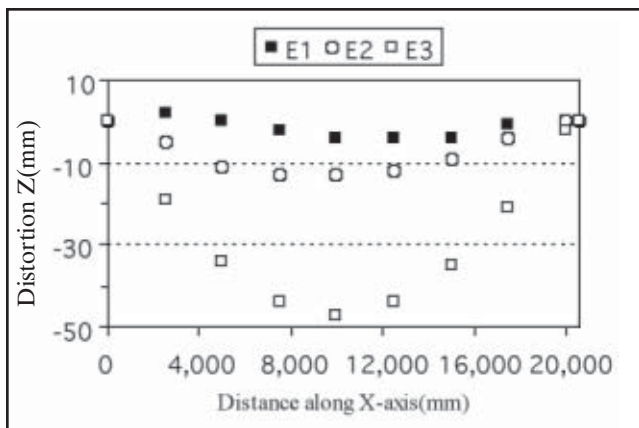


Fig. 12 — Longitudinal bending distortion with a change of induction heating temperature.

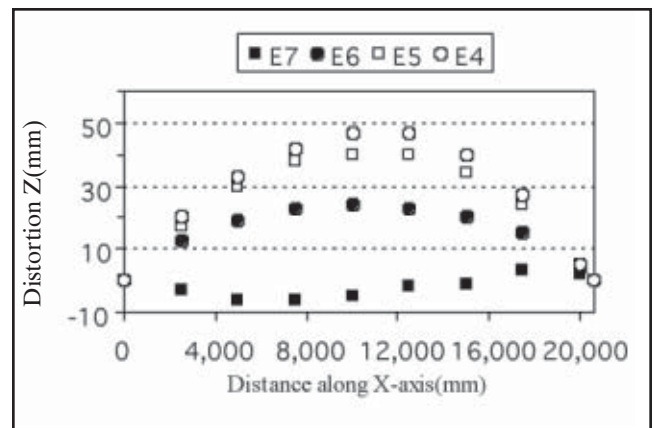


Fig. 13 — Longitudinal bending distortion with a change of location of induction heating.

the longitudinal bending distortion was produced to be within  $\pm 10$  mm in the case of Model E7. However, as the distance from the neutral axis to the induction heating source decreased, upward convex distortion to a maximum of 50 mm occurred. This is because as the distance from the neutral axis to the induction heating source decreased, the bending moment induced by induction heating became less than the bending moment induced by fillet welding.

#### Verification of the Validity by Experiments

Based on the results from the numerical analysis in the above section and the experiments in this section, it was found that longitudinal bending distortion can be controlled through physical parameters, namely the temperature and location of induction heating. The validity of this conclusion was investigated by applying the above results to large T-section structures. Models E8 and E9 in Table 2 were used, and the temperature and the location of

induction heating were calculated by Equation 1 and the experiment described in this section.

The longitudinal bending distortion of large T-section structures is shown in Fig. 14, which includes the experimental results performed twice with the same experimental conditions for the built-up beam. Based on the results of the experiments, longitudinal bending distortion was found to be within  $\pm 10$  mm at the middle of length of large T-section structures. These results mean that although the dimensions of the built-up beam change, the longitudinal bending distortion can be controlled by the temperature and location of induction heating calculated from Equation 1.

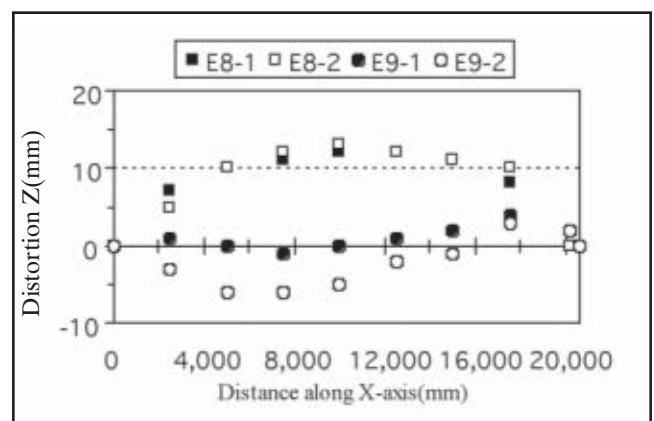


Fig. 14 — Longitudinal bending distortion for large T-section structures (Models E8 and E9).

#### Conclusions

This study proposes induction heating as a new method to mitigate longitudinal bending distortion due to fillet welding during manufacturing built-up beams. With this method, longitudinal bending

distortion can be controlled simultaneously with fillet welding, resulting in improvement of productivity and the quality of block assembly. Also, this study describes the mechanism of the longitudinal bending distortion and the effects of induction heating parameters on longitudinal bending distortion through numerical analysis and experimental results. The following results are obtained.

1. Based on the results from three-dimensional thermal elastic-plastic analysis, the longitudinal bending distortion is produced by the welding moment ( $M_w$ ), which can be obtained by multiplying the shrinkage force  $P(Q_w)$  in the welded part by the distance ( $N_w$ ) from the neutral axis on a cross section of the built-up beam to the welding heat source. Also, the magnitude of the longitudinal bending distortion increases as the shrinkage force and distance from the neutral axis to the welding heat source increase.

2. The longitudinal bending distortion induced by the bending moment due to welding can be mitigated by generating an induction moment ( $M_i$ ) with the same magnitude as the bending moment, and orientating it in the opposite direction of the bending moment. Then, the induction

moment ( $M_i$ ) is generated by controlling the intensity of induction heat input and the distance ( $N_i$ ) from the neutral axis to the induction heating source.

3. From the experiments performed to investigate the effects of intensity of induction heat input and its location on the longitudinal bending distortion, it is found that longitudinal bending distortion decreases as the temperature of induction heating becomes higher and the distance from the neutral axis to induction heating source increases. But there is a possibility of providing too much induction moment and in effect ending up with more distortion in the opposite direction.

4. By applying the temperature and location of induction heating obtained from the numerical analysis and experimental results to large T-section structures, it is concluded that longitudinal bending distortion can be controlled by the temperature and the location of induction heating for large T-section structures with dimensional changes.

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All authors should address themselves to the following questions when writing papers for submission to the Welding Research Supplement:

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- ◆ What was done?
- ◆ What was found?
- ◆ What is the significance of your results?
- ◆ What are your most important conclusions?

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1) **Abstract.** A concise summary of the major elements of the presentation, not exceeding 200 words, to help the reader decide if the information is for him or her.

2) **Introduction.** A short statement giving relevant background, purpose, and scope to help orient the reader. Do not duplicate the abstract.

3) **Experimental Procedure, Materials, Equipment.**

4) **Results, Discussion.** The facts or data obtained and their evaluation.

5) **Conclusion.** An evaluation and interpretation of your results. Most often, this is what the readers remember.

### 6) Acknowledgment, References and Appendix.

Keep in mind that proper use of terms, abbreviations, and symbols are important considerations in processing a manuscript for publication. For welding terminology, the *Welding Journal* adheres to AWS A3.0:2001, *Standard Welding Terms and Definitions*.

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# Three-Dimensional Analysis of Molten Pool in GMA-Laser Hybrid Welding

*Analytical models of GMA and laser keyhole welding are merged to achieve the simulation of hybrid welding considering the multiple reflections of laser and the Fresnel absorption theory*

BY J.-H. CHO AND S.-J. NA

## ABSTRACT

A computational analysis of a molten pool in laser-GMA hybrid welding is achieved including free-surface tracking using the well-known volume of fluid (VOF) method. The suggested three-dimensional transient numerical model includes all known analytical key features of arc welding including electromagnetic force, buoyancy, and arc pressure. In addition to the basic GTA model, molten droplets are artificially generated and allowed to fall down to the pool to cover the GMAW process. A keyhole analysis model is merged to a GMAW simulation model with the assumption that the interaction between the laser and the arc is negligible for convenience. The keyhole model is established on a unique phenomena that includes multiple reflections, Fresnel absorption model, and the recoil pressure in laser welding apart from the inverse Bremsstrahlung absorption. The result shows the flow patterns of the molten pool in GMA-laser hybrid welding, and they are compared to previously reported observation results. The molten flow at the bottom of the keyhole rises up slowly, and therefore a vortex can be observed throughout the molten pool. However, the flow pattern became increasingly complicated. The flow of the keyhole root is split into three main streams, and one stream is continuously maintained in the vortex.

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## Introduction

Welding is a complex multiphysics topic related to plasma physics, electro magnetism, and fluid dynamics including metallurgy. In addition, it is impossible to observe the welding process directly because the pool and arc plasma are very bright, and their temperatures are exceedingly high. Therefore, various types of research have been reported to monitor the welding process. A representative method is the checking of the current or voltage of gas tungsten arc (GTA) or gas metal arc (GMA) welding (Refs. 1–3). There are more sophisticated methods that directly record the pool images using a CCD camera or that use such a camera combined with optical filters and various light sources such as specific laser or halogen lamps (Refs. 4, 5). However, all of the aforementioned techniques are indirect techniques; specifically, they do not provide any information concerning the phenomena occurring inside the weld pool. In other words, they merely present the predictability of bead shapes, resulting in a lack of scientific information regarding the flow and related phenomena.

An impressive method that enables the pool to be observed directly is a real-time X-ray imaging system (Refs. 6, 7). X-rays transmitted through the workpiece in a laser keyhole welding process are focused on a CCD camera and are then reconstructed as gray-scaled images in real time. It is very useful to see the keyhole

and pores instantaneously in the weldment during the process, as it is possible to monitor the bead formation process. In spite of these advantages, it is difficult to construct the system in the actual production area, as it is expensive compared to conventional monitoring methods. Additionally, there are concerns regarding health problems related to radiation. Furthermore, the information available through this system remains insufficient if one wishes to comprehend the physical meanings of the welding process. The achieved images are two-dimensional, gray-scaled, and comparatively rough, making it difficult to understand the details of the flow in the X-ray images.

In this area, computer simulations can greatly facilitate the comprehension of molten pool dynamics. Although the analysis of a molten pool based on computational fluid dynamics is not a complete answer to the questions regarding heat and mass transfer problems in the welding process, it provides a passable answer. Simulation results show the flow of the molten pool and the formation of the weldment as well as its historical temperature profile. Hence, a number of studies regarding weld pool analysis have been reported since the 1980s.

In early simulations of arc welding, it was impossible to accomplish a flow analysis of molten metal that included free-surface tracking (Refs. 8, 9). However, due to advances in computer and numerical techniques, knowledge of the total flow patterns of the molten pool have been achieved that include the expression of the free surface (Refs. 10, 11), as well as the inclusion of droplets via a feeding wire (Refs. 12, 13).

For keyhole dynamics in the laser welding process, a geometrically assumed keyhole such as a cylindrical hole in a plate was typically used to analyze the effects in early studies that did not incorporate the expression of the free surface of molten material, as mentioned above (Ref. 14). Currently, keyhole dynamics

## KEYWORDS

Gas Metal Arc Welding  
(GMAW)  
Laser  
Hybrid Welding  
Volume of Fluid (VOF)  
Keyhole  
Fresnel

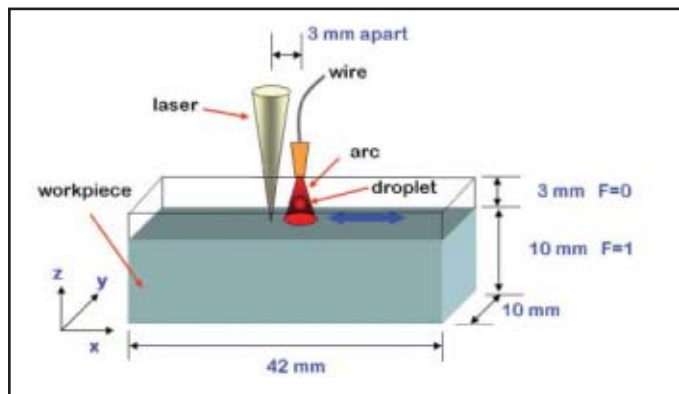


Fig. 1 — Schematic diagram of laser-GMA hybrid welding simulation.

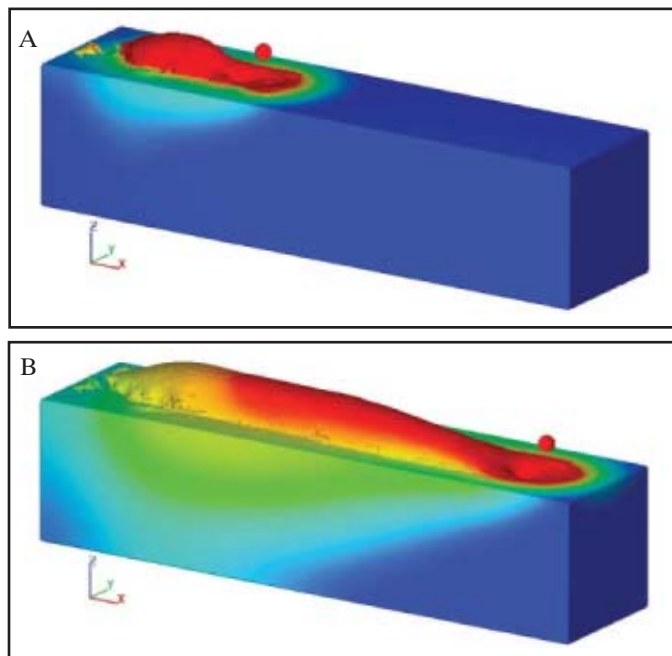


Fig. 2 — 3-D perspective views of simulation results. A —  $t=0.45$  s; B —  $t=1.8$  s.

including the evolutionary free-surface shape achieved by VOF (Ref. 15) or the level-set method are typically reported (Refs. 16, 17). One of the most important features of keyhole simulation is the multiple reflection effect. If the laser beam is considered as a bundle of rays, it can be easily understood that each of the rays travels inside the keyhole through multiple reflections at the keyhole wall until it escapes out of it. Therefore, the ray tracing profile inside the keyhole is entirely dependent on the external shape of the keyhole, which means the keyhole surface exposed to laser rays (Ref. 18). Consequently, the exact keyhole profile and a ray tracing algorithm are needed for every single time step in a simulation in order to obtain a precise energy distribution map of the keyhole surface.

In this paper, the analysis of a three-dimensional molten pool analysis is achieved for a laser-GMA hybrid welding process. Analytical models for GMA and laser keyhole welding are merged to realize the hybrid welding process in a computer simulation. A real-time ray tracing technique (Ref. 23) that takes into account a discrete grid cell in the VOF method is adopted to realize a multiple reflection effect for every time step according to the present keyhole profile. There are several assumptions and simplifications used in the analysis. First, it is assumed that the arc plasma and the laser do not interact; consequently, they are only mathematically superposed in the simulation. Secondly, both the arc and the laser are considered as surface heat flux with a Gaussian distribution. Lastly, the effect of shielding gas is not considered in the analysis. The simulation was conducted using the commercial package Flow3D. Suggested analytical model is already validated by comparing the simulation result to the experiment (Refs. 23, 24).

### Molten Pool Dynamics

To execute the molten pool analysis, three governing equations are essential, as

with other normal fluidic problems. They are the continuity equation, the momentum equation, which here is referred to as the Navier-Stokes equation, and the energy equation.

The metallic fluid in this simulation is assumed as incompressible, laminar, and Newtonian.

Based on these assumptions, the governing equations are expressed as follows. First, the continuity equation (Ref. 19), implies that the conservation of the material has the form shown in Equation 1.

$$\frac{\partial}{\partial x}(uA_x) + \frac{\partial}{\partial y}(vA_y) + \frac{\partial}{\partial z}(wA_z) = 0 \quad (1)$$

In Equation 1,  $u$ ,  $v$ , and  $w$  denote the velocity component according to each axis in the Cartesian coordinates.  $A_x$ ,  $A_y$ , and  $A_z$  denote the fractional area open to the flow in each direction.  $t$  is the time, and  $\rho$ ,  $P$ ,  $\mu$ , and  $G_z$  denote the density, pressure, viscosity, and gravitational acceleration in the momentum equation, respectively. They can be expressed as follows:

$$\begin{aligned} \frac{\partial u}{\partial t} + \frac{1}{V_F} \left\{ uA_x \frac{\partial u}{\partial x} + vA_y \frac{\partial u}{\partial y} + wA_z \frac{\partial u}{\partial z} \right\} \\ = -\frac{1}{\rho} \frac{\partial p}{\partial x} + f_x \end{aligned} \quad (2)$$

$$\begin{aligned} \frac{\partial v}{\partial t} + \frac{1}{V_F} \left\{ uA_x \frac{\partial v}{\partial x} + vA_y \frac{\partial v}{\partial y} + wA_z \frac{\partial v}{\partial z} \right\} \\ = -\frac{1}{\rho} \frac{\partial p}{\partial y} + f_y \end{aligned} \quad (3)$$

$$\begin{aligned} \frac{\partial w}{\partial t} + \frac{1}{V_F} \left\{ uA_x \frac{\partial w}{\partial x} + vA_y \frac{\partial w}{\partial y} + wA_z \frac{\partial w}{\partial z} \right\} \\ = -\frac{1}{\rho} \frac{\partial p}{\partial z} + f_z + G_z \end{aligned} \quad (4)$$

Here,  $V_F$  denotes the volume fraction in the cell in the VOF method (Ref. 20) and  $f_x$ ,  $f_y$ , and  $f_z$  indicate the viscous acceleration rates as in Equations 5–7.

$$\begin{aligned} f_x = -\frac{1}{\rho V_F} \left\{ \frac{\partial}{\partial x} (A_x \tau_{xx}) + \frac{\partial}{\partial y} (A_y \tau_{xy}) \right. \\ \left. + \frac{\partial}{\partial z} (A_z \tau_{xz}) \right\} \end{aligned} \quad (5)$$

$$\begin{aligned} f_y = -\frac{1}{\rho V_F} \left\{ \frac{\partial}{\partial x} (A_x \tau_{xy}) + \frac{\partial}{\partial y} (A_y \tau_{yy}) \right. \\ \left. + \frac{\partial}{\partial z} (A_z \tau_{yz}) \right\} \end{aligned} \quad (6)$$

$$\begin{aligned} f_z = -\frac{1}{\rho V_F} \left\{ \frac{\partial}{\partial x} (A_x \tau_{xz}) + \frac{\partial}{\partial y} (A_y \tau_{yz}) \right. \\ \left. + \frac{\partial}{\partial z} (A_z \tau_{zz}) \right\} \end{aligned} \quad (7)$$

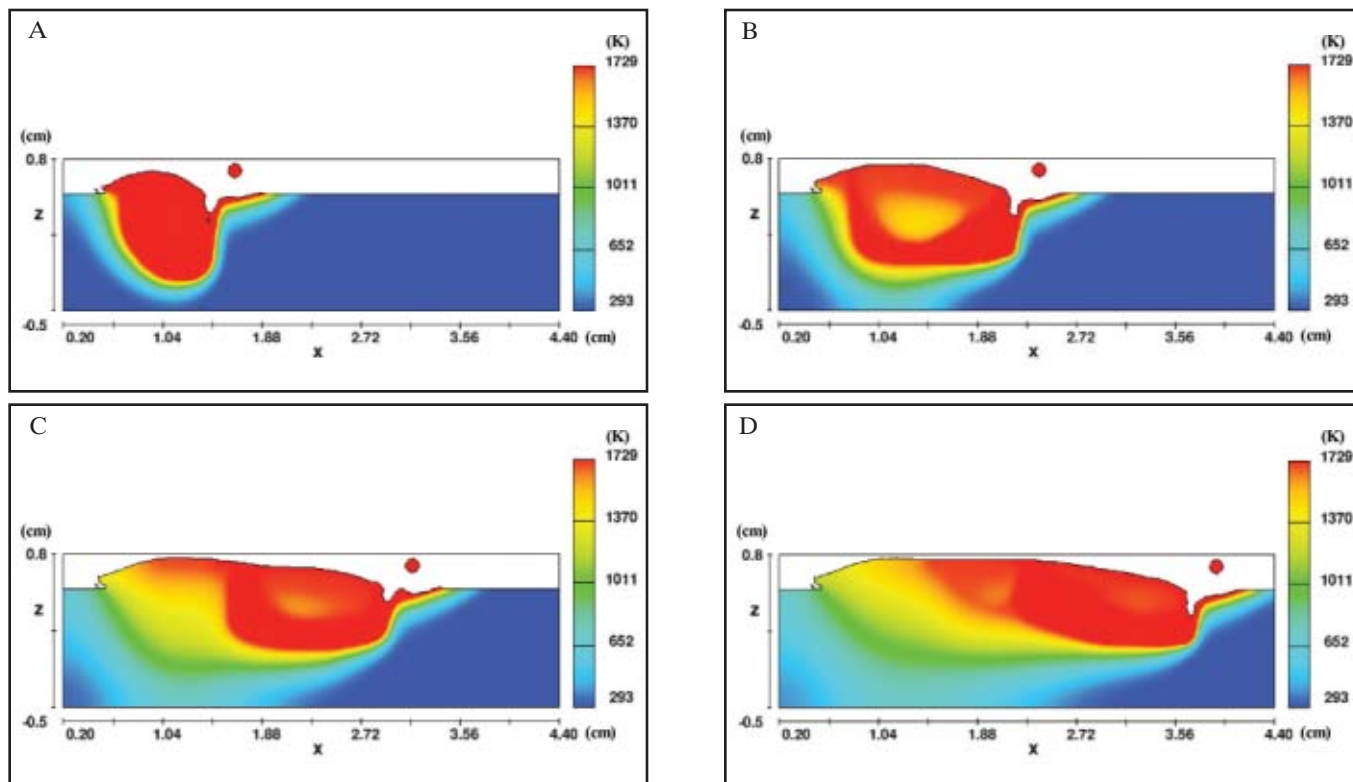


Fig. 3 — Temperature profiles of cross-sectioned side views in the simulation result. A —  $t=0.45$  s; B —  $t=0.9$  s; C —  $t=1.35$  s; D —  $t=1.8$  s.

Where

$$\begin{aligned}\tau_{xx} &= -2\mu \left\{ \frac{\partial u}{\partial x} - \frac{1}{3} \left( \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} \right) \right\}, \\ \tau_{yy} &= -2\mu \left\{ \frac{\partial v}{\partial y} - \frac{1}{3} \left( \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} \right) \right\}, \\ \tau_{zz} &= -2\mu \left\{ \frac{\partial w}{\partial z} - \frac{1}{3} \left( \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} \right) \right\}, \\ \tau_{xy} &= -\mu \left\{ \frac{\partial v}{\partial x} + \frac{\partial u}{\partial y} \right\}, \quad \tau_{xz} = -\mu \left\{ \frac{\partial u}{\partial z} + \frac{\partial w}{\partial x} \right\}, \\ \tau_{yz} &= -\mu \left\{ \frac{\partial v}{\partial z} + \frac{\partial w}{\partial y} \right\}\end{aligned}\quad (8)$$

Additionally, the energy equation based on the enthalpy method and the continuum formulation is described below.

$$\frac{\partial h}{\partial t} + (\vec{V} \cdot \nabla)h = \rho \nabla \cdot (K \nabla T) \quad (9)$$

$$h = C_p \cdot T + f \cdot L_f \quad (10)$$

Where  $f$  denotes

$$f(T) = \begin{cases} 0, & \text{if } T \leq T_S \\ \frac{T - T_L}{T_L - T_S}, & \text{if } T_S < T < T_L \\ 1, & \text{if } T \geq T_L \end{cases} \quad (11)$$

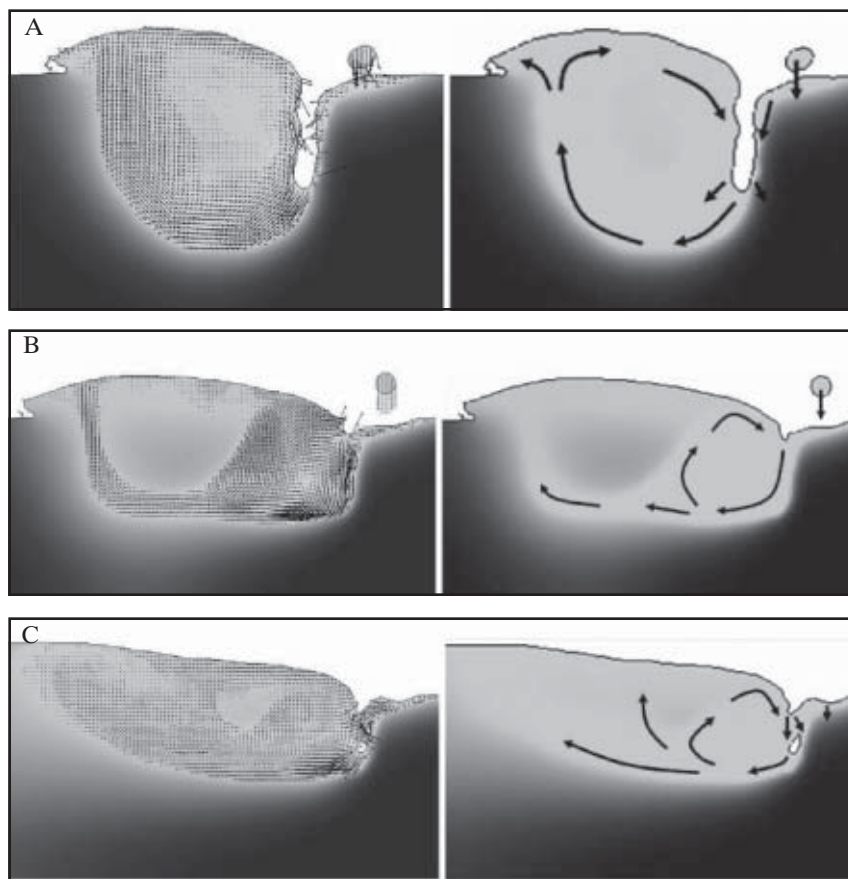


Fig. 4 — Flow patterns of simulation result in cross-sectional side views. A —  $t=0.53$  s; B —  $t=0.99$  s; C —  $t=1.96$  s.

In this equation,  $h$  and  $K$  indicate the enthalpy and the thermal conductivity, respectively, and  $T$ ,  $T_L$ , and  $T_s$ , correspondingly, denote the temperature, liquidus temperature, and solidus temperature.

In terms of the energy transfer, the laser beam is a type of complex heat source model that interacts with various materials. However, it is generally treated as a surface heat flux boundary condition in an analysis, and there is a widely accepted simple expression in the form of a Gaussian function related to the TEM<sub>00</sub> mode in laser activity with a mathematical form as in the following equation (Ref. 21):

$$q_L(x, y, z) = \frac{3Q}{\pi r_L^2} \exp\left(-3 \frac{x^2 + y^2}{r_L^2}\right) \quad (12)$$

$$r_L = r_0 + a|z_0 - z| \quad (13)$$

In Equation 12,  $Q$  indicates the nominal laser power and the coefficient 3 indicates that 95% of the total power exists inside the area of the effective radius  $r_L$ . Particularly, the laser beam is modeled to have a diverging property along the traveling path in this research. This is more realistic than earlier models of a collimated beam. Therefore, the beam model becomes a three-dimensional function by appending Equation 13 to Equation 12. The beam radius is set so as to increase linearly along the path, with a focal radius  $r_0$  at the  $z_0$  position in the  $z$  axis.

The electric arc is modeled as a type of surface heat flux with a Gaussian distribution shape. Its mathematical form is, therefore, similar to that of Equation 12 exclusive of the diverging effective radius, which is changed to a fixed radius as in the following:

$$q_A(x, y) = \frac{VI}{2\pi r_A^2} \exp\left(-\frac{x^2 + y^2}{2r_A^2}\right) \quad (14)$$

Here,  $V$  and  $I$  are the voltage and current of the arc, respectively, and  $r_A$  is the fixed effective radius of the arc. It is equal to 3 mm. In contrast to the equation of the laser heat source, this equation is a two-dimensional function. Thus, its shape remains unchanged along the  $z$  axis.

After achieving the heat source models, the pressure boundary conditions must be confirmed. In an arc welding process, the pool experiences a small deformation along its top surface due to the arc pressure caused by the massive flow of arc plasma; this has the form of a Gaussian distribution as in the following equation (Ref. 15):

$$P_A \cong \frac{\mu_0 I^2}{4\pi^2 r_A^2} \exp\left(-\frac{r^2}{2r_A^2}\right) \quad (15)$$

For a laser beam welding case, the pressure boundary condition is entirely

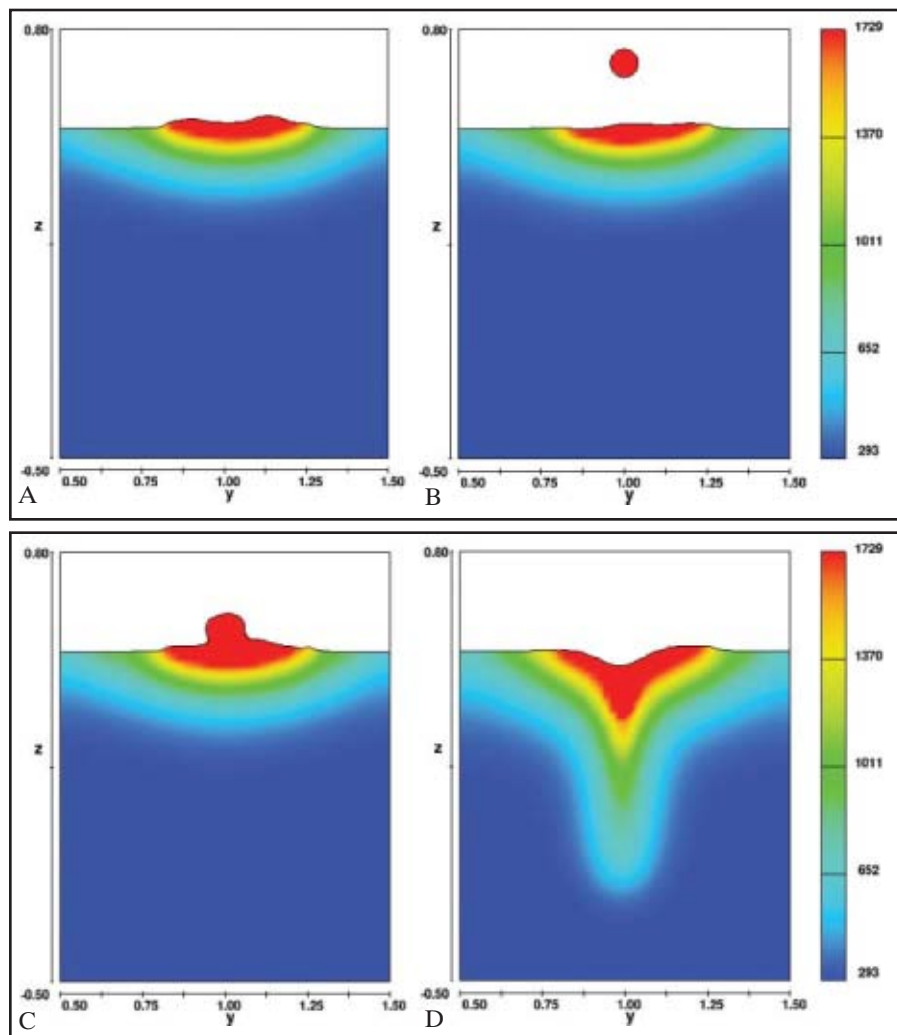


Table 1 — Material Properties and Coefficients Used in Analysis

| Properties                           | Value                        |
|--------------------------------------|------------------------------|
| Density                              | 7490 kg/m <sup>3</sup>       |
| Thermal conductivity                 | 35 W/mK                      |
| Specific heat                        | 606 J/kgK                    |
| Latent heat of vaporization          | 6084 kJ/kg                   |
| Latent heat of fusion                | 260 kJ/kg                    |
| Liquidus temperature                 | 1787.5 K                     |
| Solidus temperature                  | 1729.2 K                     |
| Liquid-vapor equilibrium temperature | 3130 K                       |
| Magnetic permeability                | 1.26e-6 H/m                  |
| Viscosity                            | 0.006 kg/ms                  |
| Thermal expansion rate               | 4.2 × 10 <sup>-5</sup> /K    |
| Surface tension                      | 1.2 N/m                      |
| Surface tension gradient             | -0.2 × 10 <sup>-3</sup> N/mK |
| Focal radius, $r_0$                  | 0.25 mm                      |
| Beam divergence in Equation 13, $a$  | 0.2                          |
| Universal gas constant               | 8.314 J/molK                 |

different from Equation 15. Deformation of the surface mainly depends on the evaporation of material in a process referred to as the recoil pressure, which is the main driving force in the creation of a keyhole. A precise mathematical model for this phenomenon does not exist, but the Equation 16 reported in 2002 is simple and can

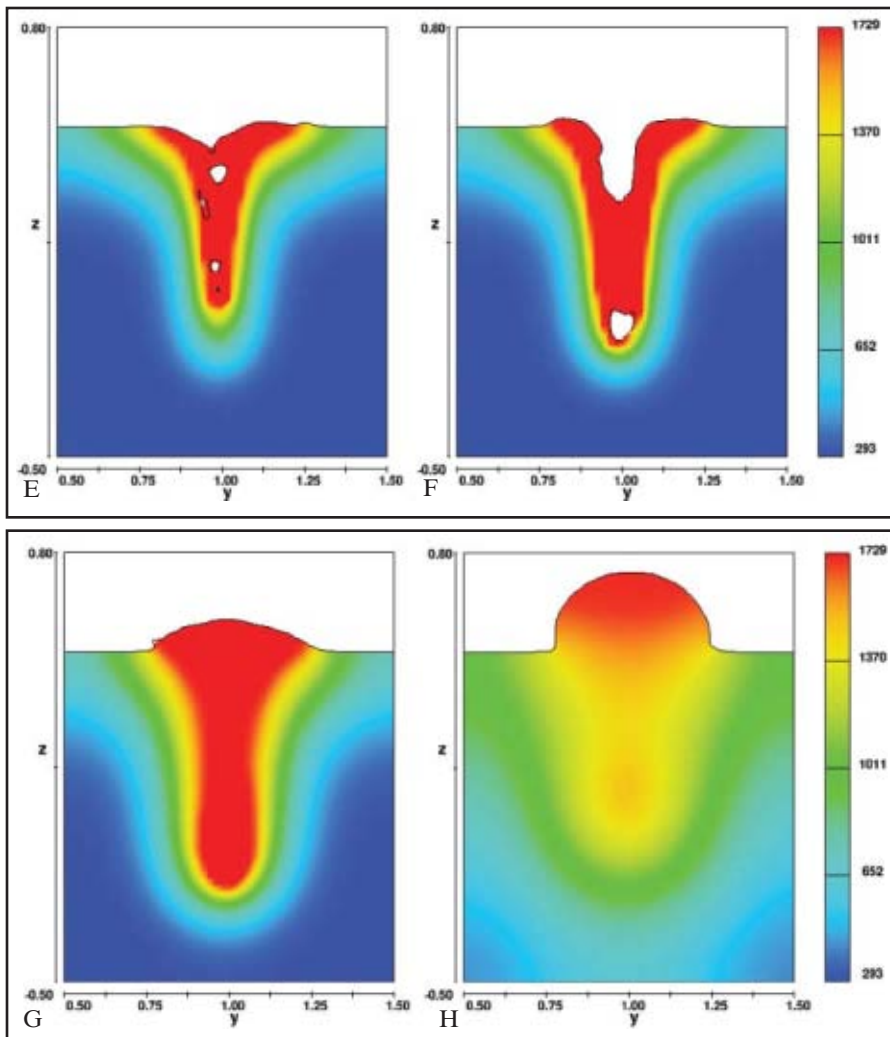


Fig. 5 — Temperature profiles of cross-sectioned front views in simulation result at positions,  $x=1.43$ . A —  $t=0.25$  s; B —  $t=0.27$  s; C —  $t=0.29$  s; D —  $t=0.38$  s; E —  $t=0.4$  s; F —  $t=0.42$  s; G —  $t=0.52$  s; H —  $t=1.11$  s.

be used in this simulation (Ref. 22).

$$P_R \cong 0.54P_0 \exp\left(\frac{\Delta H_{LV}}{RTT_{LV}} \frac{T - T_{LV}}{T_{LV}}\right) \quad (16)$$

In Equation 15,  $\mu_0$  is the permeability in a vacuum.  $P_0$  denotes the atmospheric pressure and  $\Delta H_{LV}$  is the latent heat of vaporization.  $T$ ,  $T_{LV}$ , and  $R$  indicate the surface temperature, liquid-vapor equilibrium temperature, and universal gas constant, respectively. The value 0.54 in Equation 15 is a factor that depends on the environmental pressure. This was also adopted in this research.

Heat source models and pressure models are prepared for application as boundary conditions. For the top surface, which is directly exposed to the heat sources of the arc and the laser, and for the arc and recoil pressure, the mathematical expressions are as follows:

$$K \frac{\partial T}{\partial n} = \eta_L q_L + \eta_A q_A - h_A (T - T_\infty) - \sigma_s \epsilon_r (T^4 - T_\infty^4) - q_{vap} \quad (17)$$

$$-P + 2\mu \frac{\partial V}{\partial n} = -P_R - P_A + \frac{\gamma}{R_c} \quad (18)$$

In Equation 17,  $n$  denotes the normal component,  $K$  is the thermal conductivity, and  $T$  is the surface temperature.  $\eta$  denotes the heat input efficiency, i.e., the heat absorption rate, and the subscripts  $L$  and  $A$  indicate the laser and arc, respectively. The efficiency for the laser heat source is determined by the Fresnel reflection model and multiple reflections in the keyhole, which are discussed in later paragraphs. On the other hand, the efficiency of the arc is predetermined as 0.56. The heat input efficiency of the droplets

was found to be 0.24 in this simulation; therefore, the total GMAW efficiency was set at 80%, which refers to Ref. 28. The third and fourth terms on the right side of this equation denote the heat losses caused by ambient air convection and heat radiation. Accordingly,  $h_A$  is the convection coefficient, which is 40 W/m<sup>2</sup> K here, and  $T_\infty$  is the temperature of the ambient air, set here as 293 K.  $\sigma_s$ ,  $\epsilon_r$ , and  $q_{vap}$  indicate the Stefan-Boltzmann constant, the emissivity, and the heat loss caused by vaporization, respectively. Equation 18 calculates the pressure boundary condition for the top surface including the surface tension in a flow.  $\mu$  denotes the dynamic viscosity,  $\gamma$  and  $R_c$  indicate the surface tension coefficient and the radius of the surface curvature, respectively.

All of the other boundaries, such as the rear, front, and side, are set as continuous surfaces. This implies that the material exists continuously so the normal derivatives of all the properties at the boundary are equal to zero. The zero derivative condition is intended to represent a smooth continuation of the flow through the boundary.

In addition to the high power density of the laser, the main driving force that makes the keyhole deeper is the multiple reflections of the laser beam in the keyhole. If the laser is regarded as a bundle of ray beams, all of the rays coming into the keyhole experience multiple reflections on the wall and finally reach the bottom of the keyhole. These superposed rays inside the keyhole raise the total energy absorption and obtain a deeper penetration. In this research, the ray tracing technique is triggered on for every time step following to the self-evolved three-dimensional keyhole profile. Detailed descriptions can be found in an earlier published report by the author (Ref. 23).

The molten surface of the metal is regarded as specular in this paper; thus, it was deemed reasonable to adopt the Fresnel reflection model (Ref. 25), which is widely accepted for the calculation of laser absorption rate. Reflectivity  $R_f$  at the molten surface is mainly dependent on the angle between the incident ray and surface normal  $\phi$  as follows, and the absorption rate  $\eta_f$  is then  $1 - R_f$ .

$$R_f = \frac{1}{2} \left( \frac{1 + (1 - \epsilon \cos \phi)^2}{1 + (1 + \epsilon \cos \phi)^2} + \frac{\epsilon^2 - 2\epsilon \cos \phi + 2\cos^2 \phi}{\epsilon^2 + 2\epsilon \cos \phi + 2\cos^2 \phi} \right) \quad (19)$$

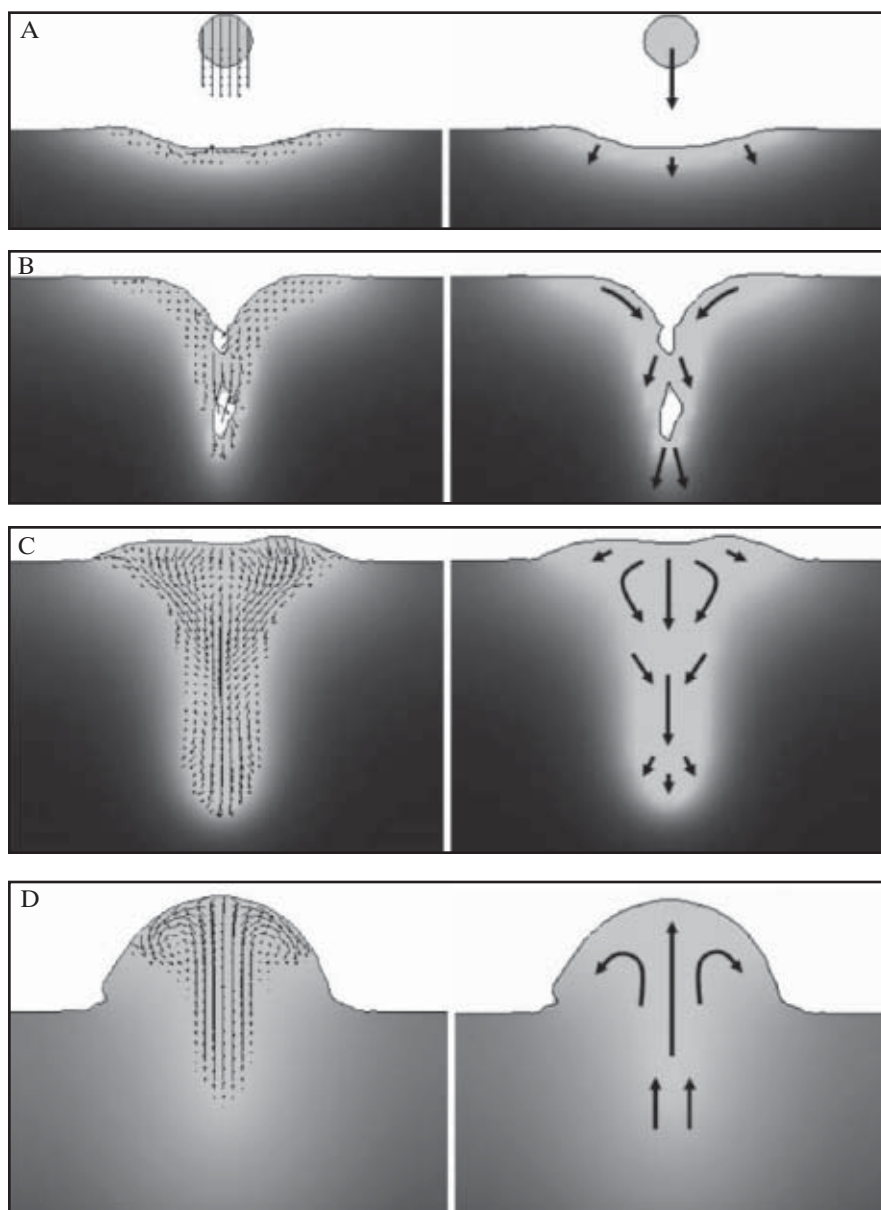


Fig. 6 — Flow patterns of simulation result in cross-sectioned front views at  $x=2.31$ . A —  $t=0.84$  s; B —  $t=0.95$  s; C —  $t=1.03$  s; D —  $t=1.9$  s.

$$\varepsilon^2 = \frac{2\varepsilon_2}{\varepsilon_1 + \left[ \varepsilon_1^2 + \left( \sigma_{st} / \omega \varepsilon_0 \right)^2 \right]^{1/2}} \quad (20)$$

The value of  $\varepsilon$  is related to the electrical conductance per unit depth of metal  $\sigma_{st}$ , and  $\varepsilon_1$  and  $\varepsilon_2$  denote the real part of the dielectric constants of metal and plasma, respectively. Additionally,  $\varepsilon_0$  indicates the permittivity of a vacuum, and  $\omega$  is one of the laser properties representing the angular frequency. The value  $\varepsilon$  is determined from the material properties and the laser type. For a CO<sub>2</sub> laser and a steel workpiece, this value is 0.08. However, it is also modifiable for several reasons. First, the

temperature of the keyhole wall is at the boiling point, which could affect the Fresnel absorption. Moreover, the method used to calculate the Fresnel absorption is approximated, and the use of a large value of  $\varepsilon$  could offset the approximations (Ref. 25). Therefore, the value of  $\varepsilon$  can be determined by trial and error to fit the simulation result to the experimental result. The aim of this research is not to determine the proper coefficient; rather, the paper is purely focused on observing the fluidic phenomena achieved using a numerical method.

In addition to the gravitational force, another body force in the flow is the electromagnetic force induced by the arc current inside the workpiece. Simplified electromagnetic force in the pool is explained

by the following equation set (Refs. 9, 26).

$$F_x = -\frac{\mu_m I^2}{4\pi^2 r_A^2 r} \exp\left(-\frac{r^2}{2r_A^2}\right) \times \left[ 1 - \exp\left(-\frac{r^2}{2r_A^2}\right) \right] \left( 1 - \frac{z}{c} \right)^2 \frac{x}{r} \quad (21)$$

$$F_y = -\frac{\mu_m I^2}{4\pi^2 r_A^2 r} \exp\left(-\frac{r^2}{2r_A^2}\right) \times \left[ 1 - \exp\left(-\frac{r^2}{2r_A^2}\right) \right] \left( 1 - \frac{z}{c} \right)^2 \frac{y}{r} \quad (22)$$

$$F_z = \frac{\mu_m I^2}{4\pi^2 r^2 c} \left[ 1 - \exp\left(-\frac{r^2}{2r_A^2}\right) \right]^2 \left( 1 - \frac{z}{c} \right) \quad (23)$$

In these equations,  $\mu_m$  is the magnetic permeability of the material,  $I$  is the arc current, and  $c$  is the thickness of the workpiece. For the coordinate value,  $x$  and  $y$  denote the distance from the arc position according to each axis, and  $z$  indicates the distance from the top of the workpiece along the  $z$  axis.

## Results and Discussion

The material adopted for the simulations was ASTM A131 steel with a thickness of 10 mm. The analytic domain was set as 42 mm in length, 10 mm in width, and 13 mm in height including the void region of the top 3 mm for free-surface tracking. In the Cartesian coordinate system, the ranges of the domain are (2 mm, 44 mm) in the  $x$  axis, (5 mm, 15 mm) in the  $y$  axis, and (−0.5 mm, 0.8 mm) in the  $z$  axis, respectively. The inter-grid distance is equal to 0.1 mm along the three axes; consequently, there is a total of 2,860,000 element cells. The physical properties of the material and coefficients used in the simulation are shown in Table 1. It took 328 hours to complete the simulation.

Figure 1 shows a schematic diagram of the solution domain of the simulations. In this figure, the  $F$  value denotes the filled portion of the fluid (material) in a cell using the VOF method; i.e.,  $F=1$  indicates that the cell is fully filled with fluid,  $F=0$  indicates that it is empty, and  $0 < F < 1$  signifies that it is partially filled. While the gas metal arc leads the welding process 3 mm ahead of the laser, the arc and laser power in this case is 2.5 kW (current 150 A and voltage 16.7 V) and 3.7 kW, respec-

tively, and the welding speed is set at 1 m/min. The instance of a 2-s GMA-laser hybrid welding process is simulated and analyzed.

In addition to the arc heat source model, it is necessary to determine the effect of droplets as a heat source in GMAW. Conventionally, droplets are treated as an additional surface heat flux with a Gaussian distribution when the free-surface tracking is not readily available. In this study, the droplets are assumed to be at a temperature 2400 K and are essentially generated to have the mass and momentum and to have fallen into the pool by the gravity and electromagnetic force. The diameter of the droplets is assumed to be equal to that of the electrode wire; consequently, the generation frequency 167 Hz is determined according to the wire feed rate of 8 m/min. The initial velocity of the droplet is assumed to have only the vertical (z-axis) component and its magnitude is 50 cm/s (Ref. 13).

Figure 2 shows three-dimensional perspective scenes of the simulation result. Droplets of welding wire are continuously generated in the void region and fall into the pool. It is observable that the surface of the molten pool is slightly dimpled due to the arc pressure in the figures. Directly behind the dimpled arc region, the keyhole opening is shown, resembling a cavity. Given that the distance between the arc and the laser is only 3 mm, the keyhole opening is located in the dimpled shape. Therefore, the keyhole and dimple are merged and can be observed as one large hole in a lateral cross-section plane near the top surface level of the workpiece. It is important to note that the shape of the free surface is maintained in a macroscopic view while the heat sources are moving forward. However, an unstable keyhole continuously repeats the generation and collapse process. Additionally, the inertia of the falling droplets causes the pool to oscillate. This is discussed in detail in the following paragraphs.

The solid and liquid regions and their boundaries are displayed in Fig. 3, which also shows the temperature profiles. In the series of figures, it is possible to observe the droplets generated above the workpiece as well as the dimpled shape at the arc position. Moreover, it is easy to compare the penetration depths of the GMA and laser welding processes. The difference is clearly distinct as the penetration depth of the GMA process does not exceed 1.5 mm while the depth of the keyhole is more than 6 mm. It is important that the free surface of the keyhole does not appear in these figures, not because the model is incorrect, but because the output file is not saved in a sufficient number of shot intervals. The results are saved every 10 ms. The keyhole is continuously repeating the generation and collapse process with a time interval

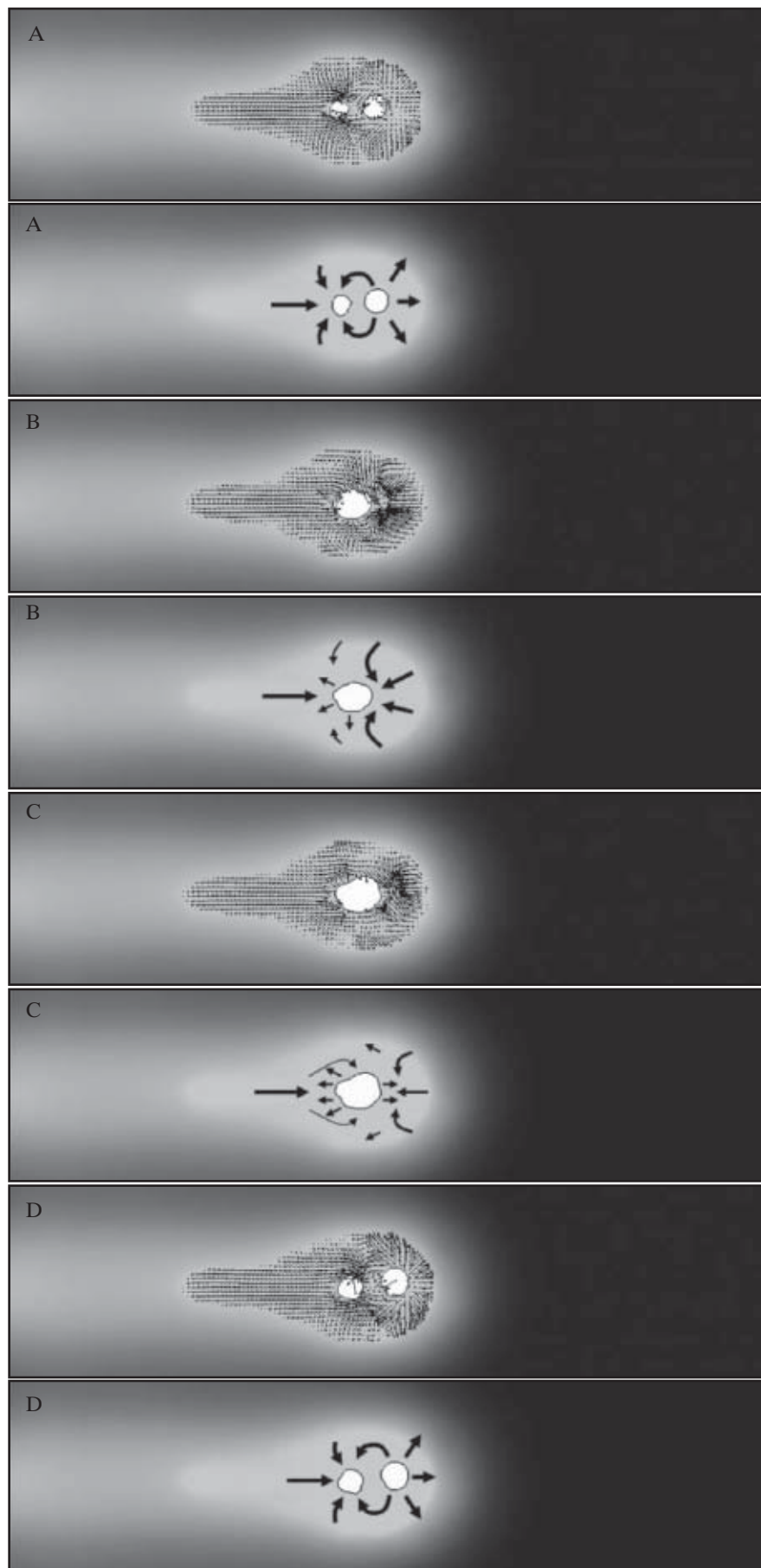


Fig. 7 — Flow patterns of the simulation result in cross-sectioned top views at  $z=0.47$ . A —  $t=1.03$  s; B —  $t=1.04$  s; C —  $t=1.05$  s; D —  $t=1.06$  s.

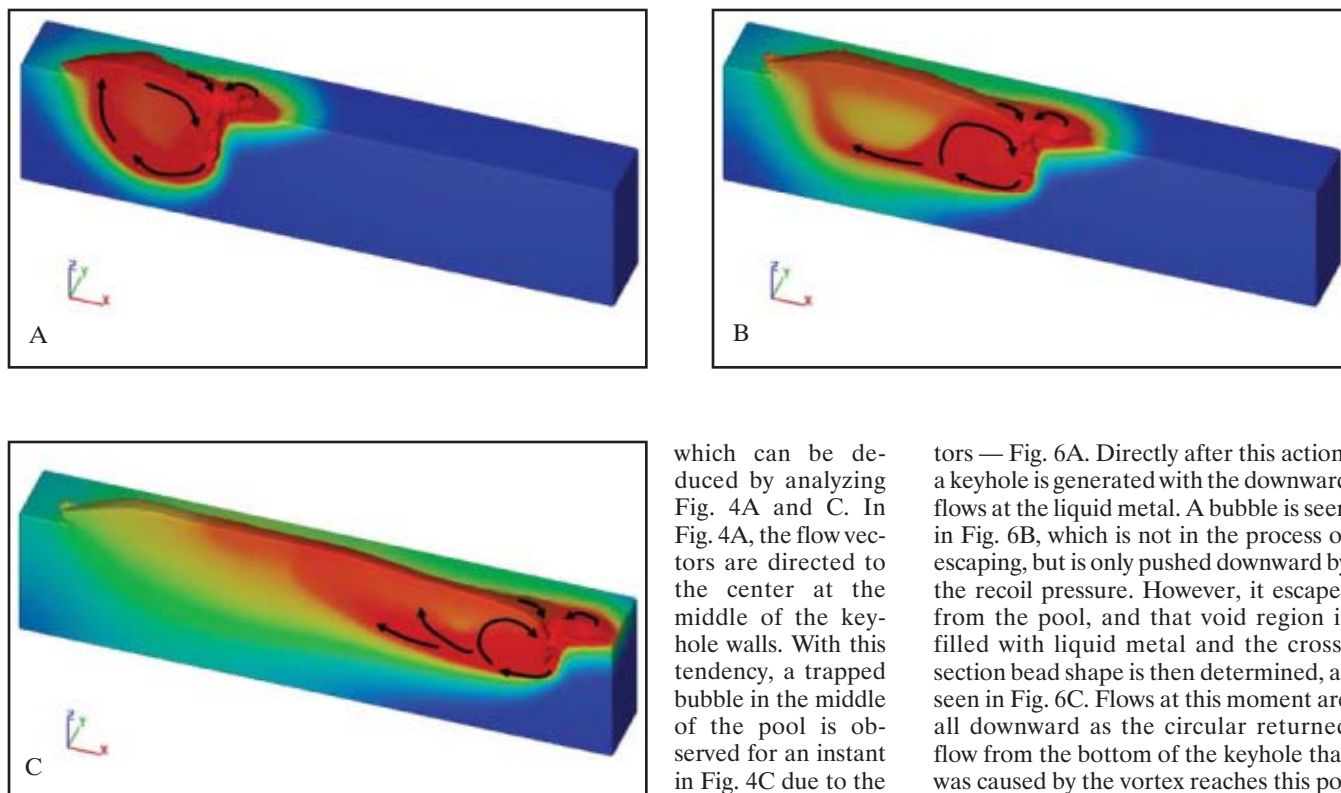


Fig. 8 — Flow patterns of simulation result in 3-D perspective views. A —  $t=0.53$  s; B —  $t=1.0$  s; C —  $t=1.96$  s.

shorter than 10 ms; therefore, the free surface of the keyhole is not observed during every time step.

Nonetheless, the generation of the keyhole was fortuitously captured at 0.53 s, as seen in Fig. 4. These figures show the flow patterns of the molten pool. Figure 4A shows the moment of keyhole generation. There is a small amount of liquid metal in the front keyhole wall and the free surface of the keyhole is slightly inclined, as was shown in a previous report (Refs. 27, 29), as the laser is a moving heat source. Near the bottom of the keyhole, flow is downward due to the repulsive force caused by the recoil pressure. The molten flow reached the bottom at the solid/liquid boundary and is directed backward and is finally lifted up owing to the buoyancy. This circular pattern causes a vortex, as seen in the figures. The vortex serves to stir the pool to form an alloy. There is only one circular vortex at the beginning of the process as seen in Fig. 4A; however, while the heat sources are marching forward, the flow pattern becomes more complex as the root flow at the bottom is split into two main streams as shown in Fig. 4B. It ultimately branches out to three streams, as seen in Fig. 4C, but the circular vortex at the beginning is maintained and continues to move forward. The collapse of the keyhole begins from the middle of the walls,

which can be deduced by analyzing Fig. 4A and C. In Fig. 4A, the flow vectors are directed to the center at the middle of the keyhole walls. With this tendency, a trapped bubble in the middle of the pool is observed for an instant in Fig. 4C due to the collapse of the keyhole.

Figure 5 shows a series of cross-sectioned front views. The sectioned plane is located at the position  $x=1.43$ , which is in the transverse middle range of the workpiece. This location was chosen to observe the entire welding process from melting to resolidification. As seen in the figures, the workpiece is melted by the pure arc first and the droplets are then added to the pool and cause the penetration to become somewhat deeper. Directly after the droplets transfer, the front keyhole walls begin to appear. In this section, it is observable that the penetration gradually deepens in the figures from 5D to 5F, which coincides with the fact the keyhole is slightly inclined, as mentioned in the previous paragraph. Trapped bubbles are also seen in the figures due to the collapse. After the simulation, there are no pores in the weldment, which can be expected owing to the trapped bubbles in the pool. It was believed that all of the bubbles escaped through the keyhole because the welding speed was not rapid enough to leave a bubble behind the keyhole. In Fig. 5G, all of the void regions are filled with liquid metal and the weld pool begins to solidify with upper streams, which finally form the top bead shape, as shown in Fig. 5H.

Flows in the front section are displayed in Fig. 6. A droplet is falling into the dimpled shape of the pool caused by the arc pressure with downward flow vec-

tors — Fig. 6A. Directly after this action, a keyhole is generated with the downward flows at the liquid metal. A bubble is seen in Fig. 6B, which is not in the process of escaping, but is only pushed downward by the recoil pressure. However, it escapes from the pool, and that void region is filled with liquid metal and the cross-section bead shape is then determined, as seen in Fig. 6C. Flows at this moment are all downward as the circular returned flow from the bottom of the keyhole that was caused by the vortex reaches this position and forms the pool. All of the flows gradually disappear from the bottom due to the solidification, and finally the remaining flows that are pushed up shape the top bead, as in Fig. 6D.

Complexities of the flow patterns are shown in the cross-section top views — Fig. 7. The position of the section plane was selected as  $z=0.47$  mm, which is only 3 mm below the top surface of the workpiece in order to observe both the keyhole and the arc dimple simultaneously. As shown in the figures, the keyhole and the arc dimple are continuously repeating the merge and separation action. It is important to note that when they are separated, flows around the arc dimple move toward the keyhole opening. However, the flows near the arc are outward and became more complex when they were merged. In the case of the separation, flow patterns toward the keyhole finally create a single hole and the outward patterns of the merged hole tend to separate the keyhole and the arc dimple. Due to this mechanism of flow patterns, the keyhole and arc dimple are repeatedly merged and separated. It can be derived that this phenomenon is repeated every 30 ms by analyzing the figures.

Figure 8 shows the three-dimensional flow patterns concluded from all of the procedures mentioned previously. Essentially, the pool has complex flow patterns. However, it is worth noting that the drawn mainstreams dominate the bead-shaping procedure. As seen here, the flows became more complicated while in the process of moving forward. The flow from the keyhole root is split into three

main streams as seen in the figure. However, one vortex induced by the keyhole phenomenon is maintained in spite of the complex circumstances.

## Conclusions

A simulation model for the analysis of the molten pool in the laser-arc hybrid welding process is proposed and an analysis is achieved using the Flow-3D commercial package. The model consists of the three major governing equations of the continuity, momentum, and energy equations. Additionally, the VOF method is adopted to realize the tracking of the free surface of the pool. Physical phenomena of arc welding in the molten pool, such as the electromagnetic force, surface tension, and arc pressure are applied as the boundary conditions or the body force of the fluid. To obtain the keyhole dynamics via laser welding, the effect of multiple reflections in the keyhole is realized with a ray-tracing technique, which is suitable for the discrete grid cell system in the FVM and the VOF methods. In addition, the Fresnel reflection model is employed as an energy absorption mechanism for the laser beam on metal surfaces. The simulation results can be summarized as follows.

- 1) Due to the flow of the keyhole bottom, a vortex exists that mainly influences the shaping of the top bead.
- 2) Trapped bubbles are observed in the pool because keyhole collapse begins from the middle height of its depth.
- 3) The welding speed is not fast enough to leave the bubbles behind the keyhole; therefore, it is inferred that the trapped air escapes through the keyhole.
- 4) The keyhole and the arc dimple are continuously repeating the merge and separation process every 30 ms in a lateral cross-section at a height of 0.47 mm. However, these parameters are dependent on welding conditions, therefore will not remain the same for other conditions.
- 5) The width of the bead is determined mainly by the GMA heat source and the penetration depth is strongly influenced by the laser.

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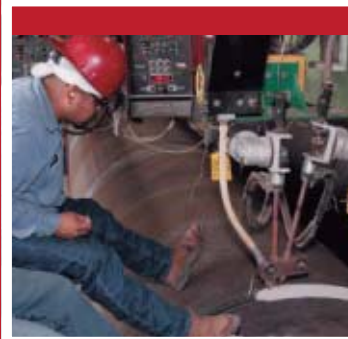
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