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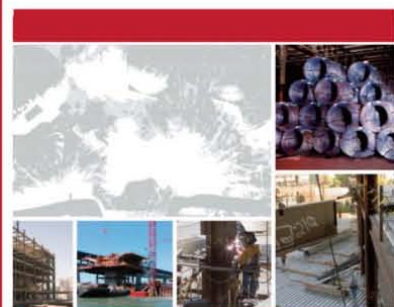
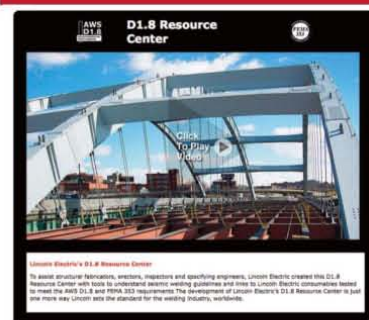
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WELDING *Journal*

January 2009



• **Tips for Good Gas Metal Arc Welds**

- **Welding Technology Abounds at the 2008 Exposition**
- **Improved Boiler Tube Cladding with GMAW-P**

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On the cover: During gas metal arc welding, the gun and consumables are exposed to continual mechanical and heat stress; therefore, proper gun maintenance and troubleshooting are essential to maintaining productivity and avoiding unnecessary downtime. (Photo courtesy of Bernard, Beecher; Ill.)

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Welding Journal (ISSN 0043-2296) is published monthly by the American Welding Society for \$120.00 per year in the United States and possessions, \$160 per year in foreign countries: \$7.50 per single issue for domestic AWS members and \$10.00 per single issue for nonmembers and \$14.00 single issue for international. American Welding Society is located at 550 NW LeJeune Rd., Miami, FL 33126-5671; telephone (305) 443-9353. Periodicals postage paid in Miami, Fla., and additional mailing offices. **POSTMASTER:** Send address changes to *Welding Journal*, 550 NW LeJeune Rd., Miami, FL 33126-5671. **Canada Post:** Publications Mail Agreement #40612608 Canada Returns to be sent to Bleuchip International, P.O. Box 25542, London, ON N6C 6B2

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PRESS TIME

NEWS

NTSB Reaches Decision on I-35W Bridge Collapse

The National Transportation Safety Board (NTSB), Washington, D.C., recently determined the probable cause of the I-35W bridge's collapse in Minneapolis, Minn., was the inadequate load capacity, due to a design error by Sverdrup & Parcel and Associates, Inc., of the gusset plates at the U10 nodes. These failed under a combination of substantial increases in the weight of the bridge, which resulted from previous modifications, and the traffic and concentrated construction loads on the bridge on the day of the accident.

"We believe this thorough investigation should put to rest any speculation as to the root cause of this terrible accident and provide a roadmap for improvements to prevent future tragedies," said NTSB Acting Chairman Mark V. Rosenker. "We came to this conclusion only through exhaustive efforts to eliminate each potential area that might have caused or contributed to this accident."

On August 1, 2007, the eight-lane, 1907-ft-long I-35W highway bridge over the Mississippi River experienced a catastrophic failure in the main span of the deck truss. One thousand feet of the deck truss collapsed, with about 456 ft of the main span falling 108 ft into the 15-ft-deep river.

The failure of Sverdrup & Parcel's quality control procedures to ensure the appropriate main truss gusset plate calculations were performed for the I-35W bridge and inadequate design review by federal and state transportation officials contributed to this; so did the generally accepted practice among federal and state transportation officials of giving inadequate attention to gusset plates during inspections for conditions of distortion and excluding gusset plates in load rating analysis.

The NTSB, as a result of its investigation, made nine recommendations to the Federal Highway Administration and the American Association of State Highway and Transportation Officials dealing with improving bridge design review procedures, bridge inspection procedures, bridge inspection, training, and load rating evaluations.

Outlook Given for Metal Forming and Fabricating Industry

In a survey by management consulting firm Homburg & Partner, Cambridge, Mass., 201 U.S. companies in the metal forming and fabricating industry were asked to give a 2009/2010 outlook on market development and specify key success factors.

Innovation came in as the top key success factor for the next three years by more than 25% of the surveyed companies. Efficient automation is the imperative goal when dealing with production costs and process management, which considered together form the most important key factors for 30% of the participants. Also, nearly 15% of the surveyed companies see expanding into global markets as the key success factor.

In the United States, industry's growth is estimated as 7% in 2009 and 10% in 2010 and worldwide as 12% in 2009 and 15% in 2010. About one-third concur the U.S. financial crisis will not render into a cash flow problem, yet it is commonly agreed this has a negative effect on growth rates for the metal forming and fabricating market. The automotive producers crisis is seen as a threat, too, but management perceives it less critically.

The firm's in-depth discussions have shown top management of market leaders predominantly disagree with the highly positive growth rates of U.S. markets, however, and instead expect they will stay flat or perhaps increase slightly positive with up to 2% in 2009, depending on the regarded segment.

ESAB Receives Major Wind Energy Industry Order

ESAB Welding & Cutting Products has made its largest ever, single-customer order for welding and cutting equipment and consumables. Wind tower manufacturer Vestas Towers A/S, a part of Vestas Wind Systems A/S, placed the multimillion dollar purchase.

This complete equipment and consumables package will be supplied. In addition, the full order comprises automated cutting equipment manufactured by the company in Florence, S.C.; heavy automation welding equipment manufactured by it in Sweden; and positioning and handling equipment supplied by its newly acquired facility in Singapore. The column and boom equipment will include ESAB's latest telescopic technology. Also, the company is well positioned to supply the welding consumables once the wind tower factory comes into production.

During 2009, the full equipment package will be delivered and installed.

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EDITORIAL

Setting Goals and Making Them Happen

I'd like to extend my best wishes to all of you in this new year, the 90th year for AWS. I hope everyone had a wonderful holiday season and that 2009 will bring with it new opportunities for each of us.

At this time of year it is natural to set goals. We all have them, both personal and professional. For many of us, our personal goals begin with a set of New Year's resolutions. We all need to have our sights set on achieving a result for the year whether it be losing some weight, getting more exercise, buying a new car, or accomplishing some repairs around the house. The list can be quite long.

In addition, most of us also have professional goals, either those we set for ourselves or, most likely, goals that are requirements from our employer. Companies have goals set by their boards of directors, committees, and other management entities. The American Welding Society is similar to the rest of corporate America in that it too sets goals. Some are set by the Finance Committee, some by our Compensation Committee, and some are set by the Board of Directors. Goal setting is the thing that actually puts us on a course or direction to being successful.

During my address at the AWS Annual Meeting in Las Vegas this past October, I listed four major areas of growth for AWS: Welding Education, Career Expansion, Technology Support, and Membership Attraction.

Welding Education includes both individuals getting into the profession at some level through education and training, and improving the awareness and pride of our profession by those outside of it, such as government and educational entities.

Career Expansion means growing in experience and knowledge or specializing one's training.

Technology Support occurs when the profession's infrastructure responds to the changes in the demand from the field applications. A lot of new designs and other developments occur when the old way of doing things or the processes and materials used will no longer do the job. Necessity has always been the catalyst for change.

Membership Attraction will occur when AWS is successful in the first three areas.

These four areas are generalized versions of goals that are part of the overall strategic plan for AWS.

During my talk at the Annual Meeting, I closed with a challenge to every person in attendance there and I now offer you all the same challenge: Bring one new person into the welding profession. I ask you to mentor, train, or counsel a neighbor, son or daughter, nephew or niece, a friend of a friend, or a kid who lives on your street. Help them to make a career goal that includes options within the welding profession. We need new people in every discipline related to welding: electrical engineers, mechanical engineers, metallurgists, welding engineers, computer programmers, welders, ironworkers, sheet-metal workers, boilermakers, pipeline welders. The list goes on and on. We need people to design and manufacture welding equipment and consumables as well as those who will use them. We also need people to set the standards and regulations used for the profession. From the earliest times, mankind has been building things. Welding lets us build bigger and better.

Goals are only an indication of what we want to accomplish; it takes a plan and hard work to make them happen. I am happy to report that our membership will hit the 55,000 mark very soon if it has not already by the time you receive this editorial. That is an indicator that we are succeeding in some of our goals. Together we can grow the infrastructure of AWS.

I plan to speak at many AWS Sections this year, and I know I'll get the opportunity to hear many success stories. Please share those stories with the entire AWS membership by sending in your monthly meeting reports to the *Welding Journal*.

In the meantime, I hope you all have a great year.



Victor Y. Matthews
AWS President



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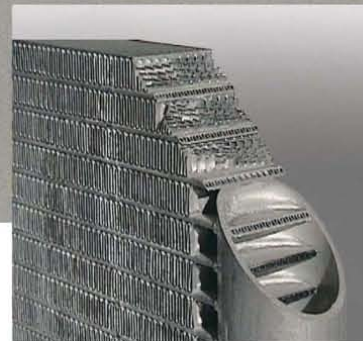
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NEWS OF THE INDUSTRY

DMI Industries Increases Production to Meet Wind Energy Demands



DMI Industries is increasing production capacity by 25% at its manufacturing facility in Fort Erie, Ontario, Canada. This will meet the need for wind towers in the northern tier of the United States and south-eastern and south-central regions of Canada.

Expansions include the addition of many new submerged arc welding stations to increase weld capacity, allowing for more than 20% greater flow of product through the facility, along with more beveling ability in plate processing. An extra fit-up line has added to the facility's capacity to build more tower sections on a week-by-week basis, and new material-handling equipment facilitates the move of more finished product.

According to Tony Claroni, Fort Erie general manager, the weld shop's increased capacity has prompted a need for more skilled workers throughout facility departments, resulting in the recent hiring of nearly 100 employees. The plant now employs more than 200 people.

To provide more towers, DMI Industries is upping production ability in Canada with several submerged arc stations for weld capacity and an additional fit-up line. The company's welders (one is shown at left) expertly manipulate tons of steel plate into towers that can be as much as 16 ft wide and more than 250 ft tall when erected. (Courtesy of DMI Industries.)

Exhibition Supporting the Welding Profession Goes Successfully



During the "Where Are the Welders?" event, many students (some of whom are pictured) learned details about gas tungsten arc welding, participated in demonstrations, and learned of career opportunities.

The first-ever "Where Are the Welders?" Instructional Forum and Career Fair attracted more than 40 high school students and parents at the Spencer High School Industrial Tech building in Spencer, Iowa, on Nov. 10. Career possibilities in industrial technology were shown during the three-hour event to students in Buena Vista, Clay, Dickinson, and Emmet counties.

"What a great way for area employers to connect with Corridor students who have a passion for welding as well as metal fabrication and machining," said Shaun Arneson, vice president, Iowa Lakes Corridor Development Corp. This agency hosted the forum and fair, part of its workforce initiative, that let welding instructors, employers, and local manufacturers share their insights on the welding and fabrication industries.

Involvement consisted of more than 12 area employers. Demonstrations included a wire weld demo by John Tatman, Maurer Manufacturing, and Chris McKay, Airgas North Central, as well as a robotic weld demo by Northwest Iowa Community College. In addition, Jeff Merryman of Employment Connections, Inc., spoke on the topic of "Job Seeking Skills"; Jamie Slipke of Rosenboom Machine & Tool, Inc., presented "Welding as a Career"; and Jeff Steiner of Polaris Industries, Inc., discussed and demonstrated "Welding Technologies and Automation."

The employers/instructors and students who attended provided an evaluation overall rating of 91% and 92%, respectively.

FABTECH International & AWS Welding Show Honored by Tradeshow Week



This award pays tribute to the FABTECH International & AWS Welding Show's square footage and exhibitor growth.

Tradeshow Week (TSW), the global exhibition industry news-magazine, recently named the FABTECH International & AWS Welding Show as a 2008 TSW *Fastest 50* winner. The fifty fastest-growing shows in North America, based on total net square footage growth and percentage of growth between 2005 and 2007, were honored. During this time, the FABTECH International & AWS Welding Show grew more than 37% from 336,795 net sq ft and 783 exhibitors to 461,627 net sq ft and 1007 exhibitors.

Friction Stir Welding Project Gets Support from the Department of Energy

Oak Ridge National Laboratory (ORNL) technologies to improve energy efficiency in industry, including flexible hybrid friction stir joining, have won funding from the Department of Energy's Industrial Technologies Program. These will bring \$7.5 million to ORNL and another \$3 million to industry partners.

Transforming friction stir welding (FSW) into a mainstream process is one of the projects. Researchers hope to develop new materials for FSW tools, hybrid friction stir welding with auxiliary heating to reduce forge load, and multipass multilayer technology for very thick sections. Ultimately, this will result in a field-deployable system providing flexibility and affordability for on-site construction. Initial applications will be for large oil and gas pipelines. Partners are as follows: Exxon Mobil Corp., ESAB Group, MegaStir Technologies, and Edison Welding Institute.

Edison Welding Institute and Technical Toolboxes Provide Training Together

The Edison Welding Institute (EWI), Columbus, Ohio, and Technical Toolboxes Inc. have executed a joint agreement to advance training and education within the energy and chemical industries. The organizations will immediately begin offering organized training. Continuing education units will be offered by the programs, allowing attendees to obtain partial college credit for the courses while learning skills and technology crucial to



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For a broader audience in the energy and chemical industries, EWI and Technical Toolboxes are offering training. Shown is mechanized gas metal arc welding with a welding operator at EWI. (© Edison Welding Institute. Photograph courtesy of Edison Welding Institute.)

their businesses. These courses and educational products will be offered at locations across North America and around the world, as well as on a customized basis at client facilities.

Eastern Wyoming College's Mobile Welding Lab Visits State Capitol



Governor Dave Freudenthal (center) jokes with Eastern Wyoming College welding program director Leland Vetter (right) before officially cutting the ribbon for the school's mobile welding lab on Oct. 28 at the Wyoming State Capitol. On the left is EWC President Dr. Tom Armstrong. (Courtesy Office of Gov. Dave Freudenthal.)

A new mobile welding lab from Eastern Wyoming College (EWC) in Torrington recently visited Wyoming's State Capitol. Governor Dave Freudenthal and other state officials toured the unit, which is housed in a large tractor-trailer.

EWC President Dr. Tom Armstrong, welding program direc-

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tor Leland Vetter, board of trustees members Carl Rupp and George Nash, and college staff were also present at the event. The governor applauded the college for its move to work with industry and mesh its programs with the current demand for skilled labor in the state.

The lab allows students and professionals to be taught welding skills at the college and job sites across southeast Wyoming. It cost just more than \$200,000, and support came from one-time funding allocated to EWC through the state's funding formula.

"This mobile welding lab has been a dream of mine for 20 years," Vetter said. "It is my hope that it will provide a regional testing and training center for business and industry that will also provide some flexibility with offerings and instructors."

Summer Street Capital Partners Obtains Tulsa Welding School



At Tulsa Welding School, recently bought by Summer Street Capital Partners, programs for structural welder, master welder, and welding technology are offered. Shown is a student performing oxy-acetylene cutting.

Private equity fund manager Summer Street Capital Partners LLC, Buffalo, N.Y., has acquired Tulsa Welding School. As a large accredited private welding school with locations in Tulsa, Okla., and Jacksonville, Fla., students are trained for welding and inspection careers in a range of specialties and applications. This transaction is also the firm's first investment in the for-profit postsecondary career school industry.

Summer Street will use its capital to add an additional 80 welding machines to the Tulsa and Jacksonville campuses. The current size of both properties will also be increased, in particular adding approximately 7000 sq ft to the Tulsa facility.

Larry Brown and Dawn Bravo, Summer Street's Postsecondary Career School Investment Team members, will join Tulsa Welding School as chief executive officer and chief marketing officer, respectively.

— continued on page 89



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Areas covered at IBSC

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

- | | |
|--------------------------------------|--|
| • Aircraft and Aerospace | • Furnace/Vacuum Brazing |
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Registration includes: Evening Reception on Monday, April 27, 2009 &
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Photo: Marty Alan McGill

Exhibit Dates and Times
Monday, April 27
 Noon – 6:00 PM
 Lunch: Noon – 1:00 PM
 Networking Reception: 6:00 PM – 7:00 PM

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

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



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Photo:
Marty Alan McGill

INTERNATIONAL

UPDATE

Valmet Automotive and Fisker Automotive to Build Hybrid Sports Car in Finland

Valmet Automotive, Helsinki, Finland, and Fisker Automotive Inc., Irvine, Calif., recently signed a contract calling for the manufacture of Fisker Karma vehicles in Finland. Valmet will be the engineering and manufacturing supplier for Fisker Automotive, and will build a new body welding line at its facilities to manufacture the new four-door, plug-in, hybrid sports sedan.

Production is set to begin in the fourth quarter of this year. The first cars will be delivered to North America; deliveries to Europe are planned to start in 2010.

"The agreement is very significant for us and our employment situation in the years to come," said Ilpo Korhonen, Valmet Automotive president. "With the planned full production volume, the cooperation with Fisker Automotive will employ some 500 blue collar workers at Valmet Automotive."

Valmet Automotive is a provider of automotive engineering and manufacturing services of premium cars. In nearly 40 years, it has produced more than 1 million vehicles and currently manufactures Porsche Boxster and Porsche Cayman for Porsche AG. Fisker Automotive is a privately owned car company, which was founded in 2007 as a joint venture of Fisker Coachbuild, LLC, and Quantum Fuel Systems Technologies Worldwide, Inc.

Tank Container Manufacturer Wins Southern Africa's Highest Welding Award

The Southern African Institute of Welding (SAIW) recently gave its highest award, the Gold Medal, to GRW Engineering from Worcester in the Western Cape. GRW, which was founded in 1996, today employs more than 500 people and manufactures road and intermodal tank containers. Founded by Gerrie Van der Merwe, his two sons, Gerhard and Wentzel, later joined the company along with Roussouw van Eeden.

"In a little more than a decade this family and friend have built up a successful company, using the best modern production

processes including a computerized materials-handling system, and laser cutting and robotic MIG/MAG automated plasma TIG welding processes," said SAIW Executive Director Jim Guild.

The gold medal is awarded in recognition of outstanding contributions to welding technology or to the SAIW.

TMK Starts Large-Diameter Longitudinal Pipe Production

TMK, Russia's largest manufacturer and exporter of pipes, recently began producing large-diameter longitudinal welded pipes at the Volzhsky Pipe Plant. Successful commissioning of a new 650,000-ton mill doubles Volzhsky's large-diameter capacity to 1.2 million tons of pipes per year.

Switzerland's HAEULSER AG manufactured the new mill, the first of its kind in Russia. It can produce longitudinal welded pipes of up to X100 grade with diameters ranging from 530 to 1420 mm and wall thicknesses up to 42 mm. Large-diameter pipes are used in long-distance oil and gas pipelines, including offshore pipelines, oilfield pipelines, general-purpose pipelines, and in the construction of heating systems and nuclear power stations.

New Trades Facility Opens at Canada's New Brunswick Community College

A new \$3 million trades facility recently opened at the St. Andrews, Canada, campus of New Brunswick Community College that will accommodate 60 students studying in the welding, electrical, and aquaculture programs.

Welding student John McNay was given the honor of cutting the ribbon to open the facility. The 1140-m² (12,270-sq-ft) building includes classrooms, labs, shop and mechanical space, a geothermal heating system, and rooms for faculty. It replaces a 30-year-old structure that most of which will soon be torn down.

Postsecondary Education, Training and Labor Minister Ed Doherty said to maintain a high quality of program delivery and training, it is important to modernize facilities and make the learning experience better and help attract more students to New Brunswick programs.

To address labor supply shortages, Doherty said, the province is increasing apprenticeship program capacity to 6200 from 3630 by 2012-13.



Gerhard Van der Merwe (right) accepts the SAIW gold medal on behalf of GRW Engineering (Pty) Ltd. in recognition of building a world-class tanker business using the application of modern welding and cutting technology from Prof. A. Koursaris, SAIW chairman. (Photo courtesy of the Southern African Institute of Welding (SAIW).)

An Important Event on Its Way?

Send information on upcoming events to the Welding Journal Dept., 550 NW LeJeune Rd., Miami, FL 33126. Items can also be sent via FAX to (305) 443-7404 or by e-mail to woodward@aws.org.

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**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



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.

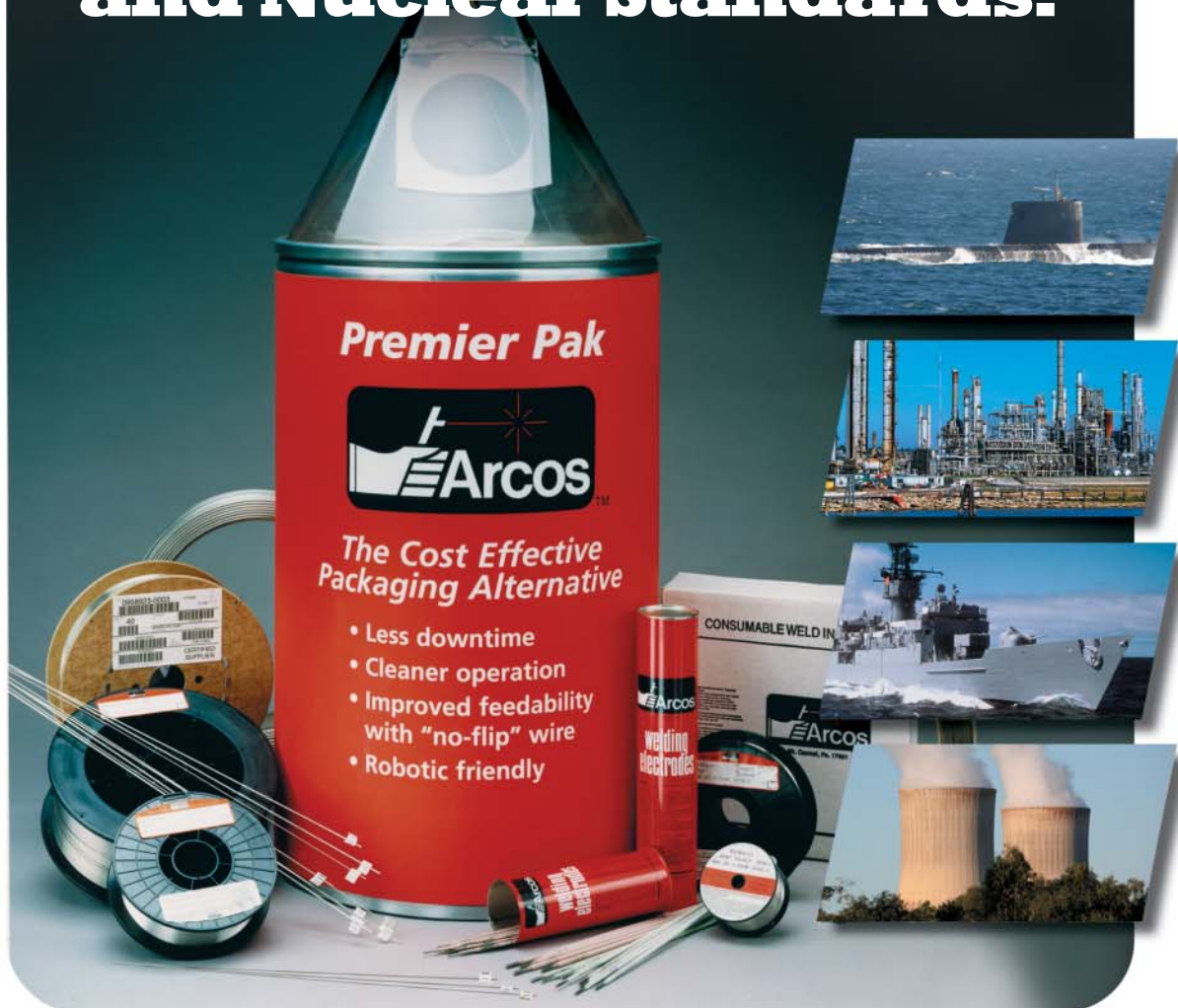
Return completed Fellow nomination package to:

Wendy S. Reeve
American Welding Society
Senior Manager
Award Programs and Administrative Support
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STAINLESS

Q&A

Q: We are trying to qualify a procedure for welding CA15 castings with E410-16 electrodes. The welds are required to be below 22 Rockwell C (R_C) hardness and pass a side bend test. We have no trouble with the hardness requirement after 1150° to 1200°F (620° to 650°C) postweld heat treatment (PWHT), but we have been failing bends. The bends break in the weld metal, but we can see no evidence of defects — no cracks or incomplete fusion. The weld metal just doesn't seem to be very ductile. How can this happen when the PWHT provides hardness below 22 R_C ?

A: CA15 is essentially the cast equivalent of 410, so that you have a matching filler metal. Table 1 lists the composition requirements for CA15 (Ref. 1) and E410-16 (Ref. 2). Note that neither the CA15 nor the E410-16 has a minimum carbon requirement, only a maximum. I expect that the root cause of your problem is in the lack of a minimum carbon content for the weld metal, as this is not the first time I've encountered this problem. To understand this, it is helpful to examine the Balmforth diagram — Fig. 1 (Ref. 3).

The Balmforth diagram makes predictions about the amount of ferrite and martensite in as-welded stainless steel welds as a function of composition. Fully martensitic compositions are on the left of the diagram, and fully ferritic compositions are on the right. In the center of the diagram is a wedge-shaped region where some ferrite and some martensite coexist in the weld, and Type 410 weld metals tend to fall in this region. Within this wedge-shaped region is a series of lines labeled with the predicted percent ferrite, increasing from left to right, and, more importantly, decreasing sharply from bottom to top.

It is important to appreciate that martensite is considerably harder and stronger than ferrite, and that in weld metal, the microstructure tends to be columnar. This means that when ferrite and martensite coexist, these two phases tend to be oriented in parallel columns roughly perpendicular to the weld surface. Then when a strain is applied to the weld metal, as in bending, the strain tends to concentrate in the ferrite, while the martensite does not yield. If the weld metal is almost all ferrite, this doesn't matter much, from the point of view of passing a bend test. Likewise, if the weld metal is almost entirely martensite, it doesn't matter much because the ferrite tends to not be continuous and the martensite must eventually yield. But if there is more

BY DAMIAN J. KOTECKI

than about 10% ferrite in a mostly martensitic weld, then the ferrite tends to be continuous and strain concentration in the ferrite results in low ductility and failure in a bend test.

Examining Fig. 1, it can be noted that any roughly 12% Cr composition of E410-16 will lie pretty much along the vertical line extending upward from the horizontal axis ("chromium equivalent") at the value "12." Along this line, a variety of microstructures can exist, realistically including more than 50% ferrite to less than 10% ferrite. It is the upper part of the line where compositions of less than 10% ferrite exist, and these are compositions that will provide the ductility necessary to pass the bend test. The vertical axis ("nickel equivalent") indicates a very strong effect of carbon content. As the carbon content increases, the ferrite content decreases. With a multiplier of 35 for carbon indicated in the nickel equivalent, a small change in carbon content has a rather large effect on ferrite content. An increase of 0.04% C would increase the nickel equivalent by 1.4%, and thereby could reduce the ferrite content, for example, from about 25% to less than 10%, all other composition variables remaining unchanged.

I expect that the filler metal you have been using has on the order of 0.05% carbon, which is what I have encountered previously. I strongly suggest that you obtain filler metal with at least 0.08% carbon. That should provide enough martensite as-welded so that there will not be continuous ferrite networks. You may then find that you will have to increase your PWHT temperature to 1250°F (675°C), or even higher, in order to reduce the weld hardness to below 22 R_C .

You might wonder why the lack of a minimum carbon content does not interfere with all-weld-metal ductility in the AWS classification test for E410-16. The AWS A5.4 classification test requires at least 20% elongation, which should pass a bend test, but the PWHT is different. The PWHT for classification is done at 1350° to 1400°F (730° to 760°C). At this higher temperature, the martensite becomes very soft and its properties are little different from those of the ferrite. But that does not

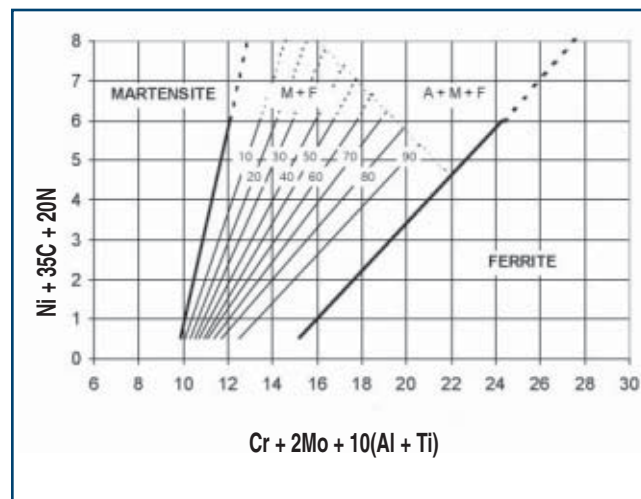


Fig. 1 — The Balmforth diagram (Ref. 3).

happen under your 1150° to 1200°F PWHT.

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

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RWMA

Q&A

Q: Which type of transformer is better for the resistance spot welding of sheet metal, alternating current (AC) or mid-frequency direct current (MFDC)? I am mostly concerned with automotive sheet metal applications but would welcome any thoughts on this subject.

A: The decision to utilize either a MFDC power supply or AC transformer for resistance spot welding is as much a processing question as it is a welding question. To help illustrate this, the following discussion of which power supply may be better for a particular application can be broken down into several parts, including processing, facilities, and welding. I also think it is important to have some historical perspective on this topic for it actually has a part in answering the question. Finally, this topic has historically generated more than a little debate within the resistance welding community so do not expect everyone to agree with this answer.

The MFDC technology was originally developed for automotive resistance spot welding in the late 1970s as a joint effort by Square D and Goodrich. Square D focused on the weld control while Goodrich concentrated on the MFDC power supply. At that point in time, General Motors was a major customer of Square D and was heavily involved in the development process of this new technology. The major motivating factor in the technology development was a reduction in the weight of the transformer. That period in time within the automotive body construction arena witnessed the migration away from traditional manually operated handguns toward robot-mounted weld guns, particularly integrated resistance welding guns called transguns. As the robots of the day were rather limited in their capacity (figure about 60 kg for that time period), the only way to incorporate a larger weld gun design was to reduce the weight of other welding system components, specifically the transformer. A secondary motivation was that MFDC permitted weld guns with large secondary loop areas to achieve higher secondary currents, in some cases in excess of 20 kA. This level of secondary current was difficult to achieve even with the utilization of hip-mounted AC transformers.

When the new MFDC power supplies were released to the plants there was little, if any, discussion concerning the benefits of lower primary power demand, nor was there any mention of the effect MFDC had on material weldability. There are most likely two reasons for this. The

BY D. F. MAATZ JR.



Examples of both an MFDC power supply (blue) and an AC transformer (green). The MFDC unit is rated at 170 kVA while the AC is rated at 65 kVA. The weight and external dimensions are similar; however, the potential electrical outputs are very different. The MFDC unit has an approximate current range of 5–45 kA (capable of welding aluminum) but the AC transformer would struggle to achieve a secondary current greater than 20 kA, mostly due to impedance limitations.

first is that the majority of body shops back then were electrically oversized with regard to primary power. Why? They were equipped to handle portable gun transformers. The primary electrical demand for portable gun transformers is huge (potentially ten times that of MFDC), and since these electrical systems were already in place, a capital cost reduction was not possible unless a “greenfield” facility was being launched. As a result, there was very little cost savings attached to the actual power system equipment side. The second reason had to do with the fact that the MFDC technology was in its infancy and the facilities engineer was not going to risk downsizing a plant power system on this new technology. The same thinking applied to the welding engineer with respect to weld quality and process robustness. Since the initial goal was mass reduction and increased secondary weld current capability, folks were not looking for, nor expecting, an improvement in material weldability.

The selection of AC vs. MFDC with regard to facilities and tooling is based on its own unique acceptance criteria. As with all choices, it is not entirely a black and white issue and some knowledge of the potential compromises and pitfalls is essential to achieve an accurate decision. From a facility perspective, the use of MFDC represents a major change in thinking as compared to AC. The following points should help illustrate the differences, and highlight both possible advantages and disadvantages for each type of power supply.

- MFDC permits equal three-phase current distribution and thus a more bal-

anced primary loading condition. An AC welding system only taps into two of the three primary bus legs and requires a fair amount of facility planning to ensure that each leg on the bus is subjected to relatively the same load. Also, because the single-phase loads are not synchronized, balancing the load on a three-phase distribution is nearly impossible.

- The selection of MFDC for a large volume installation, such as a new bodyshop, can result in reduced overall primary demand. This lower primary demand can translate into savings due to the lower costs associated with primary power distribution equipment (smaller circuit breakers, wire, etc.). But since switching from AC to MFDC requires changing from single-phase breakers and two-wire systems to three-phase breakers and three-wire systems, the true electrical facility cost may be negated. Another important consideration is that the typical AC installation requires primary cable rated at 600 V while an MFDC system generally needs higher rated primary cable between the weld control and the power supply.
- MFDC power supplies possess a broader current range than do their AC counterparts, so fewer transformer models are required to cover the full welding current spectrum. With MFDC it is possible to equip an entire body shop with two sizes of power supplies while it might take as many as ten different AC transformer models to cover the same current range.
- Within the world of general automotive

applications (up to ~25 kA) the cost of AC transgun transformers vary in price from \$800 to \$1500 while the equivalent MFDC units run from \$2000 to \$3500, depending on features. The same disparity can be seen in the weld controls required for each power supply with the MFDC suffering an approximate 20% cost penalty. A cautionary note on costs: This is one area where the application and volume can have a huge impact. Prices for the MFDC equipment used to be in excess of 2:1 over the comparable AC device, but that gap has narrowed considerably due to the economies of scale. That being said, the inherent complexity of a MFDC resistance welding power supply or weld control will most likely keep it more expensive than its AC equivalent for the immediate future.

- MFDC power supply water cooling requirements are significantly higher when compared to an equivalent AC unit, with the typical flow rate requirements twice those required of AC. The sophisticated internal water paths also dictate a higher differential pressure, and the physical conditioning (i.e., mechanical filtration, etc.) of the water must be better to prevent sediment buildup due to the tortuous water flow path. Conversely, the AC transformer is much more durable and less prone to failure with respect to water issues.
- The MFDC power supply has a much shorter life expectancy than its AC counterpart. This is due to the characteristics of a diode when it is thermally cycled and the resultant movement between the wafers in the rectifier packs. In essence the 'moving parts' of the MFDC power supply wear out. The typical life span averages 10–12 million thermal cycles, but can be higher. Additionally, the MFDC power supply is more susceptible to failure due to low water flow rates or excessive kVA demand. While these same afflictions are harmful to an AC transformer, the magnitude of the degradation is much less.
- The higher operating frequency of the MFDC power supply permits for a more controllable situation for the weld control, and results in the delivery of a more accurate weld schedule. MFDC is also less susceptible to the primary power oscillations in plants due to the output being derived from three-phase power rather than on a single-phase.

The selection of AC vs. MFDC with regard to weld quality is also based on differences between the two types of power delivery systems. However, unlike the items mentioned in the facilities discussion above, the effect of these differences on welding is not always clear. The subtle

nature of the differences between AC and MFDC and their possible effects on weld quality and process robustness really forces each application to be evaluated on its own merits.

There have been multiple peer reviewed papers published in many forums regarding the different welding characteristics of AC vs. MFDC, and the results are not always conclusive or consistent in determining which process is capable of producing better weld quality. These studies, which included advanced high-strength steels (AHSS), looked at many aspects of the two welding processes and ranged in scope from the physical properties of the weld to the effect of weld current conduction angle and its direct effect on the inherent inter-cycle cooling associated with AC power vs. the lack of inter-cycle cooling with MFDC. One auto company performed an in-house study to determine whether the polarity effects of MFDC current were significant. The responses studied included weld range comparisons, electrode life evaluations, and static and dynamic mechanical studies of weld strength. Despite all this hard work and analysis, an all-inclusive answer still has not been found. Put another way, while a particular application or specific material may benefit from utilizing either AC or MFDC, the results to date do not permit anyone to make broad statements with regard to material weldability such as "all galvanized materials weld better with AC" or that "all stack-up ratios in excess of 4:1 weld better with MFDC."

At the end of the day, there are not many automotive resistance spot welds that cannot be made with either AC or MFDC, and the selection of either of the two is going to be driven much more by facility and tooling considerations than welding. Bottom line, asking if AC or MFDC is better is like asking if a car is better than a truck. Without clarifying the criteria for a particular application the answer is really hard to determine.◆

DONALD F. MAATZ JR. is laboratory manager, RoMan Engineering Services. He is a member of the AWS Detroit Section Executive Committee, serves on the D8 and D8D Automotive Welding Committees, is vice chairman of the RWMA Technical Committee, and is a graduate of The Ohio State University with a BS in welding engineering. This article would not have been possible were it not for the assistance of Don DeCorte and other members of the RoMan team. Send your comments/questions to dmaatzt@romaneng.com, or to Don Maatz, c/o Welding Journal, 550 NW LeJeune Rd., Miami, FL 33126.



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WELDING JOURNAL 23

LETTERS TO THE EDITOR

San Jacinto College's Welding Program Praised

This letter is in reference to Howard Woodward's article, 'Inspired Welding Instructors and Great Facilities Make the Difference at San Jacinto College,' published in the November 2008 Welding Journal, pages 83-85.

I was pleased to see the article in the November issue of *Welding Journal* about the welding program at San Jacinto College. Since graduating from there in 2003, I've often felt that the San Jacinto program deserved publicity beyond the southeast corner of Harris County, Tex., where the school is located. I've also felt that Tiburcio Parras, who was mentioned in the article, deserves particular recognition. Among the several good welding instructors I had at San Jacinto, none was better than "Tivo" Parras.

I was not a typical San Jacinto student. Unlike most of my classmates who were looking for skills to start a career, I was already pretty well set. I was a professional engineer with two degrees in mechanical engineering from Rice University. After earning those degrees in the 1970s, I had gone to work for an oilfield equipment manufacturer. Ten years later, I moved to NASA's scientific balloon facility in Palestine, Tex., where I had the good fortune to work with two skilled welders. In working with those guys for several years, I came to realize that the hands-on work they did on the weldments I designed gave them an investment in those structures that I couldn't fully share. When I returned to Houston for a job at Johnson Space Center, I enrolled in the evening program at San Jacinto College, determined to learn what a welder knows. While I'm sure I was not the first engineer from the nearby petrochemical and space industries to enroll in the San Jacinto program, as far as I know I was the only one enrolled in the program during the four years I was there.

I met Tivo Parras halfway through my time at San Jacinto. When I first showed up in his GTAW class, I think Tivo was a little dubious, because, frankly, I was slow to learn the two-handed skill. Still, Tivo readily accepted me as another student on the roll, since he was a one-man recruiting machine for the welding program with a gift for bringing in and keeping students. By my second semester with him, Tivo had me pegged. He said he worried about me sometimes when he didn't see any arc light coming from my booth, because he knew

I was in there thinking about welding, instead of just welding. Nevertheless, Tivo let me continue to think and weld, because he understood that I learned by thinking, as well as by doing. He eventually gave me a simple but significant compliment when he told me, in my third semester with him, that he thought I could actually get a job as a welder.

Tivo and the other instructors at San Jacinto were excellent at teaching me "how" to weld. They offered less instruction on "why" welding processes work the way they do, so I pursued those questions on my own. I joined AWS while at San Jacinto, and I bought several books from AWS and Lincoln Electric and studied them to supplement what I was learning in class. About a year after I finished the San Jacinto program, I took Ohio's principles and practice exam in welding engineering as an objective way to gauge what I knew about the science of welding. Passing that test earned me the Certified Welding Engineer credential from AWS. I then prepared for and passed the Certified Welding Inspector exam with the help of a one-semester prep course at San Jacinto. That effort gave me yet another perspective on welding and provided me with a more common and better understood AWS credential of welding knowledge.

Training at San Jacinto opened a window onto welding for me at a time in my career when I was best positioned to enjoy the benefits. Though I had seen welding briefly in an industrial process lab course when I was an undergrad at Rice, I didn't get much out of that early exposure. It was just one of many subjects to be learned then, presented without much context to suggest how valuable an understanding of welding might be someday. In that, I think my experience was typical, and it may explain a lot about the "house divided" that I see in the welding industry today.

In learning to weld and, even more so, in training to become a CWI, I was disappointed by the level of suspicion and contempt toward engineers I found in some circles in the world of welding. I won't say anything more here to add fuel to that fire, which is always ready to flare up, but which usually generates more heat than light. Instead, I will suggest that I think there is a need (and an opportunity) for AWS to do a better job of disseminating practical welding knowledge to engineers. I think there might be two avenues for this. One would be a more direct outreach effort by AWS to mechanical and civil engineering undergraduate students. Another avenue might be a cooperative effort between AWS and community colleges to establish

some type of short, "finishing school" curriculum aimed at degreed engineers who have been out of school and in the workplace long enough to recognize that there might be a hole in their education where welding is concerned.

Certainly, there are many well-trained welding engineers around the world doing excellent work every day to advance the art and science of welding. Likewise, others are serving industry by their tireless work on refining and applying the extensive and universally respected welding codes. Unfortunately, my experience tells me it's also true that in most small to medium sized companies the person most knowledgeable about welding — the de facto welding engineer in the enterprise — is that individual who knows how to turn on the welding machine and strike an arc. In that situation, welds on the company's products and equipment may be of adequate or even superior quality. Or they may not be. Who is to say for sure if welding requirements are not effectively described in the company's product and equipment documentation and if there is not some welding knowledge link between the shop floor and the front office?

Ed Fritsch,
AWS Houston Section
P.E., CWEng., CWI

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Examining the Mechanical Properties of High-Strength Steel Weld Metals

Tensile, Charpy impact toughness, and crack-tip opening displacement toughness of high-strength steel weld metals were characterized

BY JOSE E. RAMIREZ



Fig. 1 — General view of the welded joint.

The major impetus for developments in high-strength steels (HSS) has been provided by the need for higher strength, increased toughness, and improved weldability (Ref. 1). High-strength steels with yield strengths of 450 MPa (X70) and 550 MPa (X80) are increasingly specified for

use in different structural applications resulting in weight and cost savings through the use of thinner sections (Refs. 2, 3). Additional refinement of chemical composition and processing procedures have resulted in the development and testing of higher-strength steels, X100 and X120 (Refs. 4, 5). As a result, new developments

in welding processes and consumables to produce weld metal deposits with mechanical properties essentially equivalent to the base metal are continually needed. To achieve this, however, proper understanding of chemistry- and microstructure-property relationships in HSS weld metals is required.

Characterization of High-Strength Steel Weld Metal

High-strength steel weld metals were deposited using different welding processes and commercially available consumables. Welds were produced using flux-shielded processes such as flux cored arc welding (FCAW) and shielded metal arc welding (SMAW) and gas-shielded processes such as gas metal arc welding (GMAW). Flux cored arc welding included both self- (T-8 type) and gas-shielded electrodes. Cellulosic and basic electrodes were used with the SMAW process. The nominal strength of the welding consumables ranged from 490 to 840 MPa (70 to 120 ksi). Table 1 provides a summary of the consumables, welding processes, and weld identifications (W1 to W14) used in this study. Welding parameters are summarized in Table 2. Figure 1 shows a general view of a welded joint prepared for weld metal characterization.

The mechanical characterization of the HSS weld metals deposited included tensile properties, Charpy impact properties,

JOSE E. RAMIREZ (jramirez@ewi.org) is principal engineer, Edison Welding Institute, Columbus, Ohio.

Table 1 — Summary of Base Metals, Welding Processes, Welding Consumables, and Identifications of Different Weld Metals Characterized in this Program

Welded Joint	Base Metal	Welding Process	Welding Condition	Filler Metal	Procedure/Shielding Gas
W1	Plate, SA-36	FCAW	Semiautomatic	E71T-1 ^(a)	CO ₂
W2	Plate, SA-36	FCAW	Semiautomatic	E71T-1	CO ₂
W3	Unknown	GMAW	Semiautomatic	ER70S-7 ^(b)	CO ₂
W4	Unknown	GMAW	Semiautomatic	ER70S-6 ^(c)	CO ₂
W5	Pipe, X80	SMAW	Manual	E8010-G	NA
W6	Pipe, X80	SMAW	Manual	E9010-G	NA
W7	Pipe, X80	SMAW	Manual	E9018-G	NA
W8	Pipe, X80	FCAW-S	Semiautomatic	E91T8-G	NA
W9	Plate, X100	GMAW	Automatic	ER100S-1 ^(b)	Internal/external 100CO ₂
W10	Plate, X100	GMAW	Automatic	ER100S-1 ^(c)	Internal/external, pulsed, 85Ar-15CO ₂
W11	Plate, X100	GMAW	Automatic	ER100S-1 ^(c)	Internal/external, dual torch, pulsed, 85Ar-15CO ₂
W12	Plate, X100	GMAW	Automatic	ER100S-1 ^(b)	External, pulsed, 95 Ar-5CO ₂
W13	Plate, X100	GMAW	Automatic	ER120S-1	Internal-external 100CO ₂
W14	Plate, X100	GMAW	Automatic	ER120S-1	Internal/external, pulsed, 85Ar-15CO ₂

(a) Microalloyed; (b) and (c) represent different consumable manufacturers.

Table 2 — General Welding Conditions Used to Deposit Weld Metals W1 to W14

Welded Joint	Welding consumable		Preheat/Interpass Temperature, °C	Nominal Heat Input, kJ/mm
	Root Pass	Fill Pass		
W1	E71T-1 ^(a)	E71T-1 ^(a)	RT/150	1.8 to 2.0
W2	E71T-1	E71T-1	RT/150	1.8 to 2.0
W3	ER70S-7	ER70S-7	Unknown	Unknown
W4	ER70S-6	ER70S-6	Unknown	Unknown
W5	E8010-G	E8010-G	RT/120	1.3
W6	E9010-G	E9010-G	RT/120	1.5
W7	ER70S-6, STT ^(b)	E9018-G	RT/120	1.3
W8A ^(c)	ER70S-6, STT ^(b)	E91T8-G	RT/110	0.9
W8B ^(d)	ER70S-6, STT ^(b)	E91T8-G	RT/120	1.2
W8C ^(e)	ER70S-6, STT ^(b)	E91T8-G	RT/52	1.1
W8D ^(f)	ER70S-6, STT ^(b)	E91T8-G	RT/290	1.0
W9	ER100S-1	ER100S-1	50/150	0.76
W10	ER100S-1	ER100S-1	50/150	0.80
W11	ER100S-1	ER100S-1	50/150	0.9
W12	ER100S-1	ER100S-1	50/150	0.82
W13	ER120S-1	ER120S-1	50/150	0.77
W14	ER120S-1	ER120S-1	50/150	0.85

(a) Microalloyed; (b) Surface Tension Transfer®; (c) welder A; (d) welder B; (e) low interpass temperature (cold); (f) high interpass temperature (hot).

and fracture toughness using crack-tip opening displacement (CTOD). All-weld-metal tensile properties were measured by using round ASTM E8 tensile specimens. Full-size Charpy V-notch (CVN) specimens were machined transverse to the weld length and notched through-thickness in the weld metal. Weld metal CTOD tests were conducted at -10°C following proce-

dures given in ASTM E1290-93. The CTOD weld samples were machined B × 2B in size and transverse to the weld length with the notch oriented in the through-thickness direction at the weld centerline. One hundred sixty-six CTOD tests representing the 14 weld metals were conducted.

In order to assess the variability in weld metal properties, in some of the welds,

specimens for Charpy impact testing and CTOD testing were machined with the notch or crack off the weld centerline. Additionally, specimens from some pipe welds were obtained from different locations corresponding to the 12, 3, and 6 o'clock positions. The effect of the welder on mechanical properties was considered as well.

Table 3 — Selected Chemical and Nonmetallic Inclusion Characteristics of Deposited Weld Metals (Ref. 6)

Welded Joint	Carbon Equivalent CE _{IIW}	Pcm	Oxygen Content (ppm)	Average Inclusion Diameter (um)	Carbon Content (%)	Nitrogen Content (ppm)
W1	0.326	0.177	520	0.532	0.054	73
W2	0.257	0.131	—	0.517	0.021	—
W3	0.353	0.172	460	0.391	0.066	30
W4	0.319	0.157	460	0.320	0.056	80
W5	0.268	0.151	650	0.491	0.100	210
W6	0.310	0.220	500	0.354	0.154	110
W7	0.390	0.156	460	0.311	0.060	120
W8A	0.482	0.203	110	—	0.071	370
W8C	0.537	0.228	110	0.314	0.084	323
W8D	0.509	0.215	110	—	0.074	323
W9	0.496	0.204	560	0.401	0.068	70
W10	0.485	0.202	310	0.298	0.061	80
W11	0.471	0.197	360	0.326	0.068	140
W12	0.054	0.208	260	0.367	0.055	40
W13	0.651	0.289	450	—	0.110	60
W14	0.726	0.302	280	0.299	0.100	90

Table 4 — All-Weld-Metal Tensile Properties

Welded Joint	Filler Metal	Ultimate Tensile Strength (UTS)		0.2% Yield Strength		Elongation (%)	Reduction of Area (%)
		(MPa)	(ksi)	(MPa)	(ksi)		
W1	E71T-1-M	588	85	514	75	25.4	65.5
W2	E71T-1	518	75	443	64	28.8	76.3
W3	ER70S-7	703	102	644	93	27.0	70.0
W4	ER70S-6	699	101	634	92	28.0	66.0
W5	E8010-G	609	88	539	78	23.2	56.0
W6	E9010-G	655	95	569	82	24.2	60.9
W7	E9018-G	657	95	586	85	26.2	69.1
W8A	E91T8-G	734	106	683	99	16.6	38.9
W8C	E91T8-G	754	109	667	96	16.3	29.5
W8D	E91T8-G	740	107	609	88	23.2	56.0
W9	ER100S-1	794	115	752	109	13.0	71.0
W10	ER100S-1	814	118	752	109	12.0	43.0
W11	ER100S-1	768	111	719	104	15.0	75.0
W12	ER100S-1	792	115	768	111	18.0	52.0
W13	ER120S-1	NA	NA	NA	NA	NA	NA
W14	ER120S-1	1111	161	1028	149	3.0	22.0

Observed Characteristics of HSS Weld Metals

Alloying, Microstructure, and Tensile Properties Relationships. As discussed in a previous publication (Ref. 6), the chemical composition of the deposited HSS weld metals was based on a C-Mn system with additions of deoxidizers (silicon, manganese, aluminum, titanium) and additions of various alloying elements (nickel, chromium, molybdenum, boron, niobium, vanadium, and copper). The effect of alloying levels on the hardenability of the weld metal is reflected in the carbon equivalent number (CE_{IIW}). The CE_{IIW} carbon equivalent of weld metals deposited with E70X-E80X, E90X, and E100X-E120X grade consumables range from 0.25 to 0.35, 0.31 to 0.54, and 0.47 to

0.73, respectively, as listed in Table 3.

Additionally, as reported previously (Ref. 6), two major trends were observed in the change of microstructure of the deposited weld metals as the CE_{IIW} carbon equivalent increased. The fraction of low-temperature products increased and the microstructure became finer as the carbon equivalent increased. The weld metals with a carbon equivalent between 0.26 (W2) and 0.39 (W7) consisted mainly of a ferritic microstructure with a decreasing fraction of grain boundary ferrite and an increasing fraction of lower-temperature transformation products such as side-plate ferrite and acicular ferrite. In weld metals with a carbon equivalent of 0.47 or higher (W8 to W14), an increasing fraction of lower transformation products, including martensite, was present.

The tensile properties of Welds W1 through W14 are listed in Table 4. A yield strength as high as 1030 MPa (150 ksi) was obtained in the weld metal deposited with the E120X consumable and the pulsed gas metal arc welding (GMAW-P) process (W14). As shown in Fig. 2, the weld metal strength increases with an increase in the CE_{IIW} carbon-equivalent number. In the yield strength range between 65 and 150 ksi, a good correlation was observed between the strength of the weld metal and the CE_{IIW} carbon-equivalent number of the weld deposits.

These observations indicate that, although the carbon equivalents were originally developed with the view of evaluating the base metal cold cracking susceptibility, these general empirical equations can also be useful in understanding the

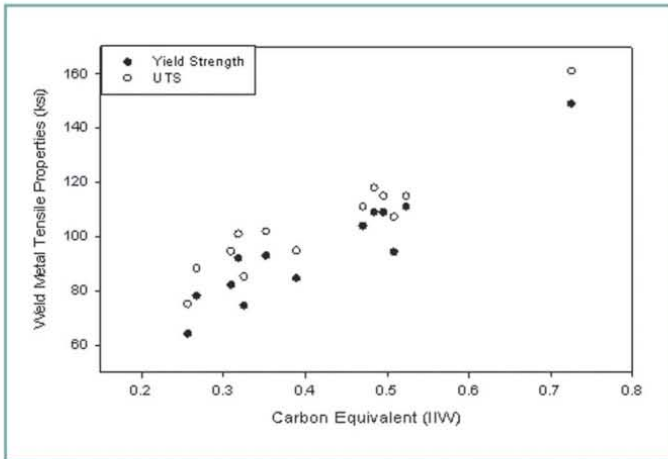


Fig. 2 — Weld metal yield and tensile strength as a function of the CE_{IIW} carbon equivalent number.

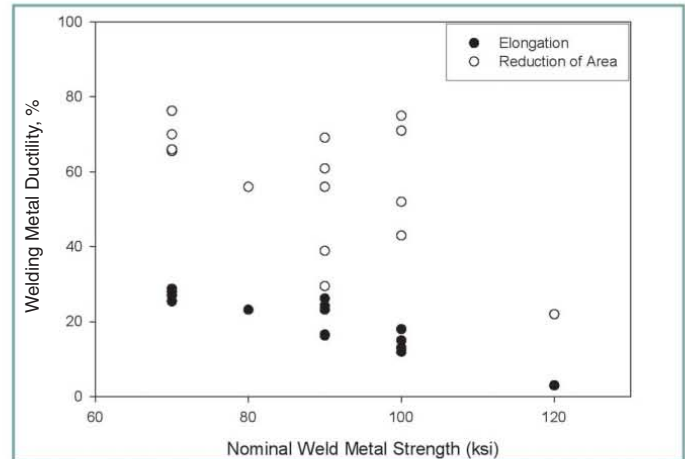


Fig. 3 — Ductility of the weld metal, percent elongation, and reduction in area as a function of the nominal strength of the consumables.

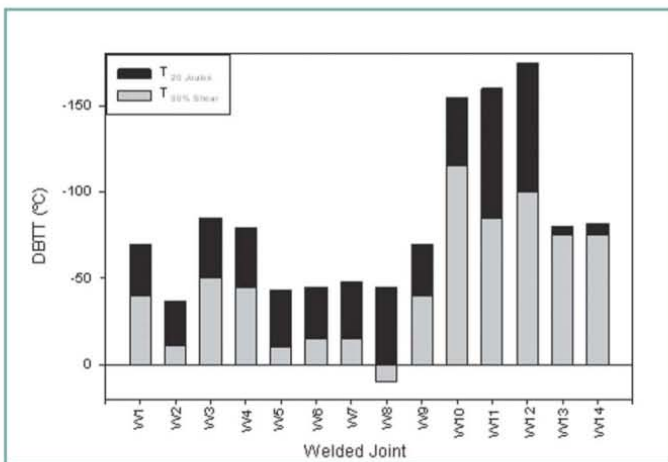


Fig. 4 — Ductile-to-brittle transition temperatures of the weld metals determined based on the 20 J and the 50% shear area criteria.

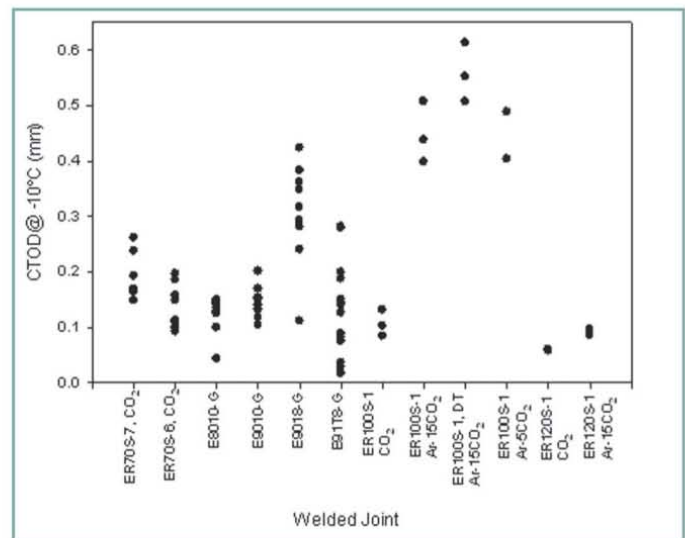


Fig. 5 — CTOD toughness of weld metals at -10°C .

complex relationship between the high-strength steel weld metal hardenability as controlled by the alloying content, the resulting microstructural transformation behavior of the weld deposit, and associated tensile properties.

Figure 3 shows the ductility of the weld metals in terms of elongation and reduction of area, as a function of the nominal strength of the welding consumable. As expected, the ductility of the weld metal decreases as the strength increases. Elongations as low as 13 and 3% were observed in weld metal deposited with E100X and E120X consumables, respectively. Therefore, the challenge in welding HSS is to provide high-strength weld metals with adequate ductility and toughness.

Impact Fracture Toughness. Weld metals W1 to W14 exhibit different impact Charpy behavior as described by the ductile-to-brittle transition curves. Figure 4 shows the ductile-to-brittle transition

temperatures (DBTT) of the deposited weld metals as determined by the 20 J and 50% shear area criteria. The DBTT 20 J of the deposited weld metals ranged from -35° to -170°C .

For practical reasons, it is important to indicate that taking into account the fracture behavior of the different deposited weld metals as described by the different shapes of the ductile-to-brittle transition curves, the use of different criteria such as absorbed energy at a specific temperature (Refs. 7, 8) may indicate different relative performances of the weld metals.

CTOD Fracture Toughness. The results of the CTOD testing at -10°C of the different weld metals are shown in Fig. 5. In general, the CTOD toughness of the weld metals at -10°C shows a lot of scattering. The CTOD of the tested welds at -10°C ranges from about 0.01 to 0.62 mm. Cracking tip opening displacement tough-

ness greater than 0.25 mm at -10°C is normally required for offshore structure applications. As observed in Fig. 5, most of the weld metal deposited did not meet this requirement. Therefore, as pointed out earlier, the greatest challenge in welding HSS is to provide high-strength weld metals with adequate ductility and toughness.

It was observed that weld metals with similar microstructures and yield strengths showed very different CTOD properties. For example, weld metal W7 showed a high maximum value of CTOD (0.45 mm) as compared to other welds with similar yield strength like weld metal W6, which showed a maximum value of CTOD equal to 0.2 mm. A similar but more pronounced difference was observed between the CTOD results of weld metal W9 and weld metals W10, W11, and W12. All these welds were made using the same welding wire type but different GMAW process modes and associated

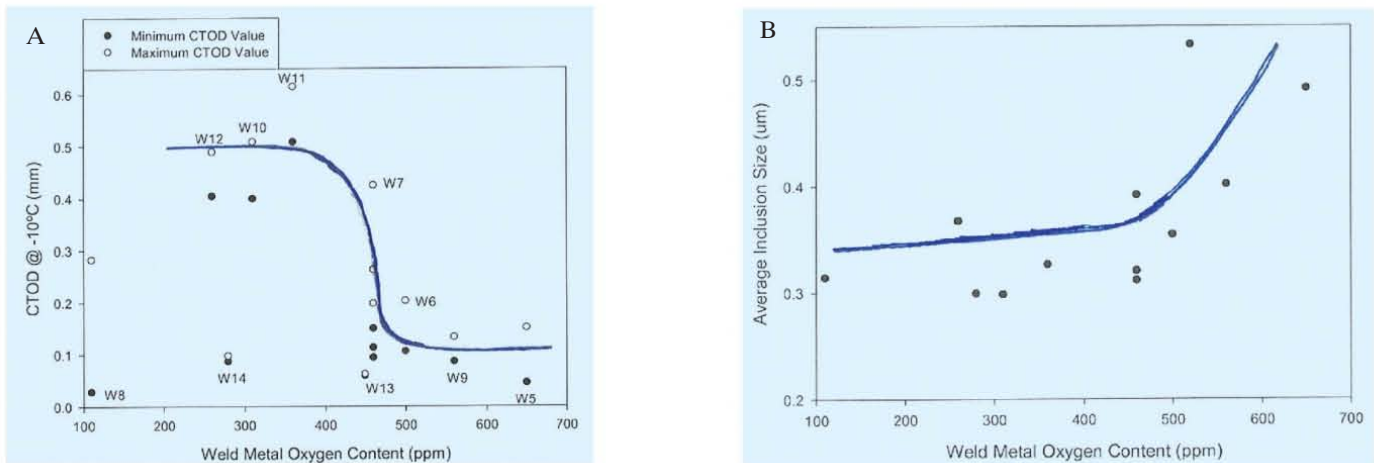


Fig. 6 — A — Weld metal CTOD as a function of weld metal oxygen content; B — average inclusion size as a function of weld metal oxygen content.

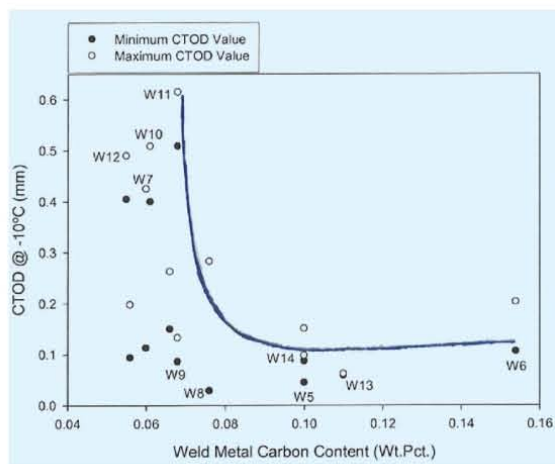


Fig. 7 — Weld metal CTOD as a function of carbon content in the weld metal.

shielding gases as listed in Tables 1 and 2. However, even though the primary microstructures of these welds were not very different (Ref. 6) and the yield strengths of all four welds were similar, ranging from 104 to 111 ksi, there was an increase in CTOD values between 4 and 6 times in welds W10, W11, and W12 (CTOD between 0.4 and 0.6 mm) as compared to the CTOD value of weld metal W9 (CTOD value of 0.1 mm).

Figure 6A shows the relationship between weld metal CTOD and the oxygen content in the weld metal. There is a good trend between weld metal CTOD and the oxygen content in the weld metal. This trend may be broken down into three distinct regions. An upper-shelf CTOD region in weld metals with oxygen content below about 360 ppm, a transition CTOD region that corresponds to weld metal oxygen content between 360 and 500 ppm, and a lower-shelf CTOD region in weld metals with oxygen content of 500 ppm or higher. This observed trend helps to explain the difference in CTOD behavior

observed in weld metals with similar yield strength and microstructure as described in the previous paragraph.

The oxygen content in weld metal W6 (CTOD_{max} value of 0.20 mm) and W7 (CTOD_{max} value of 0.45 mm) was 500 and 460 ppm, respectively. This indicates a transition from the lower-shelf CTOD to the transition CTOD region. Weld metal W6 was deposited with a SMAW cellulosic electrode (E9010-G) and weld metal W7 was deposited with a SMAW basic electrode (E9018-G). For weld metals W9 to W12, the increase in CTOD from about 0.1 mm in W9 to a CTOD value between 0.4 and 0.6 mm in welds W10 to W12 resulted from a decrease in oxygen content in the weld metal from 560 ppm in W9 to an oxygen content in the range of 260 to 360 ppm in welds W10 to W12. This corresponds to a transition from the lower-shelf CTOD region to the upper-shelf CTOD region. The lower oxygen level in weld metals W10 to W12 resulted from the GMAW-P process used with Ar (5–15)/CO₂ shielding gas as compared to the normal GMAW process with 100% CO₂ shielding gas for weld metal W9.

Figure 6B shows the average non-metallic inclusion size as a function of the oxygen content in the weld metals (Ref. 6). The average inclusion size does not change drastically for oxygen contents of up to about 450 ppm. However, a pronounced increase in the average inclusion size occurred as the oxygen content in the weld metal increased from about 460 ppm. This indicates that the distribution size of inclusions in the weld metal change toward a larger inclusion size for oxygen contents larger than 460 ppm. The in-

crease in average inclusion size increases the possibility that large inclusions can provide a crack nucleus for cleavage fracture initiation in weld metals. The improvement of CTOD toughness by switching from normal GMAW to GMAW-P procedures was not observed in the weld metal deposited with an E120X electrode even though the oxygen level decreased from 450 ppm in weld metal W13 to 280 ppm in weld metal W14 as shown in Fig. 6A. Additionally, weld W8 also showed relatively low CTOD values even though the oxygen level in these welds was only 110 ppm. Therefore, microstructural features different from nonmetallic inclusions may be responsible for the low CTOD values observed in weld metals W14 and W8.

Figure 7 shows the weld metal CTOD values as a function of carbon content in the weld metals. Carbon levels of about 0.08 wt-% or higher in the weld metal resulted in low CTOD values. This behavior may result from the presence of carbides that precipitate due to the high level of carbon present in these weld metals. Therefore, the high carbon levels and resulting precipitation of carbides may be responsible for the low CTOD values observed in weld metal W14 even at low oxygen levels. Evaluation of the origin of microcracks in high-purity iron indicated that almost every microcrack found was associated with the fracture of a carbide particle even at carbon levels below the solubility limits (Ref. 9). Therefore, carbides provide effective nucleation sites for crack initiation.

In the case of weld metal W8, the oxygen and carbon levels were 110 ppm and 0.076%, respectively, as listed in Table 4. Those levels correspond to the upper-shelf CTOD region based on oxygen content and below the critical carbon level of 0.08% identified in Fig. 7 and, therefore, do not explain the relatively low CTOD

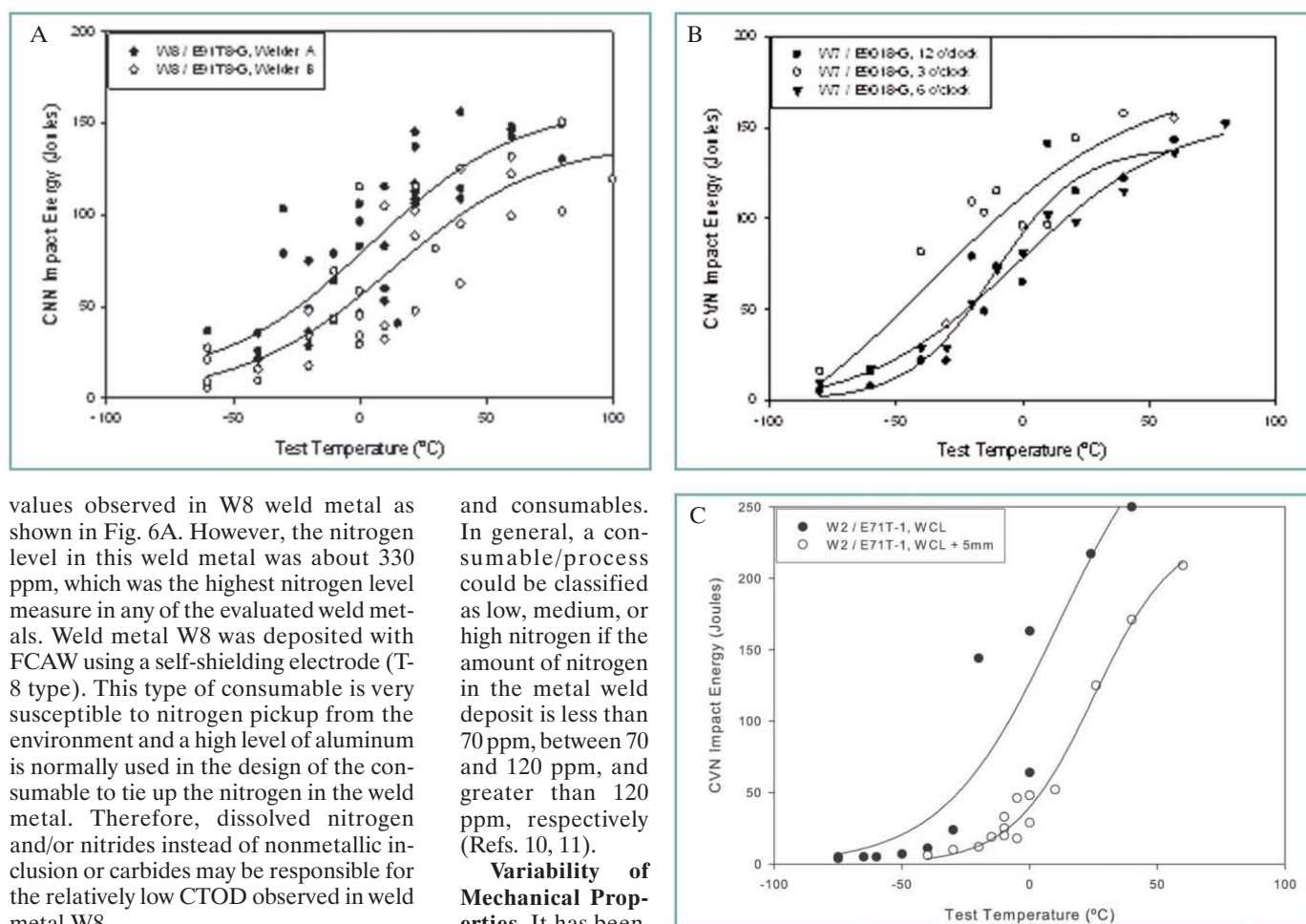


Fig. 8 — Charpy V-notch transition curves of the following: A — Weld metals deposited by two different welders; B — as a function of the sample locations; C — as a function of notch location relative to the weld centerline.

values observed in W8 weld metal as shown in Fig. 6A. However, the nitrogen level in this weld metal was about 330 ppm, which was the highest nitrogen level measure in any of the evaluated weld metals. Weld metal W8 was deposited with FCAW using a self-shielding electrode (T-8 type). This type of consumable is very susceptible to nitrogen pickup from the environment and a high level of aluminum is normally used in the design of the consumable to tie up the nitrogen in the weld metal. Therefore, dissolved nitrogen and/or nitrides instead of nonmetallic inclusion or carbides may be responsible for the relatively low CTOD observed in weld metal W8.

The observed CTOD behavior of the deposited weld metals confirms that the toughness behavior of multipass weld metal is complex and the event controlling the fracture behavior changes from system to system. Minor phases including martensite-austenite-carbide (MAC) complexes, nonmetallic inclusions, and carbides or nitrides are also present in weld metals. These minor phases may act as local brittle zones (LBZs). The morphology and distribution of LBZs have a strong influence on the toughness of the weld metal. Therefore, in order to evaluate and understand the CTOD fracture toughness behavior of high-strength weld metals, it is important to conduct fractographic analysis of the crack initiation sites and of the associated microstructural features.

The experimental observation also indicates that the welding processes used to join HSS greatly influence the CTOD properties of the resultant weld metals. Generally, the best weld CTOD metal properties are achieved with the gas-shielded processes. Gas-shielded weld metals usually contain lower amounts of oxygen and nitrogen than their flux-shielded metal arc counterparts (Ref. 6). Table 3 lists the levels of oxygen and nitrogen observed in the weld metals deposited with different welding processes

and consumables. In general, a consumable/process could be classified as low, medium, or high nitrogen if the amount of nitrogen in the metal weld deposit is less than 70 ppm, between 70 and 120 ppm, and greater than 120 ppm, respectively (Refs. 10, 11).

Variability of Mechanical Properties. It has been reported that high-strength weld metals exhibit a high degree of variability in mechanical property test results (Refs. 12, 13).

The variability of the properties of a weld metal could come from various sources such as consumable lot-to-lot variation, procedural variation, positional variation, and base material variation. In this study, it was observed that variability of Charpy impact properties of weld metals deposited with a given welding consumable and welding process may be dependent on the welder, location of the samples relative to the general layout of a pipe weld, and on the location of the notch relative to the centerline of the weld, as illustrated in Figs. 8A, B, and C, respectively.

As observed in impact fracture toughness, the results of CTOD toughness of some tested weld metals showed also variation that is dependent on the welder and location of the samples relative to the general configuration of the welded joint. Another potential source of scatter in the measurement of CTOD fracture toughness is the proportion of low toughness microstructure present at the crack tip. Experimental evidence indicates that the length of the low toughness microstruc-

ture along the crack front can influence the test results. Experimental work has indicated that lower bound fracture toughness values were obtained when more than about 15 to 20% low toughness microstructure was present along the crack front (Ref. 14).

Conclusions

The deposited HSS weld metals showed the following characteristics:

- The CE_{IIW} carbon equivalent provides a good correlation between the chemical composition, microstructure, and resulting tensile properties of the evaluated weld metals.
- The yield strength ranges between 65 and 150 ksi. A weld metal with yield strength as high as 1030 MPa (150 ksi) was obtained with E120X consumables.
- The ductility, elongation, and reduction of area of the weld metal decreases as the strength increases. Elongations as low as 13% and 3% were observed in weld metal deposited with E100X and

- E120X consumables, respectively.
- The weld metals exhibit different impact Charpy behavior. The DBTT 20 J of the deposited weld metals range from -35 to -170°C.
- The CTOD toughness of the weld metals at -10°C shows a lot of scattering and ranges from 0.01 to 0.62 mm. Weld metal yield strength does not have a clear effect on CTOD toughness. Oxygen, carbon, and nitrogen levels in the weld metal greatly affect the CTOD toughness of the weld metal.
- The best CTOD toughness was observed in weld metals with oxygen, carbon, and nitrogen levels ranging from 260 to 360 ppm, 0.055 to 0.068%, and 40 to 140 ppm, respectively. Generally, the best weld CTOD properties were achieved with gas-shielded processes.
- Variability of Charpy impact and CTOD toughness of weld metals deposited with a given welding consumable and welding process was associated with welder, location of the test samples relative to the general layout of the weld, and to the location of the notch in the test sample relative to the centerline of the weld. ♦

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Making Better Gas Metal Arc Welds

While it might at times seem like alchemy, in fact there is nothing mysterious or magical about making a good gas metal arc weld. A good weld is the result of properly functioning equipment, good technique, and the correct equipment settings for the application at hand. If any of these three elements is not in place, the result will almost certainly be a poor weld.

On the equipment side, the gas metal arc welding (GMAW) gun and consumables are often overlooked as critical elements in the process of producing high-quality welds. However, being the most handled pieces of equipment and the closest to the point of the arc, the gun and consumables are exposed to continual mechanical and heat stresses.

Two critical elements to ensure the gun and consumables do not interfere with your ability to produce high-quality GMA

welds are proper gun maintenance and correctly troubleshooting problems when they arise — Fig. 1.

Maintaining Your Equipment

Thankfully, GMAW guns and consumables don't require a lot of time-consuming maintenance and upkeep. Nevertheless, failing to spend enough time main-

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Good gas metal arc welds begin with well-maintained equipment

BY ANDY MONK AND
GREG BAUER

taining your equipment could result in spending a significant amount of time re-working bad welds.

The majority of gun and consumables maintenance simply involves checking the visible components of the equipment for problems. This includes looking for loose fittings, damaged cables, clogged diffuser ports, and the like.

Below is a component-by-component guide to minimizing downtime for re-working bad welds.

Feeder Connection. The feeder connection, which carries the electrical current and gas from the wire feeder to the

gun, should be tight fitting and free of excessive dirt and debris. The O-rings that ensure the shielding gas flows into the gun cable and nowhere else should be in good working order, i.e., not dry, cracked, or otherwise damaged.

If the feeder connection is loose and cannot be properly tightened, it will likely need to be replaced. The same goes for damaged O-rings. A dirty direct plug usually can be cleaned with an electrical contact cleaner.

Cable. Cable maintenance involves little more than inspecting it on a daily basis to ensure there are no cuts, kinks, or other

damage that could interfere with weld quality and also cause a safety hazard.

Avoid problems such as porosity, an erratic arc, and damage to the copper cable stranding by keeping the cable from bending at too sharp of an angle.

Liner. Accessing the liner can be very time consuming, so you should limit routine maintenance activity to periods when the liner is easily reached, such as during wire changeovers or when the gun is disconnected from the feeder. You can clear out any built-up debris, including metal filings from the welding wire, by using compressed air during these changeover times.

Handle and Trigger. Daily visual inspection should be conducted to ensure there are no missing screws or other damage to the handle and that the trigger is not malfunctioning. These items should be replaced as necessary if they are found to be damaged.

Neck. The neck connections, and the insulators that separate electrically live components from neutral components, should be checked on a regular basis as both a safety and weld quality measure.

Loose neck connections should be tightened or, if damaged, replaced. You should also check that the insulators are in place at either end of the neck and that they are undamaged.

Consumables. Consisting of the diffuser, nozzle, and contact tip, the consumables require regular replacement simply by virtue of their role in the welding process and proximity to the arc. Extending the life of the consumables is relatively easy, however, and you can save a significant amount of downtime and equipment costs through some simple maintenance steps — Fig. 2.

Multiple times daily, use a pair of welding pliers or a reamer to clear out any spatter or other debris that could clog the nozzle and diffuser, being careful not to damage these parts in the process.

Also, you should check the O-rings on



Fig. 1 — Proper GMAW gun maintenance and troubleshooting are essential to maintaining productivity and avoiding downtime.

the diffuser; the connections between the diffuser, neck, and contact tip; the nozzle insulator; and the contact tip on a daily basis. Loose connections can usually be tightened, but you should replace these components if any other types of damage appear.

Troubleshooting

Of course, no amount of preventive maintenance will be able to stop every

problem from occurring. So, when a problem does arise, it's important to be able to identify and correct its cause.

Often, the same problem, such as erratic wire feeding, can have more than one cause. In these cases, it's usually a good idea to conduct the troubleshooting effort by working from the easiest component to check to the most difficult.

For example, both the liner and the contact tip can be the source of erratic wire feeding. The liner takes approxi-



Fig. 2 — As seen here, GMAW gun consumables are exposed to a lot of abuse during the normal course of welding. Regularly maintaining these products can extend their life and increase a company's productivity.

mately 20 times longer than the contact tip to check, so it makes sense to begin with the contact tip and only check the liner if necessary.

Below are a few of the most common problems that occur as a result of gun and consumables malfunction.

Wire Does Not Feed. If your wire is not feeding at all, it is most likely being caused by a faulty feeder relay, control lead, adapter connection, liner, or trigger switch.

If the drive rolls are not turning when the gun trigger is pulled, it is either because an electrical continuity failure is occurring at the gun connection or the trigger is not functioning properly. Repair or replace any of these items discovered to be the cause of the problem.

If the drive rolls turn, but the wire is not feeding, there may be inadequate drive roll pressure or a blockage in the contact tip or liner. As mentioned earlier, check the contact tip and drive rolls before proceeding to the liner.

Consult the manufacturer of your wire feeder if the feeder relay turns out to be the cause of the problem.

Contact Tip Meltback. Contact tip meltback — when the wire fuses with the contact tip — occurs occasionally as a normal part of welding. If you are noticing an increase in meltback frequency, it could be a result of using the wrong contact tip recess, holding the gun too close to the workpiece, or a faulty work lead.

If you have not changed your welding parameters, shielding gas, and base metal, then it's unlikely the contact tip recess is the cause of the problem. Additionally, if those variables are the same and you are

confident you are not welding any closer to the material than normal, it may be time to consider the work lead as the cause of the meltback. Repair or replace a faulty work lead as necessary.

A final cause of increased meltback, erratic wire feeding, is discussed as follows.

Erratic Wire Feeding. If the wire is not feeding from the gun at a consistent rate, it is most likely being caused by the liner, drive rolls, or contact tip.

Begin troubleshooting an erratically feeding wire by ensuring the contact tip is the correct size for the wire being used, and that it is not damaged from excessive wear by the wire or from heat exposure from the arc.

If the contact tip is worn out from excessive wear, it could be a result of the drive rolls causing small deformities in the wire. After replacing the contact tip, be sure to check for burrs or other abnormalities along the length of the wire and adjust or replace the drive rolls as necessary. Drive rolls that are improperly tensioned, either too tight or too loose, can also lead to erratic wire feeding.

Erratic Arc. Interruptions in electrical conductivity are often the primary cause of an erratic arc. These are commonly caused by the wire maintaining only intermittent contact with a worn out contact tip instead of the constant contact required for a consistent arc. Simply replace the worn out contact tip with a correctly sized new one if this proves to be the case.

Other possible causes of an erratic arc, all of which relate to inconsistent electrical conductivity, are a neck that is too straight, a worn or kinked liner, debris buildup inside the liner, an improperly trimmed liner, and a faulty work lead connection.

Porosity. Holes in the weld bead, called porosity, are almost always caused by problems with the shielding gas coverage. This can be caused by excessive wind blowing the shielding gas away, worn out or damaged diffusers, insulators, O-rings and fittings, a ruptured gas hose, too much or too little gas flow, or a faulty solenoid.

If porosity occurs without any changes to your work environment and equipment setup, troubleshoot the problem by checking all of the previously mentioned components and replacing as necessary.

Good gas metal arc welds are not a product of luck, and poor welds can usually be attributed to operator technique, equipment malfunction, or incorrect electrical parameters. Following these maintenance and troubleshooting tips won't ensure excellent GMA welds, but will guarantee that your gun and consumables are not the cause of any problems that arise. ♦

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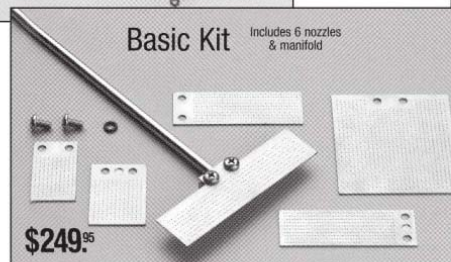
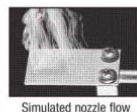
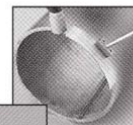
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The 2008 AWS Expo in Review

The latest high-tech equipment, welding research developments, and help for your business were all showcased at this year's welding show

BY ANDREW CULLISON, KRISTIN CAMPBELL, AND MARY RUTH JOHNSEN



Fig. 1 — A ribbon-cutting ceremony officially opened the FABTECH International & AWS Welding Show including Metalform. Shown (from left) are Michael Pellecchia, chairman, Fabricators & Manufacturers Association; Ralph Hart, president, Precision Metalforming Association; Neil Duffie, president, Society of Manufacturing Engineers; and Victor Matthews, president, American Welding Society.

A special ribbon-cutting ceremony marked the opening of the 2008 FABTECH International & AWS Welding Show introducing Metalform, held Oct. 6–8, Las Vegas, Nev. Victor Matthews, president, American Welding Society; Mike Pellecchia, chairman, Fabricators & Manufacturers Association; Neil A. Duffie, president, Society of Manufacturing Engineers; and Ralph Hart, president, Precision Metalforming Association,

all shared in the ribbon-cutting event (Fig. 1) as each grabbed the oversized handles of the ceremonial scissors and snipped the ribbon.

Once it was official, the doors of the Las Vegas Convention Center were opened to reveal long halls packed with welding and metal fabricating technology. Attendees in excess of 21,000 over the three days filled the walkways looking for just the right equipment and services that would satisfy their needs. Sixteen percent

of the attendees were international, and 56% of all the attendees were first timers. Overall total square footage was close to 400,000, with more than 175,000 being for welding equipment and related products and services.

AWS Annual Meeting

The AWS annual business meeting held on Monday, Oct. 6, was well attended. President Gene Lawson remarked that after traveling to more than 12 different countries, he was impressed by the number of countries that are seeking direction from AWS on standards development and certification programs. “The sun never sets on AWS,” he said. “And global networking is a great benefit to AWS,” he continued.

During his presidency he also visited 15 Section meetings, and was encouraged by what he saw at the local level. “There is a bright generation of leaders preparing for a bright future,” he observed.

President-elect (at the time of the meeting) Victor Matthews emphasized that AWS has developed standards that are recognized around the world. He sees AWS as a much-respected organization and that reputation is a solid foundation for continued growth. He also sees some major challenges that the Society faces.

There is still a perception of welding as a dark, dirty, and dangerous profession. High schools continue to drop welding instruction because of its image and the negative attitude of guidance counselors. There is a growing shortage of skilled welders in industry that must be addressed. There are new materials that present welding challenges, and environmental concerns that require attention. He emphasized that the Society must tackle each challenge and meet it head on. Addressing those challenges and growing the Society will guide his presidency in 2009.

ANDREW CULLISON (cullison@aws.org) is publisher, KRISTIN CAMPBELL is associate editor, and MARY RUTH JOHNSEN is editor of the Welding Journal.

Adams and Plummer Lectures

Dr. Stephen Liu, professor of Metallurgical and Materials Engineering and director Center for Welding, Joining, and Coatings Research, Colorado School of Mines, Golden, Colo., gave the Adams Lecture on the topic "Welding in the Deep Oceans: Conquest of the Other Frontier."

New sources of energy must be continually developed, but presently one of the major sources in the United States is in the Gulf of Mexico. There are approximately 5000 offshore oil rigs in the Gulf. Some of the rigs are 1500 ft tall, with most of the superstructure underwater. Damage to it from fatigue, corrosion, storm loads, or vessel impacts most likely occurs below the sea surface. Repairs then require expertise in underwater welding.

Liu has spent 20 years studying underwater wet welding. Throughout those years he has been dealing with the main challenges of the process. First, it produces a very coarse microstructure, which is poor for impact properties. There is a great amount of porosity with underwater welding, and the process produces a hard heat-affected zone, resulting in underbead cracking.

He has attacked the problems through metallurgy, developing different electrode compositions to address specific problems. For example, by balancing various elements, the microstructure can be refined by opening up the acicular ferrite range. Manganese additions in a strict range, along with very low carbon, resulted in reduced porosity. Porosity also changes with the transfer mode. Different slag formulations were developed to pick up hydrogen from the weld metal, making it more crack resistant.

The research is ongoing to find the perfect formulation that will address all the problems at the same time. Future research will investigate new formulation and ways to control the cooling rate through the addition of exothermic elements.

Thomas W. Eagar, professor of Materials Engineering and Engineering Systems at the Massachusetts Institute of Technology, delivered the Plummer Lecture. Eagar spoke on "Why Is Welding Important." He discussed the changing demands for welding education and the evolution of American manufacturing. From 1780 to 1900 was the craft period, Eagar said, in which skilled labor, who mostly learned their trades through an apprentice system, produced low-volume, custom products at a relatively high cost. From 1900 to 2000, manufacturing followed a mass production system such as that developed by Henry Ford. This involved mostly unskilled labor who produced high-volume, standard products at

relatively low cost. Today we are moving into the Lean Manufacturing period, which calls for an empowered labor force and emphasizes teamwork and continuous improvement systems such as Total Quality Management, statistical process control, and just-in-time manufacturing. The goal is to produce quality products in incremental volumes while decreasing costs.

To be successful at this, Eagar said, U.S. companies must move away from "treating our employees as mass producers." As far as welding education goes, "We need to teach the principles in welding education," he said. "We must teach students the why and how, not just what. We're not educating an empowered workforce because we're teaching what, not how and why. We want students to improve welding throughout their careers."

Over the past 30 years, welding education has improved, Eagar said, but more work needs to be done. One problem is that universities tend to teach what they can get funding for rather than what is needed.

Keynote Address and Business Improvement Seminars



Fig. 2 — During his spirited speech to a large crowd, innovator Dean Kamen brought attention to the importance of technology today and showed motivation for others to take a role in this effort.

Another highlight came on Oct. 7 in the form of Dean Kamen's Keynote Address: "Inspiring Future Generations to Lead the World in Innovation" — Fig. 2. Jim Warren, who handles FMA's educational activities, introduced him to the lectern. Kamen founded DEKA Research & Development Corp., Manchester, N.H., as well as FIRST (For Inspiration and Recognition of Science and Technology). To begin, he spoke about DEKA and showed slides detailing what has been designed/invented, including various medical devices, the iBOT™ mobility system, Segway® Human Transporter, and DARPA prosthetic arm. "My life is about trying to do things nobody's done before,"

Kamen said. Two of the company's current projects involve providing the basic human needs of water and power. "Technology can solve a lot of the world's problems," Kamen said.

FIRST comprised the second half of Kamen's speech. After questioning where the demand is to work hard, considering that most U.S. kids aspire to entertainment and sports, Kamen realized to create a passion for them doing things that matter, science and engineering should be turned into a sport using teamwork that is just as entertaining. The idea worked, and from the organization's inaugural Robotics Competition in 1992 to now, participation has grown exponentially. This positive experience where robots are built in six weeks not only gets students to solve problems, but it is fun, self-respect is gained, and students learn about different fields. "Everybody who gets involved with FIRST gets more out of it than they put into it," Kamen said. Serious adults are needed to help. "What's limiting our growth is access to mentors," Kamen added. He encouraged the audience to check out its Web site at www.usfirst.org.

Product liability litigator Gary M. Glass of Thompson Hine discussed "Taming the Product Liability Beast: Ten Things You Can Do to Protect Yourself" on Oct. 6 during the first free Business Improvement Seminar of the show.

Protecting your company from product liability claims involves plenty of work and preparation. Fear of those claims has led to a great deal of paranoia among manufacturers, he said, and caused them to place on their products all kinds of warnings that would seem unnecessary to most people. As an example, he showed a photo of a 5-gal plastic bucket with a label on the side warning that small children could fall in and drown.

Glass warned about the dangers of not managing e-mail and other documents. Letters are usually given a lot of attention before being sent out, but e-mails are more casual and off the cuff. In the case of a trial, however, all electronic communication could become evidence. He emphasized training of sales personnel because they often do not complete paperwork and may point out problems with a product in carelessly worded internal memos. Having them stick to the facts during communications can prevent problems if internal documents are searched later.

Following are Glass's ten things companies can do to protect themselves from potential product liability claims.

1. Evaluate the safe design of your products
2. Document your safe manufacturing process
3. Establish procedures to deal with OSHA

4. Train your service personnel
5. Review your contracts and procedures
6. Train your sales personnel
7. Review your insurance coverage
8. Develop a crisis and accident response plan
9. Develop a document/e-document retention and management plan
10. Conduct smart writing programs.

Products on Display

There were literally thousands of products to see throughout the two main halls of the show. Some of the welding technology that caught the attention of the *Welding Journal* editors is highlighted below.

Fume Collector Made Compact. The new Smog Hog MSH (Fig. 3) is a mist collector that had its coming out party at the Show. This unit is primarily for collecting liquid contaminants such as oil or coolant mist, but it also can collect submicron fume. The unique features of the unit include a compact size and the ability to mount vertically or horizontally directly onto the machine that is emitting the mist. The collection mechanism uses electrostatic precipitators. The motor is variable speed and it can develop 500 ft³/min of air volume, and the noise level does not reach 72dBa. The filter can be accessed through a door on the side of the unit. *United Air Specialists, Cincinnati, Ohio, (800) 252-4647, www.uasinc.com.*



Fig. 3 — The new Smog Hog mist collector can be mounted horizontally or vertically on a tool machine.

Easy Shoe Repair. Tuff Toe is a unique product that came out of the sports world, but is now available for shoes that are subjected to wear and tear in construction and industry jobs. It is a product that was originally developed for pitchers in baseball whose delivery motion entailed dragging a foot over the rough surface of the mound. The toe area of the shoe had a tendency to wear much faster than the rest of the shoe. A tough, wear-resistant liquid polyethylene product was developed that could be applied to the toe of the shoe, thereby extending its life. In fact, it

AWS Foundation Chairman Honored for Years of Service

After 15 years of service, Ron Pierce is stepping down as chairman of the AWS Foundation. From 1993, when he became chairman, to the present, he has helped the Foundation grow from the initial \$300,000 contribution by Glenn Gibson in 1989 into an organization that distributes in excess of \$360,000 a year in grants and scholarships for welding education to more than 300 recipients.

Pierce may be stepping aside, but he still plans to remain active in the Foundation. At the FABTECH International & AWS Welding Show, he was pronounced honorary chairman and trustee emeritus and presented with a proclamation honoring his many years of dedicated service. "My health is good and this affords me the opportunity to continue to be active," he said, "and I enjoy helping others." The new chairman, AWS Past President Jerry Utrachi, looks forward to leading the Foundation with the same enthusiasm and dedication Pierce has shown over these many years.

Pierce, who is also an AWS past president, started with the Foundation in 1991 as a trustee. In the early years, he noted, it was a challenge to get active participants. "We would have meetings and almost no one attended," he said. There was also the feeling that after the initial donation by Gibson and another one by Miller Electric it would be easy to get donations. That was not the case.

He admitted there were a lot of growing pains, but Pierce has seen a major change in attitude toward the Foundation and the direction of its fortunes over the years with the hiring of a professional fund raiser and improved communication with the AWS board of directors. "Our meetings are open to all, and questions can be asked on anything," he said.

Throughout his tenure he is most proud of the scholarship money that has been given to needy welding students. "Before 1989 AWS didn't have a scholarship program," he noted, "and the Sections had no money for this." Over the past 18 years, the Foundation has helped 2641 students with \$3.8 million in assistance. Pierce gets gratification from this because, "to help educate young people" is one of the major reasons he has given so much of his time to the Foundation.

Pierce also expressed satisfaction with the recent Workforce Development initiative by the Foundation. To address the growing shortage of welders, the Foundation is actively soliciting donations from industry to develop programs to meet the problem head on. As part of this initiative, the Foundation has utilized professional staff to work with industry and educational facilities to bring them together with programs that encourage young people to enter the welding field.

2008 Image of Welding Award Winners Named

The Image of Welding Award recipients were recognized by the AWS and the Welding Equipment Manufacturers Committee (WEMCO) during a ceremony on Oct. 6.

"These awards recognize individuals and organizations that have shown exemplary dedication to promote the image of welding in their communities," Bruce Vernyi, Image of Welding Committee chairman, said.

The following won the Individuals Category: **Barbara Henon, Lisa Legohn, Clyde Shetler, Ray Wildsorf, Richard Bryant, and James Owens.** They served as an inspiration to their peers and continue to motivate others in their field.

Many were honored for the Educator's Category — **Jim Burnett, Jim Goetz, Roy Lanier, Lisa Legohn, James Owens, and Ralph Young** — due to outstanding dedication to welding education and providing high-quality instruction.

In the Educational Facility Category, these institutions strived for excellence in enhancing their students' learning experience: **Bucks County Technical High School**, Fairless Hills, Pa.; **We-Me-Co Welding**, Livonia, N.Y.; **Odessa College Welding Training Center**, Odessa, Tex.; **Indian Hills Community College**, Ottumwa, Iowa; and **Pima Community College**, Tucson, Ariz.

Taking the Small Business Category were **Advanced Science and Automation Corp.**, Indianapolis, Ind., for developing a virtual welding lab to teach welding at low cost, and **Westfield Steel Co.**, Westfield, Ind., for supporting welding education and donating steel for welding competitions.

In the Large Business Category, **A&B Process Systems**, Stratford, Wis., triumphed. The 25-year-old company has implemented community outreach for welders, and promotional efforts at local, state, and national levels.

Achieving the prizes in the AWS Section Category were the **Tulsa** and **Western Carolina Sections**. While Tulsa performed extensive work on welder shortages, Western Carolina's Bob Humphrey and Bob Fellers worked with the support of local industries to revive this Section.



Winners receiving the Image of Welding Award, some of which are shown above, were presented engraved plaques for their exceptional achievements. In the front row (from left) are Jim Mosman (Odessa College Welding Training Center); Barbara Henon (Individuals Category); Ken Bice (Pima Community College); Jack Laudig (Westfield Steel Co.); Michele Robbins (We-Me-Co Welding); and Robert Pyka (Rywal-RHC Ltd.). In the back row (from left) are James Owens and Lisa Legohn (Individuals and Educator's Category); Paul Phelps (Western Carolina Section); Ray Wilsdorf (Individuals Category and speaker on behalf of the Tulsa Section); Richard Bryant (Individuals Category); Jim Burnett (Educator's Category); and Roy Lanier (Educator's Category).

Rywal-RHC Ltd., founded by Robert Pyka, succeeded in the Distributor Category for its accomplishments in modernizing the Polish market, breaking barriers of socialist ideologies, and motivating teams into collaborative work.

In addition, one winner from each of the seven categories listed above had an opportunity to speak. All the winners were also invited to talk on-camera after the ceremony so a video could be produced and distributed in a commemorative DVD to celebrate their achievements and help inspire others.

"Everyone of these awardees today represents the drive, professionalism, integrity, passion, commitment, and inspiration for welding," Vernyi said. There were numerous nominees from which to choose. "It was a very difficult decision we had to make as a committee to come up with the awardees that we have today. I wish we could've named everyone a winner this year," Vernyi concluded.

Contestants Demonstrate Their Talents in Weld-Off

Six competitors tried their best during the 2008 Weld-Off Competition sponsored by AWS at the Show. The event took place over three days from Oct. 6-8 and



The contestants of this year's Weld-Off Competition, pictured along with the pressure vessels they fabricated, are (from left) Mohammed Farhat, Mason Winters, Andrew Pellissier, Westley Smith, Joshua Steinbrecher, and Joe Young.

can be seen applied to a pair of Nolan Ryan's shoes that hang in the Baseball Hall of Fame commemorating one of his record-setting seven no-hitters. The liquid is applied with a specially designed applicator — Fig. 4. It sets in five minutes and cures at room temperature in 24 hours. The material is available in five different colors. Tuff Toe, Inc., Orange, Calif., (800) 888-0802, www.tufftoe.com.



Fig. 4 — After Tuff Toe is applied, it sets up as a wear-resistant material in 24 hours.

Cutting for Big or Small Applications.

Torchmate is a family-owned integrator that designs CNC cutting systems for a variety of needs — Fig. 5. The company can design cutting systems for small job shops from \$4000 to larger industrial uses for \$40,000. It can configure all of the cutting processes, including laser and waterjet cutting. Software programmed ready to go is provided in the service. The design footprint could be as small as 4 x 4 ft or as large as 10 x 40 ft. Technical support is unlimited and free. Torchmate, Reno, Nev., (866) 571-1074, www.torchmate.com.



Fig. 5 — Torchmate configures cutting systems for large or small operations. The tubing for the framing of this off-road recreational vehicle was cut by this system.



The Weld-Off winners were announced Oct. 8 at an awards dinner. In the front row (from left) are Joshua Steinbrecher (silver medalist), Mason Winters (gold medalist), and Mohammed Farhat (bronze medalist); middle row (from left) are AWS Vice President John Mendoza, Joe Young, Westley Smith, Andrew Pellissier, and AWS Past President Ernest Levert; and last row (from left) are AWS President Victor Matthews, SCC Chair and AWS Past President Ed Bohnart, AWS Vice President John Bruskotter, and Program Manager, Skills USA, James Kregiel. (Photo courtesy of Marines Maldonado.)

consisted of 19 hours of competition.

Mason Winters won the gold medal. His instructor is Mike Tryon, and he hails from the College of Eastern Utah-Price, Utah. **Joshua Steinbrecher** took the silver medal. Scott Tennant is his instructor, and he comes from Northeast Wisconsin Technical College-Green Bay, Wis. **Mohammed Farhat** earned the bronze medal. His instructor is Jake Holland, and his school is Washtenaw Community College, Mich.

These top three SkillsUSA contestants will compete for two positions at the U.S. Open Weld Trials to be held during the summer of 2009. It is there the TeamUSA welder will be selected, and this individual will attend on-site, intensive training programs by major welding organizations as well as represent the United States at the 40th WorldSkills Competition (WSC) in Calgary, Alb., Canada, Sept. 1-6, 2009. The U.S. Open Weld Trials TeamUSA welder will receive a \$40,000, four-year scholarship through the AWS Foundation and sponsored by Miller Electric Mfg. Co., \$1000 in AWS publications, and a four-year AWS membership.

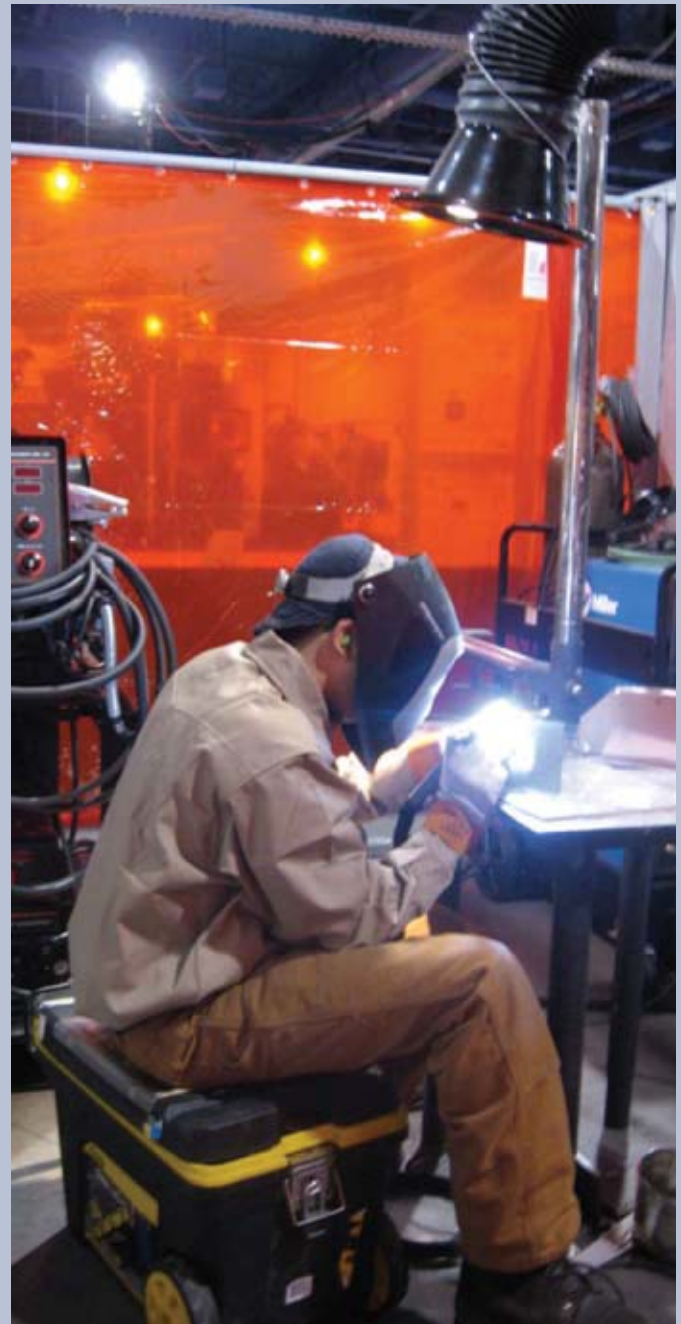
The other Weld-Off contestants were **Joe Young**, Washtenaw Community College, Mich., instructor Jake Holland; **Andrew Pellissier**, Truckee Meadows Community College, Nev., instructor Scott Holcomb; and **Westley Smith**, Penn College of Technology, Pa., instructor James Colton.

Twenty-four potential SkillsU.S.A. candidates, all prior secondary and post-secondary state gold medalist contestants, competed for one of six USA invitations to this 2008 Weld-Off Competition where skills were tested in specific processes and personal development, including:

- SMAW/GMAW/GTAW/FCAW test plates and pipes (RT and bend tests);
- Stainless steel and aluminum sheet metal weldments;
- SMAW/GMAW/GTAW/FCAW pressure vessel (tested using water pressure at 1000 lb/in.²); and
- Physical and mental conditioning needed to accept the challenge of pursuing an international gold medal.

The Weld-Off competitors also received a \$1000 scholarship for books, tuition, or lab fees and a one-year AWS membership.

"We've got six of the finest young welders in the country. They've all won their state gold medal. They're all champions," Ed Bohnart, chairman of the AWS Skills Competition Commit-



A competitor is shown hard at work welding on the last day of competition.

tee (SCC), said. "These people have been competing over the last two years against thousands of welders."

"You got to be very dedicated. To be functioning at this level is amazing," Bohnart added, considering these competitors must be less than 23 years old during the year of the WSC to qualify.

Bohnart provided encouragement to the contestants; worked with the AWS Certified Welding Inspectors who served as judges to make sure the contest was fair and impartial; and met with the public.

The AWS SCC arranged the Weld-Off's welding machines, accessories, consumables, testing agencies, and test equipment. The event's sponsors and suppliers included the United Association of Plumbers and Pipefitters, Local 72, Atlanta, Ga., and Local 525, Las Vegas, Nev., which provided all of the destructive and nondestructive testing of the welds.

Purge without Gas. Solar Flux was a military secret during WW II when it was used to purge the weld joints of stainless steel exhaust manifolds for Navy aircraft. Today, it is still being used as an alternative to gas purging in the welding of stainless steel and high-nickel superalloys. It is not intended for applications that require noncontamination, such as food processing equipment. It will leave a glass-like residue after welding that, depending on the application, should be removed. The material is a fine powder that is mixed with methanol when ready to apply. The paste that develops is then brushed onto the weld joint. The methanol evaporates leaving a thin flux cover that assists weld deposition and purges oxygen and oxide contaminants. *Solar Flux, Morehead City, N.C., (888) 211-3511, www.solarflux.com.*

Robot Controller Adds Features. Motoman's NX100 robot controller (Fig. 6) is capable of interfacing with a programming pendant that incorporates a graphic simulation of the robot's path. The memory can handle 60,000 steps and 10,000 instructions. New programs can be taught that incorporate high-cycle time analysis. The controller is capable of handling the multiple tasks of up to four robots, including a total of 36 axes for robots and external components. The idea was to design the unit as a system cell/robot controller for multitasks and move beyond a single robot controller. The unit is capable of connecting to various field bus networks. *Motoman, Inc., West Carrollton, Ohio, (937) 847-6200, www.motoman.com.*



Fig. 6 — The NX100 robot controller is capable of handling up to four robots.

SmartTCP Goes after the Small Batch. Normally, robotic applications are considered most desirable when they are for large production runs. SmartTCP is a company that specializes in robotic automation for small batch applications. The key to making small runs is the company's software that minimizes programming time by teaching the robot to weld through a 3-D CAD model. The company claims that programming time is reduced enough to make the welding of components in small batches economical. The target applications are industries with large or complex parts such as heavy industry, locomotives, shipyards, and construction. A complete gantry welding system is offered (Fig. 7), and CEO Efi Lebel claims that a system can be installed and in production in five weeks. *SmartTCP, Inc., Farmington Hills, Mich., (248) 994-1042, www.smarttcp.com*



Fig. 7 — SmartTCP offers complete automation systems for small batch robotic applications.

Welding and Fabrication Curtains Enclose Large Areas. Curtain Walls™ were developed out of a need to protect workers from UV light — Fig. 8. And not only is 100% UV light blocked, the curtains also confine welding fumes; feature reinforced hems, chain-weighted bottoms, have 14-oz reinforced vinyl top and bottom panels meeting the NFPA-701 test for fire retardancy, are mildew/rot resistant, and are OSHA approved. Standard curtains consist of a black bottom, yellow weld-view center, white top, and come in sizes 8, 9, 10, or 12 ft high by 6, 12, or 24 ft wide. With custom curtains, the 12 color options for top and bottom are blue, white, green, yellow, red, gray, purple, maroon, beige, black, orange, and teal; its center weldview area can be in yellow, red, blue, gray, and green; and sizes range from 6 to 60 ft high by any width. Everything is specially made to fit the user's application, and delivery is in five to seven days, even on custom orders. They are priced by linear foot based on the height. *Goff's Enterprises, Inc., Pewaukee, Wis., (800) 234-0337, www.goffscurtainwalls.com.*



Fig. 8 — Running on a steel track and roller system for easy gliding, Curtain Walls™ use Velcro® to make taking apart and putting them together simple.

Digital Synergic Pulse Welding Improves Weld Cosmetics. The PowerMaster® SP (Fig. 9) and PowerMaster® SP automation range of power supplies feature synergic pulse, and the Tweco® Pulse Master gas metal arc gun incorporates smart touch controls. These fully digital microprocessor-based machines offer weld control using a pulsing and synergic wave design to give precise, repeatable welds on virtually any weldable material type from thin gauge to plate. Additionally, simultaneous microprocessor control of the wire feed, arc current, and voltage ensures a clean gas tungsten arc like fin-



Fig. 9 — The PowerMaster® 320SP is portable and welds nonferrous materials up to 1/4-in. plate.

ished appearance on aluminum alloys with gas metal arc welding productivity. This equipment includes technologies such as Smart MIG™; TwinPulse™; HDP™ (High Definition Pulse); HSP™ (High Speed Pulse); EasyLink™; SmartLogic™; JobTool™; TipTronic™; and FTT™ (Fresh Tip Treatment). In particular, the PowerMaster® 320SP is complete with 320-A maximum output, 4-roll wire feed system, 33/44-lb spool capacity, 77-lb weight, and 29.3 × 13.4 × 19.6 in. dimensions — Fig. 9. The PowerMaster® 400SP offers a maximum output of 400 A and is available in two configurations — as a fully integrated version or a separate remote feeder system. The integrated variant has a 4-roll wire drive system and is supplied standard with running gear. This product weighs 215 lb, and its dimensions are 43.9 × 17.5 × 33.7 in. Push/pull systems for production welding with 3/4-in. aluminum wires can be run. *Thermal Arc®, St. Louis, Mo., (800) 426-1888, www.thermalarc.com.*

Plasma System Features 45-A Output Current and 50% Duty Cycle. The Powermax45® is a portable plasma cutting and gouging system — Fig. 10. It offers a recommended 1/2-in. cut capacity and 1-in. severance; for gouge capacity, the metal removed per hour is 6.2 lb. This single-gas system (air or nitrogen) is designed for hand-held and mechanized applications. It cuts stainless steel, copper, and aluminum. The 37-lb product is useful in HVAC duct cutting, truck and trailer fabrication, and facility and equipment maintenance of all types. Other highlights are as follows: Conical Flow™; patented drag-cutting technology; Boost Conditioner™; CNC interface and Fast Connect™ torch connection; and Powercool™. Standard system components include a power supply; T45v hand torch or T45m machine torch; extra consumables for cutting and gouging; 20-ft work cable with clamp; and carry strap. Development came through market research, talking with plasma end users, and working with an engineering team for its design. The list price is \$2019. *Hypertherm, Inc., Hanover, N.H., (800) 643-0030, www.powerfulplasma.com.*



Fig. 10 — Users of Powermax45®, shown in action above, will benefit from its easy use, good cut quality, and long consumable life.

Multipurpose Welding Machine Gives a Smooth Arc. The MultiMaster® 300X is a ready-to-weld package offering good performance for gas metal arc, DC gas tungsten arc, and covered electrode welding — Fig. 11. An improvement on the 260 model, it presents a more conventional-style machine. In addition, this product is optimized for use with the company's Dual Shield X series of flux cored wire and is beneficial for welders currently using shielded metal arc welding who would like to use flux cored wire. ESAB's proprietary Super Switch™ technology features a high-speed, solid-state power control. The machine offers DC welding output from 15 to 300 A at 40% duty cycle. Extra qualities include fan on demand, a heavy-duty four-drive roll stand with serrated Dual Shield X series wires in 0.045- and 0.052-in. diameters, a 400-A, 15-ft gun setup for the same diameters, a large-capacity tool box, and an "easy-on" cylinder tray. Also, the package contains a power source, built-in four-roll wire feeder, factory-installed undercarriage and cylinder rack, torch, contact tips, regulator/flowmeter, electrode holder and plug, and all necessary hoses and cables. The cost is about \$4000. *ESAB Welding & Cutting Products, Florence, S.C., (800) 372-2123, www.esab.com.*



Fig. 11 — As a single-phase unit, the MultiMaster® 300X is useful for medium to small shops. It offers easy setup.

Just Grip, Roll, and Go to Achieve Critical Temperature Measurements. The Tempilstik-Pro™ is a fast, easy-to-use, and accurate temperature indicator — Fig. 12. The product features a thumb-wheel advancement and retraction system that makes advancing the chalk as easy as moving your thumb, and this can be done with-

out taking your gloves off; no fumbling or dropping should occur. Development came through talking to welders who said indicators were hard to use with their gloves on. One quick swipe of this patent-pending product across the surface and, when it melts it gives an instant, accurate indication that the rated temperature has been reached. It is beneficial for welders working on critical applications such as pressure vessels, offshore oil rig fabrication, pipeline construction, and architectural and structural projects. It melts within ± 1% of rated temperature. The temperature ranges available are from 100° to 700°F. *Tempil®, S. Plainfield, N.J., (800) 757-8301, www.tempil.com.*



Fig. 12 — Stroke the workpiece during heating, and Tempilstik-Pro™ will make a distinct mark by melting at the point of contact once the surface reaches the product's rated temperature.

Small Cell Teaches Students to Program Robots. Since many companies are addressing work force issues through automation, many schools are finding it necessary to include automation programming in their curriculums. In order to address the need to teach students robot programming, The Lincoln Electric Co. partnered with FANUC Robotics to offer a compact Education Cell designed for educational institutions, training departments, and other facilities interested in teaching robotic programming for gas metal arc welding — Fig. 13. The cell measures 81 in. tall × 27 in. wide × 65 in. long and is on casters. It can fit through a standard doorway and be moved easily from classroom to classroom. No special power is needed; it can be plugged into single-phase power. Everything needed for operation is included: a Lincoln Power Wave® 355M welding power source and AutoDrive™ 4R90 wire feeder; FANUC Arc Mate 50iC/5L robot with R30iA Mate controller and teach pendant; integrated gas cylinder; fume extraction mounting; integrated safety measures; and a number of FANUC software options. List price of the Robotic Education Cell is \$35,000–\$40,000. *The Lincoln Electric Co., Cleveland, Ohio, (216) 383-2667, www.lincolnelectric.com.*



Fig. 13 — This small-sized robot welding cell can be wheeled from one classroom to another to train students about robot programming.

SMAW Electrodes Were Boilermaker Tested. The company's new Boilermaker line of low-alloy shielded metal arc electrodes were developed specifically for water wall tube repairs. They provide low spatter levels and a good bead wash. The four electrodes — Boilermaker 18 (AWS E7018), Boilermaker A1 (E7018-A1), Boilermaker B2 (E8018-B2), and Boilermaker B3 (E9018-B3) — were then given to journeymen from Boilermaker Local 108 to use and evaluate, hence the name — Fig. 14. Five hundred pounds of the electrodes were given to a power plant as a test, company representatives said, and 100% of the welds made with them were X-rayed. The normal reject rate is 7%, but the welds made with the new electrodes had a reject rate of 4.3%. The B2 electrodes are available in 3/8-in. diameter and 12-in. lengths. The length allows welders



Fig. 14 — Journeymen from Boilermaker Local 108 tested Hobart's new SMAW electrodes and offered their input on how well they performed water wall tube repairs.

to bend the electrode so it can be used in the tight spaces common to boiler tube repairs and allows for nonstop welding, lessening the chance of starting and stopping porosity. The other electrodes are available in 3/8- and 1/2-in. diameters and in 14-in. lengths. *Hobart Brothers Co., Troy, Ohio, (800) 424-1543, www.hobartbrothers.com.*

Cordless Band Saw Can Be Held One-Handed. The STX-250C-NB portable band saw weighs 9 lb with the 18-V nickel cadmium battery in place. It allows the user to safely make overhead cuts while standing on a ladder or scaffolding. The saw has a cutting capacity of 2 1/2 in. and can cut steel, stainless steel, aluminum, plastic, PVC, wood, and a variety of other materials. It features a 21,000 rev/min, heavy-duty DC motor and a bimetal blade. The saw lists for \$319. Options are a \$79 kit that includes a nylon tool bag, extra blade, two batteries, and a safety shield and the ST-CS250 cutting station that provides a stable platform on which to use the saw. As a safety feature, when the saw is put into the station, a magnetic override disables the saw's switch and it then must be turned on and off using the station's lockout switch. The band saw and cutting station together weigh 19 lb — Fig. 15. *Stout Tool Corp., Wixom, Mich., (877) 337-8688, www.stouttool.com.*



Fig. 15 — Stout Tool's cordless, hand-held band saw can be used on its own or placed into the optional cutting station as shown here.

Brake Stops Grinding Wheel Faster. The company now offers two new models of 5- and 6-in. grinders with a mechanical disc brake that stops the wheel in 3 s after the grinder is switched off. This reduces the risk of accidents caused by a still-turning wheel. At this time, the brake is only available on the WB11-125 Quick and WB11-150 Quick models of the company's Metal Masters line, but Vice President David Smith said plans are to eventually put it on all the models that include a dead man's switch. Other improvements to the line include a change from a single- to a double-sealed bearing for better durability and more resistance to overload, a

fully encapsulated switch, almost totally enclosed carbon brushes to keep grinding dust out of the motor, and a 25% increased air flow. *Metabo, West Chester, Pa., (800) 638-2264, www.metabousa.com.*

Cleaning with Dry Ice. The company's new Aero Series dry ice blast cleaning systems were designed to use less air and less dry ice while offering more aggressive cleaning action. They can remove greases, dirt, and oils that could present problems for welding. The line includes the Aero 40, the most commonly used size; Aero 80-DX (Fig. 16), the most aggressive cleaner with a high blast pressure; and the Aero C100, a fully pneumatic model geared toward the contractor market. These machines all have larger hoppers than previous models (the numbers in the model names indicate the number of pounds of dry ice their hoppers can hold). Each machine features the company's patented SureFlow System that allows use of a full load without clogging, 360-deg radius mobility, and all-terrain, no-flat wheels. The Models 40 and 80 feature trigger-activated hopper agitations and the C100 offers automated hopper agitation as well as twice the hose length of previous pneumatic models (up to 100 ft). The company offers more than 100 cleaning nozzles for the machines and they can be custom designed for a particular application. *Cold Jet, LLC, Loveland, Ohio, (800) 337-9423, www.coldjet.com.*



Fig. 16 — The Aero 80-DX dry ice blast cleaning system from Cold Jet offers a blast pressure range of 30–140 lb/in.² for aggressive cleaning action.

See You Next Year

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Pulsed Technology Increases Cladding Travel Speed

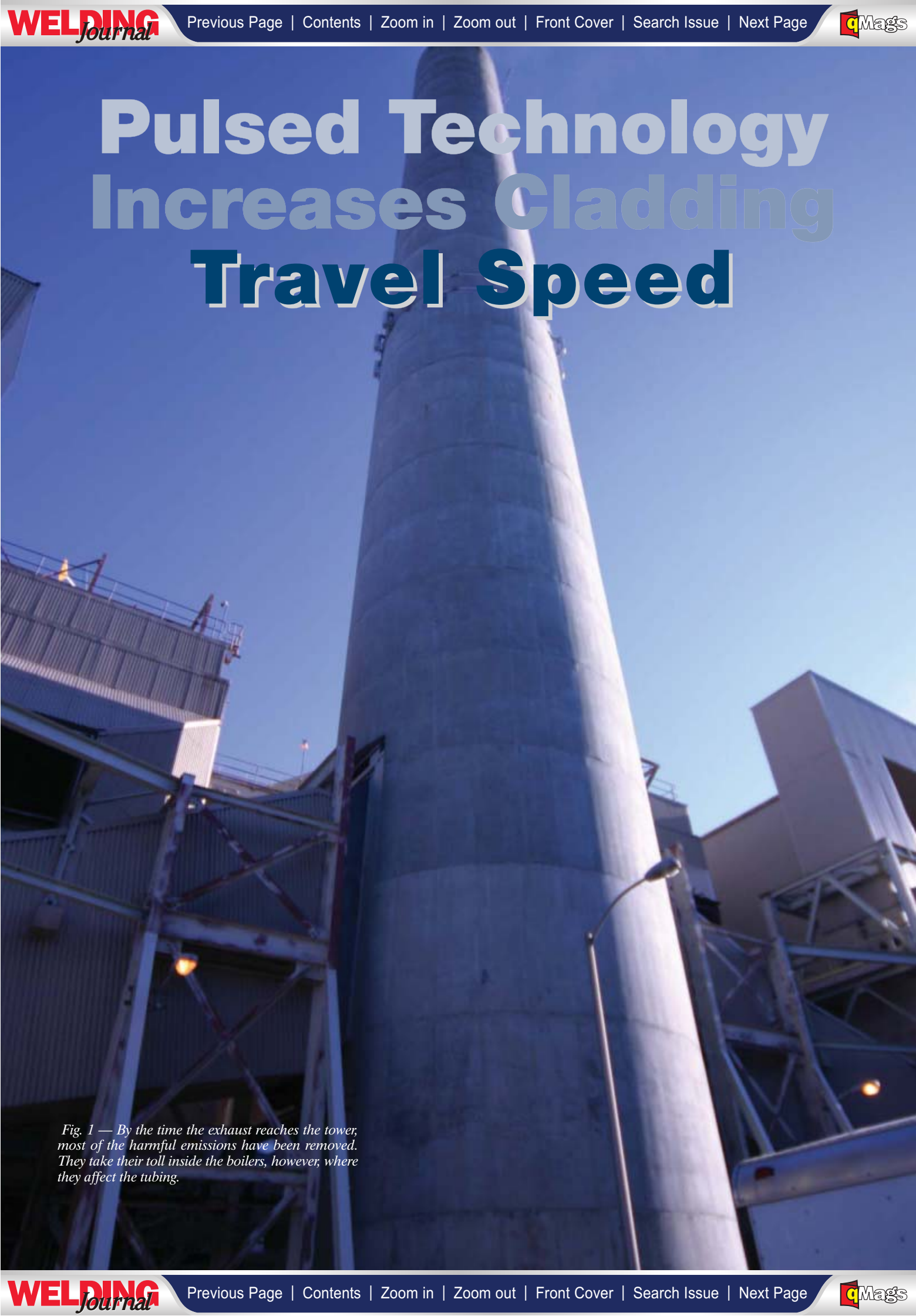


Fig. 1 — By the time the exhaust reaches the tower, most of the harmful emissions have been removed. They take their toll inside the boilers, however, where they affect the tubing.

A company that converts trash to energy achieved faster welding speeds when it began utilizing newer pulsed gas metal arc power sources

BY JIM RAPPL

That can of garbage sitting in your kitchen might not be worth its weight in gold, but it contains enough energy to power a light bulb for 24 hours — at least it could once Covanta Energy gets a hold of it.

At its more than 30 plants around the world, Covanta takes municipal solid waste — trash that would otherwise fill landfills — and turns it into energy. For every 10 tons of waste received, Covanta

- Reduces it to ash that is 10% of its original volume
- Recycles 500 lb of metal
- Generates 5200 kWh of power.

According to Covanta, every ton of municipal solid waste converted to energy avoids the need to import one barrel of oil or mine one-quarter ton of coal.

The company feeds the waste into combustion chambers constructed of steel tubes (Grades 28, 213, A213) that contain water. The burning waste turns the water into steam, which then spins turbines. Unfortunately, the gases emitted during the process can corrode mild steel within a few years — Fig. 1. That's where Brad Hooper and his team come in. Hooper is supervisor for the NorthEast Regional Maintenance cladding program for Covanta Energy.

To extend tube life by up to 15 years, Hooper's team uses the pulsed gas metal arc welding (GMAW-P) process to clad the tubes with Inconel™ 625, a high-nickel-content alloy known for its combination of high-temperature corrosion resistance, toughness, and strength — Fig. 2. Because Hooper's team operates during scheduled shutdowns, and because the team moves from one Covanta facility to another, they must adhere to tight schedules. Any lost time can throw off months of planning and affect several facilities.

The cladding process leaves little room for error. Maintaining the proper amount of metallurgical dilution between the mild carbon steel tubes and the Inconel cladding demands controlling the total heat input created by the welding process. Pulsed GMAW helps the company achieve high productivity while controlling heat input.

Extending Service Life

During regularly scheduled maintenance shutdowns, every inch of tubing is ultrasonically measured. The tubing starts

with a 0.235-in. wall thickness. When it thins to 0.140 in. thick, the company clads it with a 0.070-in. layer of Inconel 625, which extends tubing life up to 12 to 15 years, according to Hooper. Without cladding, the tubes would last a couple of years before needing replacement.

During the cladding process, the molten Inconel partially melts the base metal and combines with it.

"Maintaining the proper dilution rate is critical when applying Inconel," Hooper said. "When you apply it to the carbon steel, you need a dilution rate that keeps it from wanting to fall off the tube. However, the dilution rate needs to be low enough so that it doesn't either pull the iron up into the face of the weld or impact the free chromium content and reduce Inconel's corrosion-resistant properties. To get the desired dilution rate (7 to 10% of the base metal) and keep it from cracking, you need to use a pulsed GMAW arc."

With GMAW-P, the power source switches between a high peak current and a low background current. The peak current pinches off a spray transfer droplet and propels it toward the weld. The background current maintains the arc, but is too low for metal transfer to occur.

"Pulsed GMAW helps to control the heat," Hooper explained. "A straight (spray transfer) GMAW process adds too much heat to the molten metal, which reduces chrome content in the finished product. With too much heat, you get a higher iron dilution rate and decreased corrosion resistance."

Complicated Problems

Although GMAW-P provides a solution, older technology complicated the process of establishing and maintaining pulsing parameters. Some combinations of base metals and welding wires required an engineer to set all of the parameters.

"Some contractors thought all you had to do was buy a pulsed GMAW machine," Hooper said. "But there was more to it. We had to program the trim (arc length), the actual pulsed frequency, delay time of the pulse (pulse width), and other parameters for every individual wire size and type. Our previous power sources weren't very user-friendly. It took somebody who had been around them a long time to be able to set them to weld Inconel. You couldn't just send in a new kid to turn a



Fig. 2 — Inconel cladding protects the tubes that make up the boiler, extending their lives from 3 to 15 years. To maintain the proper dilution rate, GMAW-P is used.

machine on and set it for Inconel. You had to know exactly what button to push or you'd be welding with the wrong processes or wrong parameters."

The difficulty in dialing in the previous machines led to lengthier training periods and required Hooper to closely monitor machine settings with most of his operators.

For a solution to this problem, Hooper and Gregg Pruett, Covanta regional maintenance manager, sought out new pulsed GMAW technology.

Simple Pulsing Solutions

The newest generation of pulsed GMAW welding systems use advanced technology to do the following:

- Reduce training time to a few hours for experienced welders.
- Simplify machine setup to the point where an operator is ready to weld within 30 s after turning on the machine.
- Relieve operators and engineers from the burden of setting complex pulse parameters.
- Use simple controls that enable welders to customize arc length and arc cone width to match their personal preferences and/or application requirements.
- Increase travel speeds and eliminate arc restrikes (unintended short circuits).

For simple operation, Covanta selected a system that featured factory-set pulsing programs. While several such

JIM RAPPL is with Miller Electric Mfg. Co. (www.millerwelds.com), Appleton, Wis.



Fig. 3 — Brad Hooper walks through the four-step setup for setting pulsed GMAW parameters on the XMT 350 MPA. The units retain settings for each process, so they can easily be switched from GMAW-P to SMAW and back with a simple turn of the knob.

models are available, the company selected a model (the XMT® 350 MPA from Miller Electric Mfg. Co.) that included programs for the wire types (nickel alloy) and diameters (0.035 and 0.045 in.) used for cladding.

When using the unit's factory-set programs, operators use the process selector control knob to select from available welding processes (gas metal arc welding, pulsed gas metal arc welding, shielded metal arc welding, and gas tungsten arc welding). Additionally, a mode is available for operators using voltage sensing wire feeders for gas metal arc or pulsed gas metal arc welding.

After selecting a process, the operator then uses a single pushbutton and control knob to scroll through menus to select the preferred arc shape for weld pool control and desired bead appearance, wire diameter and type, and shielding gas for the application at hand — Fig. 3. The system

only provides correct options, preventing such errors as selecting 100% argon shielding gas for a steel wire.

The operator then sets the desired wire feed speed on his or her remote control wire feeder, and the power source tells him the best voltage/arc length setting to achieve optimal results. The operator, however, can adjust this setting for any wire feed speed and tailor the arc length as desired.

For the most part, the company's operators set welding parameters once, accounting for the dilution rate, penetration, and their preferences, and that's the only time they touch the controls.

The Long and Short of It

When performing the cladding process or when using highly alloyed metals, operators need to tailor the arc length to suit their needs, shortening the arc to reduce

heat input and help the operator “push the (pool) around and get the desired tie-in,” Hooper explained — Fig. 4. Shortening the arc with the older pulsed GMAW units would often lead to short circuits that would cause inclusions in the weld bead or other defects that would require reworking. As a result, welders held a longer than desired arc. Longer than desired arc length can cause more heat to be applied to the weldment.

Hooper said that with the older technology, the company's welders couldn't weld faster than 300 in./min without experiencing a lot of shorts. With the newer power sources, they average 350–400 in./min and can even weld 500–540 in./min in some applications.

When he mentions “tailoring the arc,” Hooper is referring to two additional controls available on newer GMAW-P systems. When switching from standard GMAW to pulsed GMAW, the control knob that operators think of as “voltage control” instead enables them to adjust arc length to match their personal preference or joint configuration.

This arc length control helps set optimum welding parameters, reducing unintended short circuits and flare-ups, such as when the operator needs a long electrode extension to reach into a tight space.

The other control adjusts the width of the arc cone. Using a lower setting results in a wider arc cone that has greater wetting action, increased weld pool fluidity, and a flatter weld bead. A higher setting narrows the arc cone, which produces a narrower, faster-freezing weld bead with less heat input.

Lastly, as Hooper noted, with today's microprocessors, software at the heart of pulsed GMAW technology also addresses the issue of short circuits and subsequent arc re-strikes. Newer systems sample arc characteristics thousands of times per second and include feedback loops that can react to changing arc conditions and clear short circuits before they adversely affect the weld pool or throw unmelted wire and/or spatter.

In addition to benefiting other types of cladding, the newer GMAW-P technology can address productivity and quality issues in other pulsed GMAW/alloy metal applications requiring portability, notably those in power piping, petrochemical, and shipbuilding.

Easier training, more operator control, eliminating inclusions and rework, 30% faster travel speeds, and freeing the maintenance technician have important ramifications for Covanta.

“We try to minimize downtime in the facilities as far as boiler availability. Time to us is money, Pruett said.” New pulsed GMAW systems help Covanta achieve that goal. ♦



Fig. 4 — Operators need to be able to hold a short arc length for maximum weld pool control.



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CONFERENCES

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Joining Dissimilar Metals Conference
Orlando, Fla.
March 3, 4

International Brazing & Soldering Conference
Orlando, Fla.
April 26-29

12th Aluminum Welding Conference
Toronto, Ont., Canada
May 5, 6

Shipbuilding Conference
New Orleans, La.
June 16, 17

**Weld Cracking VII Conference:
'The Heat-Affected Zone'**
Columbus, Ohio
June 9, 10

**Welding of Corrosion-Resistant Alloys
Conference**
New Orleans, La.
October 6, 7

Adhesive Bonding Conference
Chicago, Ill.
November 16

Welding of Chrome-Moly Steels Conference
Chicago, Ill.
November 17

Orbital Welding Conference
Chicago, Ill.
November 18

International Thermal Spray Conference
Chicago, Ill.
November 18

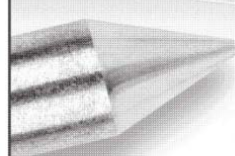
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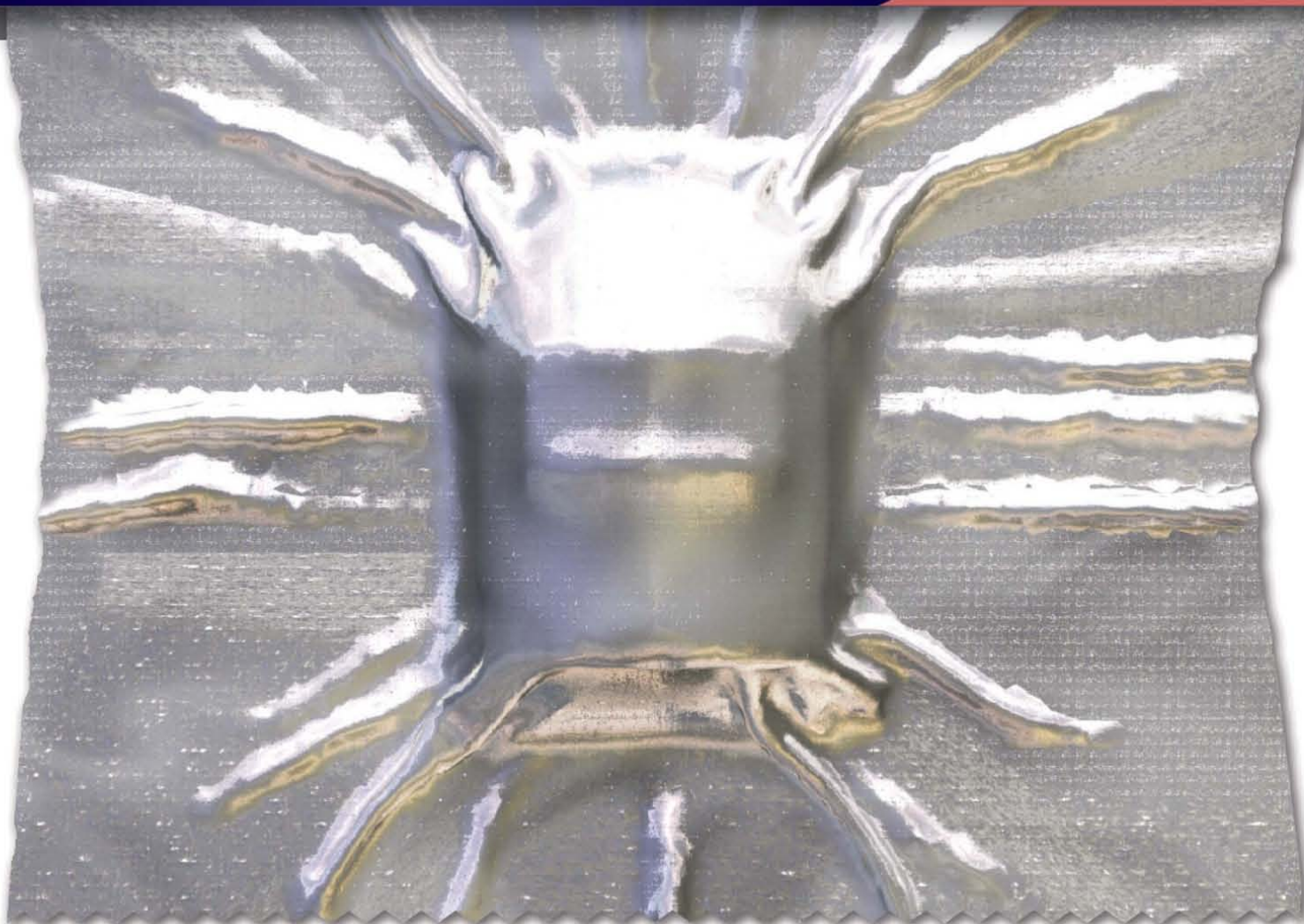


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PACE 2009, The Power of Paint and Coatings. Feb. 15–18, New Orleans Convention Center, New Orleans, La. Visit www.pace2009.com.

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

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

◆ **GAWDA Spring Management Conf. 1.** March 22–24, Chicago, Ill. Sponsored by Gases and Welding Distributors Assn. Visit 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; or call (407) 380-1553.

ABB Automation & Power World 2009. March 24–26, Orlando World Center Marriott, Orlando, Fla. Visit www.abb.com/a&pworld.

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.

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, www.sme.org/nano.

North American Steel Construction Conf. and AISC Steel Construction Expo. April 1–4, Phoenix, Ariz. Visit www.aisc.org.

The Aluminum Assn. Spring Meeting. April 20–22, Omni La Mansion del Rio, San Antonio, Tex. Visit www.aluminum.org.

◆ **GAWDA Spring Management Conf. 2.** April 22–24, Asheville, N.C. Sponsored by Gases and Welding Distributors Assn. Visit 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.

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.

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.

Offshore Technology Conf. May 4–7, Reliant Center, Houston, Tex. Visit 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.

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

Advanced Manuf. Expo. and Plant Maintenance & Design Engineering Show. May 19–21, Place Bonaventure, Montreal, Que., Canada. Contact Society of Mfg. Engineers, (800) 733-4763, 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.

Beijing-Essen Welding & Cutting Fair. June 2–5, Shanghai, China. Visit www.beijing-essen-welding.de.

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

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; 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.

First Int'l Conf. on Welding Technologies. June 11–13, Gazi University, Ankara, Turkey. Visit 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.

Western Manufacturing Technology Show. June 16–18, Northlands Park-AgriCom, Edmonton, Alb., Canada. Contact Society of Manufacturing Engineers, (800) 733-4763; or visit www.sme.org.

6th Int'l Expo on Electrical Engineering, Equipment, and Contractors. July 8–10, Shanghai, PR, China. Visit www.2456.com/ep.

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

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

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

◆ **Welding Corrosion-Resistant Alloys Conf.** Sept. 22, 23, New Orleans, La. Contact American Welding Society, (800/305) 443-9353, ext. 229; or visit www.aws.org.

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

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

The Aluminum Assn. Annual Meeting. Oct. 25–27, Charleston Place, Charleston, S.C. Visit www.aluminum.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.

♦ **Adhesive Bonding Conf.** Nov. 16, Chicago, Ill. Held during the FABTECH International & AWS Welding Show. Contact American Welding Society, (800/305) 443-9353, ext. 455; or visit www.aws.org.

♦ **Welding Chrome-Moly Steels Conf.** Nov. 17, Chicago, Ill. Held during the FABTECH International & AWS Welding Show. Contact American Welding Society, (800/305) 443-9353, ext. 455; or visit www.aws.org.

♦ **Int'l Thermal Spray Conf.** Nov. 18, Chicago, Ill. Held during the FABTECH International & AWS Welding Show. Contact American Welding Society, (800/305) 443-9353, ext. 455; or visit www.aws.org.

♦ **Orbital Welding Conf.** Nov. 18, Chicago, Ill. Held during the FABTECH International & AWS Welding Show. Contact American Welding Society, (800/305) 443-9353, ext. 455; or visit www.aws.org.

♦ **Power-Gen Int'l**, Dec., 8–10, Las Vegas, Nev. Contact American Welding Society, (800/305) 443-9353, ext. 455; or visit 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.

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.

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

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

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

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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
Pittsburgh, PA	Feb. 1-6	Feb. 7
Denver, CO	Feb. 1-6	Feb. 7
Seattle, WA	Feb. 1-6	Feb. 7
Miami, FL	EXAM ONLY	Feb. 19
Milwaukee, WI	Mar. 1-6	Mar. 7
Indianapolis, IN	Mar. 1-6	Mar. 7
Atlanta, GA	Mar. 1-6	Mar. 7
Houston, TX	Mar. 8-13	Mar. 14
San Diego, CA	Mar. 8-13	Mar. 14
Norfolk, VA	Mar. 8-13	Mar. 14
Miami, FL	EXAM ONLY	Mar. 19
Rochester, NY	EXAM ONLY	Mar. 21
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
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

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
Long Beach, CA	Feb. 2-6	Feb. 7
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

For information on any of our seminars and certification programs, visit our website at 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.



SOCIETY NEWS

BY HOWARD M. WOODWARD

AWS Elects National and District Officers for 2009



*Victor Y. Matthews
president*



*John C. Bruskotter
vice president*



*John L. Mendoza
vice president*



*William A. Rice Jr.
vice president*

The American Welding Society elected its incoming slate of national officers Oct. 6 at the AWS Annual Meeting held during the FABTECH International & AWS Welding Show in Las Vegas, Nev. The officers take their posts on Jan. 1.

Victor Y. Matthews, an AWS Distinguished Member and past District 10 director, was elected president. Matthews has worked with The Lincoln Electric Co. since 1963, where he currently is responsible for consumables, GTA and SMA welding machines, plasma arc cutting machines, inverters under 300 A, and is liaison to the Italian subsidiaries. He has been a member of the Cleveland Section for 39 years.

John C. Bruskotter was elected to his third term as an AWS vice president. He operates Bruskotter Consulting Services, working for an independent oil and gas operator. He is a past chairman of the

New Orleans Section and a past District 9 director.

John L. Mendoza was elected to his second term as an AWS vice president. Mendoza, a past District 18 director, is a journeyman welder, AWS Certified Welding Inspector, and Certified Welding Educator. He has performed power plant maintenance for CPS Energy, San Antonio, Tex., for 33 years.

William A. Rice Jr. was elected to his first term as an AWS vice president. Rice serves as a part-time CEO for OKI Bering Supply, and is a member of the boards of trustees for several health and financial organizations in West Virginia. He worked for Airgas from 1993 to 2001 where he served as its president and COO.

Donald B. DeCorte has been elected a director-at-large. DeCorte is vice president, sales and marketing, a member of the board of directors, and a co-owner of



*Donald B. DeCorte
director-at-large*

RoMan Mfg. Inc., in Grand Rapids, Mich., where he has worked for 15 years. He has been a member of the AWS Detroit Section since 1980.

Thomas A. Siewert has been elected a director-at-large. Siewert is the leader of the Structural Materials Group at the National Insti-



*Thomas A. Siewert
director-at-large*

tute of Standards and Technology in Boulder, Colo. During the past 25 years, his group has conducted investigations into the causes of failures of pipelines and buildings, including the collapse of the World Trade Center towers, as well as studying weld sensing and consumables issues.

District Directors Take Their Posts on January 1st



*Michael Wiswesser
District 3 director*



*Kenneth A. Phy
District 6 director*



*George D. Fairbanks
District 9 director*



*Sean P. Moran
District 12 director*



*Mace Harris
District 15 director*



*John R. Bray
District 18 director*



*Nanette Samanich
District 21 director*

Michael Wiswesser has been elected to his first term as District 3 director. Wiswesser is operations manager at Welder Training and Testing Institute (WTTI) in Allentown, Pa. He has directed the expansion of a number of educational programs, including welding and nondestructive testing. He serves as vice president of WTTI's board of directors, and serves as treasurer on the Pennsylvania Association of Welding Educators board of directors.

Kenneth A. Phy has been elected to his first term as District 6 director. Phy has worked in the nuclear power industry since 1986. Currently, he is senior project manager at Entergy Nuclear Operations, Inc., James A. FitzPatrick Nuclear Power Plant in Lycoming, N.Y.

George D. Fairbanks Jr. has been elected to his first term as District 9 director after fulfilling the last two years of John C. Bruskotter's term. Currently, he is president of Fairbanks Inspection & Testing Services. Previously, he was senior welding inspector at Gonzales Industrial X-Ray. He holds numerous certifi-

cations, including Certified Welding Inspector and Certified Welding Educator. In 2004, he received the National Dalton E. Hamilton CWI of the Year Award.

Sean P. Moran has been reelected to serve a second term as District 12 director. Currently, he is a business development manager at Hobart Brothers Co., an ITW company. He joined the ITW welding group in 1999 as a welding engineer. He has worked ten years as a welding instructor for secondary and postsecondary public and private institutions. Moran is a Certified Welding Inspector, Certified Welding Educator, and Certified Welding Supervisor. He is a vice chair of the Education Scholarship Committee and the Volume 3 Handbook Committee, and is a member of the Product Development and D1.1 Committees.

Mace Harris, an account manager at Valley National Gases in Richfield, Minn., has been reelected to his second term as District 15 director. Earlier, he worked for Reynolds Welding Supply as a route salesman, and as a mechanic and a welder. An AWS member since 1990

with the Northwest Section, Harris plays a leadership role in the Minnesota SkillsUSA welding contests.

John R. Bray, after fulfilling the term vacated by John Mendoza, has been elected to his first term as District 18 director. Since 1996, Bray has served as president of Affiliated Machinery, Inc., in Pearland, Tex., one of the Associated Equipment LP companies. An AWS member since 1988, he was elected to the Houston Section Membership Committee in 1989, and has since served in most posts, including Section chairman.

Nanette Samanich has been elected to her first term as District 21 director. Currently, she is a senior inspector with Ninyo & Moore in Las Vegas, Nev. She is a Certified Welding Inspector, an ACCP Level II visual inspector, and a certified fireproofing inspector. Samanich has served AWS in the Nevada Section as chairman (2001-2004), and as District 21 deputy director from 2000 to 2001, and from 2006 to the present. She has received the AWS District Meritorious Award, and Section and District CWI of the Year Awards. ♦

Accredited Test Facility (ATF) Auditors Train in Miami



All active AWS Accredited Test Facility (ATF) auditors met at the Society's headquarters in Miami Oct. 28–30 for a mandatory training program conducted by Senior Auditor **David Diaz** with guest speakers **Stanley Raymond** and **Jeffrey Hufsey**. The purpose of the training was to standardize auditing practices that related to the AWS Accredited Testing Facility Program. In attendance were auditors **James Sekely**, **Steven Snyder**, **Charles**

McGowan, **Lyndsey Deckard**, **John Bossone**, and **Hector Garcia**. Attending were representatives from the International Assn. of Bridge, Structural, Ornamental, and Reinforcing Iron Workers **Edward Abbott**, **Michael McDonald**, **Richard Munroe**, **Grady Brown**, **Jim Galik**, and **Michael Relyin**; representatives from the International Training Institute for the Sheet Metal and Air Conditioning Industry **Michael Harris**, **Michael**

Sloan, **Timothy Mihalik**, **Michael Miller**, **Steve Kowats**, and **George Donovan**; and representatives from World Engineering Xchange (WEX) Ltd. **Jeffrey Kennedy** and **Jim Bunce**. AWS staff members participating in the program included Executive Director **Ray Shook**, Deputy Executive Director **Cassie Burrell**, and Certification Department representatives **John Filippi**, **Priti Jain**, **Terry Perez**, **Emil Pagoaga**, and **Frank Lopez Del Rincon**.

Lilama Technical & Technology College 2 Becomes the First Vietnamese AWS Accredited Test Facility



AWS Deputy Executive Director **Cassie Burrell** (red sweater) presents the Accredited Test Facility (ATF) membership plaque to **Le Van Hien**, director, Lilama Technical & Technology College 2 based in Dong Nai, Vietnam. The college is the first accredited test facility in Vietnam. Shown above are (from left to right) **Martha Concepcion**, **Cassie Burrell**, **Priti Jain**, **Le Van Hien**, **Steve Snyder**, **Terry Perez**, **John Filippi**, **Peter Howe**, **Vu Quang Huy** (assistant to the director), and **Emil Pagoaga**. **Steve Snyder** performed the audit accrediting the facility.

Tech Topics

Interpretations — D1.1, Structural Welding Code — Steel

Subject: Procedure Qualification — Material and Position

Code edition: D1.1:2002

Code provision: Clause 4

AWS Log: D1.1-02-I07

Inquiry 1: Is it the intent of AWS D1.1, 1990 and later editions, that a prequalified welding procedure may be used with a foreign material specification (e.g., JIS or DIN) provided that the foreign material specification is determined to be of equivalent in chemical composition and mechanical properties to an ASTM material permitted in AWS D1.1 for use with prequalified welding procedures?

Response: No, see Clause 3.3.

Inquiry 2: Is the intent of AWS D1.1, 1990 and later editions, that a procedure previously qualified in accordance with ASME Section IX, is acceptable for use in AWS D1.1 applications without respect to the position in which the welding procedure was qualified (since ASME Section IX imposes position restrictions only on welder qualifications, and not on welding procedure qualifications)?

Response: No, but may be permitted by Subclause 4.1.1.2.

Subject: Tables 4.2 and 4.14

Code edition: D1.1:2006

Code provision: Tables 4.2 and 4.14

AWS Log: D1.1-06-I02

Inquiry 1: AWS D1.1 Table 4.2 appears to be silent regarding base metal qualification on unequal base metal thicknesses — as might occur in a corner or T-joint. For a corner or T-joint, does AWS require that both base metals qualified on the WPS to fall within the range qualified?

Response: No, see 4.9.1.1. The procedure needs to be qualified for the thickness of the weld.

Inquiry 2: Note “d” of AWS D1.1 Table 4.2 states that a CJP groove weld on any thickness will qualify any PJP groove weld for any thickness. Therefore, if a fabricator has a WPS that was qualified on a ½-in. plate CJP groove weld, then the WPS is qualified for a CJP weld on a base metal thickness up to ½ in. However, as allowed by Note d, if the fabricator does not have a WPS to cover a base metal thickness greater than ¼ in. for welding a CJP groove weld, then the fabricator may revert to a PJP using this WPS so that any thickness of plate or pipe can be welded. Is this the intent of Note d from Table 4.2?

Response: No, see 1.4.1. The fabricator cannot change from a CJP to a PJP without the approval of the Engineer.

Inquiry 3: Table 4.14 of AWS D1.1 does not contain SAW or GMAW processes for CVN test requirements. If CVN testing is required by the PO, what

are the test locations required by AWS D1.1 for these processes?

Response: Table 4.14 has been revised in D1.1:2008 to include the SAW and GMAW processes. CVN test locations are located as noted in 4.34 unless otherwise specified in the contract documents.

Subject: Clause 4.10.3, Table 4.2 Note “d”

Code edition: D1.1:2006

Code provision: Clause 4.10.3, Table 4.2

AWS Log: D1.1-06-I04

Inquiry: Paragraph 4.10.3 and Table 4.2 Note “d” seem to contradict each other. When a WPS has been qualified for a CJP groove and is applied to a PJP groove are macroetch tests required?

Response: Yes, macroetch tests are required. See 4.10.3.

Subject: PQR Retest

Code edition: D1.1:2006

Code provision: Subclause 4.8.5

AWS Log: D1.1-06-I05

Inquiry: I don’t have enough length to remove the specimens for the retest and I have to repeat the side bend. Can I weld a new test piece, done using the same parameters of WPS used initially to manufacture specimens for the retest?

Response: Retests for that particular type of test specimen may be performed with specimens cut from the same WPS qualification material, see 4.8.5.

Standards for ANSI Public Review

A5.12M/A5.12:200X (ISO 6848:2004 MOD), *Specification for Tungsten and Oxide Dispersed Tungsten Electrodes for Arc Welding and Cutting*. Revised — \$25. Review expired 12/29/2008.

A5.22/A5.22M:200X, *Specification for Stainless Steel Flux Cored and Metal Cored Welding Electrodes and Rods*. Revised — \$42. Review expires 01/12/2009.

C6.1-89 (R200X), *Recommended Practices for Friction Welding*. Reaffirmed — \$25. Review expired 12/29/2008.

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 dur-

ing 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.

Standard Approved by ANSI

A5.14/A5.14M:2009, *Specification for Nickel and Nickel-Alloy Bare Welding Electrodes and Rods*. Approved 10/28/2008.

ISO Standards for Public Review

ISO/DIS 14171, *Welding consumables — Solid wire electrodes, tubular cored electrodes and electrode/flux combinations for submerged arc welding of nonalloy and fine-grain steels — Classification*

ISO/DIS 14174, *Welding consumables — Fluxes for submerged arc welding and*

electroslag welding — Classification

ISO/DIS 14341, *Welding consumables — Wire electrodes and deposits for gas shielded metal arc welding of nonalloy and fine-grain steels — Classification*

ISO/DIS 7291.2, *Gas welding equipment — Pressure regulators for manifold system used in welding, cutting and allied processes up to 30 000 kPa (300 bar)*

Technical Committee Meetings

Jan. 15, Committee on Personnel and Facilities Qualification. Miami, Fla. Contact: J. L. Gayler, ext. 472.

Jan. 29, International Standards Activities Committee. Miami, Fla. Contact: A. R. Davis, ext. 466.

Jan. 29, 30, Technical Activities Committee. Miami, Fla. Contact: J. L. Gayler, ext. 472.

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Generon IGS is a division of Innovative Gas Systems (IGS), a global technology company that specializes in systems that produce industrial nitrogen, oxygen, and process gas separations. IGS also has operating facilities in Germany, Italy, Russia, China, Thailand, and the Middle East region.

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4Front Engineered Solutions
1612 Hutton Dr. #140
Carrollton, TX 75006

Advanced Entertainment Tech
735 Los Angeles Ave.
Monrovia, CA 91016

BuhlerPrince
670 Windcrest Dr.
Holland, MI 49423

Cambridge Materials Testing
1177 Franklin Blvd., Unit 2
Cambridge, ON N1R 7W4, Canada

Contratistas Civiles & Mecanicos
Av 27 de Febrero 1760 Alameda
Santo Domingo 10902
Dominican Republic

Cro Magnon Corp.
1509 East Tower Phil
Stock Exchange Center
Exchange Rd., Ortigas Center
Pasig City 1700, Philippines

Downey Metal Products
907 Oothcalooga St.
Calhoun, GA 37001

Falat Pejvak Co.
Unit 12, No. 2, 4th St. Gandhi St.
Tehran 1517739516, Iran

G2 Metal Fab
224 Rickenbacker Cir.
Livermore, CA 94551

Gainey Machine & Fab. LLC
961 Patrick Hwy.
Hartsville, SC 29550

Imperial Fabricating Co.
160 Kirby Dr.
Portland, TN 37148

Industrial Global Supply SA de CV
Benito Juarez N. No. 109
Queretaro 76000, Mexico

ITA Industrial
Estrada Do Gramado 290
Embu São Paulo 06833902, Brazil

J Julian & Asociados SA
EPS #A-611, 8260 NW 14th St.
Doral, FL 33126

MGS Inc.
178 Muddy Creek Church Rd.
Denver, PA 17517

Mantenimiento & Construcciones SA
Alcaldediaz 6th St. #602
Panama El Dorado, Panama

Red Head Oil and Gas Services Co.
Dammam King Saud Bin Abdulaziz St.
Najd Bldg., Dammam 31433
PO Box 10907, Dammam Eastern
Province, Saudi Arabia

Ribolt Fabrication LLC
13814 KY 57
Tollesboro, KY 41189

Smith Metal Works
PO Box 852
Phenix City, AL 36870

Tri-Angle Welding Supply
520 Crane St., Unit A
Lake Elsinore, CA 92530

Supporting Companies

Caltrop Corp.
2200 Powell St., Ste. 1125
Emeryville, CA 94608

Icesa Welding Systems
Ave. San Vicente 7,
San Miguel Xochimanga
Atizapan Estado de Mexico 52927
Mexico

ITER dba MIS
PO Box 363453
San Juan, PR 00936

The Rose Corp.
401 N. 8th St.
Reading, PA 19601

Powell-Delta/Unibus Div.
515 Railroad Ave.
Northlake, IL 60164

Membership Counts

Member Grades	As of 12/01/08
Sustaining.....	508
Supporting.....	309
Educational.....	484
Affiliate.....	467
Welding distributor.....	49
Total corporate members.....	1,817
Individual members.....	49,419
Student + transitional members.....	5,315
Total members.....	54,734

Stegner Controls
3333 Bald Mountain Rd.
Auburn Hills, MI 48326

Educational Institutions

Ashland County/
West Homes Career Center
1783 S.R. 60
Ashland, OH 44805

Earle C. Clements Job Corps Academy
2302 U.S. Hwy. 60 E.
Morganfield, KY 42437

Panola College
678 Roughrider
Center, TX 75935

Pirad International Inspection Co.
Eram St. Alley #2, Faramod Bldg.
First Fl., Unit #1
Shiraz, Fars 71438-37416, Iran

Plumber's L. U. No. 1, Training Center
37-11 47th Ave.
Long Island City, NY 11101

PVD Technical Training and
Certification Joint Stock Co.
Dong Xuyen Ind. Zone, 30/4 Rd.
Rach Dua Ward, Vung Tau City, SR
Vietnam

Southwestern Oregon C. C.
1988 Newmark Ave.
Coos Bay, OR 97420

Sury Engineering Technology
Temple Gate, Thalasserry
Kannur, Keral G70102, India

Taft Union High School
701 7th St.
Taft, CA 93268

Member-Get-A-Member Campaign

Shown are the Nov. 11 standings for the 2008–2009 campaign. See page 67 of this *Welding Journal* or visit www.aws.org/mgm for rules and prize list. Call the Membership Dept., (800) 443-9353, ext. 480, regarding your status.

Winner's Circle

Sponsored 20+ new members.

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

J. Compton, San Fernando Valley⁷
E. Ezell, Mobile⁶
J. Merzthal, Peru²
G. Taylor, Pascagoula²
L. Taylor, Pascagoula²
B. Mikeska, Houston¹
R. Peaslee, Detroit¹
W. Shreve, Fox Valley¹
M. Karagoulis, Detroit¹
S. McGill, NE Tennessee¹
T. Weaver, Johnstown/Altoona¹
G. Woomer, Johnstown/Altoona¹
R. Wray, Nebraska¹
M. Haggard, Inland Empire¹

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

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 3 or more students.

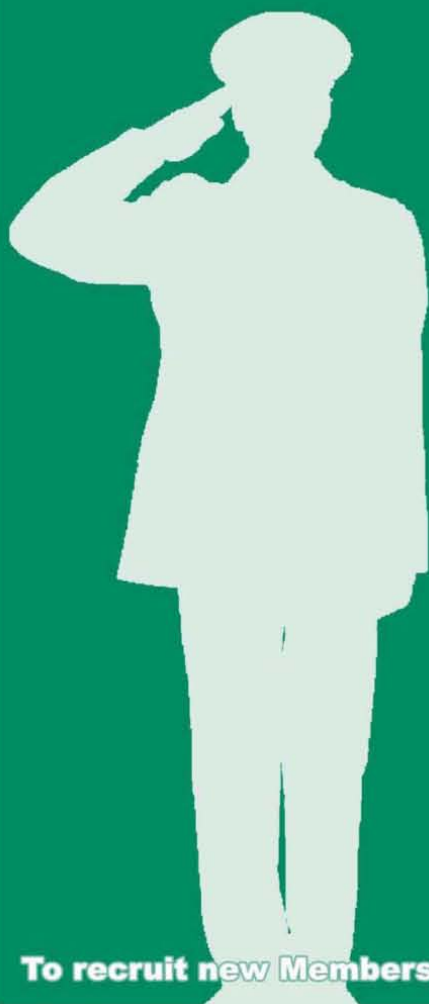
D. Berger, New Orleans — 110
B. Benyon, Pittsburgh — 41
A. Baughman, Stark Central — 36
A. Rowe, Philadelphia — 36
A. Zinn, Eastern Iowa — 34
T. Moore, New Orleans — 32
J. Carney, Western Michigan — 26
E. Norman, Ozark — 26
S. Siviski, Maine — 26
R. Newman, Maine — 24
R. Cook, Utah — 23
D. Schnalzer, 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
W. Geiger, North Central Florida — 3
D. Hamilton, Chattanooga — 3
J. Hayes, Oklahoma City — 3
D. Saunders, Holston — 3

Gov. Whitman Confers with Society Staff



Christine Todd Whitman, cochair of CASEnergy Coalition and a former governor of the state of New Jersey and Environmental Protection Agency administrator, met with Executive Director Ray Shook at AWS headquarters in Miami, Fla., Oct. 12 to discuss energy initiatives. The CASEnergy (Clean and Safe Energy) Coalition is an advocacy organization for nuclear energy. Whitman is also president of the Whitman Strategy Group, a consulting firm that specializes in government relations and environmental and energy issues. She currently serves on the boards of directors of S. C. Johnson and Son, Inc., Texas Instruments, United Technologies, and the Council on Foreign Relations.



AWS IS ON A MISSION

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

MISSION: AWS is looking for individuals to become part of an exclusive group of AWS Members who get involved and win. Give back to your profession, strengthen AWS and win great limited-edition prizes by participating in the 2007-2008 Member-Get-A-Member Campaign. By recruiting new members to AWS, you're adding to the resources necessary to expand your benefits as an AWS Member. Year round, you'll have the opportunity to recruit new members and be eligible to win special contests and prizes. Referrals are our most successful member recruitment tool. Our Members know first-hand how useful AWS Membership is, and with your help, AWS will continue to be the leading organization in the materials joining industry.



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

PRIZE CATEGORIES

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

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

President's Roundtable: Recruit 9-19 new Individual Members and receive an American Welder™ camouflage t-shirt, hat and an AWS key chain.

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

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

SPECIAL PRIZES

Participants will also be eligible to win prizes in specialized categories. Prizes will be awarded at the close of the campaign (June 2008).

Sponsor of the Year: The individual who sponsors the greatest number of new Individual Members during the campaign will receive a plaque, a trip to the 2008 FABTECH International & AWS Welding Show, and recognition at the AWS Awards Luncheon at the Show.

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

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

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

LUCK OF THE DRAW

For every new member you sponsor, your name is entered into a quarterly drawing. The more new members you sponsor, the greater your chances of winning. Prizes will be awarded in November 2007, as well as in February and June 2008.

Prizes Include:

- ★ Complimentary AWS Membership renewal
- ★ American Welder™ camouflage t-shirt
- ★ American Welder™ camouflage hat

SUPER SECTION CHALLENGE

The AWS Section in each District that achieves the highest net percentage increase in new Individual Members before the June 2008 deadline will receive special recognition in the *Welding Journal*.

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

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



American Welding Society

Visit www.aws.org

SPECIAL OFFER FOR NEW AWS INDIVIDUAL MEMBERS – TWO YEARS FOR \$135 (a \$25 savings)

★ PLUS... Get a popular welding publication for only \$25 (\$192 value)

AWS MEMBERSHIP APPLICATION

4 Easy Ways to Join or Renew:

- ✉ Mail this form, along with your payment, to AWS
- ☎ Call the Membership Department at (800) 443-9353, ext. 480
- 📠 Fax this completed form to (305) 443-5647
- 💻 Join or renew on our website <www.aws.org/membership>

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

Last Name _____

First Name _____ M.I. _____

Title _____ Birthdate _____

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

Primary Phone () _____ Secondary Phone () _____

FAX () _____ E-Mail _____

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

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

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

ADDRESS

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

Company (if applicable) _____

Address _____

Address Con't. _____

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

PROFILE DATA

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

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

PAYMENT INFORMATION (Required)

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



New Member? ☐ Yes ☐ No

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

Domestic Members add \$25 for book selection (\$192 value), and save up to 87%†.....\$ _____ (Optional)
International Members add \$75 for book selection (note: \$50 is for international shipping) ††..\$ _____ (Optional)
(Note: Book Selection applies to new Individual Members only – Book selections on upper-right corner)

TOTAL PAYMENT\$ _____

AWS STUDENT MEMBERSHIP†††

☐ Domestic (Canada & Mexico incl.).....\$15
☐ International\$50
TOTAL PAYMENT.....\$ _____

NOTE: Dues include \$18.70 for *Welding Journal* subscription and \$4.00 for the AWS Foundation.
\$4.00 of membership dues goes to support the AWS Foundation.

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

- ☐ Check ☐ Money Order ☐ Bill Me
☐ American Express ☐ Diners Club ☐ Carte Blanche ☐ MasterCard ☐ Visa ☐ Discover ☐ Other

Your Account Number _____

Expiration Date (mm/yy) _____

Signature of Applicant: _____ Application Date: _____

Office Use Only

Check # _____ Date _____ Account # _____

Source Code **WJ** _____ Amount _____



American Welding Society

ISO9001 Registered Organization

Miami, FL 33144-0367

Telephone (800) 443-9353

FAX (305) 443-5647

Visit our website: www.aws.org

Member Services Revised 5/4/06

†Two-year Individual Membership Special Offer: applies only to new AWS Individual Members. ††Discount Publication Offer: applies only to new AWS Individual Members. Select one of the four listed publications for an additional \$25; International Members add \$75 (\$25 for book selection and \$50 for international shipping); Multi-Year Discount: First year is \$80, each additional year is \$75. No limit on years (not available to Student Members). †††Student Member: Any individual who attends a recognized college, university, technical, vocational school or high school is eligible. Domestic Members are those students residing in North America (incl. Canada & Mexico). This membership includes the *Welding Journal* magazine. Student Memberships do not include a discounted publication. **Airmail Postage Option:** International Members may receive their magazines via Airmail by adding \$99 to the annual dues amount.

BOOK/CD-ROM SELECTION

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

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

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

☐ **New Member** ☐ **Renewal**

A free local Section Membership is included with all AWS Memberships
Section Affiliation Preference (if known):

Type of Business (Check ONE only)

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

Job Classification (Check ONE only)

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

Technical Interests (Check all that apply)

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

SECTION NEWS



Jim Shore (left) receives his chairman's pin from Russ Norris, District 1 director, at the joint Boston and Maine Sections' program.

District 1

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

BOSTON & MAINE

NOVEMBER 3

Activity: More than 50 members of the Boston and Maine Sections toured the Westinghouse Nuclear Component Manufacturing Facility in Newington, N.H. Highlighted was welding of the stainless and high-alloy steels used in the nuclear power industry. The presenters included **Tim Chase, Jon Stuart, and Bob Digiulio**. The dinner was held at Newick's Lobster House where **Jim Shore** was presented his chairman's pin by **Russ Norris**, District 1 director.



Shown at the joint Boston and Maine Sections' program are (from left) Tim Chase, Tom Ferri, Jon Stuart, and Bob Digiulio.



Manning the welding booth at the Old Colony Regional Vo-Tech High School career day are (from left) Stacy DeTerra, Bryan Buckley, Jason Wood, Shawn Casey, Cory Calise, and Katharina Callahan. The booth was set up by the Central Mass./Rhode Island Section members.

CENTRAL MASSACHUSETTS/ RHODE ISLAND

NOVEMBER 5

Activity: The Section participated at the Old Colony Regional Vo-Tech High School, Rochester, Mass., career awareness days for the eighth-grade students in the school district. Manning the welding booth were students **Stacy DeTerra, Bryan Buckley, Jason Wood, Shawn Casey, Cory Calise, and Katharina Callahan**. They distributed the Iron Man comic books and allowed the boys and girls to practice GTA and GMA welding projects. About 300 students visited the booth during the event.



Welding was popular with the eighth-grade students at the Old Colony Regional Vo-Tech High School career day event, supported by the Central Mass./Rhode Island Section.



Shown at the Green & White Mountains Section event are (front, from left) Richard Fuller, Chair Ray Hendersen II, Perley Lund, Jennifer Eastly, and Ernie Plumb; (back, from left) Joe Torkarski, Gilbert LeClair, Phil Witteman, Gary Buckley, John Steel, and Geoff Putnam.



Taking care of Connecticut Section business are (seated, from left) Walt Chojnacki, Chair Gary Shubert, and John Matthews; (standing, from left) District 1 Director Russ Norris, Bob Cullen, and Nino Olivares.



Shown at the Maine Section business meeting are (seated) Ray Roy, and (standing, from left) Chair Scott Lee, Mike Gendron, and Russ Norris, District 1 director.

CONNECTICUT

OCTOBER 28

Activity: The Section held a business meeting at Jacoby's Restaurant in Meriden, Conn. Chairman **Gary Shubert** discussed a Section scholarship program, **Walt Chojnacki** outlined the Section's finances, and **Bob Cullen** reported on the Section's educational program activities. **Nino Olivares** presented ideas for tours the members could take, and District 1 Director **Russ Norris** presented District and national news items.

GREEN & WHITE MTS.

NOVEMBER 13

Speaker: **Russ Norris**, District 1 director
 Topic: Oxyfuel gas safety

Activity: The presentation included a test on oxyfuel safety dos and don'ts, followed by a video presentation on the subject from Victor-Thermadyne. The program included a lively discussion on various gas safety topics.

MAINE

NOVEMBER 20

Activity: The Section held a business meeting at Metso Paper Co. in Biddeford, Maine. Attending to business were Chairman **Scott Lee**, **Mike Gendron**, **Ray Roy**, and **Russ Norris**, District 1 director.

District 2

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

LONG ISLAND

NOVEMBER 13

Activity: The Section members toured Underwriters Laboratories, Inc., in Melville, N.Y., to study its safety testing facilities for household appliances, industrial controls, wire and cable, and security



Shown at the Long Island Section's tour are (from left) Anthony Zampelli, Cory Drogler, Barry McQuillen, Ken Messemer, Paul Iannotta, Thomas Mazzarella, Rishi Prashad, Chair Brian Cassady, Jack McEnerney, Ray O'Leary, Joe Tuffarelli, Joe Tuffarelli Jr., and Harland Thompson.



Student Alicia Hagan addressed the York-Central Pa. Section program in October.

and signaling devices. Later, the Long Island Section members viewed the AWS video, *Hot Bikes, Hot Cars, Cool Careers*.



Claudia Bottenfield received the District and Section Meritorious Awards from District 3 Director Alan Badeaux (right), and Josh Seitzer at the York-Central Pa. program.

District 3

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

YORK-CENTRAL PA.

OCTOBER 2

Speaker: **Alicia Hagan**, student

Affiliation: York County School of Technology

Topic: Her trip to Australia

Activity: **Claudia Bottenfield** was awarded the District Meritorious Award and the Section Meritorious Award by **Alan Badeaux**, District 3 director.

YORK-CENTRAL PA./LANCASTER

NOVEMBER 6

Activity: The York-Central Pa. and Lancaster Section members toured Salvaging Creativity in York, Pa. Also attending were **Josh Seitzer** and his welding students at York County School of Technology. The company salvages junk for creating art projects. **Patrick Sells**, owner, conducted the tour.



Shown at the York-Central Pa. and Lancaster Sections' tour are welding students and (far left) Alan Badeaux, District 3 director, and Josh Seitzer (far right), welding instructor.



Charles Crumpton (left), Florida West Coast past chair, is shown with presenter Chris Woods at Pop's Painting, Inc.



South Carolina Section past chairs Will Hunt (left) and Howard P. Jones are shown at the September underwater welding tour.



Shown at the South Carolina Section program are (from left) Program Chair Ron Vann with Trident T. C. welding instructors Jim Stallsmith, Matt Hansknecht, Ed Dawson, and Jimmy Suggs.



Shown at the Cincinnati Section November program are (from left) Treasurer Ken Calardo, speakers Phil Russo and Jeff Minter, and Section Chair Uwe Aschemeier.

District 4

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

District 5

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

FLORIDA WEST COAST

NOVEMBER 12

Activity: The Section members met at Pop's Painting, Inc., in Lakeland, Fla. Chris Woods led the tour and described the company's procedures for industrial sandblasting and painting. A raffle was held to raise funds for the Section's scholarship program.

SOUTH CAROLINA

SEPTEMBER 17

Activity: The Section members toured International Diving Institute to see demonstrations of underwater welding and cutting. Sergio Smith, CEO, made the presentations. Attending were past chairmen Will Hunt (1969–1970) and Howard P. Jones (1971–1972; 1978–1979), and welding staff and students from Trident Technical College.

District 6

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

NORTHERN NEW YORK

NOVEMBER 4

Speaker: Mario Berriola, asst. director of education
Affiliation: N.Y. State Dept. of Correctional Services
Topic: Rehabilitation vocational training used in the New York correctional system
Activity: The meeting was held at Mill Road Restaurant & Tavern in Latham, N.Y.

District 7

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

CINCINNATI

OCTOBER 28

Speaker: Uwe Aschemeier, senior welding engineer
Affiliation: Terracon Consultants
Topic: Comparison of 2006 and 2008 revisions of AWS D1.1, *Structural Welding Code — Steel*

NOVEMBER 18

Speakers: Jeff Minter, senior project manager, and Phil Russo, superintendent
Affiliation: Ben Hur Construction Co.
Topic: Presentation on the structural steel erection of the Ascent Building, a high-rise constructed in Covington, Ky., designed by Daniel Liebeskind.
Activity: This Cincinnati Section program was held in Cincinnati, Ohio.

COLUMBUS

OCTOBER 16

Activity: Fifty-three members representing eight technical societies in the Columbus, Ohio, area met at CC Technologies — A DNV Company, in Dublin, Ohio, to tour the facility's laboratories. **Michiel Brongers**, senior project manager, made a presentation on corrosion then led the tour.

DAYTON

OCTOBER 14

Activity: The Section members toured the Packard Automobile Museum in Dayton, Ohio. **Al Hounshell** led the tour and presented the history of the car company and details about many of the cars on display.

DAYTON and INDIANA

NOVEMBER 11

Activity: The Dayton Section and Indiana Section members met at Southern Ohio Forge and Anvil Association in Troy, Ohio, to see demonstrations of forging and forge welding of steel. **Steve Roth** forged an ax head from a flat piece of steel then forge welded a high-carbon tip into the ax head.

JOHNSTOWN/ALTOONA

APRIL 30

Activity: The Section participated in a students' day program featuring a Lincoln Electric mobile demonstration unit. The welding students from five area schools received awards for their welding achievements. In attendance were welding instructors **John Kish** and **George Seese**.

MAY 23

Activity: The Johnstown/Altoona Section hosted its 41st annual golf outing at Chestnut Ridge Golf Resort in Blairsville, Pa.

SEPTEMBER 23

Activity: The Johnstown/Altoona Section members toured the J & J Truck Bodies facility in Somerset, Pa. **Michael Riggs**, senior VP manufacturing, conducted the tour.

OCTOBER 14

Activity: The Johnstown/Altoona Section members toured the Brookville Equipment Corp. facilities in Brookville, Pa., to study the fabrication of locomotives and mining equipment. The presenters and tour guides included **Michael White**, sales and marketing specialist, and **Sheila**



Michiel Brongers (fifth from left) headed the CC Technologies support team that presented a guided tour for the Columbus Section and seven other local technical organizations.



Shown at the Dayton Section October program are tour guide Al Hounshell (left) with Chairman Steve Whitney.



Steve Roth showed the Dayton and Indiana Section members how to forge weld at the November program.



Dayton and Indiana Section members and local welding students studied forge welding techniques at the November program.

Hockman, human resources manager.

NOVEMBER 11

Activity: The Johnstown/Altoona Section members toured RNDT in Johnstown, Pa., to learn techniques for nondestructive testing of welds and materials. Talks were presented by **Fred Raco Jr.**, president, and **Allan Thomassy Jr.**, vice president. Topics included radiography using X and gamma rays, magnetic particle, ultrasonic, and dye liquid penetrant testing techniques. Twenty-six members, students, and guests attended the program.



Johnstown/Altoona Section Chair John Kish (left) presents a speaker gift to Michael Riggs at the September program.



Shown at the Pittsburgh Section program are (front, from left) Howard MacKay, Harry Flick, Rick Donaldson, Mike Komlos, Marvin Huck, a student, Todd Parker, a student, Roger Hilty and (back, from left) Josh Chiapetta, Kris Schott, Chris Simmons, Greg Phillips, Dennis Moore, Tom Geisler, John Menhart, Dave Daugherty, Ron Campbell, and two students.



Shown at the November Johnstown/Altoona Section program are (from left) Chairman John Kish, and Secretary Bill Krupa with presenters Fred Raco Jr. and Allan Thomassy Jr.



Shown at the April Johnstown/Altoona Section program are award-winning Altoona Area Vo-Tech welding students with their instructors John Kish (left) and George Seese (right) holding the Section banner.

PITTSBURGH

OCTOBER 14

Activity: The Section members and Student Chapter members toured the Curtiss-Wright Electro-Mechanical Corp. in Cheswick, Pa., to study the high-tech welding techniques used to manufacture pumps for the USS *Nautilus* and U.S. Navy submarines. The products included motors up to 17,500 hp with pump capacities up to 85,000 gal/min. Guiding the tour were **Marvin Huck**, plant engineer, and **Mike Komlos**, welding engineer.

District 8

Joe Livesay, director
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HOLSTON VALLEY

OCTOBER 21

Speaker: **Bob Thomas**, educator
 Affiliation: Unicoi County High School
 Topic: Welding careers and educational programs offered in the state of Tennessee

Activity: The executive committee met to discuss plans for upcoming events. Regular meetings will be normally scheduled for the first Tuesday of each month. The program was held at Maple Grove Restaurant in Unicoi, Tenn.

WESTERN CAROLINA

OCTOBER 21

Speaker: **Michael Dortch**
 Affiliation: AlcoTec Wire Corp.
 Topic: Aluminum welding

Activity: Vice Chair **Duke Moses** introduced the four winners of Section scholarships and their school representatives.

Elaine Huff and **Bob Fellers** represented Greenville Technical College with their winning student **Earnest Pickens**. Student **John Horne** won for Spartanburg Technical College. Tri-County Technical College staff **Paul Phelps** and **Haley Sitton** appeared with winning welding students **Clinton Hall** and **Tony Durham**.

District 9

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

ACADIANA

OCTOBER 21

Speaker: **Bruce A. Hallila**, welding manager

Affiliation: Pellerin Milnor Corp.

Topic: Robotic welding procedures used at Pellerin Milnor Corp.

Activity: Hallila, a member of the New Orleans Section, discussed the manufacture of commercial laundry equipment using stainless steels and mild carbon steel welding techniques.

NEW ORLEANS

OCTOBER 21

Speaker: **Craig Collins**, operations manager

Affiliation: Dynamic Industries

Topic: Job safety and welding education

Activity: The 83 attendees included more than 50 welding students from various schools and local unions. Chairman **Matthew Howerton** presented a plaque to Collins and an appreciation plaque to Dynamic Industries for sponsoring the event. **Ed Cannon** of Dynamic Industries won the 50/50 raffle prize.

District 10

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DRAKE WELL

NOVEMBER 11

Activity: The Section members toured Welding Technologies, Inc., and Shaw Industries, Inc., in Franklin, Pa. **Jasen Fry**, general manager, and **Jesse Hernandez**, production manager, conducted the tour of the welding, fabrication, and machine shops.

District 11

Eftihios Siradakis, director
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Shown at the Western Carolina Section scholarship presentation are (from left) Elaine Huff, Bob Fellers, Earnest Pickens, John Horne, Clinton Hall, Paul Phelps, Haley Sitton, and Tony Durham.



New Orleans Section Chair Matthew Howerton (far right) poses with Dynamic Industries staff at the October program.



Shown at the Acadiana Section program are Chair Mike Skiles (left) with speaker Bruce Hallila.



New Orleans Section Chair Matthew Howerton (right) presents a speaker plaque to Craig Collins.

DETROIT

NOVEMBER 13

Activity: The Section held its technical meeting and awards presentation event at Robo-Vent in Clawson, Mich. **John Reid**, president, **Jim Reid**, VP, and **Pat Gilmour**, business development manager, presented demonstrations of controlling ventilation situations frequently encountered in industrial welding using the lat-

est methods for improving workplace air quality. **Don Czneriewski** was cited for his work on the Sheet Metal Conferences, Christmas parties, and golf outings, and **Connie Frost** was thanked for her work on the Patrons Fund, Sheet Metal Conference, and Ladies' Night events. Both received Section Appreciation Awards for their years of hard work and dedication to Section activities.



Shown at the Detroit Section program are (from left) Pat Gilmour, Jim Reid, John Reid, and John Bohr, Section vice chairman.



Northern Michigan Section tour members pose at Albrecht Custom Welding shop.



Shown at the Milwaukee Section tour are (from left) Chairman Jerry Blaski, Roger Warren, and Michael Wabiszewski.



Shown at the joint Chicago Section and ASNT chapter meeting are (from left) John Zafer, speaker Luke Banks, and Hank Sima.



Big kids and little rode Albrecht's train during the Northern Michigan Section's tour.

NORTHERN MICHIGAN

OCTOBER 27

Activity: This program included a tour and a pizza dinner at Albrecht Custom Welding in Karlin, Mich. **Butch Albrecht**, owner, detailed his precision welding techniques used for making oilfield tooling. Showcased was Albrecht's favorite hobby construction project, a welded aluminum train consisting of a electric engine, flat-bed car, coal car and an Airgas tanker, built to a scale of 1:8. The train runs on a half-mile-long track on the premises. Activities included train rides for everyone and a tour of the welding and machine shop areas. In attendance were members from Northwestern Michigan College, Air Gas Great Lakes, AlcoTec Wire Co., Purity Cylinder Gases, Actron Steel, Traverse Bay Area Career Tech Center, and Wexford Missaukee Career-Tech Center.

District 12

Sean P. Moran, director

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MILWAUKEE

NOVEMBER 13

Activity: The Section members toured Maynard Steel Casting Co., in Milwaukee, Wis., to study its methods for making one-of-a-kind and mass-produced castings from 50 to 65,000 lb. Conducting the tour were **Michael A. Wabiszewski**, CEO, and **Roger Warren**, senior welder.

District 13

W. Richard Polanin, director

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rpolanin@icc.edu

CHICAGO

OCTOBER 15

Speaker: **Luke K. Banks**, technical support manager, digital X-ray products
Affiliation: GE Inspection Technologies
Topic: New imaging inspection using computed radiographic testing
Activity: Members of the local chapter of ASNT attended this program, held at Bohemian Crystal Restaurant.

District 14

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INDIANA

OCTOBER 15

Speaker: **Butch Weidner**

Affiliation: Hobart Filler Metals Div.

Topic: The reintroduction of metal core

Activity: The program was held at the Indiana Oxygen corporate office in Indianapolis, Ind.



Chris Mann (left) and Keith Simpson show their awards at the Iowa Section program.



Butch Weidner discussed metal core wires for Indiana Section members in October.

District 15

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District 16

David Landon, director
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dlandon@vermeermfg.com

IOWA

NOVEMBER 6

Speaker: **Mike Rahn**, welding instructor
Affiliation: Des Moines Area C. C.

Topic: Nondestructive testing techniques

Activity: District 16 Director **Dave Landon** presented **Chris Mann** the Section and the District Private Sector Educator Awards, and **Keith Simpson** the Section and the District Instructor Awards. Mann and Simpson are educators affiliated with the Des Moines Area C. C.



Mike Rahn discussed nondestructive testing for the Iowa Section members.



Kansas City Section past Chair Dennis Wright (left) chats with Gene Lawson, AWS president, at the SkillsUSA competition.

KANSAS CITY

JUNE 26

Speaker: **Gene Lawson**, AWS president

Affiliation: ESAB Welding & Cutting

Topic: The SkillsUSA competition

Activity: Lawson attended the SkillsUSA competition held in Kansas City, Mo., and attended the Section's monthly meeting held at KC Masterpiece Barbecue & Grill in Kansas City where he talked about the shortage of skilled welders in the United States.



Gene Lawson (left) receives a plaque from Joel Pepin, Alberta Section vice chair, for presenting the keynote speech.



Speaker Kelly Ewton (left) chats with Adam Enslinger at the Tulsa Section program.

District 17

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jjones@thermadyne.com

TULSA

OCTOBER 28

Speaker: **Kelly Ewton**, representative

Affiliation: Sheet Metal Workers School

Topic: Accredited Test Facilities (ATFs) and training

District 18

John Bray, director
(281) 997-7273
sales@affiliatedmachinery.com

District 19

Neil Shannon, director
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neilshnn@msn.com

ALBERTA

OCTOBER 17

Activity: The Section held its annual fall seminar for 80 attendees featuring six speakers who addressed the theme Weld-



Shown during an Alberta Section excursion to Syncrude Canada Ltd. are (from left) John Zhou, Chairman Matthew Yarmuch, Mike Hurlbert, and Gene Lawson, AWS president.



Jacob Wakelam (right) accepts a scholarship check from welding instructor Loc Hepburn at the British Columbia Section program.



Presenting the British Columbia Section tenth anniversary cake are (from left) Neil Shannon, District 19 director; retiring Treasurer Donna Baldry; and incoming Treasurer Brenda Moe.

ing Considerations for Corrosive Service. **Gene Lawson**, AWS president, with ESAB Welding & Cutting, was the keynote speaker. Lawson's talk concerned how the changing welding environment creates job opportunities. Other speakers included **Gary Coates**, Nickel Institute; **Digby D.**



Ronald Clough receives his Silver Membership Award from Pat Newhouse, British Columbia Section chair.

MacDonald, Pennsylvania State University; **William F. Newell**, Euroweld; **Viwek Vaidya**, Air Liquide; and **John Bringas**, Codes and Standards Training Institute. Formerly known as the Northern Alberta Section, this event also celebrated the Section's official name change to Alberta Section. Lawson afterward toured businesses in the region, including Syncrude Canada Ltd., University of Alberta Canadian Centre for Welding and Joining, and the Northern Alberta Institute of Technology's welding program.

BRITISH COLUMBIA

OCTOBER 23

Speaker: **Keith Daly**

Affiliation: Lincoln Electric. Co. — Canada

Topic: Fume control strategies KD 001-003

Activity: **Neil Shannon**, District 19 director, participated as the Section celebrated its tenth anniversary at the Piping Industry Trades School in Delta, B.C., Canada. **Ronald Clough** received his Silver Membership Award for 25 years of service to the Society. The Bruce Third Welding

Scholarship was presented to **Jacob Wakelam** by Loc Hepburn, a Kwantlen University College welding instructor. **Donna Baldry**, long-time Section treasurer, was celebrated on her retirement.

SPOKANE

NOVEMBER 12

Speaker: **Phil Zammit**

Affiliation: Brooklyn Iron Works, Inc.

Topic: Welding economics — weighing the costs of fillet weld sizes

Activity: The program was held in the Oxarc demo room in Spokane, Wash.

District 20

William A. Komlos, director

(801) 560-2353

bkoz@arctechllc.com

COLORADO

OCTOBER 16

Speaker: **Mike Ross**, technical sales representative

Affiliation: Fanuc Robotics

Topic: Implementing robotic welding systems the easy way

Activity: **Jeff Connors** received the Colorado Section CWI of the Year Award. The program was hosted by **Myron Delgado**, Lincoln Electric technical sales representative, at the company's facility in Englewood, Colo.

District 21

Nanette Samanich, director

(702) 429-5017

weldor07@aol.com

LONG BEACH/ ORANGE COUNTY

OCTOBER 7

Activity: The Section members attended a product demonstration event hosted by the Praxair facility in Costa Mesa, Calif. Presenters included **Diana Valdez**, Praxair store manager, and **Chris Sherm** of Hypertherm.

LOS ANGELES/ INLAND EMPIRE

OCTOBER 29

Activity: The Section members toured Metalogic Inspection Services for a theoretical discussion presented by **Keith Chizen** followed by a demonstration of the company's "Metaphase" adaptation of the phased array ultrasonic testing technology suited for use with boiler tubes and pipe welds.



Speaker Kerry Shatell (left) is shown at the Sacramento Valley Section program with Chairman Don Robinson.



Shown at the the Colorado Section program are (from left) speaker Mike Ross, Chairman James Corbin, and CWI Award winner Jeff Connors.



Long Beach/Orange County Section Chairman Cary Chiu presents an appreciation certificate to Diana Valdez in October.



Shown at the L.A./Inland Empire Section program are (from left) William Bentley, Kenny MacDonald, Victor Figueroa, Ron Mann (rear), Chair George Rolla (front), Robert Davis, Tony Barraza, and presenter Keith Chizen.

District 22

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

SACRAMENTO VALLEY

OCTOBER 15

Speaker: **Kerry Shatell**, welding engineer
Affiliation: Pacifica Gas and Energy
Topic: Techniques used to safely weld pipelines pressurized with natural gas
Activity: Attending were representatives from Butte, American River, and Consumnes River Colleges, and **Ken Morris** from GNB, Inc. The program was held at Hometown Buffet.

SAN FRANCISCO

NOVEMBER 5

Speakers: **Jim Newton**, president, and **Lynne Angeloro**, director of educational services
Affiliation: TechShop, Menlo Park, Calif.
Topic: "From Dreams to Reality"
Activity: The speakers discussed their facility that serves as an open-access public workshop. District 22 Director **Dale Flood** presented **Andre Lopez** the Section Meritorious Certificate Award, **Dale Phillips** the District 22 Dalton E. Hamilton CWI of the Year Award, and **Scott Miner** the Section Educator Award.



Shown at the San Francisco Section awards-presentation ceremony are (from left) Dale Phillips, District 22 Director Dale Flood, Andre Lopez, and Scott Miner.



San Francisco Section Chair Liisa Pine (left) is shown with presenters Jim Newton and Lynne Angeloro.

Guide to AWS Services

American Welding Society
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www.aws.org; (800/305) 443-9353; FAX (305) 443-7559
(Staff telephone extensions are shown in parentheses.)

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and regulatory issues of importance to the weld-
ing industry.

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RWMA — Resistance Welding Manufacturing Alliance

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

WEMCO — Welding Equipment Manufacturers Committee

Manager
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Welding Handbook

Welding Handbook Editor
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Publishes the Society's monthly magazine, *Weld-
ing Journal*, which provides information on the
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Society activities. Publishes *Inspection Trends*, the
Welding Handbook, and books on general welding
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Director, Int'l Business & Certification Programs
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EDUCATION SERVICES

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Technical Publications

AWS publishes about 200 documents widely used
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Handbook, Soldering Handbook

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bers Assignment

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Welding Qualification, Structural Welding

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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
informal and should not be used as a substitute for
an official interpretation.

Nominees for National Office

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

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

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

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

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

Treasurer: To be eligible to hold the

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

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

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

E-mail the letter to Gricelda Manalich, gricelda@aws.org, 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; 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; www.awspubs.com
Toll-free (888) 935-3464 (U.S., Canada)
(305) 824-1177; FAX (305) 826-6195

Welding Journal Reprints

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

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

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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.

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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.

WELDING

WORKBOOK

Datasheet 302

Narrow Groove Gas Metal Arc Welding

An efficient method for joining heavy-section carbon and low-alloy steels with minimal distortion is narrow groove gas metal arc welding. It is a multipass GMAW technique used to join heavy-section materials when the weld joint has a nearly square butt configuration with a minimal groove width (approximately 13 mm [$\frac{1}{2}$ in.]). Figure 1 shows a typical narrow groove joint configuration.

Using this narrow groove technique to weld joints requires special precautions to ensure the tip of the electrode is positioned accurately for proper fusion into the groove faces. Figure 2 shows some of the wire feeding methods that have been successfully used in production environments.

Figure 2A illustrates how two wires with controlled cast and two contact tips can be used in tandem. The arcs are directed toward each groove face, producing a series of overlapping fillet welds. The same effect can be achieved with one wire by means of a weaving technique. This involves oscillating the arc across the groove during welding. This oscillation can be created mechanically by moving the contact tip across the groove (Fig. 2B); however, this technique is impractical and seldom used because of the small contact tip-to-groove face distance.

Figure 2C shows another mechanical technique, which uses a contact tip bend to an angle of about 15 deg. Along with a forward motion during welding, the contact tip twists to the right and left, giving a weaving motion to the arc.

A more sophisticated technique is depicted in Fig. 2D. During feeding, this electrode is formed in a waved shape by the bending action of a flapper plate and feed rollers as they rotate. As the feed rollers press the wire against the bending plate, it is continuously deformed plastically into the waved shape. The electrode is almost straightened while passing through the contact tip, but it recovers its waviness after passing through the tip. The continuous consumption of the waved electrode oscillates the arc from one side of the groove to the other. This produces an oscillating arc even in a very narrow groove with the contact tip remaining centered in the joint.

Figure 2E shows another method that was developed to improve groove face penetration without moving the contact tip. This twisted electrode technique consists of two intertwined wires that, when fed into the groove, generate arcs from the tips of the two wires. Due to the twist, the arcs describe a continuous rotational movement that increases penetration into the groove face without any special weaving device.

Because these arc oscillation techniques often require special feeding equipment, another method has been developed in which a larger electrode (2.4–3.2 mm [0.093–0.125 in.] in diameter) is fed directly into the center of the groove from a contact tip situated above the plate surface. Wire placement is still critical, but there is less chance of arcing between the contact tip and the workpiece and standard welding equipment can be used. It does have a more limited thickness potential and is normally restricted to the flat position, however.

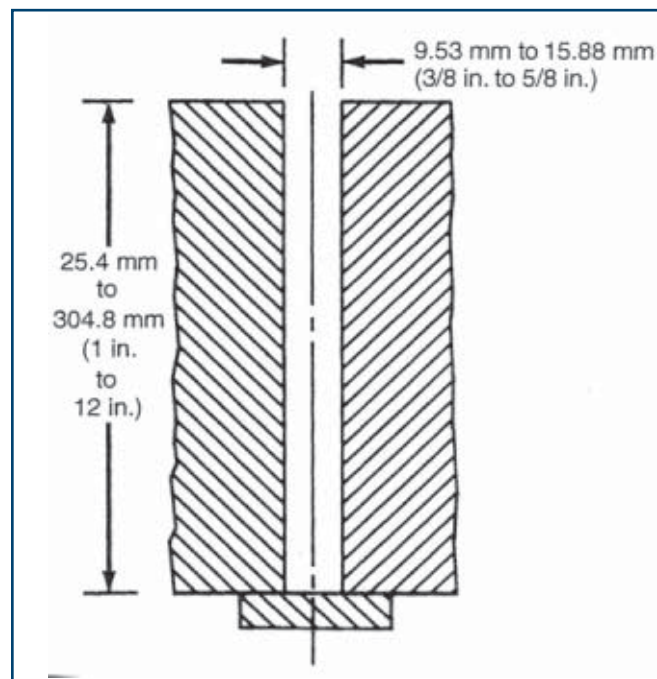


Fig. 1 — Typical joint configuration for narrow groove gas metal arc welding.

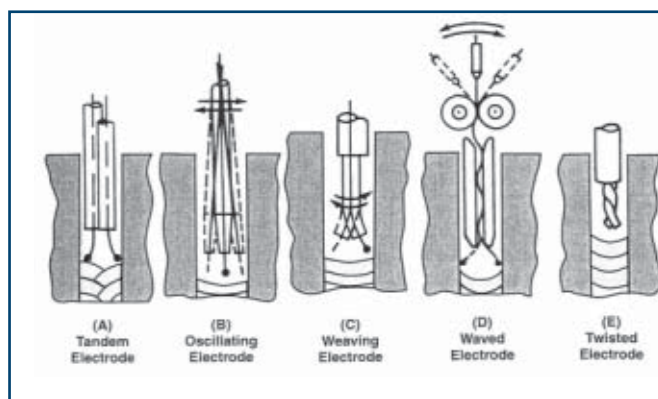


Fig. 2 — Typical wire feeding techniques for narrow groove gas metal arc welding.

Excerpted from the *Welding Handbook*, Vol. 2, ninth edition.



AWS FELLOWSHIPS

To: Professors Engaged in Joining Research

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

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

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

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

THE AWARDS

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

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

DETAILS

The Proposal should include:

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

In addition, the proposal must include:

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

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

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

Yours sincerely,

Ray W. Shook
Executive Director
American Welding Society



American Welding Society

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



CLASS OF 2010 COUNSELOR 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 COUNSELOR ACCOMPANY THE NOMINATION PACKET. IF NOMINEE IS SELECTED, THIS STATEMENT MAY BE INCORPORATED WITHIN THE CITATION CERTIFICATE.

****MOST IMPORTANT****

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

SUBMITTED BY:

PROPOSER _____

AWS Member No. _____

The proposer will serve as the contact if the Selection Committee requires further information. The proposer is encouraged to include a detailed biography of the candidate and letters of recommendation from individuals describing the specific accomplishments of the candidate. Signatures on this nominating form, or supporting letters from each nominator, are required from four AWS members in addition to the proposer. Signatures may be acquired by photocopying the original and transmitting to each nominating member. Once the signatures are secured, the total package should be submitted.

NOMINATING MEMBER: _____ Print Name _____

AWS Member No. _____

NOMINATING MEMBER: _____ Print Name _____

AWS Member No. _____

NOMINATING MEMBER: _____ Print Name _____

AWS Member No. _____

NOMINATING MEMBER: _____ Print Name _____

AWS Member No. _____

SUBMISSION DEADLINE JULY 1, 2009



Nomination of AWS Counselor

I. HISTORY AND BACKGROUND

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

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

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

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JUNE 2-5, 2009

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Welding Institution of CMES



China Welding Association (CWA)



Electric Welding Machine Committee of CEEIA



German Welding Society (DVS)



Messe Essen GmbH



Co-sponsors: American Welding Society (AWS)

Korea Welding Industry Cooperative (KWIC)

The Japan Welding Engineering Society (JWES)

For Info go to www.aws.org/ad-index

For more details please visit the Show website: <http://essen.cmes.org>

Contact Information: Ms. Wen Email: whj@cmes.org Tel: 0086-10-6397 2404 Fax: 0086-10-6398 0554

NEW

LITERATURE

Gas Monitoring Systems Detailed in Brochure



The eight-page, full-color *Mechanical Room Guide* brochure describes the company's equipment options for mechanical equipment room refrigerant monitoring systems. Highlighted are the applicable codes and standards, the sequence of operations, equipment selection and location, accessories, and closeout procedures. The brochure can also serve as a useful guide to help determine the correct refrigerant monitoring systems for specific applications, including refrigerant data and suggested alarm levels to suit all installations and industries.

Honeywell Analytics
www.honeywellanalytics.com
(800) 538-0363

Aluminum Statistical Review Released

The *Aluminum Statistical Review* — 2007 assembles in one place the most important data available on the North American aluminum industry. It includes information on every cycle of the aluminum production process from primary aluminum to markets for finished goods to the recovery of aluminum scrap. The Review is divided into five major sections: supply, shipments, markets, foreign trade, and world statistics. This 2007 edition contains an eleven-year summary (1997–2007) as well as historical statistics on the aluminum industry. It is intended as an educational tool designed to support members of the aluminum industry, financial analysts, government agencies, students, and the general public. Included are text, tables, and charts to provide year-end figures and other data on U.S. and

Canadian shipments, markets, supply, and foreign trade. Available as a download from the Web site bookstore “what’s new” page or as a CD, the document is \$175 list, \$90 for association members.

The Aluminum Association
www.aluminum.org/bookstore
(703) 358-2976

Literature Pictures Aircraft Maintenance Products



A 12-page, full-color brochure details the company's lines of metal finishing hand tools specifically designed for processing the diverse range of materials used in the aircraft industry. The products are specified for finishing titanium, composites, nickel-based, and cobalt-based alloys with demanding operating parameters. Eight product groups are depicted covering ten key application categories from cutting and grinding to cleaning and polishing. In addition to several application photographs, it presents a clear aircraft outline diagram with callouts identifying six main areas where the use of abrasive and cutting tools as well as power brushes and power tools is required. These include the aircraft exterior skin, landing gear, engines, wings, tails, and cabin interiors.

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

Poster Urges Workers to Use Hearing Protection

The company has released a new full-color poster detailing the care and maintenance of earplugs and earmuffs. De-



signed for display on work site bulletin boards, the poster provides clear instructions for each type of hearing protection device. It offers concise answers to common questions about the devices, while serving as a constant reminder to workers to wear their hearing-protection devices on the job and how to wear them properly. Four panels discuss care of single-use earplugs, multiple-use earplugs, banded earplugs, and earmuffs. Information includes instructions for inspection prior to use, cleaning, and the recommended duration of wear before replacement is required.

Sperian Hearing Protection, LLC
www.howardleight.com
(800) 430-5490

Cylinder Products Catalog Viewable Online

The 252-page hydraulic cylinder catalog can be viewed or downloaded from the company's Web site. Detailed technical specifications, charts, dimensioned mechanical parts drawings, and exploded views are presented for each product. Step-by-step illustrated instructions are given for seal replacement and new rod cartridge kit installation. Also shown are tie rod designs, ordering code chart, mounting types, pipe connections, stroke length charts, and examples of calculating cylinder dimensions based on force, buckling, and cushioning capacity.

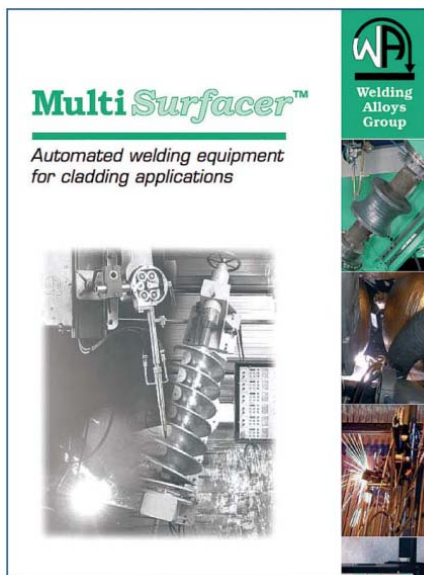
Bosch Rexroth Corp.
Industrial Hydraulics
www.boschrexroth-us.com
(610) 694-8300



Brochure Details Hardfacing Equipment

An eight-page, profusely illustrated, full-color brochure details a number of products in the company's lines of stationary and portable automated welding equipment for hardfacing applications. Setups are illustrated for processing petrochemical valves, screw flights, pipe-forming rolls and large forming rolls for the steel industry, and crusher rolls. Units include fully programmable welding parameters and machine functions with multiprocess capability. Shown are various welding heads, workpiece holding and movement systems, fume extraction, and arc shielding boxes with various weld patterns including flat, internal rotary, external rotary, spiral, helix, chevron, sine wave, zig-zag, and square wave.

Welding Alloys (USA) Inc.
www.welding-alloys.com/usa/machines
(859) 525-0165



D1 Code References Issued on CD and Book Formats

All 59 standards referenced by AWS D1.1/D1.1M:2008, *Structural Welding Code — Steel*, are now available on a CD and in printed copy. The *ASTM Standards for Welding* serves as a handy companion to the D1.1 code to provide the resources necessary for quality professionals, inspectors, supervisors, and quality-conscious engineers and managers to interpret the D1.1 specification and the test methods used in the code. The 8.5- × 11-in. soft-cover edition has 450 pages. Both CD and printed editions are priced at \$395.

ASTM International
www.astm.org
(610) 832-9500

Welding Products Catalog Updated



A 52-page, well-illustrated catalog updates the company's product lines of mild-steel and low-alloy covered electrodes, steel solid wires, tubular wires, and hardfacing and stainless steel products. Each electrode is clearly identified by AWS number designation, product description, typical applications, chemical analysis, mechanical properties, Charpy V-notch impact values, stock diameters with recommended operating current values and type of current, and approvals and conformances. Included are detailed graphic and tabular information on welding wire packaging parameters, short circuit transfer welding parameters, and spray transfer welding parameters, as well as comprehensive information on tubular wires.

Hobart Brothers Co.
www.hobartbrothers.com
(800) 424-1543

NEWS OF THE INDUSTRY

— continued from page 11

Industry Notes

- **Empire Industries Ltd.** and the **Athabasca Chipewyan First Nation Holding Corp.** recently announced through their joint ownership of Sorge's Welding Ltd., they have acquired Lemax Machine & Welding, Fort McMurray, Alberta, Canada, for \$1.2 million plus working capital.
- At www.olympus-ims.com, **Olympus** has launched a Web site with content on its many products; application notes; software downloads; a PDF library; and an educational theory section.
- Patent US 7,434,491 B1 dated Oct. 14, 2008, has been assigned to **Motoman Inc.**, Dayton, Ohio, for the Moto-Mount® compliant tool mounting system with George Sutton Jr., Donald J. Metz, and Daniel W. Slanker named as the inventors.
- An in-line U-Bend manufacturing center has been incorporated in **RathGibson's** Janesville, Wis., facility. The system includes a laser mill, bright annealing, U-Bender, and drawing.
- **MagneGas Corp.**, Tampa, Fla., has signed an agreement with Boca BioFuels, Inc. to distribute MagneGas for the metal cutting and welding market in the Greater Atlanta area.
- When the Fox Cities Chamber of Commerce and Industry, Inc., Appleton, Wis., presented its 2008 Manufacturer of the Year Awards, **Performance Welding, Inc.** won the Small Manufacturer Category.
- More than 40 distributors attended **Airco Distributor Association's** 13th annual meeting held recently in Las Vegas, Nev. Among its highlights were sessions to discuss product lines.
- **Jergens, Inc.**, Cleveland, Ohio, has acquired Bock Workholding Inc. with U.S. headquarters in Ford City, Pa., and sales partners in Europe, Asia, and Australia.
- Under the American Chemistry Council's Responsible Care® program, **Linde North America** has received certification of its Vancouver, Wash., manufacturing facility and its South Bend, Ind., carbon dioxide plant.

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.)

Primary Author (Full Name):						
Affiliation:						
Mailing Address:						
City:	State/Province	Zip/Mail Code	Country:			
Email:						
Co-Author(s):						
Name (Full Name): Affiliation: Address: City: State/Province: Zip/Mail Code: Country:		Name (Full Name): Affiliation: Address: City: State/Province: Zip/Mail Code: Country:				
E-Mail:		E-Mail:				
Name (Full Name): Affiliation: Address: City: State/Province: Zip/Mail Code: Country:		Name (Full Name): Affiliation: Address: City: State/Province: Zip/Mail Code: Country:				
E-Mail:		E-Mail:				
Answer the following about this paper Original submittal? Yes ☐ No ☐ Progress report? Yes ☐ No ☐ Review paper? Yes ☐ No ☐ Tutorial? Yes ☐ No ☐ What are the welding/Joining processes used? What are the materials used? What is the main emphasis of this paper? Process Oriented ☐ Materials Oriented ☐ Modeling ☐ To what industry segments is this paper most applicable? Has material in this paper ever been published or presented previously? Yes ☐ No ☐ If "Yes", when and where? Is this a graduate study related research? Yes ☐ No ☐ If accepted, will the author(s) present this paper in person? Yes ☐ Maybe ☐ No ☐						
Keywords: Please indicate the top four keywords associated with your research below 						
Guidelines for abstract submittal and selection criteria: - Only those abstracts submitted on this form will be considered. Follow the guidelines and word limits indicated. - Complete this form using MSWord. Submit electronically via email to techpapers@aws.org <table style="width: 100%;"> <tr> <td style="vertical-align: top; width: 33%;"> Technical/Research Oriented - New science or research. - Selection based on technical merit. - Emphasis is on previously unpublished work in science or engineering relevant to welding, joining and allied processes. - Preference will be given to submittals with clearly communicated benefit to the welding industry. </td> <td style="vertical-align: top; width: 33%;"> Applied Technology - New or unique applications. - Selection based on technical merit. - Emphasis is on previously unpublished work that applies known principles of joining science or engineering in unique ways. - Preference will be given to submittals with clearly communicated benefit to the welding industry. </td> <td style="vertical-align: top; width: 33%;"> Education - Innovation in welding education at all levels. - Emphasis is on education/training methods and their successes. </td> </tr> </table> ☒ Check the category that best applies: ☐ Technical/Research Oriented ☐ Applied Technology ☐ Education				Technical/Research Oriented - New science or research. - Selection based on technical merit. - Emphasis is on previously unpublished work in science or engineering relevant to welding, joining and allied processes. - Preference will be given to submittals with clearly communicated benefit to the welding industry.	Applied Technology - New or unique applications. - Selection based on technical merit. - Emphasis is on previously unpublished work that applies known principles of joining science or engineering in unique ways. - Preference will be given to submittals with clearly communicated benefit to the welding industry.	Education - Innovation in welding education at all levels. - Emphasis is on education/training methods and their successes.
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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

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

MUST BE RECEIVED NO LATER THAN MARCH 13, 2009

PERSONNEL

Nooter/Eriksen Announces Six Promotions



Joseph Schroeder



Michael Filla

Nooter/Eriksen, Inc., Fenton, Mo., an engineering firm specializing in the design of heat recovery steam generators for the power industry, has recently announced six promotions. **Donald H. Lange**, formerly executive vice president, was appointed president. Lange succeeds **Vernon L. Eriksen**, president emeritus, who retired Dec. 31. **Timothy S. Peterson**, formerly vice president of operations, was appointed executive vice president. **Joseph S. Schroeder**, formerly vice president en-



Yuri Rechtman



Phillip Hanks



Timothy Peterson



Donald Lange

gineering, was appointed senior vice president — engineering. **Michael J. Filla**, formerly director of sales and marketing, was appointed vice president — sales and mar-

keting. **Phillip J. Hanks**, formerly director of continuous process improvement, was appointed vice president of operations, and **Yuri M. Rechtman**, formerly director of thermal design, was appointed vice president — thermal engineering.

RathGibson Opens Three Overseas Offices

RathGibson, Lincolnshire, Ill., a supplier of welded stainless steel, nickel, and titanium tubing, has opened new offices in Mumbai, India; Vienna, Austria; and Singapore. Joining its Greater China team are **Louisa Zhang**, **Irene Wang**, and **Sunny Sun**; **Michael Edinburgh** was named manager — business development, India, and **Gilbet Boon** designated ASEAN regional business manager based in Singapore. **Steve Soroko** was named as the company's first director — business development for Europe, based in Vienna.

Aluminum Assn. Makes Leadership Changes

The Aluminum Association, Arlington, Va., has named **Dale Chittum**, **Jean-Marc Germain**, **Kevin Person**, **Layle K. Smith**, and **James Robertson** to its board of directors. **Fernando Simoes Henriques** and **Jean Simon** have joined as members of the chairman's advisory council. Chittum is with ARAMARK Uniform Services; Germain is president of Novelis North America, a supplier of aluminum rolled products; Person is vice president of sales and marketing at Wagstaff Inc., a supplier of aluminum casting technology; Smith is president and CEO and a member of the board of directors of Covalence Specialty Materials Corp.; and Robertson is executive director business development at Cattron Group Int'l, a supplier of wireless remote controls for industrial applications. Henriques is president of Hydro's Extrusion Americas unit, and Simon is president of Primary Metal — North America, Rio Tinto Alcan.

In another announcement, the Association named **David L. Oberholtzer**, director, corporate services, Valimet, Inc., its 2008 Marlan Boultinghouse Award winner. In the industry for 35 years, Oberholtzer has been a member of the Safety and Property Protection Committee for 20 years and served as chair from 1991 to 1993.

Motoman Names Two VPs

Motoman Inc., Dayton, Ohio, has appointed **John P. Donlon** vice president

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For info go to www.aws.org/ad-index



Thomas Schockman



John Donlon

U.S. sales and **Thomas J. Schockman** as vice president, finance and accounting, and CFO. Donlon, with more than 28 years in the industry, most recently was vice president, sales and marketing, for Union Switch & Signal in Pittsburgh, Pa. Schockman previously served as director of financial planning and analysis and corporate controller for Robbins & Myers, Inc., Dayton, Ohio.

Plant Manager Named at Welding Alloys



Tim Ehlman

Welding Alloys Group, Florence, Ky., a manufacturer of flux cored welding wires for hardfacing applications, has named **Tim Ehlman** plant manager. Prior to joining the company, Ehlman was plant manager at ZF Sachs Automotive of

America for 15 years.

Jet Edge Appoints Int'l Sales Manager



Dave Anderson

Jet Edge, Inc., St. Michael, Minn., a manufacturer of ultrahigh-pressure waterjet systems, has appointed **David J. Anderson** as its new international sales manager. In the industry for 15 years, Anderson previously was an advisor to U.S.

and foreign businesses regarding risk management, sales processes, and marketing management.

Laser Cladding Services Appoints President

Gremada Industries, Inc., Houston, Tex., has tapped its vice president of sales and marketing, **James P. Kowske**, to serve as president of its subsidiary, Laser Cladding Services, Ltd. Kowske will continue in his role as the company's vice president.

Navy Metalworking Center Names Technical Director

The office of Naval Research recently approved the Navy Metalworking Center's recommendation to appoint **Robert E. Akans** technical director. Akans has 24 years of experience in the aluminum industry, most recently serving as director, manufacturing technologies, at Concurrent Technologies Corp.

VP Named at MISTRAS



Jim Redmon

MISTRAS Group, Inc., Princeton Junction, N.J., has promoted **Jim Redmon** to vice president for its Asset Integrity Management Services Center of Excellence. Previously, Redmon was manager of the PCMS software division.

Lincoln Electric Appoints Two VPs



Earl Ward



Steve Hedlund

Lincoln Electric Holdings, Inc., Cleveland, Ohio, has elected **Steven B. Hedlund** to the newly created position of vice president, strategy and business development, and **Earl L. Ward** to the newly created position of vice president, mergers, acquisitions, and investor relations. Previously, Hedlund was vice president of growth and innovation for Master Lock Co. Ward previously was treasurer and vice president of investor relations at the former Washington Group Int'l that is currently known as the Washington division of URS Corp.

Obituaries

Lawrence Allen Creager

Lawrence Allen Creager died Oct. 2 in Fenton, Mo., from complications following surgery. An AWS member since 1989, Creager served more than 25 years in the welding industry, holding sales management positions with Tweco/Arcair, OKI Bering, and ABICOR Binzel. He is survived by his wife, Karen, two daughters, and four grandchildren.

Richard Arthur Huber



Richard A. Huber

Richard Arthur (Dick) Huber, 79, died July 22, 2008, at his home in Oak Ridge, Tenn. An AWS member since 1958 and a Life Member, he served as chairman of the Northeast Tennessee Section (1978–1979), and as AWS president (1990–1991). He was

scheduled to receive his Gold Membership Award for 50 years of service to the American Welding Society at the recent AWS Welding Show.

After serving two years in the U.S. Army, Huber became involved with the welding of pressure vessel steels for Alco Products, Inc., in Schenectady, N.Y. He received his bachelor's degree in chemistry from Michigan State University in 1952, and his master's in metallurgy from Rensselaer Polytechnic Institute in 1959. Later that year he started work for Union Carbide (later Marietta Energy Systems, Inc.) Nuclear Div. Y-12 Plant as a welding engineer. In the 1960s, he introduced electron beam welding to the facility and published several papers on the topic. In 1972, Huber transferred to the Assembly Div. as supervisor of the Metallurgical Joining Section, responsible for the production joining activities of the Y-12 Plant, and later became group leader of the newly combined Assembly and Development Joining groups.

Huber was active with St. Stephen's Episcopal Church in Oak Ridge, Tenn., where he served in many capacities, including driving for F.I.S.H. (Fellowship In Serving Humanity).

Flying was his favorite activity. He held IFR and commercial flying licenses, and piloted many cross-country flights. A certified scuba diver, Huber also engaged in golf, tennis, bowling, fishing, and playing duplicate bridge, and was an avid soccer fan for his grandchildren. Following his retirement in 1992, he and his wife traveled extensively in their RV, visiting Alaska and their far-flung family members. He is survived by his wife, Elaine, four sons, Richard Michael, Timothy Todd, Gregory Evans, Laurence Edward, and Kevin Lee Hayes a son they adopted in 1980, three brothers James, Alan, and Patrick, and several nieces and nephews.

Charles Leigh Foster II

Charles Leigh "Chuck" Foster II, 58, died suddenly Nov. 1 in China while traveling on business. An AWS member since 1985, he was active with the San Francisco Section. He is survived by his wife Rosalie.

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1991	Robert Pope*

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Annual FABTECH International & AWS Welding Show

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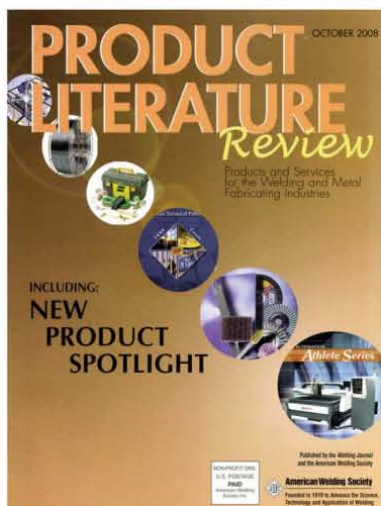
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A CCT Diagram for an Offshore Pipeline Steel of X70 Type

The diagram developed is valid for the heat-affected zone for welding operations where relatively rapid heating up to 1200°C occurs

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ABSTRACT

By means of dilatometry and metallographic analyses, a continuous-cooling transformation (CCT) diagram valid for the heat-affected zone (HAZ) in welding operations with relatively rapid heating up to about 1200°C on an offshore pipeline steel of X70 type has been established along with the linear thermal expansion coefficients for the austenite and bainite phases. A dilatometer was built for this purpose. For comparison reasons, the steel was also tested in a commercial dilatometer using larger samples than in the laboratory-built dilatometer. The importance of using relatively small dilatometry samples in order to minimize the inaccuracy associated with the temperature gradients has been substantiated by means of mathematical modeling showing that cylindrical samples of 20-mm length and 3-mm diameter are sufficiently small.

Introduction

Modeling of stresses and deformations induced during welding of phase-transforming steels requires constitutive equations quantifying the flow stress during the viscoplastic deformation of the material. The establishment of such equations is demanding as a series of complex phenomena should be accounted for, such as work hardening, strain rate sensitivity, and the flow stress dependency on the specific mixture of phases appearing at the different temperatures. The phase transformations per se also lead to so-called transfor-

mation plasticity when stresses are applied, and the volumetric strains associated with the transformations along with the thermal strains constitute the driving force for the stress/deformation development. Additional scientific challenges have to be dealt with when the equation parameters are to be experimentally determined.

The complexity in developing reliable constitutive equations for welding stress and deformation in steels indicates a need for simplified approaches. Indeed, constitutive equations applied in most engineering models today are relatively simple (Refs. 1–4) and often based on the ideal plasticity assumption, taking the flow stress of each phase to be given by the temperature-dependent yield stress for that phase in combination with a mixture law (Ref. 2). A new approach in accordance with these ideas was recently presented along with the determination of the temperature- and microstructure-dependent flow stress for a pipeline steel of X70 type (Ref. 5). This approach requires prior knowledge of the relevant continuous-cooling-transformation (CCT) diagram providing information about the involved phases and the temperatures at which the phase transformations take place during continuous cooling.

Continuous-cooling-transformation diagrams can be established by means of

dilatometry experiments (Refs. 6–11) in which the volume expansion/contraction associated with temperature changes and phase transformations are quantified. Such an experiment reveals how the length change of an unloaded specimen varies with temperature, and this is usually quantified by means of a dilatometry curve similar to that shown schematically in Fig. 1. For ferritic steels, the upper and lower straight lines correspond typically to pure ferrite and austenite phases with slopes equal to the respective linear thermal expansion coefficients. The transformations between the phases, during which the phases coexist, are furthermore reflected in the nonlinear parts of the dilatometry curves.

The purpose of the present article is to report the establishment of a CCT diagram valid for the heat-affected zone (HAZ) in welding operations with relatively rapid heating up to about 1200°C of the offshore X70 pipeline steel with the composition given in Table 1. This diagram has, to the knowledge of the authors, not been reported elsewhere in the open scientific literature. Hulka et al. (Ref. 12) has published similar X70 data; however, the chemical composition in their investigated steel was different from that in Table 1. This difference influences significantly the microstructure and hardenability.

In order to obtain small temperature gradients in the samples, a new dilatometer was built, and for comparison reasons, the steel was also tested in a commercial dilatometer (Ref. 13) using larger samples than in our laboratory-built dilatometer. The experimental procedures are outlined in the following section. The results, including metallographic examination of the samples, are presented and discussed later along with a presentation of the final CCT diagram.

KEYWORDS

Continuous Cooling
Transformation Diagrams
Dilatometry
Heat-Affected Zone
Phase Transformations
Pipeline Steels

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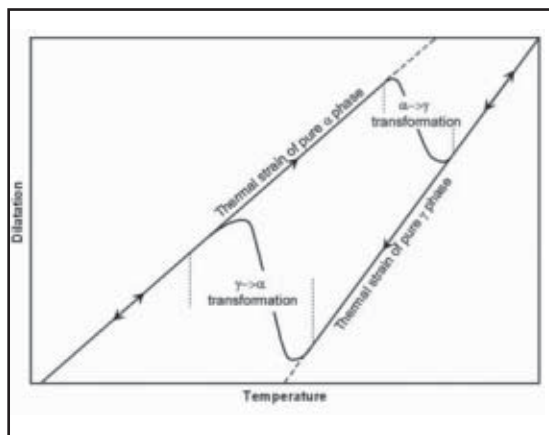


Fig. 1 — Schematic dilatometry diagram of a ferritic steel.

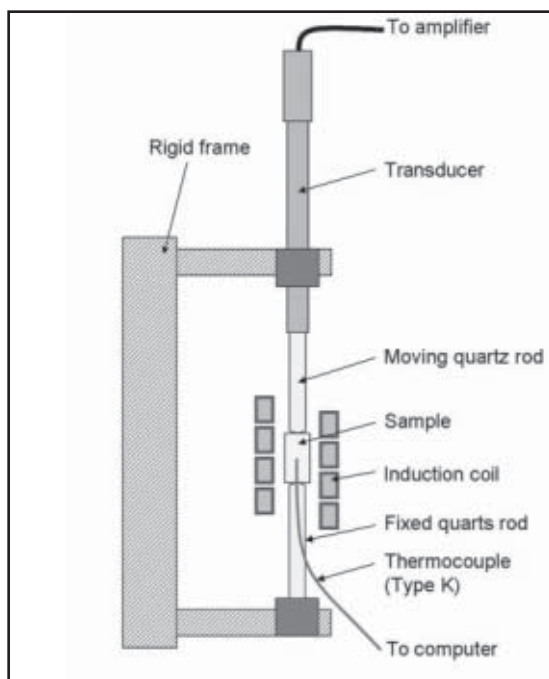


Fig. 2 — Schematic drawing of the laboratory-built dilatometer.

Experimental Procedures

For the laboratory-built dilatometer, cylindrical samples of 20-mm length were machined from the API 5L X70 (Ref. 14) pipeline base metal. Two sets, having diameters of 3 and 10 mm, respectively, were made with the purpose of studying how different geometries would respond to the rapid heating and cooling cycles and thus affect the measurements. The samples for the commercial dilatometer were 65 mm long and had a 10 × 10 mm² cross section. All samples were machined such that the

dilatometry measurements were carried out in the longitudinal direction of the pipe.

Experimental Setup and Testing

A schematic drawing of the laboratory-built dilatometer is shown in Fig. 2. It consists of a displacement transducer mounted in a rigid frame, and the sample is mounted between two quartz rods, one moving and one fixed. A spring-loaded moving quartz rod is connected to the transducer. Heating of the sample is provided by means of an induction coil, while cooling of the specimen is accomplished by flushing the sample with helium and/or argon. The temperature was recorded by a Type K thermocouple, with wire diameter of 0.5 mm, spot welded to the sample surface at mid-length. Upon heating/cooling, the sample expands/contracts and pushes on the quartz rods. This movement was captured by the displacement transducer and recorded by the computer. The sensitivity of the dilatation measurements is, based on data given by the displacement transducer manufacturer (Ref. 15), estimated to correspond to a fraction transformed of about ± 3.1%.

In the commercial dilatometer (Ref. 13), the sample is mounted in water-cooled copper clamps and heated by the Joule effect. Controlled cooling is accomplished by reducing the electric current such that there is a net heat flux from the sample to the cold copper clamps.

The dimensional changes were measured over the cross section of the sample, limited to a gauge length of around 10 mm.

The samples, both for the laboratory-built and the commercial dilatometer, were subjected to thermal cycles similar to those in welding operations of rapid heating (150°C/s) to a peak temperature, T_p , of 1200°C prior to cooling. The cooling times between 500° and 800°C, $\Delta t_{8/5}$, were about 5, 10, 20, and 100 s. Dilatometry curves similar to the one schematically shown in Fig. 1 were established for each sample geometry and cooling time. Extractions of

transformation start and finish temperatures from the dilatation curves were done manually. An estimated accuracy of ± 5°C in the manual determination of transformation start and end temperatures is expected based on the following procedure. A baseline was drawn on top of the linear portion of the dilatation curves from approximately 100°C above the transformation start. The transformation start temperature was found where the dilatation curve starts to deviate from this baseline. Similarly the transformation finish temperature was found by means of the baseline drawn from approximately 100°C below the transformation finish temperature. This procedure is schematically illustrated in Fig. 3. For the most rapid cooling time, i.e., $\Delta t_{8/5}$ of 1.4 s, the transformation temperatures were determined by derivation of the cooling curve, since the dilatation curve in this case was too rugged.

Continuous-cooling-transformation diagram data were obtained over about two orders of magnitude in cooling time ($\Delta t_{8/5}$), also the linear thermal expansion coefficients of the high- and low-temperature phases, austenite and bainite, respectively, were determined from the dilatometry curves during cooling.

Microstructure and Temperature Gradients in the Samples

The metallographic samples were ground to a 1000-grit finish and polished using 3- and 1-μm diamond spray prior to etching in a 2 vol-% nital solution to reveal the microstructure. The microstructure of the base metal and of the samples after the dilatometry tests was characterized by means of light microscope point counting. For each sample, at least 1000 points were counted at a magnification of 500× using a 10 by 10 grid in the microscope. The microstructure constituents were classified as martensite (M), upper bainite, lower bainite and acicular ferrite (B), grain boundary or polygonal ferrite (F), and pearlite (P), where the letters in parentheses are the usual symbols that in the present article are used in Table 2. The metallographic examination also included measurements of Vickers hardness (HV_{10}).

The relatively high heating and cooling rates imposed by the induction heating and gas cooling lead to temperature gradients in the radial sample direction. The heat transfer in the 3- and 10-mm-diameter axisymmetric samples was, therefore, quantified by means of the FEM software *WeldsimS* (Ref. 16). Brief descriptions of the governing equations, phase transformation model as well as geometries and boundary conditions employed in the simulations with *WeldsimS* are all given in the Appendix. In the simulations, the fastest measured surface cooling curve for the 10-

Table 1 — Chemical Composition of the X70 Pipeline Steel (elements in wt-%)

C	Si	Mn	P	S	Cr	Ni	Al	Cu	Mo	Nb	V	Ti	N
0.09	0.30	1.71	0.012	0.001	0.07	0.05	0.05	0.04	0.02	0.05	0.01	0.02	0.005

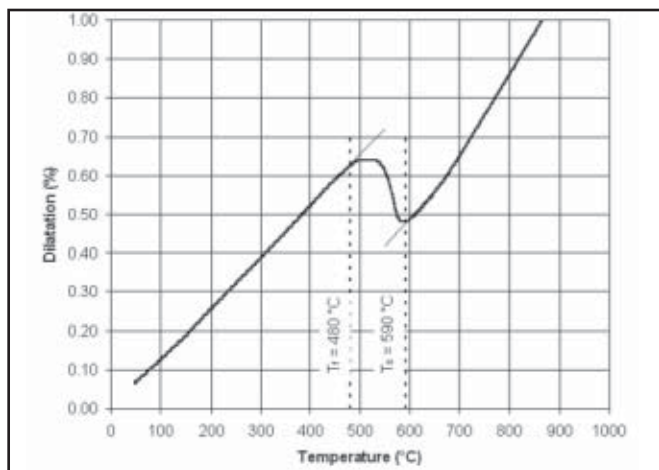


Fig. 3 — Illustration of procedure for manual transformation temperature determination from dilatation curve acquired from 3-mm-diameter sample with $\Delta t_{8/5} = 23.5$ s.

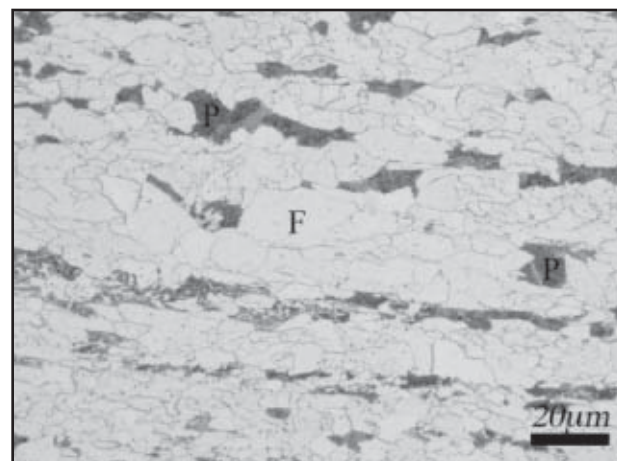


Fig. 4 — Microstructure in the base metal.

mm-diameter samples was imposed as boundary condition, i.e., a thermal cycle with $T_p = 1200^\circ\text{C}$ and $\Delta t_{8/5} = 5.5$ s.

Results and Discussion

Experimental Results

The initial microstructure of the base metal shown in Fig. 4 consisted of mainly ferrite (86%) with bands of pearlite (14%). The average hardness was 200 HV₁₀.

Altogether 11 dilatometry curves were established, and typical results obtained in the laboratory-built and commercial dilatometer are shown in Fig. 5. Note that dilatometry curves were obtained only during cooling in the laboratory-built dilatometer since the transducer was strongly affected by noise from the induction coil used during heating. This means that the phase boundaries upon heating, i.e., A_{c1} and A_{c3} , were determined solely on the basis of the commercial dilatometer tests.

The results from the dilatometry measurements are summarized in Table 2. In all cases, the austenite decomposition resulted in the formation of bainite and/or martensite, and the transformation from austenite to bainite is shifted toward lower temperatures as $\Delta t_{8/5}$ is decreased. Typical microstructures are shown in Fig. 6

For the highest values of $\Delta t_{8/5}$ (> 20 s), the transformation product is bainite. Even the highest cooling times, $\Delta t_{8/5} = 107.2$ and 109.4 s, resulted in a fully bainitic microstructure, as evidenced for $\Delta t_{8/5} = 107.2$ s by the micrograph in Fig. 7. This result is somewhat unexpected since microstructure constituents such as grain boundary ferrite or polygonal ferrite are more usual at this high $\Delta t_{8/5}$ (Ref. 17). The observation is, however, in agreement with similar findings reported by Hulka et al. (Ref. 12). For the lower values of $\Delta t_{8/5}$

(< 10 s), martensite is formed in addition to bainite. As expected, the increase in martensite fraction for decreasing $\Delta t_{8/5}$ is accompanied by an increase in the hardness (Ref. 18).

The martensite transformation start temperature, denoted by M_s , as well as the A_{c1} and A_{c3} temperatures were finally determined. While the determination of M_s was based on 3-mm-diameter samples, A_{c1} and A_{c3} were determined on the basis of the square samples using the commercial equipment. The results were $M_s = 437^\circ\text{C}$, $A_{c1} = 760^\circ\text{C}$, and $A_{c3} = 920^\circ\text{C}$. The experimentally determined value of M_s is close to that calculated by the empirical formulas in Ref. 19 to be 444°C .

The average linear thermal expansion coefficients were determined from the dilatometry curves, during cooling, to 2.09×10^{-5} and $1.29 \times 10^{-5} \text{ K}^{-1}$ for the austenite and bainite phases, respectively. These values are close to data reported by Takahashi (Ref. 20).

The CCT Diagram

The CCT diagram shown in Fig. 8 was established on the basis of all dilatometry and metallography data summarized in Table 2, which includes all three sample geometries and the use of both the laboratory-built and the commercial dilatometer. The diagram reveals that the cooling rate dependent onset temperature for the phase transformation occurs at about the same temperature for all three sample

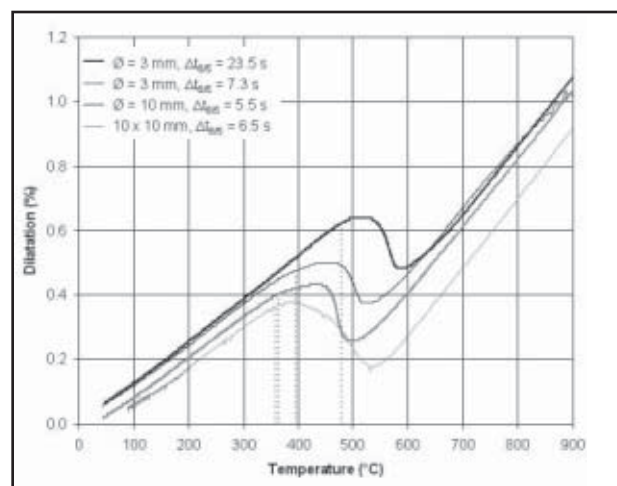


Fig. 5 — Example of dilatometry curves obtained by the laboratory-built dilatometer (cooling only) and by the commercial dilatometer. The transformation temperatures of 480° , 395° , 365° and 360°C for the different samples are indicated by the dotted lines.

geometries. The temperatures at which the transformation is finished is, however, lower for the larger samples; the difference being about 30°C between the 10-mm- and 3-mm-diameter samples when $\Delta t_{8/5}$ is about 5 s.

The bainite start curve occurs at slightly higher values for $\Delta t_{8/5}$ and lower temperatures than the curve in the X70 CCT diagram in Ref. 12. Our result indicates that the hardenability of the tested material is higher than that of the material investigated in Ref. 12, which in turn may be attributed to the slight difference in chemical composition between the two steels.

It is believed that the sample geometry-dependent finish temperatures can be explained by a relatively large radial temperature gradient in the cylindrical specimens with the lower temperature at the surface during cooling. Since the measured dilatation is plotted vs. surface temperature, a too

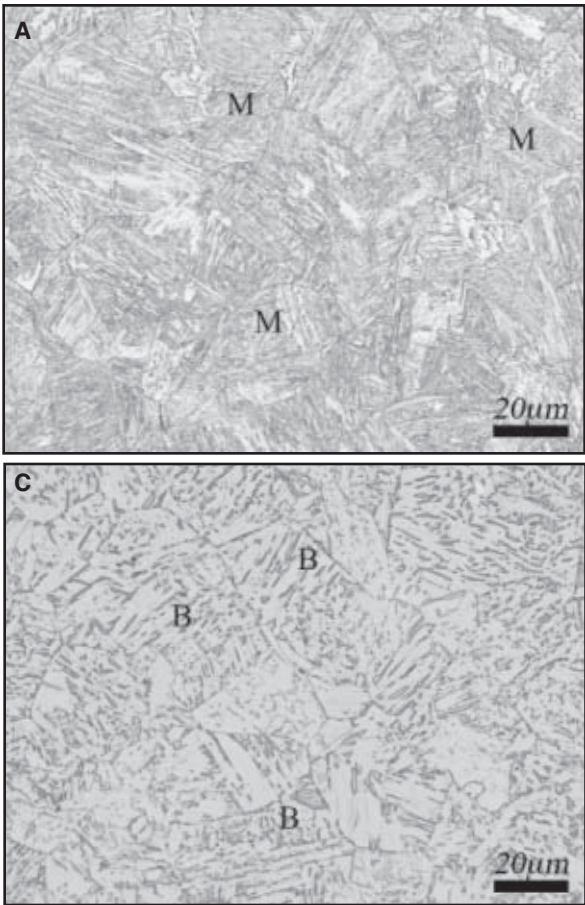


Fig. 6 — Microstructure in samples with 3-mm diameter subjected to thermal cycles in the dilatometry tests. A — $T_p = 1215^{\circ}\text{C}$, $\Delta t_{8/5} = 1.4$ s; B — $T_p = 1197^{\circ}\text{C}$, $\Delta t_{8/5} = 7.3$ s; C — $T_p = 1217^{\circ}\text{C}$, $\Delta t_{8/5} = 23.5$ s.

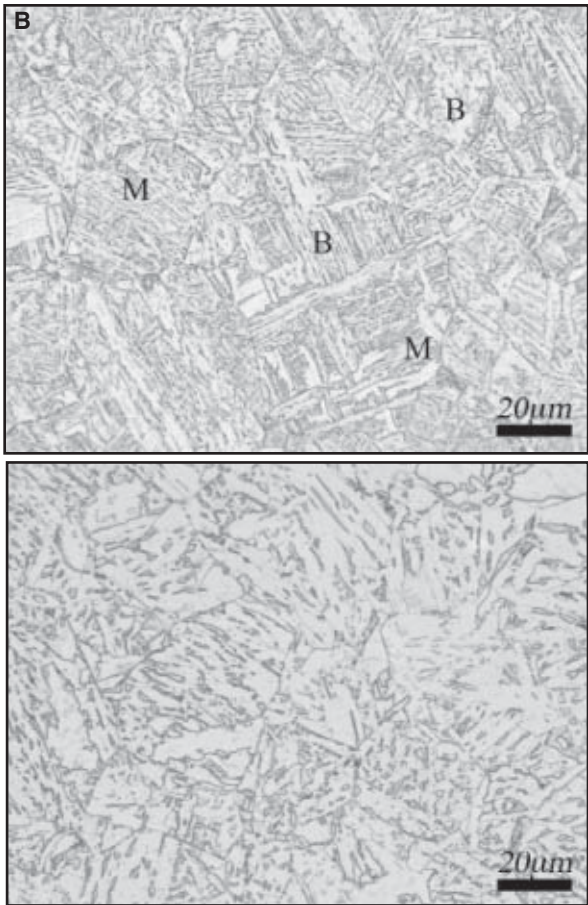


Fig. 7 — Microstructure in a dilatometry sample with 10-mm diameter subjected to a thermal cycle with $T_p = 1200^{\circ}\text{C}$ and $\Delta t_{8/5} = 107.2$ s.

low value of the latter compared to the average temperature in the sample would result in an artificially low value for the transformation. And the inaccuracy will increase with sample size and cooling rate due to the corresponding increase in temperature gradient. This assumption is supported by the findings of Alexandrov et al. (Ref. 21) who suggested that the temperature gradient in

the sample cross section was a possible reason for the delay in the dilatometer response in experiments comparing single-sensor differential thermal analysis to dilatometry. Relatively large longitudinal temperature gradients exist also in the square samples. Walsh et al. (Ref. 22) examined the magnitude of such gradients as well as the

major factors affecting the gradients in an experimental setup similar to that used in the commercial dilatometer in the current investigation. The specimen maximum temperature of about 1200°C was obtained in the mid position between the water-cooled copper clamps; the clamped ends being kept at about 4°C . It is believed that the lower transformation finish tem-

Table 2 — Results from the Dilatometry Measurements

Sample geometry	T_p [$^{\circ}\text{C}$]	$\Delta t_{8/5}$ [s]	T_s [$^{\circ}\text{C}$]	T_f [$^{\circ}\text{C}$]	Microstructure [vol.-%]			Hardness [HV10]
					M	B	Std. Dev.	
Diameter 3 mm	1215	1.4	437	295	100	0	0.0	340
Diameter 3 mm	1197	7.3	530	395	62	38	3.7	277
Diameter 3 mm	1217	23.5	590	480	0	100	0.0	212
Diameter 10 mm	1233	5.5	540	365	57	43	4.4	268
Diameter 10 mm	1230	9.8	590	410	28	72	5.0	252
Diameter 10 mm	1250	21.7	590	480	0	100	0.0	225
Diameter 10 mm	1200	107.2	630	490	0	100	0.0	202
Square, 10 × 10 mm	1204	6.5	560	360	66	34	4.5	294
Square, 10 × 10 mm	1210	10.2	585	410	46	54	5.1	264
Square, 10 × 10 mm	1206	22.6	610	480	0	100	0.0	231
Square, 10 × 10 mm	1217	109.4	620	530	0	100	0.0	209

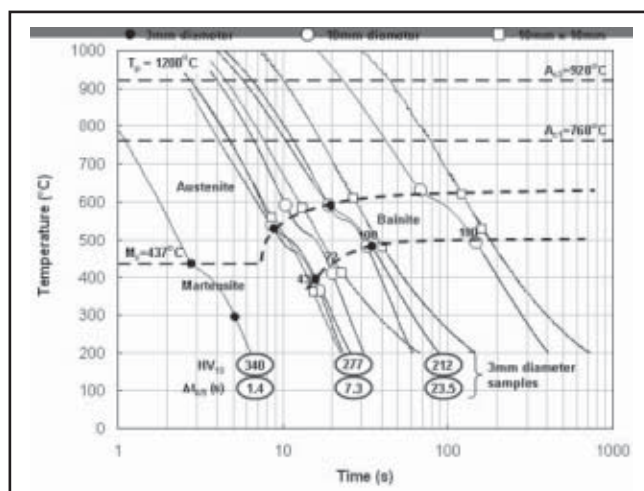


Fig. 8 — CCT diagram for the X70 steel obtained after cooling from 1200°C using different cooling rates.

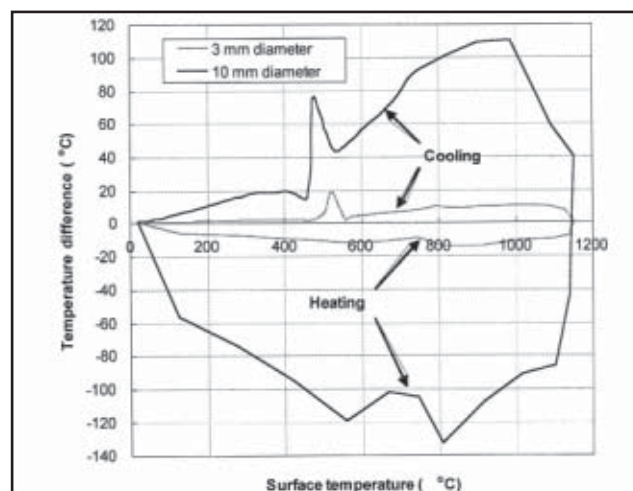


Fig. 9 — Computed temperature differences ($T_{center} - T_{surface}$) between the sample center and surface as a function of temperature during heating and cooling. The calculated results apply for cylindrical samples of 3- and 10-mm diameter subjected to a thermal cycle with $T_p = 1200^\circ\text{C}$ and $\Delta t_{8/5} = 5.5$ s.

peratures occurred as a result of a measured surface temperature during cooling being lower than the average temperature in the sample cross section. The transformation finish will thus apparently occur at a temperature lower than the average temperature in the sample cross section.

The existence of thermal gradients within the cylindrical samples was verified by the previously mentioned *WeldsimS* simulation. Figure 9 displays the temperature difference between the center and the surface of the samples as a function of temperature during heating and cooling. It is seen that there is a relatively large temperature difference for the 10-mm-diameter sample, while this difference is much smaller for the 3-mm-diameter sample. Note also the impact of phase transformation during cooling on the temperature gradients for the sample of 10-mm diameter in the temperature interval 400°–550°C. During cooling, the ferritic transformation starts at the surface of the sample and as transformation heat is removed, the temperature difference between surface and center decreases. When the transformation is finished in the surface region; the temperature difference between surface and center increases due to the removal of transformation heat in the sample center. When transformation is complete in the whole sample cross section, temperature differences decrease again. It should also be mentioned that temperature gradients within the sample may induce plastic deformations, which in turn may affect the phase transformation during cooling (Ref. 23).

Conclusions

A CCT diagram valid for the HAZ in welding operations with relatively rapid heating to about 200°C for X70 pipeline steel with composition given in Table 1 has

been established by means of dilatometry and metallographic analyses. The M_s , A_{c1} , and A_{c3} temperatures were found to be 437°, 760°, and 920°C, respectively. At cooling times $\Delta t_{8/5}$ of below 10 s, the microstructure of the samples consists of a mixture of bainite and martensite, with formation of a fully martensitic microstructure at the shortest cooling time. Cooling times above 20 s resulted in the formation of 100% bainitic microstructure. Even at cooling times $\Delta t_{8/5}$ as high as 109 s, 100% bainite was formed. Also, the linear thermal expansion coefficients for austenite and bainite were measured. The values are 2.09×10^{-5} and $1.29 \times 10^{-5} \text{ K}^{-1}$, respectively. The importance of using relatively small dilatometry samples in order to minimize the inaccuracy associated with the temperature gradients has been substantiated by means of mathematical modeling showing that cylindrical samples of 20-mm length and 3-mm diameter are sufficiently small.

Acknowledgments

The authors thank Hallvard Fjær at the Institute for Energy Technology, Norway, for carrying out the heat transfer calculations. Financial support from the Norwegian Research Council through the RESIA STORFORSK Project (Project No. 167397/V30) is gratefully acknowledged.

Appendix

Analysis of Thermal Gradients during the Dilatometry Experiments

In order to assess the thermal gradients in the samples during the dilatometry experiments, the FEM software *WeldsimS* was employed (Refs. 5, 16). In this model, the effect of the phase transformations on

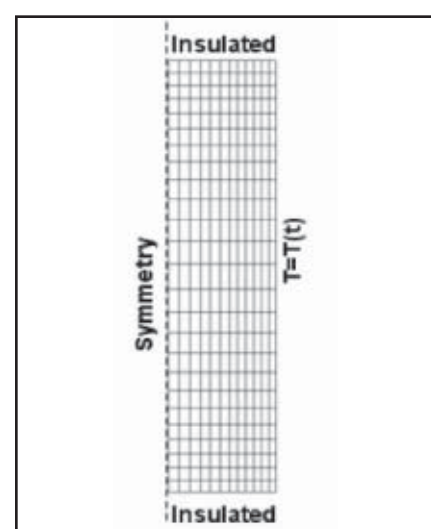


Fig. 10 — FEM mesh employed in the heat transfer analysis of dilatometry experiment with the 10-mm samples as well as boundary conditions employed in the simulations.

the heat transfer is taken into account. The heat transfer and phase transformation modules of *WeldsimS* are described in more detail in Refs. 5 and 16. Brief descriptions of both models as well as the conditions for the heat transfer analysis carried in the present work are outlined below.

Model Description

In *WeldsimS*, the metallurgical state of steel is characterized by the fractions p_i of its different constituents (e.g., austenite, ferrite, pearlite, bainite, and martensite) satisfying the condition

$$\sum p_i = 1 \quad (1)$$

By assuming linear mixing laws, and by defining an enthalpy H_i for each phase by

$$H_i(T) = H_i^0 + \int_{T_0}^T c_{p,i}(T) dT \quad (2)$$

The equation for the transient heat transfer can be written as

$$\sum_i \rho_i p_i c_{p,i} \dot{T} + \sum_i \rho_i \dot{p}_i H_i = \nabla \cdot \left(\sum_i \rho_i \lambda_i \nabla T \right) + Q \quad (3)$$

where ρ_i , λ_i , $c_{p,i}$, and T denote, respectively the density, thermal conductivity, specific heat for phase i , and the temperature. H_i^0 is the enthalpy of phase i at the reference temperature T_0 and Q is the internal heat source. T and p_i in Equation 3 are derivatives with respect to time. Note that the second term on the left side of Equation 3 represents the transformation heat associated with the phase change.

Solving Equation 3 requires the knowledge of the phase proportions p_i . For this purpose, the anisothermal transformation kinetics model by Leblond and Devaux (Ref. 24), which has previously been implemented in *WeldsimS*, is employed. Up to five metallurgical phases (austenite, ferrite, pearlite, bainite, and martensite) can be taken into account in *WeldsimS*. To illustrate the modeling equations in the case of two phases (denoted 1 and 2), one has to distinguish between the $1 \rightarrow 2$ ($p_1 > 0$) and the $2 \rightarrow 1$ ($p_2 > 0$) transformations. For each case, the rate of transformation is given by

$$\dot{p}_1 = \left(\frac{p_{21}^{eq}(T) - p_1}{\tau_{21}(T)} \right) \cdot f_{21}(\dot{T}) \quad (2 \rightarrow 1 \text{ transformation}) \quad (4)$$

$$\dot{p}_2 = \left(\frac{p_{12}^{eq}(T) - p_2}{\tau_{12}(T)} \right) \cdot f_{12}(\dot{T}) \quad (1 \rightarrow 2 \text{ transformation}) \quad (5)$$

where p_1 and p_2 denote the fraction of phase 1 and 2, respectively, with $p_1 + p_2 = 1$. p_{21}^{eq} (p_{12}^{eq}) is the value of p_1 (p_2) at equilibrium for a given temperature, and τ_{21} (τ_{12}) is the characteristic time for the transformation $2 \rightarrow 1$ ($1 \rightarrow 2$). The functions $f_{21}(\dot{T})$, and $f_{12}(\dot{T})$ allow for taking into account the effect of the cooling rate. All these parameters are obtained by fitting the phase fractions from various heating/cooling curves to hit correctly the A_{C1}/A_{C3} (during heating) and the start/end temperatures for the ferritic transformations shown in CCT diagrams (during cooling).

Application to X70 Steel

To obtain the modeling results of Fig. 9, 2-D axis-symmetry models have been

established using cylindrical geometries with the same radii and heights as the samples employed in the dilatometry experiments (i.e., $5.0 \times 20.0 \text{ mm}^2$ and $1.5 \times 20.0 \text{ mm}^2$). Figure 10 shows the mesh employed in the thermal analysis as well as the thermal boundary conditions. Due to symmetry reason, the computation domain corresponds to half of the sample. The mesh is made of 300 elements and 338 nodes. Thermophysical data in the modeling were taken from the literature and are the same as those applied in Ref. 16. Parameters used for the phase transformation model are based on the work of Ref. 5 and were extracted using the CCT diagram of Hulka et al. (Ref. 12), which is obtained for a steel similar to the X70 material studied in the present work.

As seen in Fig. 10, a time-dependent temperature is imposed as a thermal boundary condition on the vertical surface of the cylinders, while the top and bottom surfaces are insulated. For both geometries, the imposed temperature as a function of time corresponds to the surface measurements for the thermal cycle with $T_p = 1200^\circ\text{C}$ and $\Delta t_{8/5} = 5.5 \text{ s}$. For this cycle, the peak temperature is reached after approximately 10 s of heating time.

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Metallurgical Investigation into Ductility Dip Cracking in Ni-Based Alloys: Part I

Quantifying cracking susceptibility during the first thermal cycle using the Gleeble® hot ductility test

BY F. F. NOECKER II AND J. N. DUPONT

ABSTRACT

Alloy 690 (A690) is a Ni-Cr-Fe alloy with excellent resistance to general corrosion, localized corrosion, and stress corrosion cracking. However, the companion filler metal for A690, Filler Metal 52 (FM52), has been shown by several researchers to be susceptible to ductility dip cracking (DDC), which limits its widespread use in joining applications. The Gleeble® hot ductility test was used to evaluate the DDC susceptibility of wrought Alloy 600 (A600) and A690, along with their companion filler metals, Filler Metal 82H (FM82H) and FM52, throughout the heating and cooling portions of a simulated weld reheat thermal cycle. Both macroscopic mechanical measures (ductility and ultimate tensile strength (UTS)) and microscopic measures (normalized crack length) of DDC were quantified and compared. The greatest resistance to DDC was observed in A600 and A690 during heating where no DDC cracks formed even when the samples were fractured. Both A690 and FM52 were found to form an intermediate on-cooling dip in ductility and UTS, which corresponded to an increase in DDC crack length normalized per grain boundary length. Ductility dip cracks were preferentially oriented at a 45-deg angle to the tensile axis and were of a wedge type appearance, both of which are indicative of grain boundary sliding (GBS). The hot ductility and cracking resistance of FM82H remained high throughout the entire thermal cycle. DDC susceptibility in both FM52 and FM82H decreased when the thermal cycle was modified to promote coarsening/precipitation of intergranular carbides. These intergranular carbides appear to decrease DDC susceptibility by limiting grain boundary sliding. A more detailed treatment of microstructural and microchemical evolution during the weld thermal cycle and their influence on the mechanism(s) of DDC is discussed in the Part II companion paper (Ref. 1).

Introduction

Nuclear energy provides for nearly 15% of the world commercial electrical power production with France, Sweden, and the Ukraine deriving nearly 50% or more of their electrical power from nuclear energy (Ref. 2). Nuclear reactors produce 20% of electrical power in the United States (Ref. 2), and power nearly 100% of aircraft carriers and submarines in the U. S. Navy's fleet (Ref. 3). For their safe and reliable operation, nuclear reactors require materials that are highly corrosion resistant, particularly to intergranular stress corrosion cracking (IGSCC).

For more than 40 years, Ni-Cr-Fe alloys such as A600 have been used for several key components in nuclear reactors due to their corrosion resistance. However, A600 has been found to be particularly susceptible to IGSCC in certain applications and environments (Refs. 4, 5). The replacement alloy for A600 is A690, which has excellent resistance to general corrosion, localized corrosion, and IGSCC in a wide range of environments (Ref. 6). Alloy 690 has been replacing A600 in United States commercial power plants since 1988 (Ref. 7). However, the companion filler metal for A690, FM52, has been shown by several researchers to be susceptible to ductility dip cracking (DDC), which limits its widespread use. This has resulted in the undesirable situation where FM82H, the companion weld filler metal to A600, may be used to join A690 due to its weldability despite its susceptibility to IGSCC in applications where the improved corrosion resistance

of FM52 is desired, thereby compromising the service life of the component for weldability.

There are several key characteristics of DDC. First, as the name "ductility dip" implies, there is significant reduction in ductility that occurs at intermediate temperature, corresponding to approximately 0.5 to 0.8 homologous temperature (T_m) of the alloy. Secondly, DDC is an intergranular form of cracking. Third, there are no liquid films associated with DDC. Unlike other common forms of weld cracking, such as liquation and solidification cracking, DDC is a solid-state phenomenon.

A substantial amount of research has recently been performed on ductility dip cracking in these alloys (Refs. 8–19) and in other austenitic alloys (Refs. 20–27); however, the mechanism of DDC is not fully understood and may differ among different alloys. Several hypotheses have been proposed to include grain boundary sliding (Refs. 13, 16, 25–28), intergranular impurity element embrittlement (P, S, and H) (Refs. 9–11, 16, 20, 21, 23), and intergranular second phase precipitation (Refs. 11, 19, 27, 29).

Multiple techniques have been used to evaluate DDC susceptibility. These include multipass welds, and Varestraint- and Gleeble®-based testing. Multipass welds and Varestraint tests have several limitations that make them less than ideal for a carefully controlled investigation into the mechanism of DDC. In both techniques liquid films can form, which can confound the interpretation of cracking results. Furthermore, many multipass weld tests utilize in excess of 100 weld passes. Each region of a multipass weldment experiences a different thermal history, which will result in different microstructures and potentially different DDC susceptibility levels throughout the

KEYWORDS

Alloy 690 (A690)
Alloy 600 (A600)
Filler Metal 52 (FM52)
Filler Metal 82H (FM82H)
Ductility Dip Cracking (DDC)
Ultimate Tensile Strength (UTS)
Grain Boundary Sliding (GBS)

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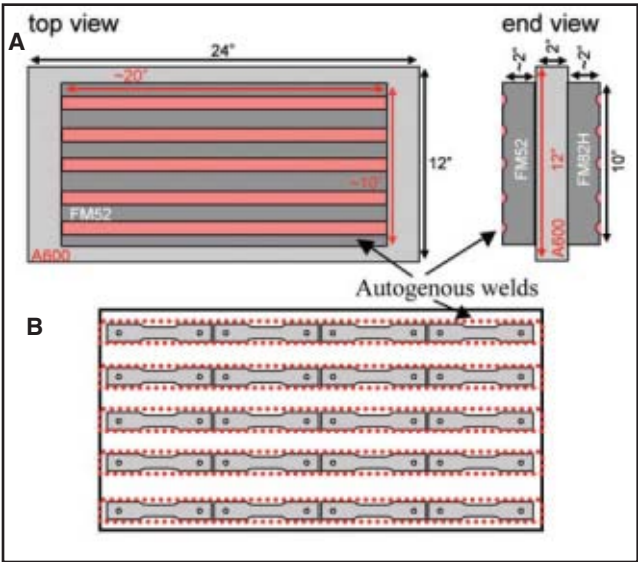


Fig. 1 — Preparation of FM52 and FM82H as-solidified weld metal samples. A — FM52 and FM82H were deposited onto A600, then autogenous welds were made onto weld pad buildup. B — layer of autogenous welds sectioned from weld pad, then dogbone specimens sectioned from this layer. All dimensions in inches.

sample. Thus, it is extremely difficult to confidently identify causes of DDC given such complex thermal mechanical history. Lastly, it is difficult, if not impossible, to capture and study the elevated temperature microstructure and microchemistry existent at grain boundaries using these tests because of their inherent difficulty of rapidly quenching the weld at precise time/temperatures in the weld thermal cycle. Because DDC forms intergranularly, understanding the microchemical and microstructural evolution at the grain boundaries during a weld reheat thermal cycle is key to furthering the mechanistic understanding of DDC.

There are several advantages to using a Gleeble®-based test to investigate the metallurgical mechanism(s) that cause DDC. First and foremost, the thermal profile can be carefully controlled. Proper control of peak temperature in the Gleeble® eliminates the formation of liquid films and the aforementioned problems associated with them. The precise control over the weld thermal cycle also enables the weld mechanical properties to be quantified at precise temperatures/times throughout the weld reheat thermal cycle. Lastly, a Gleeble®-based test produces a

large volume of material that has experienced the same thermal history, particularly compared to fusion-based welding tests where the temperature gradients can be very high (Ref. 30). The larger volume of material greatly aids the identification and characterization of detrimental microstructures, and/or segregants that may form at temperatures/times in the weld reheat thermal cycle.

The vast majority of previous studies that used hot tension/Gleeble®-based tests to investigate DDC have only evaluated cracking susceptibility while the material is being heated (on-heating), or cooled (on-cooling), but not both. Since the material in any heat-affected zone (HAZ) experiences both heating and cooling, this investigation will evaluate both the on-heating and on-cooling DDC susceptibility.

Although Gleeble®-based testing has many advantages, little is known about how the macroscopic mechanical measurements of an alloy's behavior, like ductility and ultimate tensile strength, correlate to DDC susceptibility. Furthermore, some hot tension/Gleeble®-based work has shown that DDC susceptibility has a stroke rate dependence (Refs. 8, 24, 31);

therefore, a suitable stroke rate for DDC testing of the alloys of interest in this investigation must be identified.

The overall objectives of this work were threefold. The first objective was to identify the temperature regime in which the alloys under investigation are metallurgically most susceptible to form DDC cracks. This was accomplished by using a carefully controlled thermal cycle representative of typical multipass welding to determine the DDC susceptibility during the first weld thermal cycle using the Gleeble® hot ductility test. Toward this end a suitable stroke rate must be identified that will reliably reproduce DDC in alloys that are known to be susceptible based on previous welding experience. Second, the macroscopic properties of the reheated metal will be compared to the microscopic formation of ductility dip cracks. Although the Gleeble® hot ductility test has been used in the past to evaluate DDC susceptibility of alloys, there has yet to be a study that identifies the relationship between DDC formation, which occurs on the microscopic scale, and its effects on macroscopic mechanical properties (ductility, strength). The final objective is to investigate the effects of peak temperature and isothermal hold, both of which should affect

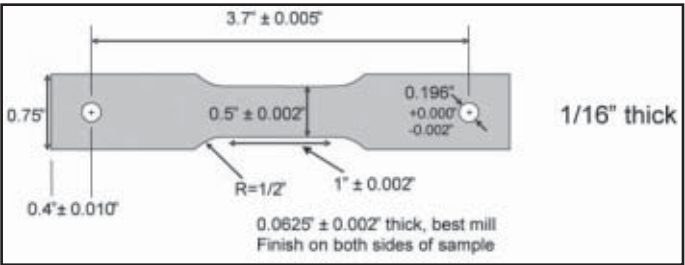


Fig. 2 — Schematic of the Gleeble® specimen.

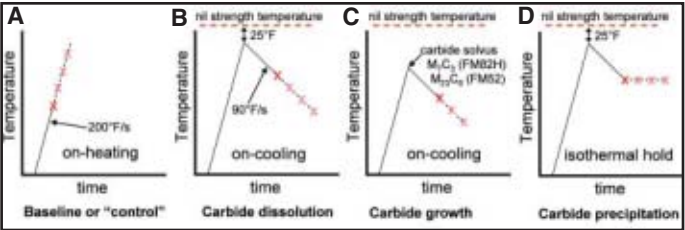


Fig. 3 — Schema for Gleeble® weld reheat thermal cycle showing samples that were hot ductility tested both on-heating and on-cooling.

Table 1 — Alloy Compositions in Weight-Percent

	Ni	Cr	Fe	C	Mn	S	Si	Cu	Nb	Ti	Al	Ti+Al	P	Mo	Other
A600	75.67	14.7	8.22	0.079	0.36	0.001	0.25	0.01	—	—	—	—	—	—	—
FM82H	71.52	20.38	2.26	0.049	2.99	0.002	0.06	0.01	2.28	0.3	0.04	0.34	0.002	—	<0.5
A690	60.75	29.28	9.12	0.025	0.17	<0.001	0.08	0.01	<0.01	0.3	0.22	0.52	0.005	0.01	—
FM52	59.12	29.13	10.08	0.027	0.25	<0.001	0.13	0.01	<0.01	0.51	0.71	1.22	0.003	0.01	<0.5

the volume fraction of intergranular precipitates, on DDC susceptibility. A more detailed treatment of microstructural and microchemical evolution during the first thermal cycle, and how that relates to the mechanism(s) of DDC, are discussed in the Part II companion paper (Ref. 1).

Experimental Procedure

Sample Preparation

Four alloys were investigated as part of this work: A600 (UNS: N06600) and A690 (UNS: N06690) along with their respective companion filler metals FM82H (AWS: ERNiCr-3) and FM52 (AWS: ERNiCrFe-7). Nominal compositions for each alloy are given in Table 1. A600 and A690 form the base metal material in multipass weldments; therefore, they were tested in the wrought condition as part of this work. Alloy 600 and A690 Gleeble® specimens were fabricated directly from 1-in.- (25.4-mm-) thick plate with the width, length, and thickness of the specimens corresponding to the thickness, longitudinal, and width directions of the plate, respectively. Select A690 specimens were also tested in the as-solidified condition.

Unlike A600 and A690, the starting material condition of FM52 and FM82H in the weldment is as-solidified. To best study the DDC susceptibility of the weld metals, they should be in the same condition as they are in a multipass weld before they experience the first thermal cycle. This requires FM52 and FM82H be tested in the as-solidified condition as part of this work. FM52 and FM82H only come in weld wire form, therefore the weld metal was first deposited by successive beads on a plate of A600 to form a weld pad buildup as shown in Fig. 1A. The corresponding welding parameters are given in Table 2. A total of 18 layers of weld deposits were made for each alloy (FM82H and FM52), each approximately $\frac{1}{8}$ in. (3.2 mm) thick. To ensure that weld metal dilution did not affect the weld metal chemistry in the final Gleeble® samples, all of the samples were made from the top 0.75 in. (19 mm) or 7 layers of weld pad buildup. Weld metal dilution from the A600 base metal did not play a role in the chemistry of the final weld metal samples due to the large number of weld passes between the base metal and the samples, and the relative compositional similarity in the three Ni-Cr-Fe alloys: FM82H, FM52, and A600.

Autogenous welds were then made on this weld pad buildup to produce regions of as-solidified weld metal that corresponded to the longitudinal axis of the tensile specimens that were subsequently tested in the Gleeble® — Fig. 1A. It was important to ensure this as-solidified material did not see a significant reheat during a subsequent au-

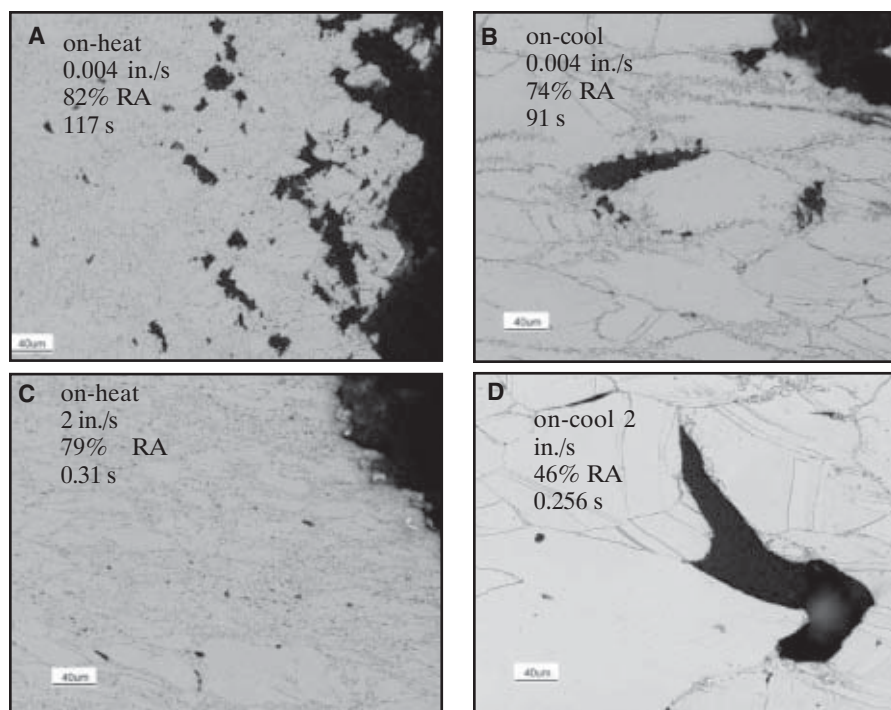


Fig. 4 — LOM photomicrographs of A690 Gleeble® hot ductility specimen tested at 1600°F using 0.004 in./s stroke rate (A and B) and 2 in./s stroke rate (C and D). A and C were tested on-heating while B and D were tested on-cooling. %RA and time under strain, in seconds, are provided on each micrograph.

togenous weld pass for it to be considered “as-solidified.” Therefore, sufficient spacing had to be maintained between the autogenous welds to prevent microstructural changes in a previously deposited pass. Time-temperature transformation (TTT) diagrams were used to determine the maximum temperature the previously deposited weld pass could experience during the brief time interval typical of welding without changing the precipitate microstructure. Since TTT diagrams for FM52 and FM82H are not available in the literature, they were calculated based on the nominal composition of each alloy using JMatPro 3.0 (Refs. 32, 33). It was found that a transient peak temperature of 575°F (302°C) should not cause significant changes in precipitate volume fraction. Preliminary work showed that a 2-in. (50.8-mm) separation between auto-

genous weld centerlines would ensure that the maximum temperature in a previous autogenous weld pass never exceeded 575°F. Welding parameters for the autogenous welds are given in Table 2. These same welding conditions were also used to make select A690 as-solidified specimens.

A thin layer (~ $\frac{1}{8}$ in. (1.6 mm) thick) of the weld pad containing autogenous welds was then sectioned from the weld pad buildup using wire electrical discharge machining (EDM). Gleeble® hot ductility test specimens were sectioned from this layer using waterjet cutting as shown in Fig. 1B. The final tensile specimen specifications are shown in Fig. 2. For the FM82H and FM52 specimens, the entire sample was comprised of as-solidified weld metal. The same design was also used with the A600 and A690 test specimens,

Table 2 — Weld Pad and Autogenous Weld Parameters

Parameter	Weld pad	Autogenous welds
Shielding gas/flow (ft ³ /h)	Ar / 43	He / 160
Electrode	5/32 in. diam., 2% Ceriated-Tungsten	5/32 in. diam., 2% Ceriated-Tungsten
Electrode included angle	50 deg	180 deg
Current (A)	310	247
Potential (V)	12	15.5
Travel speed: (in./min)	6.7	3.4
Magnetic oscillation: (cycles/min)	100	100
Hot Wire		n/a
Diameter (in.)	0.045	n/a
Current (A)	80	n/a
Potential (V)	6.2	n/a
Feed rate (in./min)	170	n/a

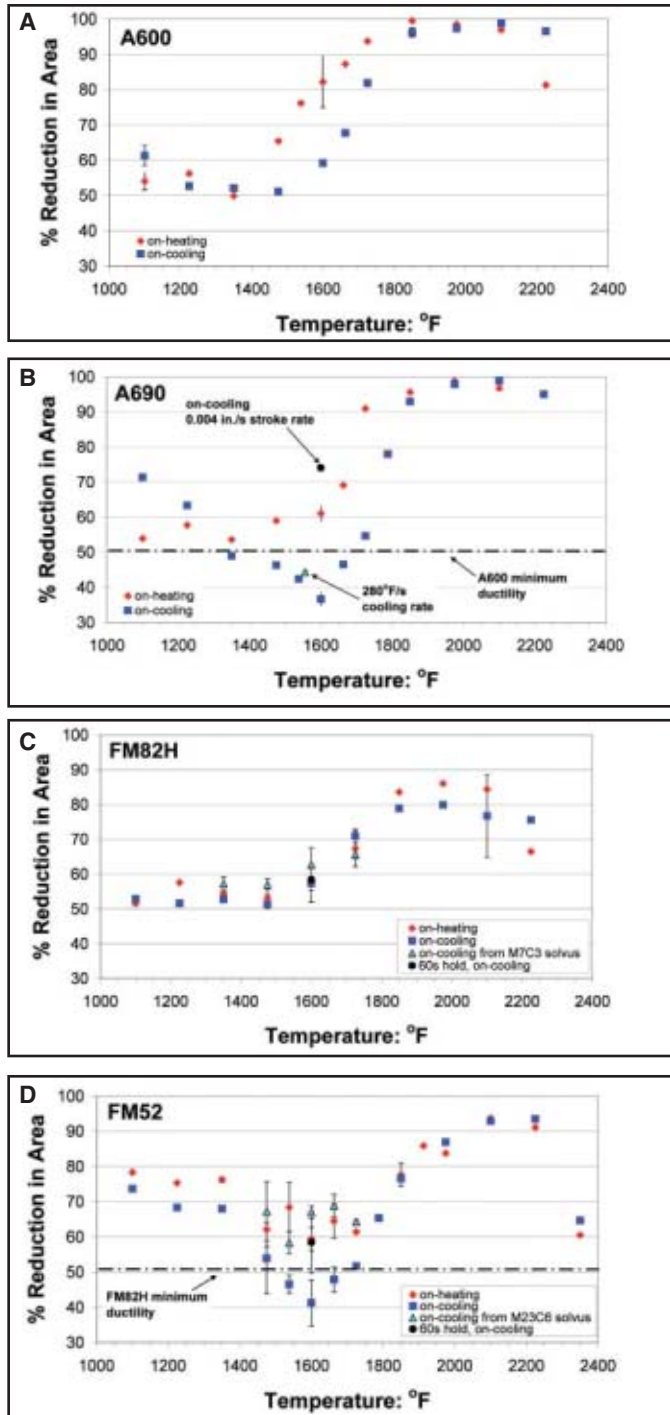


Fig. 5 — On-heating and on-cooling hot ductility curves for the following: A — A600; B — A690; C — FM82H; and D — FM52. FM82H and FM52 hot ductility curves also include on-cooling data from their respective carbide solvus temperatures.

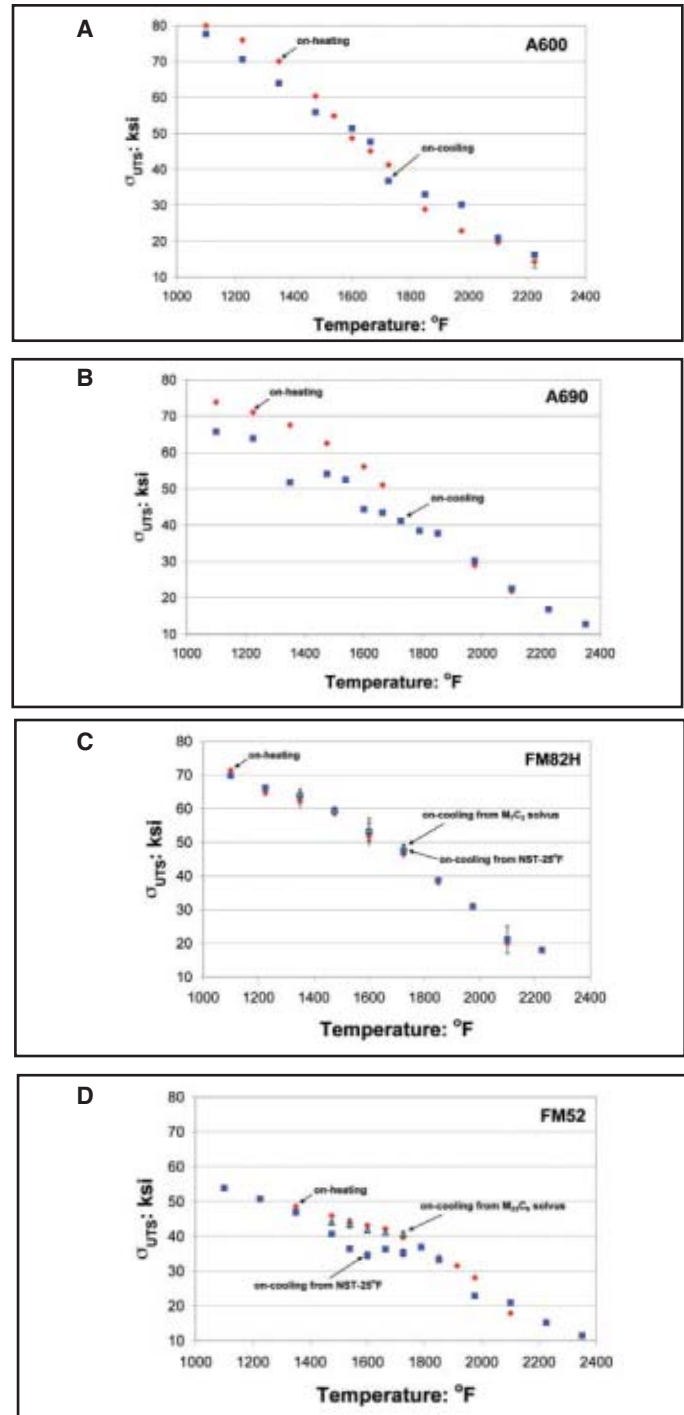


Fig. 6 — On-heating and on-cooling UTS data for the following: A — A600; B — A690; C — FM82H; and D — FM52. FM82H and FM52 UTS curves also include on-cooling data from their respective carbide solvus.

which were machined directly from 1-in.-thick wrought plate.

Testing Parameters and Design

The average cooling rate for this sample design when held in the water-cooled Gleeble® “vacuum jaws,” and allowed to free cool, was approximately 15°F/s (8°C/s). Cooling rates greater than this re-

quired a gas cooling apparatus that was fabricated for this work. It was found that the average cooling rate could be increased to more than 255°F/s (142°C/s) by using a He gas quench. Commercial-grade helium resulted in significant gray oxidation of the samples, therefore Grade 6 helium (99.9999% pure) was used for this work, which resulted in an oxide-free surface finish.

To ensure that liquid films would not form during Gleeble® testing, the Nil Strength Temperature (NST) was determined using procedures outlined elsewhere (Ref. 34). The NSTs for all four alloys are listed in Table 3. Five to six specimens from each alloy condition were tested. From these data, the average NST and 95% confidence interval (CI) were calculated. It was found that a peak temperature correspond-

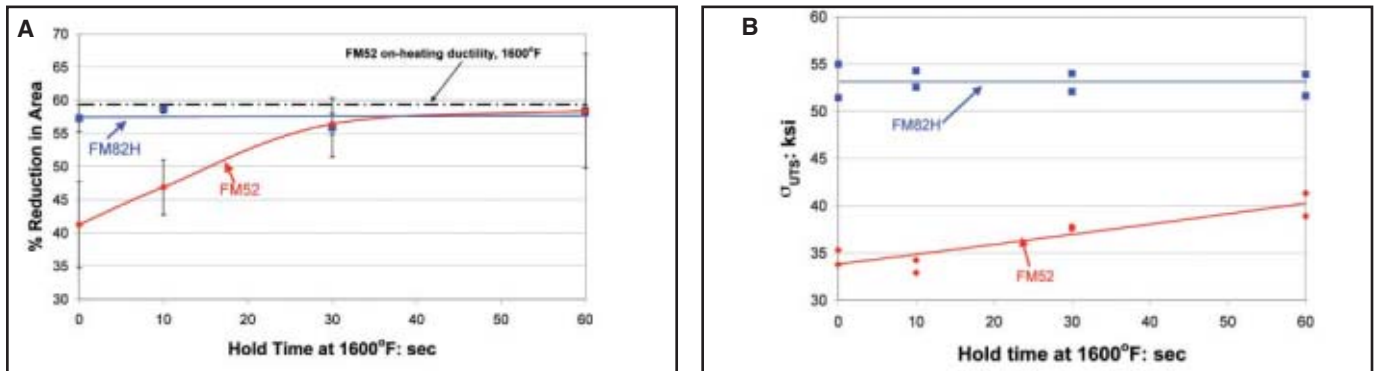


Fig. 7 — Effect of on-cooling hold time at 1600°F. A — Reduction in area; B — UTS.

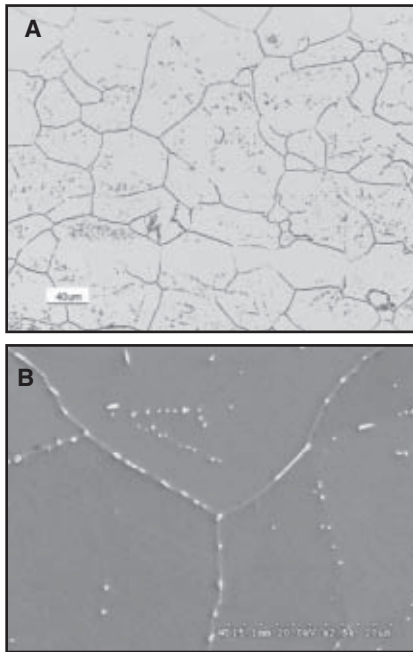


Fig. 8 — As-received A600 micrographs revealing equiaxed grains and grain boundaries decorated with coarse carbides. A — LOM; B — SEM.

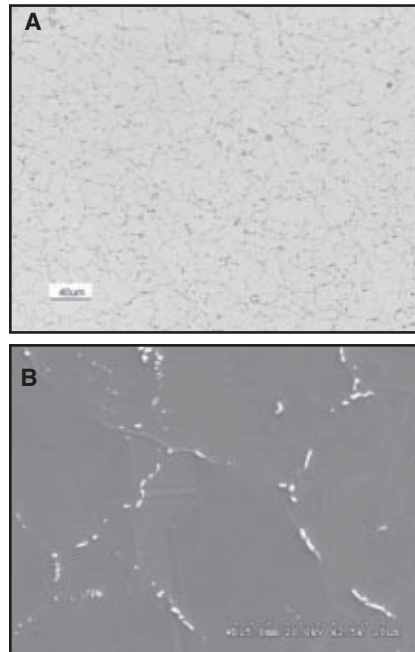


Fig. 9 — As-received A690 micrographs revealing equiaxed grains and grain boundaries decorated with coarse carbides. A — LOM; B — SEM.

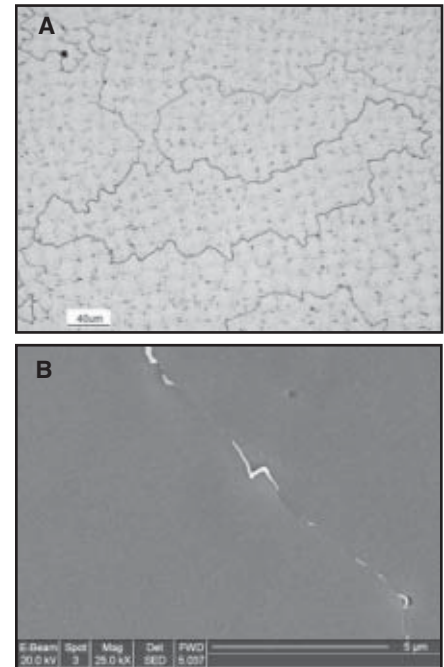


Fig. 10 — As-solidified FM82H micrographs revealing elongated grains and grain boundaries decorated with fine carbides. A — LOM; B — SEM.

ing to the average NST [25°F (13°C)] would provide a 95% confidence that the NST would not be exceeded.

Figure 3 is a graphical depiction of the four thermal cycle conditions tested as part of this work. The locations marked with an X represent temperatures at which hot ductility tests were performed. The heating rate for the on-heating tests was 200°F/s (111°C/s), as shown in Fig. 3A. The cooling rate for all on-cooling tests (Fig. 3B and C) was 90°F/s (50°C/s). He gas quench was used to augment the cooling rate in the “on-cooling” samples because the maximum “free cool” cooling rate that could be obtained was so low (15°F/s). The heating and cooling rates were based upon thermocouple measurements taken from a standard weld joint during typical multipass welding conditions. Samples were hot ductility tested at 125°F (51°C) intervals between 1100°F (593°C) and the peak temperature for

each alloy. Smaller temperature intervals of 62.5°F (17°C) were used in some cases

to provide more detail within temperature ranges of interest.

Table 3 — Nil Strength and Peak Test Temperatures

Alloy	NST ± 95% CI: °F	Peak T, NST-25°F
A600	2446 ± 10	2421
FM82H	2364 ± 17	2339
A690	2447 ± 10	2422
FM52	2428 ± 12	2403

Table 4 — JMatPro Calculated Carbide Solvus Temperatures for the Predominant Carbides in Each Alloy and Maximum Time above Calculated Carbide Solvus Temperatures during Simulated Weld Reheat Thermal Cycle

Alloy	Intergranular Carbide	Calculated Carbide Solvus (°F)	Maximum time above calculated carbide solvus (s)
A600	M ₇ C ₃	1859	9.1
FM82H	MC	2196	2.3
FM82H	M ₇ C ₃	1967	6.0
A690	M ₂₃ C ₆	1972	7.3
FM52	M ₂₃ C ₆	2077	5.3

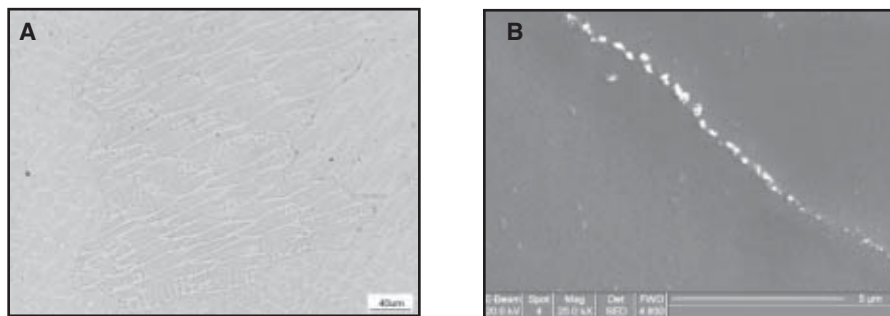


Fig. 11 — As-solidified FM52 micrographs revealing elongated grains and grain boundaries decorated with fine carbides. A — LOM; B — SEM.

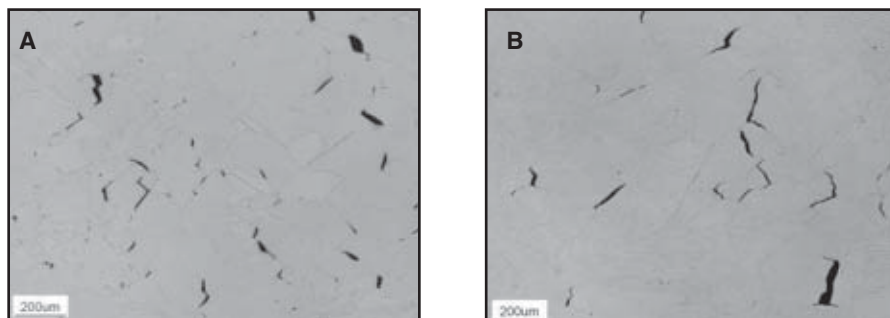


Fig. 12 — LOM micrographs of DDC cracks in A690 hot ductility specimens tested at 1600°F on-cooling. A — Wrought; B — welded condition. Tensile axis is oriented horizontal to the image. These cracks are characteristic of wedge shaped cracks.

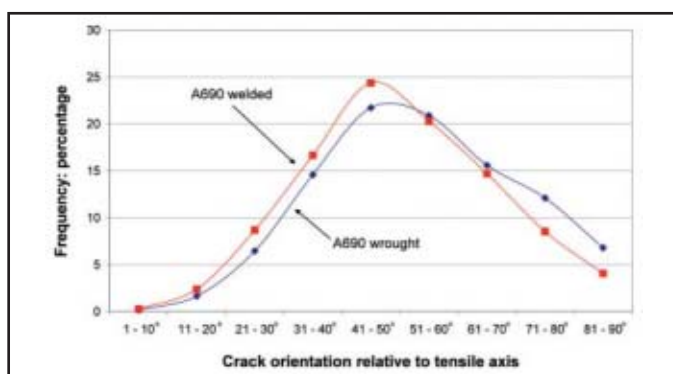


Fig. 13 — Angular distribution of DDC crack orientation with respect to the tensile axis for A690 at 1600°F on-cooling in wrought and welded conditions.

Since several researchers have suggested carbides as contributors to DDC, the effect of carbide dissolution and coarsening/precipitation was investigated through the use of two peak temperatures. The first peak temperature, NST-25°F, was above the carbide solvus of each alloy (see Table 4). It was expected that this would result in some degree of carbide dissolu-

tion — Fig. 3B. The $M_{23}C_6$ and M_7C_3 carbide solvus temperature for FM52 and FM82H, respectively, were used as the other peak temperature — Fig. 3C. No carbide dissolution was expected to occur since the samples were heated to the solvus temperature and then immediately cooled. This thermal cycle would potentially result in carbide coarsening.

Determination of the expected stable carbide and its solvus temperature was necessary for this work. Several carbides can form in FM82H and FM52 based upon their thermal history. Both alloys contain TiC and TiN, which have melting points in excess of 5000°F (2760°C) (Ref.

35), and are thought to be directly transferred from the welding wire (Ref. 12). The predominant second phase in as-solidified FM82H is Nb-rich MC carbide, which forms as a terminal solidification product (Refs. 11, 12). Due to the lack of TTT diagrams for these alloys in the literature, they were calculated using JMatPro, which predicted that M_7C_3 is the second carbide to form after the solid-state MC precipitation reaction in FM82H. The volume fraction of M_7C_3 that forms in FM82H will be a function of the free carbon available after the precipitation of MC carbides. FM52 does not contain significant (<0.01 wt-%) Nb. The predominant carbide formed by the solid-state reaction is $M_{23}C_6$. The JMatPro calculated carbide solvus temperatures for each alloy composition are listed in Table 4. The $M_{23}C_6$ and M_7C_3 carbides were expected to experience the greatest degree of dissolution during the NST-25°F peak temperature. The JMatPro calculated carbide solvus temperatures were found to be in reasonable agreement with values determined experimentally: The $M_{23}C_6$ solvus ranged in temperature from 1868°F (1020°C) and 2024°F (1107°C) in A690 (Refs. 36–39), while the M_7C_3 was found to vary between 1688°F (920°C) and 2012°F (1100°C) in A600 (Ref. 40).

The last thermal cycle evaluated is shown schematically in Fig. 3D. The weld metal alloys were subjected to an isothermal hold for 10 to 60 s at the on-cooling ductility minimum temperature, which was found to be 1600°F (871°C). Based upon the JMatPro calculated TTT diagrams for these alloys, it was expected that this hold would result in carbide precipitation.

DDC susceptibility has been found to increase with decreasing stroke rate in both Invar (Ref. 24) and 310 stainless steel (Ref. 8) when tested on-heating. To date, the effect of stroke rate on DDC susceptibility has not been examined in the alloys under investigation in this work. Therefore, initial work was performed to determine the effect of two different stroke rates (0.004 and 2 in./s: 0.1 and 50.8 mm/s) on A690, which is known to be susceptible to DDC. These stroke rates comprise the upper and lower bounds for Gleeble®-like hot tensile tests (Refs. 24, 41). The effect of stroke rate was evaluated at 1600°F on-heating and on-cooling from the elevated peak temperature. This temperature was chosen because this was shown to be the ductility minimum temperature for multipass weld FM52 specimens (Ref. 42), which have a nominal composition very similar to A690.

All hot ductility testing was performed using a Gleeble® 1500D. For the percent reduction in area (%RA) measurements, the initial cross-sectional area of the samples was measured with micrometers, and

Table 5 — Vickers Micro-Indentation Hardness Values for Various FM52 Thermal Conditions. Note: All Samples Were Unstrained and Water Quenched from Their Respective Temperatures

FM52 condition	HV ± 95% confidence interval
1600°F on-heating	171 ± 3
1600°F on-cooling from NST-25°F	155 ± 2
1600°F on-cooling 60 s hold	165 ± 3
2350°F 10 min hold	146 ± 2

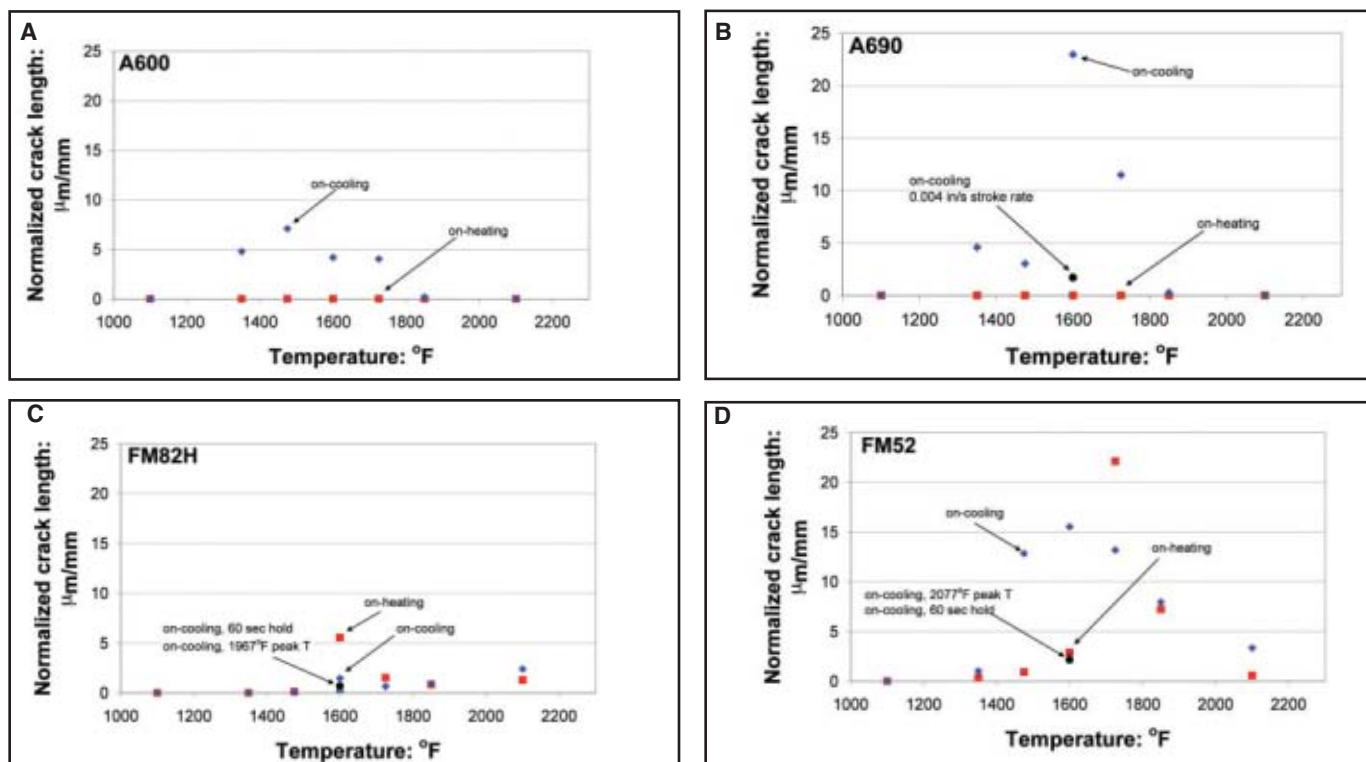


Fig. 14 — Total intergranular crack length per grain boundary length. A — A600; B — A690; C — FM82H; and D — FM52.

the final cross-sectional area was measured using a stereoscope connected to quantitative image analysis software, in a similar fashion as used in other research (Ref. 18). This provided for a more accurate measurement of %RA, particularly in samples where the final cross-sectional shape was not rectangular. Two measurements were made of each fractured surface, resulting in four measurements per tested specimen. The %RA measurement error was found to fall within the size of the data symbols in the hot ductility plots. When multiple samples were tested under the same conditions, the average was plotted with standard deviation error bars. The ultimate tensile strength (UTS) was calculated for each alloy based upon load measurements recorded from Gleeble® load cell data. An acquisition rate of 2000 hertz was used during the loading portion of the test to ensure the peak load could be identified.

Microstructural and Micromechanical Characterization

Select samples were sectioned and mounted in thermosetting epoxy so that the longitudinal-transverse orientation of each test specimen could be viewed. Standard metallographic techniques were used to prepare the samples to a 0.05-μm colloidal silica finish. The samples were then electrolytically etched at 2–3 V for 3–10 s in a solution containing equal parts by volume of water, and sulfuric and phosphoric acid. Bright field light optical microscope (LOM)

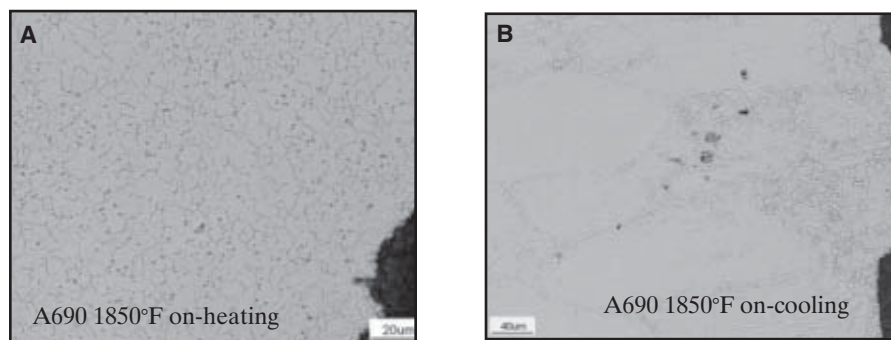


Fig. 15 — LOM images of A690 hot ductility samples revealing dynamically recrystallized grains. A — 1850°F on-heating; and B — 1850°F on-cooling.

images were captured using a Reichert-Jung MF3 metallograph. The angular relationship between grain boundaries that ductility dip cracked and the tensile axis were made using LOM images.

Ductility dip crack length measurements were made using a Nikon Optiphot LOM with a drawing tube attachment that allowed for concurrent viewing of the sample and the cursor of a digitizing pad. Crack length data were normalized with respect to total grain boundary length within a field of measurement so that the cracking behavior of different alloys at various temperatures can be compared on an equal basis. The total grain boundary length within a field of measurement is a function of 1) the surface area of the sample from which crack length was measured and 2) the grain size of the sample. This

normalization was conducted in the following manner. The total grain boundary length within a unit surface area is given by $L_{GB} \text{ Total/GB}$ (Ref. 43):

$$L_{GB}^{Total} = \left(\frac{\pi}{2} \bar{N}_L \right) \cdot SA \quad (1)$$

where $\bar{N}_L$ is the number of intersections per unit length of line with units of mm^{-1} , and SA is the surface area in mm^2 . This value of $\bar{N}_L$ can be calculated directly from grain size using the following equation that is derived from ASTM E112 (Ref. 44):

$$\bar{N}_L = 1119.3d^{-0.9993} \quad (2)$$

where grain size (d) is measured in μm. Grain size data were measured for these alloys at select temperatures in the weld

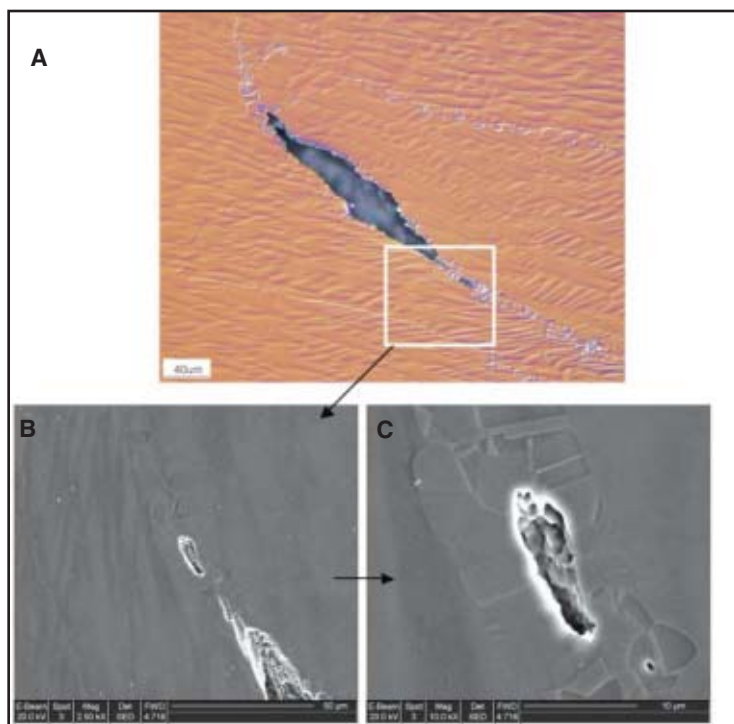


Fig. 16 — Ductility dip crack in FM52 at 2100°F on-cooling as seen using the following: A — Differential image contrast in LOM; B — SEM at low magnification; and C — SEM at high magnification. Recrystallization along grain boundary impedes ductility dip crack growth.

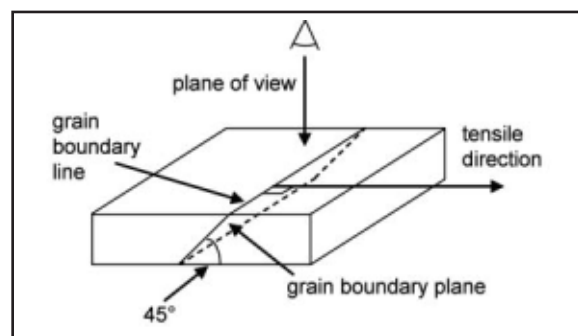


Fig. 17 — Schematic showing how orientation of grain boundary plane with the tensile direction (45 deg) can be different than the grain boundary line with the tensile direction (90 deg).

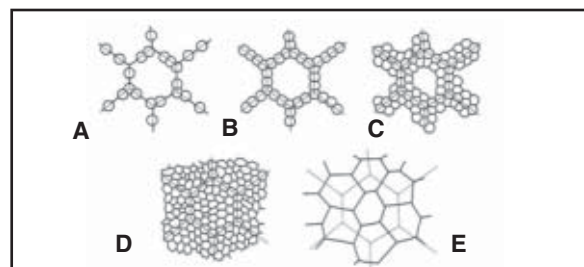


Fig. 18 — Influence of starting grain size on dynamic recrystallization behavior from Ref. 64. A–D show the development of completely recrystallized grain structure when the grain size is large compared to the recrystallized grain size. In E, the initial and recrystallized grains have similar sizes.

thermal cycle using water-quenched specimens. Equation 1 can be combined with Equation 2 to result in the following:

$$L_{GB}^{Total} = \frac{\pi}{2} (1119.3d^{-0.993}) \cdot SA \quad (3)$$

The total measured DDC crack length within any given sample was divided by the total grain boundary length within the field of measurement (L_{GB}^{Total}) to provide the average crack length per length of grain boundary ($\mu\text{m}/\text{mm}$).

The general microstructure and chemistry of second phases were characterized using either an FEI DB 235 or Hitachi 4300 Schottky field emission gun scanning electron microscope (FEG-SEM) with an energy-dispersive spectrometer (EDS). All operation was performed using 20 keV accelerating voltage. An Everhart-Thornley detector, commonly known as a secondary electron detector (SED), was used for all SEM images. The scale markers differ for the two microscopes. Images captured using the Hitachi 4300 use a 10 dot marker with the scale indicated on the lower-right corner of the image. Samples mounted in epoxy were lightly coated with carbon to prevent charging. The above conditions enabled particles as small as 20 nm in size to be resolved.

Lastly, to determine whether the thermal history had an annealing effect on FM52, 20 Vickers micro-indentation

hardness measurements were made on each of four select samples according to ASTM E384 (Ref. 45). All of the specimens were water quenched and unstrained (Ref. 1). The four thermal histories evaluated were 1) 1600°F on-heating, 2) 1600°F on-cooling from the NST-25°F temperature, 3) 60-s hold at 1600°F on-cooling from the NST-25°F temperature, and 4) 10-min hold at 2350°F (1288°C). The heating and cooling rate (for on-cooling samples) was the same as used above: 200°F/s (111°C/s) on-heating and 90°F/s (50°C/s) on-cooling.

Results

Effect of Stroke Rate

Representative microstructures for the slow stroke rate and fast stroke rate tests performed at 1600°F on-heating and on-cooling are shown in Fig. 4. There was little difference between on-heating and on-cooling ductility for the slow stroke rate samples, which was 82% and 74%RA, respectively. Conversely, the fast stroke rate on-cooling test resulted in a significant ductility loss as compared to the on-heating test using the same stroke rate: 46% vs. 79%RA, respectively. Although 46% is an appreciable degree of ductility, what is significant is that the ductility decreased 42% as compared to the on-heating test.

Microstructurally, this intermediate

temperature on-cooling reduction in ductility was caused by a large number of ductility dip cracks — Fig. 4D, which were not present in the on-heating sample tested at the same stroke rate — Fig. 4C. Both on-heating samples exhibited intergranular cavitation with transgranular void coalescence occurring in the slower stroke rate sample — Fig. 4A. The slower stroke rate, on-cooling sample did have some ductility dip cracks, but they were surrounded by recrystallized grains. The ductility dip cracking was much more severe in the fast stroke rate on-cooling sample. The total normalized DDC crack count in the fast stroke rate on-cooling sample was 23.0 $\mu\text{m}/\text{mm}$ while that for the slow stroke rate on-cooling sample was only 1.7 $\mu\text{m}/\text{mm}$.

These results are significant for several reasons. This is the first investigation into the effect of stroke rate on hot ductility in a Ni-based, solid-solution-strengthened Ni-Cr-Fe alloy. Second, previous researchers showed that slower stroke rates increased DDC in 310 stainless steel (0.1 vs. 100 mm/s) (Ref. 8) and Invar (0.094 vs. 13 mm/s) (Ref. 24); however, this work reveals just the opposite effect for the alloys investigated in this work where faster stroke rates result in more DDC. The causes for these differences in stroke rate and hot ductility behavior are discussed later. Lastly, the faster stroke rate resulted in a more adverse testing condition for DDC, while reproducing the DDC mech-

anism, therefore it was used for all subsequent hot ductility testing.

Mechanical Behavior

The on-heating and on-cooling hot ductility curves for all four alloys are shown in Fig. 5. The on-heating curves of A600 and A690 are similar. The ductility of both alloys degrades on cooling with that of A690 falling below that of A600 between the temperature of 1663°F (906°C) and 1475°F (802°C). The on-cooling ductility from the reduced stroke rate (0.004 in./s) A690 test at 1600°F is also displayed in Fig. 5. This further illustrates the remarkable increase in ductility brought about by using the slower stroke rate. Testing A690 in the as-solidified condition at the ductility minimum temperature (1600°F on-cooling) had no effect on the hot ductility ($37 \pm 3.3\%$ RA) as compared to the wrought condition ($37 \pm 1.9\%$ RA).

In an effort to prevent the formation of carbides, A690 was cooled at approximately 280°F/s (155°C/s) to a temperature within the ductility dip range. The results of two tests are also shown in Fig. 5B. Tripling the cooling rate (90° to 280°F/s) had no effect on the intermediate temperature hot ductility of A690.

The hot ductility of FM82H remains unchanged throughout the weld thermal cycle both on-heating and on-cooling. The on-heating hot ductility of FM52 is higher than that of FM82H at any given temperature on-heating, although there is a small dip in ductility between 1475° and 1775°F (802° and 968°C). When FM52 is cooled from the NST-25°F peak temperature to the intermediate temperature (1663°–1538°F: 906°–837°C), the ductility drops significantly below that of FM82H. The on-cooling hot ductility curves of FM52 and A690 are remarkably similar even though they were tested in two different conditions: wrought and as-solidified for A690 and FM52, respectively.

Peak temperature plays a significant role in the on-cooling behavior of FM52. When cooled from the $M_{23}C_6$ carbide solvus (2077°F), where negligible carbide dissolution is expected to occur, the on-cooling hot ductility is indistinguishable from the on-heating hot ductility. This on-cooling behavior is remarkably different than when FM52 is cooled from the NST-25°F (2403°F). In FM82H, cooling from the M_7C_3 solvus temperature (1967°F) peak temperature resulted in a similar hot ductility as the NST-25°F on-cooling tests.

The on-heating and on-cooling UTS curves for all four alloys are shown in Fig. 6. The on-heating and on-cooling behavior of A600 is relatively unchanged. The on-cooling UTS of A690 is less than it is on-heating at temperatures of 1663°F and below. There is little change in the on-

heating and on-cooling UTS of FM82H. To the contrary, there is a significant intermediate temperature dip in the on-cooling UTS of FM52 as compared to its on-heating behavior. The UTS of FM82H is at least 10% greater than that of FM52 at all points in the thermal cycle and up to 50% greater at intermediate temperatures on-cooling where there is a dip in the UTS of FM52. Much like the %RA results, both FM52 and A690, which are known to be susceptible to DDC, exhibit an on-cooling reduction in UTS.

Modifying the on-cooling thermal cycle significantly affects the UTS of FM52, while that of FM82H remains unchanged. Peak temperature plays an important role in the UTS of FM52. Cooling from the $M_{23}C_6$ carbide solvus eliminates the dip in UTS that is observed when the alloy is cooled from the NST-25°F peak temperature. In FM82H, lowering the peak temperature to the M_7C_3 solvus temperature has little effect on the on-cooling UTS. The effect of isothermal hold time at 1600°F on-cooling from the NST-25°F peak temperature on ductility and UTS are presented in Fig. 7. Ductility and UTS recover in FM52 with hold time at 1600°F, while there is little change in the mechanical behavior of FM82H since the alloy exhibited no initial loss in strength or ductility.

Table 5 shows the results of the micro-indentation hardness measurements that were made on samples that were unstrained and water quenched. As expected, the softest condition was the isothermal hold at 2350°F. The lowest hardness of the three 1600°F conditions was on-cooling from NST-25°F, which is the thermal condition that results in the ductility minimum in FM52.

Microstructural Characterization

Photomicrographs of as-received A600 and A690 are shown in Figs. 8 and 9. The grain boundaries of both alloys are decorated with coarse carbides, although these carbides are different in each alloy. The predominant intergranular carbide in A600 is M_7C_3 (Ref. 46), whereas A690 primarily forms $M_{23}C_6$ (Ref. 47). Additionally, the grain size of A690 is smaller than that of A600. Figures 10 and 11 reveal the as-solidified microstructures for FM82H and FM52, respectively. The carbides are not as prominent in the weld metal alloys

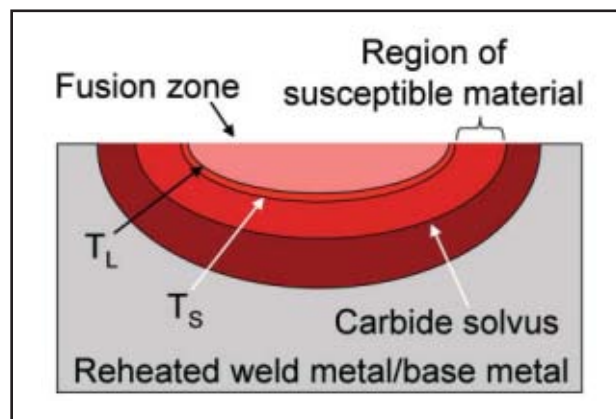


Fig. 19 — Schematic of HAZ where solidus and liquidus temperatures are indicated by T_S and T_L , respectively. Region of HAZ heated above the carbide solvus temperature is made more susceptible to DDC.

as they are in the wrought alloys as evidenced by the SEM micrographs where the magnification for the weld metal alloys is ten times that for the wrought alloys. Both weld metal alloys have larger grain sizes than the wrought materials, which is to be expected. The serrated grain boundary morphology of FM82H is significantly different than the grain boundaries of the other three alloys, which are comparatively straight. A more detailed discussion of each alloy's microstructure is presented elsewhere (Ref. 1).

Figure 12A and B are LOM micrographs taken from A690 hot ductility samples tested at the ductility minimum temperature, 1600°F on-cooling, in the wrought and as-solidified condition, respectively. The tensile axis is oriented horizontal to the image. The appearance of these cracks is characteristic of wedge-type cracks (Ref. 48) that are seen in creep rupture. Qualitatively, these cracks appear to occur on boundaries that are preferentially oriented at a 45-deg angle to the tensile axis. To better quantify this observation, the angle with respect to the tensile axis was measured for more than 600 cracks in each specimen and is shown in Fig. 13. These results confirm that the DDC cracks form preferentially at an angle of approximately 45 deg to the tensile axis. This is the direction at which the shear stress is the highest.

The results of normalized DDC crack length measurements are given in Fig. 14. What is most striking is the absence of DDC in both A600 and A690 when tested on-heating. This is in stark contrast to the on-cooling behavior of both alloys where ductility dip cracks are observed between the temperatures of 1850°F (1010°C) and 1350°F (732°C) for both A600 and A690. The change in on-cooling behavior is particularly remarkable for A690, which had the greatest total crack length all four alloys at 1600°F on-cooling, while no cracks formed at the same temperature on-heating.

ing. The normalized crack length of A690 at this temperature on-cooling was greatly reduced from 23 to 1.7 $\mu\text{m}/\text{mm}$ in the sample tested at the slower stroke rate (0.004 in./s).

Ductility dip cracks were observed in FM82H and FM52 both on-heating and on-cooling. The magnitude of DDC crack length, and the temperature range at which they were observed, was greater for FM52 than FM82H. In general, the amount of DDC in FM52 was greater on-cooling than on-heating, whereas there was little difference between the on-heating and on-cooling cracking behavior of FM82H except at 1600°F on-heating. Cooling from the respective carbide solvus temperature reduces the ductility dip cracking susceptibility of both FM82H and FM52.

Hot ductility samples were examined using LOM to determine the nature and extent of recrystallization. Two general types of recrystallized grain structures were observed in the hot ductility samples: uniform and localized. Figure 15A is a LOM micrograph showing the uniform recrystallization behavior in A690 at 1850°F on-heating. This type of recrystallization behavior was only observed in A600 and A690 samples on-heating, and associated with the greatest resistance to DDC. The second type of recrystallization behavior is shown in Fig. 15B, which is taken from A690 at 1850°F on-cooling. The recrystallized grains are much more localized along the grain boundary. This type of recrystallized grain structure was observed in A600 and A690 on-cooling, and in both FM82H and FM52 on-heating and on-cooling. Localized recrystallized grains were often found ahead of DDC cracks, as shown in Fig. 16 for FM52 at 2100°F on-cooling. This figure also shows that DDC cracks can form at temperatures above the M_{23}C_6 carbide solvus (2077°F: 1136°C) where these intergranular carbides have been fully dissolved (Ref. 1) and are not expected to precipitate during hot ductility testing.

Discussion

Much of the recent research into DDC has been performed within the welding community, and it has been viewed as a weldability issue. However, DDC has also been investigated in materials that undergo thermomechanical treatment. As early as the 1960s, intergranular cracks that were formed at temperatures above 0.5 T_m were recognized as the most common cause of fracture in hot working of materials (Ref. 49). Hot working is characterized by temperatures above 0.5 T_m and strain rates between 10^{-3} – 10^3 s^{-1} (Ref. 50). This is significant because strain rate and temperature affect deformation mechanisms. Addition-

ally, hot working research has investigated the same range of strain rates and temperatures that have been used in the weldability studies of DDC, including this investigation where the strain rate was between approximately 1 and 2 s^{-1} and the temperature ranged between approximately 0.55 and 0.95 T_m . Ductility dip cracking has long been observed during the hot working of materials, although not using the DDC nomenclature (Refs. 49–51). Therefore, the hot working literature can be quite useful in furthering the understanding of DDC in weld metal.

Comparison of Ductility and UTS

Using carefully controlled hot torsion quench studies on A600, Shapiro and Dieter found that intergranular cracks formed at the peak torque (Ref. 51). The peak torque is analogous to peak load, or UTS, in the tension (Gleeble®) testing performed in the present investigation. The intermediate temperature dip in ductility in A690 and FM52 also results in a decrease in UTS. Both mechanical measures of DDC have the same root cause: the formation of ductility dip cracks. As these cracks form, they impair an alloy's ability to macroscopically deform and strain harden, thereby decreasing both ductility and the UTS.

Additionally, both ductility and UTS recover with hold time in FM52. Neither exhibits an intermediate temperature dip when FM52 is cooled from the M_{23}C_6 solvus temperature (where carbide dissolution is not expected due to the very short time at the solvus temperature). Both mechanical measures of DDC investigated in this work provide reasonable predictions of a material's DDC susceptibility. The advantage of using UTS as a measure of DDC susceptibility is in its simplicity. There are no post-test measurements when using UTS, unlike %RA. Rather, the peak load can be directly obtained from the load cell data generated during the test. It should be noted that UTS may not be a good indicator of DDC susceptibility in other alloy systems and conditions. Further, work may be needed to assess this.

Comparison of Mechanical and Microstructural Data

The crack count data provide insight into how microstructural features (cracks) affect macroscopic properties (ductility and UTS). The ductility minimums in both FM52 and A690 correspond to the peak in maximum crack length per length of grain boundary. The crack count data also reveal key information regarding cracking susceptibility that could not be discerned from the macroscopic measurements of ductility and UTS. The following are sev-

eral examples. First, the on-heating hot ductility data for FM82H are very similar to those of A600 and A690, yet only FM82H forms DDC cracks on-heating. This difference in cracking susceptibility can only be discerned from the microscopic DDC crack measurements (Fig. 5 vs. Fig. 14). Second, the hot ductility of FM52 is similar to, and often higher than, FM82H (Fig. 5) during the on-heating portion of the thermal cycle, yet FM52 has a greater tendency to form DDC — Fig. 14. This difference underscores that mechanical measurements of DDC are not only affected by the formation of DDC cracks, but also by an alloy's ability to dynamically recover and recrystallize. The effects of alloy composition on dynamic recovery and recrystallization must be considered when comparing hot tensile data between alloys. It has been shown that alloying additions of Nb decrease both dynamic recovery and dynamic recrystallization in austenite (Ref. 52). Reducing these two restoration processes may explain why the on-heating ductility between the temperatures of 1100° and 1350°F of FM82H, which contains Nb, is equal to or lower than that of FM52 even though FM82H has higher resistance to DDC than FM52.

Overall, the mechanical and microstructural measures of DDC are complementary. Crack length measurements on fractured hot tensile specimens provide direct information about an alloy's propensity to form ductility dip cracks. However, these measurements do not provide information on the level of stress or strain at which DDC cracks form. The strain at which DDC cracks begin to form can be inferred from the mechanical measures of DDC: ductility and UTS. As DDC cracks nucleate and grow, they form internal free surfaces that decrease the effective cross-sectional area of the sample and impair the alloy's ability to carry a given load. The formation of ductility dip cracks thereby brings about a reduction in UTS as compared to an alloy condition that is more resistant to DDC (e.g., FM52 1600°F on-heating vs. 1600°F on-cooling). Furthermore, the DDC cracks degrade an alloy's ability to deform, which will result in a decrease in %RA since premature fracture will occur due to the nucleation and growth of DDC cracks, as opposed to a purely ductile mechanism, such as microvoid coalescence. The similar on-cooling hot ductility behavior of A690 and FM52 indicate that DDC cracks form at approximately the same level of strain, even though their grain size is significantly different: $93 \pm 13 \mu\text{m}$ vs. $263 \pm 13 \mu\text{m}$, for A690 and FM52, respectively at 1600°F

on-cooling (Ref. 1).

While the specific reason for the particularly high value at 1725°F for FM52 on-heating is currently not known, as pointed out in the discussion section, the high value of normalized crack length generally correlates with the minimum in ductility (i.e., compare Figs. 5 and 14). Reasonable agreement exists between the macroscopic mechanical measures of DDC and microscopic cracking susceptibility; therefore, the hot ductility test reliably predicts which alloys will exhibit a greater tendency to DDC.

Microstructural Factors Affecting Ductility and UTS

Qualitatively, it has been suggested that DDC cracks form over a preferred orientation of angles oriented between 45 and 90 deg to the tensile axis (Ref. 9). This qualitative observation appears consistent with the cracking observations for A690 at the on-cooling ductility minimum (1600°F) as seen in Fig. 12. Quantification of these cracking data shows that there is indeed a preference for cracks to form along boundaries oriented 45 deg to the tensile axis (Fig. 13), for samples tested in wrought and as-solidified condition, which is the angle at which maximal shear is expected to occur. However, the distribution of cracks is not normal about 45 deg, which would be expected if grain boundary sliding was an operative mechanism in DDC. Rather, the distribution is skewed to higher angles. The distribution for the wrought data is more skewed than it is for the as-solidified. This difference in these two distributions is probably due to the difference in grain shape. The wrought sample consisted of equiaxed grains, whereas the grains in the as-solidified sample were preferentially oriented with respect to the tensile axis, thereby introducing some bias into the crack orientation measurement.

Nonetheless, both the wrought and as-solidified data are not normal about 45 deg. This is due to the limitations of the stereological technique employed. Figure 17 is a schematic illustration that shows how a grain boundary plane may be oriented within a given volume of material. In this instance, the intersection of the grain boundary plane with the plane of view forms a grain boundary line that is orientated at a 90-deg angle to the tensile axis. This is the angle that is measured using standard image analysis techniques. In reality, the angle between the grain boundary plane and the tensile axis is at 45 deg. It is not possible to measure this angle from a single plane of view. Ideally, the orientation of the grain boundary plane could be plotted as a function of angle with

respect to the tensile direction. Some attempts have been made to correct for the limitations of measuring the orientation of the grain boundary line to the tensile axis. Scriven and Williams attempted to measure the angular distribution of cavitated boundaries in copper that was subjected to fatigue testing at 400°C (Ref. 53). Their angular distribution curve is very similar to that seen in Fig. 13 for DDC cracking in A690. They concluded that this type of angular distribution demonstrates that boundaries oriented in the direction of maximal shear preferentially cavitated. With reference to DDC of A690, grain boundaries oriented along the direction of maximal shear force are most likely to ductility dip crack. This suggests that grain boundary sliding is an operative mechanism in DDC.

Furthermore, the ductility dip cracks in both the wrought and as-solidified samples (Fig. 12) are shaped like wedge-type cracks (w-cracks) that are observed during creep at high stresses and low temperature (Ref. 54). It is widely accepted that wedge-type cracks are formed as a result of grain boundary sliding (GBS) (Refs. 48, 54–57). There are two general types of GBS: Lifshitz and Rachinger (Ref. 58). Lifshitz sliding is the direct result of stress-directed diffusion of vacancies, whereas Rachinger sliding is accommodated by intragranular deformation (Ref. 58). During Rachinger GBS, the grain boundaries remain contiguous if the intragranular deformation can fully accommodate the GBS. Wedge-type cracks form when intragranular slip occurs at a slower rate than GBS. As such, alloy changes that impede intragranular slip but do not also decrease GBS would be expected to increase the propensity to form wedge cracks. This may be the case with A690 and A600, which are both solid-solution-strengthened alloys. Alloy 690 contains approximately 15 wt-% more chromium than A600, and is also more susceptible to DDC. The increased chromium concentration in A690 may sufficiently strengthen the grain interior to disrupt the balance of GBS and intragranular slip necessary to avoid intergranular cracking. Similarly, the susceptibility to form wedge cracks could be decreased by changes to the alloy that impede grain boundary sliding, like the formation of intergranular precipitates and/or serrated grain boundaries. As discussed in the second paper in this series, both A690 and FM52 have fewer obstacles to grain boundary sliding at the ductility minimum temperature than either A600 or FM82H (Ref. 1). The combined increase in intragranular strength and decrease in resistance to GBS may significantly contribute to the DDC susceptibility of A690 and FM52.

Wedge-type cracks have been observed in the hot torsion of Nickel 270 at tempera-

tures ranging from 800°F (427°C) up to 2000°F (1093°C) with strain rates up to 70 s⁻¹ (Ref. 59). However, wedge cracks are not expected to form during hot tension testing of nickel at strain rates higher than 1 s⁻¹ for temperatures less than 1700°F (927°C) (Ref. 55). This indicates that the difference in loading condition (tension vs. torsion) may affect the formation of wedge cracks. Nonetheless, in this current work DDCs form as wedge-type cracks; therefore, GBS appears to play a significant role in DDC given the test conditions employed.

Dynamic recrystallization has been cited by several authors in the welding literature as an elevated temperature recovery mechanism that brings about an increase in hot ductility at temperatures above the ductility dip temperature (Refs. 11, 26, 60). Recovery and recrystallization are the two general classes of restoration processes that reduce the internal energy of a deformed material. Recovery consists of the rearrangement of dislocations into low angle boundaries, which delineate subgrains. Recovery requires that the dislocations be able to climb and cross-slip, which are hindered in materials with moderate to low stacking fault energy where the dislocations disassociate into partial dislocations. In materials with low stacking fault energy, recrystallization is the preferred method of recovery since the climb and cross-slip of dislocations is not necessary (Ref. 61). Rather, new unstrained grains form at locations of high lattice strain energy that is brought about by inhomogeneities in the deformed microstructure. These can include grain boundaries, twin intersections, and shear bands (Ref. 62).

Dynamic recrystallization (DRX) is a function of strain rate, temperature, stored deformation energy in the form of dislocations, and grain size (Refs. 63, 64). Forming dynamically recrystallized grains significantly increases ductility (Ref. 50). The noticeable increase in on-heating hot-ductility in A600 and A690 at temperatures of 1600°F (871°C) and above can be explained by the increase in dynamically recrystallized grains. One way dynamically recrystallized grains act to increase ductility at elevated temperatures is by preventing ductility dip crack propagation. This can be seen in Fig. 16 where the ductility dip crack is completely surrounded by recrystallized grains that prevent its further growth.

In the micrographs for A690 shown in Fig. 15A and B, the strain rate and temperature (1850°F) are the same; however, there is a significant difference in recrystallization behavior. This can be explained by a change in intergranular carbide distribution that affects both grain size and the delocalization of grain boundary stresses. The intergranular carbides observed in as-received A690 (Fig. 9B) dissolve during the peak temperature portion

of the thermal cycle that is above the $M_{23}C_6$ solvus temperature, which results in grain growth. The average grain size of A690 at 1850°F on-heating is approximately 30 μm , while that at 1850°F on-cooling is 88 μm (Ref. 1). Grain size has a significant effect on DRX. In austenite it has been shown that smaller initial grain sizes decrease 1) the critical strain required for dynamic recrystallization and 2) the temperatures required for DRX given a certain strain (Ref. 65). Furthermore, recrystallized grains will tend to localize along the grain boundary and form a necklace structure as the initial grain size increases (Ref. 63). A similar effect also occurs in A600 where the dissolution of M_7C_3 results in an increase of on-cooling grain sizes and localization of dynamically recrystallized grains to the grain boundaries.

The dissolution of intergranular precipitates acts in three ways to affect the dynamic recrystallization behavior. The first way is by localizing grain boundary stresses. Bruemmer et al. (Refs. 66, 67) performed a series of elegant in-situ deformation studies of A600 using a high-voltage electron microscope (HVEM) to study the effects of intergranular precipitates on deformation behavior of A600. Intergranular precipitates were found to be the principal dislocation sources in A600. These intergranular precipitates acted to delocalize stresses that formed along grain boundaries during deformation. This resulted in more homogeneous plastic deformation in A600 samples that were heat treated in order to form a high density of intergranular precipitates (Ref. 67). Conversely, A600 that was subjected to a thermal treatment that resulted in fewer intergranular carbides exhibited deformation that was localized to the region surrounding the grain boundary (Ref. 67). Based on this, it is expected that fewer intergranular carbides will result in strain localization along grain boundaries, and further prevent complete dynamic recrystallization.

The second way dissolution of intergranular carbides affects DRX is by increasing the susceptibility of grain boundaries to DDC cracking. Forming ductility dip cracks generates internal free surfaces that can no longer bear the loading force. This decreases the amount of deformation energy that the material can effectively convert into strain energy. This decrease in strain energy in the crystal reduces the driving force to bring about complete DRX.

Thirdly, dissolution of intergranular carbides increases the grain size. When the grain size is large compared to the recrystallized grain size the DRX grains will first form along grain boundaries, then additional DRX grains will form into the grain

interior as deformation increases. This is seen in Fig. 18A–D (Ref. 63) where a necklace structure of DRX grains forms along the grain boundaries when the initial grain size is significantly larger than the recrystallized grain size. With increasing deformation, the necklace structure is filled up with additional DRX grains. However, if DDC cracks form this process will be interrupted. When the initial and recrystallized grain sizes are similar, recrystallized structure will appear like that shown in Fig. 18E. This later structure is what is observed in both A600 and A690 at temperatures above 1600°F on-heating — Fig. 15A and B.

Due to their role in delocalizing grain boundary stresses, intergranular precipitates may act to inhibit DDC nucleation. Thermal cycles that promote carbide precipitation/coarsening result in decreased DDC normalized crack length, as can be seen in Fig. 14. This is observed when the peak temperature is lowered to the respective carbide solvus temperatures in FM82H and FM52, and when these alloys are subjected to an isothermal hold at 1600°F for 60 s. An increase in intergranular carbide precipitation is also expected to occur in the slow stroke rate testing performed on A690 at 1600°F. The time under load in this condition was approximately 90 s, which is longer than the isothermal hold time required to recover the hot ductility of FM52 (which has nearly the same nominal composition as A690) at the same temperature. The decrease in strain rate is also expected to lower the critical strain required to form dynamically recrystallized grains, as has been shown in Ni and Ni-Fe alloys (Ref. 68). This can be seen qualitatively in Fig. 4B and D where there are significantly more dynamically recrystallized grains in the slow stroke sample tested at 1600°F on-cooling.

Whereas thermal cycles that resulted in the dissolution of intergranular carbides were found to increase DDC susceptibility, modifications to the thermal cycle that promoted the formation of intergranular carbides decreased DDC susceptibility. In particular, an isothermal hold at the on-cooling ductility minimum for FM52, 1600°F, resulted in a recovery of both ductility and UTS. Time at elevated temperature can allow for recovery and recrystallization to soften an alloy, which may lead to an increase in ductility. Therefore, microhardness measurements were made on unstrained samples of FM52 that underwent four different thermal treatments followed by a water quench. The ductility minimum temperature, 1600°F, is the temperature of interest; therefore, microhardness measurements were made on 1600°F samples in three different conditions: 1) on-heating, 2) on-cooling from NST-25°F, and 3) on-cooling from NST-25°F followed by a 60-s hold. The hardness of these three samples was

compared to a fourth sample that acted as a control, which was subjected to a thermal treatment that would be expected to result in softening: an isothermal hold at 2350°F (1288°C) for 10 min. The results reveal that the 1600°F on-cooling from NST-25°F sample had the lowest hardness of the three 1600°F thermal conditions (Table 5). Only the sample subjected to a 10-min hold at 2350°F was softer. The higher hardness of both the 1600°F on-heating and 60-s hold sample is most likely due to their higher volume fraction of $M_{23}C_6$ precipitates. This shows that the recovery of ductility in FM52 with hold time is not the result of annealing.

FM82H consists of two microstructural features that work to its advantage in preventing DDC nucleation and propagation. The most obvious distinctive feature of FM82H are the serrated grain boundaries (Fig. 10A), which are expected to be highly resistant to grain boundary sliding. Less obvious is the stability of the Nb-rich MC carbides that form in FM82H, which is much more stable during the peak temperature portion of the thermal cycle than the $M_{23}C_6$ (A690 and FM52) and M_7C_3 (A600) intergranular carbides (Ref. 1). These carbides likely act to further impede grain boundary sliding and DDC nucleation.

It should be noted that DRX is generally not observed adjacent to DDC cracks in multipass welds. This is probably a result of the lower levels of strain that the alloys experience during multipass welding as compared to hot ductility testing. Increasing total strain promotes DRX. However, as this work shows, the faster strain rate results in a greater loss of on-cooling ductility at the ductility dip temperature. Furthermore, the DDC mechanism is reproduced in the hot ductility test, even if the recovery mechanisms observed in the hot ductility test may not be operative in multipass welds.

Further Insights Into the Mechanism of DDC

The results in this work show that intergranular precipitates play a key role in suppressing ductility dip cracking. As mentioned previously, thermal cycles designed to dissolve precipitates increase an alloy's tendency to localize strain along the grain boundaries and form DDC. Conversely, thermal cycles that result in precipitation and growth of intergranular carbides decrease DDC susceptibility. The following test conditions all promoted intergranular precipitation and all resulted in decreased DDC susceptibility:

1. Cooling FM82H and FM52 from their respective carbide solvus temperatures
2. Isothermal hold at the on-cooling ductility minimum temperature
3. Slower stroke rate at on-cooling ductility minimum temperature.

This work indicates that regions of the reheated weld metal where the peak temperature exceeds the intergranular carbide solvus temperature will be made vulnerable to DDC. This is shown schematically in Fig. 19 where several key isotherms are overlaid onto a HAZ. Regions heated above the carbide solvus, but below the liquidus, are expected to become more vulnerable to DDC. The size of this vulnerable region of weld metal can be decreased by forming intergranular precipitates that are stable at higher temperature, as is the case in NbC forming FM82H.

Ductility dip cracking forms preferentially along grain boundaries oriented at a 45-deg angle with respect to the tensile axis. This indicates that grain boundary sliding plays a role in DDC. Furthermore, DDC cracks are observed at temperatures above the $M_{23}C_6$ carbide solvus for FM52 (2100°F (1149°C) both on-heating and on-cooling. This can be explained by grain boundary sliding, but not by the current form of the precipitation-induced cracking hypothesis (Refs. 19, 29) since at 2100°F $M_{23}C_6$ carbides in FM52 are 1) not present and 2) not expected to form during the hot ductility test since the test temperature is above the $M_{23}C_6$ solvus (2077°F (1136°C)). Further insights into the DDC mechanism and the influence of microstructural condition on DDC susceptibility will be discussed in the Part II companion paper (Ref. 1).

Conclusions

The DDC susceptibility of Alloys 600 and 690 have been investigated along with their companion filler metals (FM52 and FM82H, respectively) using a combination of Gleeble® hot ductility testing and microstructural characterization techniques. The following conclusions can be drawn from this research:

1. A high stroke rate (2 in./s (50.8 mm/s)) resulted in greater DDC susceptibility in the Gleeble® hot ductility test than a slower stroke rate (0.004 in./s (0.1 mm/s)) at the ductility minimum temperature of 1600°F on-cooling. Slower stroke rates are expected to result in more intergranular precipitation and dynamic recrystallization.

2. Ductility and UTS are reliable macroscopic indicators of DDC in the solid-solution-strengthened, Ni-based alloys tested in this work. Additionally, they provide an indirect measure of when DDC begins to form in an alloy.

3. Crack count measurements on hot ductility specimens provide a more direct assessment of cracking susceptibility than macroscopic mechanical measures (ductility and UTS); however, crack counts are much more time consuming and do not provide information on the strains/stresses required to form DDC.

4. The greatest resistance to DDC was observed in A600 and A690 at all temperatures on-heating. Strain was uniformly distributed within these samples as evidenced by uniform dynamically recrystallized grains.

5. The hot ductility of FM52 and A690, both of which are susceptible to DDC, both dipped well below the minimum ductility of A600 and FM82H when cooled from a near NST peak temperature.

6. In general, alloys were most susceptible to form DDC when cooled from a peak temperature near the NST of the alloy and tested at an intermediate temperature corresponding to a homologous temperature of approximately 0.72.

7. Peak temperature has a significant effect on the on-cooling DDC susceptibility of FM52. DDC resistance is increased when FM52 is cooled from the $M_{23}C_6$ solvus temperature, as compared to the super solvus NST-25°F peak temperature. The near NST peak temperature results in the dissolution of intergranular $M_{23}C_6$ carbides (Ref. 1), which promotes grain boundary sliding and DDC.

8. Hot ductility and UTS can be recovered in FM52 by isothermally holding at the ductility minimum temperature for 60 s. This recovery is not associated with an annealing effect. This recovery appears to be the result of decreased susceptibility to grain boundary sliding due to increased intergranular carbide coverage.

Acknowledgments

This work was funded by a Naval Nuclear Propulsion Program Fellowship sponsored by Naval Reactors Division of the U.S. Department of Energy. The authors would like to thank Dr. George Young Jr., Tom Capobianco, Steve Rooney, and Dan Bozik of Lockheed Martin for their assistance in this work. Additionally, Noecker thanks Dr. Tom Lienert of Los Alamos National Laboratory for his continuing interest in this work and helpful discussions.

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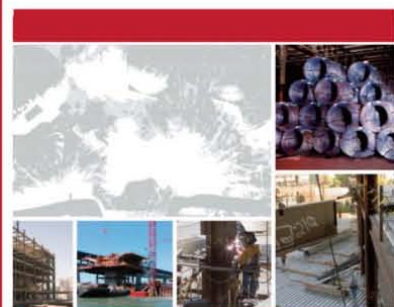
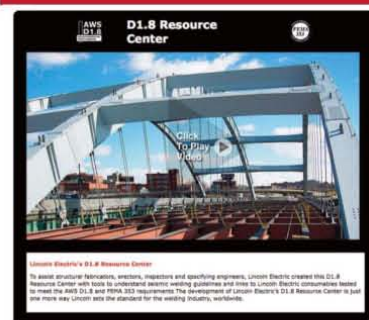
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