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- Miami, Florida .......................April 22-26
- Denver, Colorado .................... Sept. 16-20
- Chicago, Illinois ...................... May 20-24
- Cleveland, Ohio ...................... Oct. 14-18
- Las Vegas, Nevada ................... July 15-19
- San Francisco, California ......... Nov. 4-8

Register now by calling the AWS Conferences Dept. at (800) 443-9353, Ext. 223, or visit the AWS Website at www.aws.org. Attending the full week of the Clinic nets you a FREE copy of the new AWS D1.1: 2002 Structural Welding Code - Steel.

The New D1.1: 2002 Structural Welding Code - Steel

Engineers, designers, architects and fabricators depend on the D1.1 Code to ensure the integrity of welded steel structures. New material in this year's expanded, 502-page edition includes:

- a new section on responsibilities of engineers, contractors and others
- revised information on design of welded connections, limits of fillet weld length, definition of T-joints, and fatigue limits of weld and joint types
- clarification on matching filler metals to construction materials
- guidelines for Charpy V-notch testing and commentary or ultrasonic testing.

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Eclipse Aviation Assembles Its First Jet Cabin with Friction Stir Welding

Finished friction stir welds can be seen surrounding the lower door jamb of the Eclipse 500 jet.

Eclipse Aviation Corp., Albuquerque, N.Mex., recently announced it has successfully used friction stir welding (FSW) to assemble the lower cabin of its first Eclipse 500 jet. The company is believed to be the first to use FSW in production on thin-gauge aircraft aluminum.

The company plans to use friction stir welding in place of rivets in the assembly of most major assemblies of the Eclipse 500. It is working closely with the Federal Aviation Administration on the certification of the FSW technology.

"While we have been completing friction stir welds using production tooling and thin materials for some time now," said Vern Raburn, president and CEO, "assembling one of the components for the first Eclipse 500 jet is a very significant milestone."

MTS Systems Corp., Eden Prairie, Minn., is working under contract for Eclipse to develop the production system and to assist in the development of the weld patterns for the FSW process being used on the aircraft.

"The benefits of friction stir welding are numerous," said Oliver Masefield, vice president of engineering for Eclipse. "It eliminates the need for thousands of rivets, resulting in reduced assembly costs, better quality joining, and stronger and lighter joints. Because this process is significantly faster than other structural joining processes, we can drastically reduce the cycle time in production."

EWI Awarded $46 Million Contract to Continue Operating Navy Joining Center

The U.S. Navy recently awarded Edison Welding Institute (EWI), Columbus, Ohio, and a team of leading defense contractors and other companies the contract to continue operating the Navy Joining Center (NJC) for the Navy’s Manufacturing Technology Program (MANTECH).

The contract, which came following a nationwide competition, is valued at $46 million and extends operation of the NJC through 2007. EWI, which serves as the managing partner, has operated the NJC since its inception in 1993.

Welding and related materials joining technology are used extensively in the production of Navy surface ships, submarines, combat vehicles, aircraft, missiles and electronics, and have a major impact on the cost and readiness of new systems as well as on the maintenance and repair of existing systems.

Congresswoman Deborah Pryce (R-Ohio) said, "The NJC provides high-quality technology to assist the U.S. Navy in carrying out its mission in an efficient and cost-effective way, which ultimately saves American taxpayers money. I am proud to have played a role in securing these resources, which will not only benefit EWI in Columbus but will also help the Navy’s MANTECH Program continue its valuable work for our country’s defense. With the war on terrorism, now more than ever, we need to make sure that our armed services maximize productivity through utilizing cost-saving technology."

For more information, contact Harvey Castner, NJC director, at (614) 688-5000, FAX (614) 688-5001, or via e-mail at harvey_castner@ewi.org.
AWS Certification is the welding industry's most respected sign of approval.

AWS CWI/CWE Prep Course and Exam Schedule, May - June 2002

**MAY 2002**

<table>
<thead>
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*Students registered for API 1104 Seminar must bring API 1104, 19th edition, to the seminar. All other books will be provided.

AWS reserves the right to cancel or change the published date of any exam prep course or exam listed in this brochure if an insufficient number of registrations are received.

**JUNE 2002**

<table>
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Allow six weeks for application review and processing. Call (800) 443-9353, ext. 273 for specifics on fast tracking your application.

Prep Course Schedule

**D1.1 Code Clinic**...........................................Monday

**API Code Clinic** (evenings: 6:00 - 10:00 p.m.)........................Tuesday-Wednesday

**Welding Inspection Technology**...........................Tuesday - Thursday

**Visual Inspection Workshop**.................................Friday

**Exam**.............................................................Saturday

To register or for more information on an exam prep course, call 800-443-9353, Ext. 229; to request an application for CWI exam qualification, call Ext. 273. Visit our website www.aws.org/certification for additional dates.

**American Welding Society**

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Plan now to become an AWS Certified Welding Inspector.
Industry and Education Must Work Together

As some of you may know, I am a professor at Moraine Valley Community College in Palos Hills, Ill. I also work extensively as a welding consultant. Through my work in these two capacities, I have become well acquainted with many welding education programs and with a variety of industries. I have also become aware of the problems each are facing.

Welding-related companies are experiencing problems obtaining adequate numbers of qualified, well-trained welding personnel. One reason for this is that schools, on many levels, do not support their welding programs. Oftentimes, counselors — because of their lack of expertise in technical areas — do not direct students to the welding field. Counselors are unaware of the earnings potential and possibilities for growth in our industry. They do not consider welding a viable career.

Some school welding programs are being closed. Others are seeing funds channeled away from welding toward more traditional education programs by administrators who are unaware of the importance of welding and the employment possibilities it provides. In addition, for many welding programs, funds are not increased to keep up with the rate of inflation. These programs slowly lose the ability to keep up with changes in technology. They can't buy enough types of electrodes to offer the various procedures used by industry, procure the consumables needed to allow training at the necessary levels, or purchase the variety of shielding gasses needed for students to experience the various welding conditions used in different industries. These shortages prevent students from experiencing process variations, such as gas metal arc spray transfer. With reduced budgets, important process applications cannot be taught and welding instructors cannot pursue continuing education to keep themselves abreast of changing welding technology.

Industry is suffering from an acute shortage of skilled and trained welders. When welders are available, they often lack the specific skills industry needs. Schools just can't teach students everything they need to know for the reasons I previously stated. As a result, students entering the work force often lack even the entry-level welding skills an industry requires.

Industry needs to work with local schools to solve these problems. Industry representatives should contact the local welding program's instructor and offer their assistance by donating equipment, supplies, and scrap metal. Companies should inform instructors about the specific skills, jobs, tasks, required quality levels, etc., they need, then help instructors gain this knowledge by providing them with training at their facilities. By working at company sites, instructors will not only learn what is needed at the necessary levels, but can also understand what is needed for the industry. They can then become involved in the welding advisory committee of their particular school or school system. As advisory committee members, they can have a positive influence on a welding program and help keep programs open.

In addition, local companies should have their human relations staff contact the school's counseling department. They can emphasize to counselors the importance of welding and the job opportunities that await students upon graduation. Industry pays taxes that support the schools. In turn, schools should help local industry. This can only be done by the two groups working together. Welding instructors must make themselves available to their local industry and industry must become involved with schools.

James E. Greer
AWS Vice President and Chair, AWS Certification Committee
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A collection of industry news from the Internet

Research and Development Focus of Web Site

National Center for Manufacturing Sciences (NCMS). The mission of NCMS is “to lead the rapid development of cross-industry collaborative R&D teams to enhance the global competitiveness of its manufacturing industry partners as well as ensure a strong economy and national defense.” The organization’s Web site details its portfolio of more than 50 active projects, including ones on laser-engineered net shape forming, rapid prototyping technology advancement, and thermal spray coatings, as well as already completed projects. The project listings include descriptions, contact information for the project managers, and Web site addresses.

The site also includes manufacturing-related news items, a calendar of NCMS events, conference and workshop information, membership information, and copies of the organization’s NCMS at a Glance newsletter.

Visitors can also examine demonstration versions of the Product News Network (PNN) and the Managing Automation Software Guide (MASG). PNN allows searches for new industrial product information by product categories. MASG provides access to a wide variety of manufacturing information, including help for preparing specifications and requests for proposals.

http://www.ncms.org

Site Highlights Laser Applications

GSI Lumonics Inc. Visitors can ask for advice on the use of lasers through the “Ask an Applications Expert” service on the company’s Web site. Users can submit any type of laser processing question via e-mail, and the site provides suggestions for the type of details needed for the company to provide answers. The inclusion of drawings or photos is encouraged.

Answers are provided within two business days either by return e-mail or by telephone. The “Get Samples Processed” section allows users to submit sample parts for processing using lasers by filling in and submitting a form with application details. This service is available to users interested in the company’s cutting, drilling, and welding laser sources.

The site also includes plenty of product and service information, news about the company, and job opportunities.

The “Welding, Cutting, and Drilling” section includes a page called “Tech Tips.” A recent tip explained how pulse energy, average power, peak power, and pulse duration power are all related, noting, “The laser’s ability to weld, cut, or drill depends upon pulse energy and peak power. Average power simply determines the processing speed. For example, when seam welding stainless steel, a pulse energy of about 5 J is needed for a penetration of about 0.5 mm. The peak power needed from the laser is about 1.2 kW, so a pulse duration of 4 ms is used to produce the 5-J pulse. The laser pulses can occur at 1 per second (5 W average power) for 0.5-mm penetration or as high as about 70 per second (350 W average power) for the same penetration. The only difference is that when producing 350 W, the laser seam welding speed is 70 times faster than at 5-W average power.”

http://www.gsilumonics.com

Gases and Welding Equipment Featured

Union Industrial Gas Group (UIG). This Houston, Tex., based firm is the parent company of a group of strategically aligned firms that provide repackaged industrial, medical, and specialty gases, as well as the distribution of related welding equipment, industrial supplies, welding rental equipment, and repair services. Its Web site offers information about its product line, member companies, vendor partners, and employment opportunities, as well as a company profile and customer support services. Visitors can access Material Safety Data Sheets for the gases and access an on-line version of the Ames Health and Safety Manual.

The site provides links to its on-line store (also available at www.weldingstoreonline.com), which offers an electronic catalog featuring thousands of products sorted by category. A photo is included of each product offered. The search function allows users to quickly search for the availability and location of specific items. Once an on-line account is established, customers can track their orders or refer back to the order history to reference past purchases. When an order is placed, the site’s software automatically calculates the shipping charges depending on the customer’s location and choice of transportation.

http://www.union-gas.com

Site Showcases Welding Software

Computer Engineering, Inc. The Web site focuses on the company’s line of ASME and welding engineering software. The site provides descriptions of each product, pricing information, and details on technical support and training programs. Demonstration programs can be downloaded, as well as maintenance releases for acquiring the most current version of the company’s software, conversion utilities for converting programs that have changed file formats, shareware and utilities, and beta versions of new software.

http://www.computereng.com
The impact of welding upon America's economy is dynamic. In the broad industrial spectrum, modern welding technology is essential in the total manufacturing process.

Welding offers design flexibility, production efficiency, and unmatched economy. As a result, it is widely used in the auto industry, in aerospace, transportation, steel construction, military weapons, and myriad household and leisure items that make life easier and more enjoyable. In fact, welding is utilized in more than 50% of the products that make up the country's Gross Domestic Product. In heavy manufacturing industries alone, more than $7.8 billion are pumped annually into our national economy.

At the forefront of the industry is the American Welding Society, one of the nation's premier technical organizations. For more than 83 years it has been dedicated to advancing the science, technology, and application of welding.

The Society develops the codes and standards used in all facets of welding, from outer space to specialized underwater processes. Each year, nearly $500,000 is invested in research and educational support programs. The AWS certification of welders, inspectors, and welding engineers is recognized worldwide by industry professionals.

Topping its service to industry is the Society's prestigious Welding Show, held annually in a major mid-America manufacturing hub. As a vertical welding industry event, it offers companies a unique opportunity to showcase their products before an influential international audience. A vast array of seminars and technical sessions present the newest technology and its practical application. From welder to CEO, the Show is a major forum for career development and business expansion.

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Visit our Web site at www.aws.org
UPCOMING CONFERENCES

SECOND WELDING IN FOOD INDUSTRY APPLICATIONS CONFERENCE
April 17-18, 2002 — St. Louis, Mo.
The American Welding Society is offering a one and one-half day conference on the welding and use of austenitic stainless steels in the food industry. AWS has become particularly involved in food industry welding with the issuance of AWS D18.1 Specification for Welding of Austenitic Stainless Steel Tube and Pipe Systems in Sanitary (Hygienic) Applications, and the companion D18.2 on weld discoloration levels. The Conference will also report on a document being developed on welding vessels and equipment. Some other program items include the properties of stainless steels for food applications, design and welding of equipment, CIP in the food industry, and inspection of welds for food services. The conference starts the afternoon of April 17 and runs through mid-afternoon April 18, 2002.

CLADDING, SURFACING AND THERMAL SPRAY CONFERENCE
April 17-19, 2002 — Chicago, Ill.
Perhaps the best way to improve the properties of a metallic component, be it new or used, is to coat it with another material, one that will extend the part life by providing greater resistance to corrosion, to heat, to abrasion, to impact. Industry is still learning to make excellent use of many conventional processes, such as submerged arc welding, arc welding, plasma arc surfacing, laser cladding, high-velocity oxygen-fuel spray, explosive cladding, and roll bonding to provide this necessary surface protection. Several newer technologies are starting to become more prominent on the wear-resistance scene. Among these newer processes are electrospark alloying, braze cladding, and cold gas dynamic spray. There are, obviously, hosts of methods that can be used to keep steel mills and power plants running, to keep road construction equipment in operation, to keep cars operating, and to keep mining machinery on the job. What are these methods? How can they be used to improve the profits of the company you work for? The answers can be found in the Conference on Cladding, Surfacing and Thermal Spray, which will be held on April 17-19, 2002, in Chicago.

NONDESTRUCTIVE TESTING OF WELDS CONFERENCE
May 22-23, 2002 — Houston, Tex.
An important conference on the Nondestructive Testing of Welds is coming up in Houston, Tex., on May 22-23. Those who attend this conference will be brought up to date on the very latest

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developments in NDE that are sure to improve the inspection of all kinds of weldments. To mention a few, topics such as alternating field measurement, the ultrasonic testing of resistance spot welds, digital radiography, and phased array techniques will be described by industry experts. NDE expert Chuck Hellier will be on hand to discuss the need for ethics in nondestructive testing. The latest developments in techniques for visual testing will be on the agenda, and attendees will come away with a better understanding of D1.1 UT requirements. The two-day conference at the Houston Hobby Airport Hilton will end up with a valuable roundtable.

THIRD WELD CRACKING CONFERENCE:
CAUSES AND CURES
June 11-12, 2002 — New Orleans, La.
Brought back by popular demand, the 3rd Weld Cracking Conference will move into the Royal Sonesta Hotel on Bourbon Street in New Orleans on June 11-12, 2002. In a keynote address, Jon Lee of Chicago Bridge & Iron will inform the audience why weld cracking is such an important issue. Dr. Carl Cross will then discuss the hot cracking of steel and aluminum weldments. James Sims will be on hand to talk about the mysteries of cold cracking. Other speakers will address cracking in stainless steel and titanium. Experts from the shipbuilding and structural steel industries will also be sharing the podium. But, it will not be all doom and gloom: A number of speakers will discuss various ways to eliminate the problems of cracks in weldments through advantageous use of such methods as ultrasonic testing, preheat, and shot peening.

CONFERENCE AND EXHIBITION ON GAS METAL ARC WELDING
September 17-18, 2002 — Orlando, Fla.
GMAW is the most active segment within the entire welding industry. Innovations are prevalent. Keeping up with these innovations can be a full-time job in itself. Industry is constantly changing its procedures in order to accommodate some new technology. Welding engineers, in particular, will find a thoroughly planned conference on GMAW to be a “must”. Topics would be drawn from four main categories: Filler metal, power sources, shielding gases and automation. Under filler metals for steels, there are solid wires, flux-cored wires and metal core wires. Vastly improved power sources are being introduced. Robotics is becoming enormously popular among users of GMAW. Also, the conference should not be restricted to steels, but should include information about the welding of stainless steel and aluminum as well.
Q: We have been trying to qualify a procedure in order to weld test samples for a bend test for an in-house certification. The material is 2 x 5 x 3 inch 416 stainless steel bar stock welded to the same size 304 stainless steel bar stock. It is a V-groove butt joint with a 3/4-in. root opening and a 2 x 1/2 x 7 in. backing bar of 304 stainless steel. We are using GTAW with 308L welding wire, 100% argon, and a preheat of 400-500°F. The bend tests are breaking next to the weld heat-affected zone. According to the Welding Handbook (Vol. 4, Materials and Applications — Part 2, page 250) 308 or 309 filler metal should be able to be used. We also need to pass the tensile test when qualifying the procedure. Would 312 stainless steel filler be better to use? What changes can we make to ensure the coupons pass the bend test?

A: You may be asking for the impossible. You didn’t indicate to which standard the 416 is purchased, but, since you state it is bar stock, I will assume it is purchased to ASTM A582/A582M, Specification for Free-Machining Stainless Steel Bars. Type 416 stainless steel is a martensitic stainless steel, very similar in composition to 410 stainless steel bar, which is specified in ASTM A276, Standard Specification for Stainless Steel Bars and Shapes. The difference between 416 and 410 is the high sulfur in the 416, which makes it more easily machinable but more difficult to weld. Table 1 compares the compositions of these two steels along with the composition of Type 304 bar stock as given in ASTM A276 and AWS A5.9 ER308L filler metal.

Martensitic stainless steels, such as 410 and 416, can be provided in a variety of heat treatment conditions to achieve various combinations of strength and hardness. ASTM A582/A582M Type 416 does not have a strength requirement, but it does have a hardness requirement of 248 to 302 Brinell, which converts to approximately 116 to 146 ksi (800 to 1000 MPa) tensile strength. The heat-affected zone (HAZ) of the 416 will be at least as hard as the base metal in the as-welded condition, which results in a rather large strength mismatch with both the 304 base metal and the ER308L filler metal. The 304 base metal and the filler metal are likely to have tensile strengths in the vicinity of 80 ksi (550 MPa). This mismatch with the 416 base metal and 416 HAZ will produce strain concentration at the weld interface during bending, likely leading to fracture with only modest overall bending. A transverse tensile should fracture in the 304 base metal, assuming no cracking in the weldment.

But, even if you make a sound weldment, I doubt you can pass an ASME 2T bend test with either 410 or 416 base metal, at 248 to 302 Brinell, on one side of the joint, 304 base metal on the other side of the joint, and ER308L filler metal in the as-welded condition. I should note there is no elongation requirement for 416 stainless in ASTM A582/A582M. A 2T bend test requires about 20% elongation in the material, and I doubt the 416 stainless would pass such a test without a weld in it. If I wanted 410 stainless to pass the 2T bend test, I would want the 410 to be annealed at 1350 to 1400°F (730 to 760°C), or mill-annealed, either of which would soften the 410 to below 200 Brinnell hardness and increase its ductility to more than 20% elongation. Because of the sulfide inclusions in the 416 stainless, I am not even sure that such an anneal, which would reduce the hardness to below the ASTM A582/A582M requirements, would make 416 pass the 2T bend test before welding, let alone after welding.

A change to ER312 stainless filler metal might improve the bending angle before fracture in the as-welded condition, but I still doubt it can successfully pass a 2T bend test. The main benefit of using the ER312 would be to improve the strength match with the 416 stainless. The tensile strength of 312 weld metal is typically about 110 ksi (760 MPa), which would reduce the strain concentration at the weld interface. But, if you select 312 filler metal, that would preclude using any sort of postweld anneal to improve joint ductility. Although useful for improving ductility in 410 or 416 stainless, the 1350 to 1400°F anneal will seriously embrittle 312 filler metal because the ferrite in the 312 will transform to hard, brittle, sigma phase. So, 312 filler metal is only useful in the as-welded condition, which leaves the HAZ hard.

You indicated that fracture in bending is occurring in the 416 HAZ. It is quite possible you are actually getting hot cracks in the HAZ or in the weld metal near the HAZ before bending even begins. The words “free-machining” in the title of ASTM A582/A582M are invariably a tip-off to expect hot cracking problems in the weld metal and heat-affected zone. The high sulfur that makes 416 free-machining also tends to produce a lot of hot cracking problems. Even the high ferrite of 312 filler metal won’t guarantee freedom from hot cracking when welding 416 stainless.

In short, I don’t think you can successfully pass a 2T bend test with a weldment that includes 416 stainless, regardless of filler metal used. If it is essential to a 2T bend test be passed with martensitic stainless welded to 304 stainless, I suggest you change from 416 stainless to 410 stainless. If the weldment must be used in the as-welded condition, purchase the 410 in the mill-annealed condition and try ER312 filler metal. If you can use a postweld heat treatment, stick with ER308L filler metal and anneal at 1350 to 1400°F (730 to 760°C) after welding. You will find a little sigma in the ER308L after PWHT, but not enough to cause you to fail the bend test.

While the Welding Handbook indicates a sound weld, including 416 stainless, can be made with 308L or 312 filler metal, it does not indicate a 2T bend test can be passed. The Welding Handbook is only giving a suggestion for a sound weld with limited ductility.

Q&A BY DAMIAN J. KOTECKI

Table 1 — Stainless Steel Compositions

<table>
<thead>
<tr>
<th>Steel</th>
<th>C, %</th>
<th>Mn, %</th>
<th>Si, %</th>
<th>Cr, %</th>
<th>Ni, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>416</td>
<td>0.15</td>
<td>1.25</td>
<td>0.06</td>
<td>0.15</td>
<td>1.00</td>
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<tr>
<td>410</td>
<td>max.</td>
<td>max.</td>
<td>max.</td>
<td>min.</td>
<td>max.</td>
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<tr>
<td>304</td>
<td>0.08</td>
<td>2.00</td>
<td>0.045</td>
<td>0.030</td>
<td>1.00</td>
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<tr>
<td>ER308L</td>
<td>0.03</td>
<td>1.00</td>
<td>0.03</td>
<td>0.03</td>
<td>19.50</td>
</tr>
</tbody>
</table>

DAMIAN J. KOTECKI is Technical Director for Stainless and High-Alloy Product Development for The Lincoln Electric Co., Cleveland, Ohio. He is a member of the AWS ASD Subcommittee on Stainless Steel Filler Metals; AWS D1 Structural Welding Committee, Subcommittee on Stainless Steel Welding; and a member and past chair of the Welding Research Council Subcommittee on Welding Stainless Steels and Nickel Base Alloys. Questions may be sent to Mr. Kotecki c/o Welding Journal, 550 NW LeJeune Rd., Miami, FL 33126 or via e-mail at Damian_Kotecki@lincolnelectric.com.
Get the latest facts and code requirements for bridge building with carbon and low-alloy construction steels.

The American Welding Society has released the latest version of the D1.5 Bridge Welding Code, outlining requirements of the American Association of State Highway and Transportation Officials (AASHTO) for building highway bridges made from carbon and low-alloy construction steels. Chapters cover inspection, qualification, structural details, stud welding, welded joint details, workmanship and more. This new edition features the latest AASHTO revisions and NDE requirements, as well as a section providing a "Fracture Control Plan for Nonredundant Bridge Members." The 250-page ANSI-approved document contains 35 tables, 77 figures, and several annexes. Welding and construction professionals and designers will find this book essential for all forms of bridge work.

NEW EDITION HIGHLIGHTS:
- Implementation of U.S. Customary Units
- Provisions for undermatching electrode usage
- Added commentary section
- New requirements for the modified WPS qualification tests

AWS Bridge Welding Code (D1.5M/D1.5:2002):
List Price ................................ $180.00
AWS Members...............................$135.00

To order your copy of the D1.5:2002 Bridge Welding Code, phone Global Engineering Documents at (800) 854-7179, or visit their webpage at: www.global.ihs.com.

American Welding Society
Founded in 1919 to Advance the Science, Technology and Application of Welding
Navy Contracts New Class of ‘All-Metric’ Ships

Construction has begun on the first LPD 17 class ships, which are known as “Amphibious Transport Dock Ships of the 21st Century,” and are being designed and built exclusively using metric units. The USS San Antonio began construction in December 2000 with a keel laying ceremony at Northrop Grumman Corp.’s Avondale Operations in New Orleans, La. It is expected to be delivered in November 2004. The second ship, USS New Orleans, began prefabrication startup in February.

Avondale is the lead shipyard responsible for design and construction of the 12-ship program and is expected to build eight of the ships. Bath Iron Works in Maine is contracted to produce the other four.

The LPD class ships will measure 208 m long and 32 m wide. All design and shop drawings are in metric units and equipment suppliers have been directed to provide metric components. This contract is a departure from past Navy practice where U.S. customary units were employed. In previous designs, as need arose, metric equivalent units were provided, a practice referred to as “soft” metric conversions. The LPD 17 class ships will instead have rational metric units. For example, instead of specifying ⅜- or ⅝-in. fillet welds, shop drawings will call for 8- or 10-mm sizes.

The American Welding Society, along with other technical societies, has been urging the use of metric units in U.S. industry. Since the 1970s, many of its standards have provided dimensions according to the modern metric system.

Companies Make Donations in the Aftermath of September 11th

Following the September 11th terrorist attacks on the World Trade Center in New York and the Pentagon in Washington, D.C., many welding-related companies responded with donations of money or goods. Following are some of the contributions made by AWS Sustaining Member companies in the aftermath of September 11:

- Northrop Grumman Corp. and its foundation contributed $1 million for the victims and families of victims. An employee campaign to collect contributions was also set up that would match up to $250,000 on a dollar-for-dollar basis.
- Vermeer Mfg. Co. delivered a Vermeer E800 Evacuator to the World Trade Center site. To clean the emergency vehicles, pits covered with grates were created so vehicles could drive up to portable truck washers. The Evacuator was used to clean the pits under the grates.
- BMW Mfg. Co. donated $1 million in cash and ten new BMW X5 sport activity vehicles to the American Red Cross. One hundred police motorcycles were donated to the city of New York to help replace equipment lost from the police department’s motor pool.
- Harris Welco delivered three large shipments of welding hard goods and gloves to welding distributors in the New York area.
- Inweld Corp., OCI Chemical Corp., and Mills Welding & Specialty Gases each made monetary donations to various charities offering disaster relief.
- Steiner Industries sent more than 7500 pairs of welding and work gloves to relief workers at the World Trade Center site.
- Harris Calorific has delivered more than seven tons of equipment. On September 11, the company was called to supply equipment through the Federal Emergency Management Agency. It also responded to several welding distributors in New York who needed assistance in providing steel cutting equipment at the World Trade Center site.

Aircraft Nose Art Honors Victims and Heroes of September 11

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The design for the aircraft nose art the U.S. Air Force will display to recognize the heroes and victims of the September 11th terrorist attacks.

Nose art with the words “Let’s roll!” will be displayed on various aircraft throughout the U.S. Air Force as a way of recognizing the heroes and victims of the September 11th attacks on the United States.

Todd Beamer, a passenger on Flight 93, was overheard on a cellular phone reciting the Lord’s Prayer and saying “Let’s roll!” before he and other passengers charged the terrorists to take control of the flight. The intended target for the plane, which
eventually crashed into a field in western Pennsylvania, is believed to have been either the White House or the U.S. Capitol building.

The nose art design depicts an eagle soaring in front of the U.S. flag, with the words “Spirit of 9-11” on the top and “Let’s roll!” on the bottom. The Thunderbirds and other Air Force demonstration teams will apply the artwork on all aircraft, while major commands and wings will be authorized to apply the artwork to one aircraft of their choice.

NASSCO Purchases ESAB’s Largest Cutting Machine Ever

ESAB Cutting Systems recently delivered the largest cutting machine it has ever produced to NASSCO in San Diego for the company’s new large panel fabrication line.

The system includes an ESAB Avenger 4 “Telerex” gantry, which measures almost 90 ft wide. It will be used to perform cutting, marking, grinding, and beveling operations on steel panels up to 16 meters square. The machine is equipped with two 7-axis triple-torch oxyfuel beveling heads that will be used to cut the sides, ends, and interior cut-outs of the panel; a high-speed belt grinder that can remove 2-in.-wide strips of primer paint across the panel’s width; and an ink-jet marker that will mark layout lines and text on the panel. The system is controlled by ESAB’s Vision NT CNC system that allows complete automation of all processes from a single operator station.

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Industry Notes

- Applied Robotics, Inc., Glenville, N.Y., recently received the Export Award for Medium Manufacturer at the Capital Region World Trade Center and Global Business Network’s Fourth Annual Excellence in Export Awards. To qualify for the award, a company had to have gross sales of under $50 million, a minimum of four years of progressive exporting, and at least 20% of its total sales exported. More than 35% of Applied Robotics’ sales have gone into markets outside the United States. The Excellence in Export Awards recognize companies in the Capital Region that have succeeded in making a sustained effort to increase their export sales.

- The Resistance Welder Manufacturers’ Association (RWMA) recently awarded scholarships to Zachary Klumpp and Joel Diller, both students at Ferris State University in Big Rapids, Mich. In addition to the scholarships, which will be used toward the resistance welding program at the university, each student received an RWMA Resistance Welding Manual, Fourth Edition, and a certificate of recognition. The RWMA Scholarship Fund was created in 1994 with a grant from Jacquelin Craig, wife of the late Emmet A. Craig, for whom the RWMA Resistance Welding School is named.

- Friction Stir Link, Inc. (FSL), Menomonee Falls, Wis., recently signed an agreement with ABB, Inc., New Berlin, Wis., in which the company will incorporate ABB robots into robotic friction stir welding systems FSL builds and integrates. This is the first agreement between ABB’s Automation and Technology Products group and an integrator focusing on robotic friction stir welding systems.

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

**WE MAKE**

<table>
<thead>
<tr>
<th>Stainless</th>
<th>Cast Iron</th>
<th>Cobalt</th>
<th>AISI</th>
<th>Nickel</th>
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<td>904L FC</td>
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</tr>
</tbody>
</table>

THE ABOVE ARE JUST A FEW OF THE CORED WIRES THAT WE MAKE. FOR MORE INFORMATION CALL:

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Circle No. 6 on Reader Info-Card
Engine-Driven Welding Generator Improves Performance

The company's Trailblazer 301 G engine-driven welding generator has been updated to provide 25 additional amps of CV power and an extra 1500 W of auxiliary power. In all, the generator has a 300-A output and 10,000-W peak auxiliary power rating at 104°F. The company offers the Trailblazer DC for those who do not need AC weld output, with the same features and benefits as the 301 G at a lower price and with a simpler control panel. Both multiprocess, CC/CV machines provide a 20- to 300-A DC output (100% duty cycle at 300 A, 25 V) for shielded metal arc, gas tungsten arc, gas metal arc, and flux cored arc welding.

Miller Electric Mfg. Co.
1635 W. Spencer St., Appleton, WI 54912-1079

Arc Stud Weld Head Provides Total Control

The company's weld head has a linear motor drive that precisely times and controls lift heights, plunge velocity, and depth penetration of each attachment in the drawn arc stud welding process. The system replaces conventional electromagnetic devices and achieves consistent weld accuracy within 0.3 mm through a closed-loop optical encoder that monitors stud movements throughout each cycle. Online programming of the linear motor allows variations in lift heights, including individual weld sequences. These instant adjustments maintain constant arc voltage and ensure proper melting of base metal and stud head. The system reacts immediately to the slightest irregularity in the weld zone by modifying the speed and distance of the stud, allowing the weld head to operate without a reference probe in most applications. Overheating in the weld zone is eliminated, a crucial benefit in aluminum welding, where less heat is required to reach melting points.

Emhart Fastening Technologies
P.O. Box 868, Mt. Clemens, MI 48046-8868

Modular Fixturing Aligns Piping

The company's modular fixturing eliminates the necessity of welding pipes
on-site for power generation, chemical, water works, sewage treatment plants, etc. The fixturing aligns and welds pipes, flanges, and fittings in-house. Adapter plates orient flange bores plugged right into the fixturing system grid pattern.

Bluco Corporation
509 Weston Ridge Dr., Naperville, IL 60543

Reliable Inverters Include Built-In Arc Force

The company's Invertec line of inverters provides low-cost, reliable precision welding performance. Models include the Invertec® V160S for shielded metal arc welding and the Invertec V160T for DC and the Invertec V205T AC/DC, both for gas tungsten arc welding. Each offers inverter performance with reliable starting and smooth arc characteristics, including built-in arc force. The machines feature large controls and are portable and lightweight. The V160S and T units come with a carry strap for added portability. All three inverters offer a full three-year warranty on parts and labor.

The Lincoln Electric Co.
22801 St. Clair Ave., Cleveland, OH 44117-1199

Air Purifying Respiratory System Blows Fresh Air over Face

The company's NIOSH-approved, powered air-purifying respiratory system is lightweight, comfortable, and easy to use. The motorized, battery-operated system blows a constant supply of fresh, filtered air over the face, creating a protective positive pressure inside the respirator head top. Head tops are designed and engineered to offer protection from harmful gases, vapors, and particulates. The system works with both P3 and AEP3 filters. A variety of interchangeable head tops and multiple welding helmets/auto-darkening filter combinations are available to use with the system. Each comes with a quick-release bayonet fitting.

ArcOne
85 Independence Dr., Taunton, MA 02780

Welding Camera Provides Real-Time Video Imaging

The company's video imaging line, WeldCam, provides real-time video imaging of any welding process. The product line is comprised of two different models allowing for diverse applicability. Model C80L is a small, lightweight, self-contained video imager. Model C90 has a very small, tethered imaging head for hard-to-reach and space-restricted locations. The systems provide video imagery of the weld pool, electrode, and feed wire without being overwhelmed by the arc's plasma light, which frequently interferes.
with other welding camera systems. Because the camera is essentially blind to the welding arc, a very pliable and precise image is provided. The systems are easy to use, have no tedious alignments, as with spot cameras, and operators do not have to be imaging experts to obtain a functional image.

Control Vision Inc.
P.O. Box 51365, Idaho Falls, ID 83405

Two-Gas Mixer with Surge Tank Mixes Shield Gases

![Two-Gas Mixer with Surge Tank](image1)

The company's high-capacity, two-gas mixer with an 11-gallon surge tank is ideal for liquid cryogas applications, delivering precisely mixed gases accurate within 1.5% at up to 1100 ft³/h. The mixer requires no electrical hookup and no electrical service or special wiring. The mixer's stainless steel cabinet is weather-tight, lockable, and contains both inlet and outlet regulators. The extra-large surge tank provides a ready reserve of mixed gas to offset any large and sudden withdrawal. The reserve can be used to avoid shutting down welding stations during system maintenance operations. The mixer can be used with argon and carbon dioxide and is adjustable from 0 to 100% for both primary and secondary gases. It has a flow capacity of up to 30–1100 ft³/h.

Smith Equipment
2601 Lockheed Ave., Watertown, SD 57201

Welding Robot Has Improved Motion Range and Speed

The company's Model B arc welding robot has a compact design with improved motion range and speed. The design simplifies installation, maximizes reach capability within confined areas, and enables high-density installation of robots and peripherals. Model B has a payload capacity of 6 kg exclusively designed for arc welding and cutting applications. The controller and software are standard with the series of robots.

FANUC Robotics North America, Inc. 117
3900 W. Hamlin Rd., Rochester Hills, MI 48309-3253

Machine Vision System Performs 3D Weld Inspection

![Welding Robot with Improved Motion Range and Speed](image2)

The company's 3D machine vision systems examine the welded joint of a steel wheel for missing welds, length, porosity, burn-t-in and edge notches, weld position, thickening at the beginning of a weld, unfilled end craters, and height and width of the weld. Two to three profile sections are required for reliable defect detection. This results in a detectable defect size of 1 mm. Measurement range and measurement time can be adapted.

VITRONIC 118
Hasengartenstrasse 14a, 65189 Wiesbaden, Germany

Marking Unit Is Portable for In-Plant or Outdoor Applications

![Portable Marking Unit](image3)

The company's portable marking unit features an integrated processor, built-in keyboard, LCD screen, and a battery pack, allowing the operator full mobility...
for in-plant or outdoor permanent marking applications. The unit marks metal, plastics, wood, and other materials on flat, concave, and circular surfaces, horizontally or vertically. The hand-held unit allows for left- or right-handed operation. A molded attachment allows the unit to be suspended from the operator's belt or an overhead hook, keeping it out of the way when not in use. The integrated marking software is easy to program and adapts to user's marking requirements. No in-depth operator training is needed.

Pro-Pen
9800 S Southern Pine Blvd., Charlotte, NC 28273

Brushless Drive System Provides High Performance

The company's high-performance, AC servodrive system for shape-cutting provides 8 A of continuous output current and is capable of up to 1-kW continuous and 2-kW peak power per axis. Globally compatible, it is available in 2- or 3-axis, performance-matched drive packages designed for shape-cutting application and for any cantilever or gantry machine. The unit is a digital AC brushless sinusoidal servo design that is customer configurable to any output power requirement. Diagnostic LED indicators monitor all operating functions. Windows®-based software is included; users can download the latest software updates off-line.

Cleveland Motion Controls
7550 Hub Pkwy., Cleveland, OH 44125-5794

High-Purity Regulator Alarm Warns of Gas Depletion

The company's alarm system for wall-mounted high-purity regulators addresses the needs of small- to medium-volume users requiring an uninterrupted supply of specialty gas. The alarm provides early warning of cylinder depletion for small-volume, single- or two-cylinder applications. An audio-visual system provides warning when cylinder contents are nearly depleted, utilizing a pressure switch gauge for visual warning and a remote alarm for additional audible and visual warning. The set point on the pressure switch gauge is adjustable in the field to allow adequate time for ordering a replacement cylinder. The alarm is available with alarm gauges in 600, 4000, 6000, and 10,000 lb/in.$^2$ models.

Concoa
1501 Harpers Rd., Virginia Beach, VA 23454

Plasma Cutting System Has Input Sensing

The company's Powermax1000© G3 Series™ portable hand plasma cutting system cuts fast and economically. The power supply incorporates input sensing that allows the operator to run on voltages from 200 to 600 V, 1- or 3-phase, and CE models 230 to 400 V, 3-phase, without the need for manual linking. The system's Boost Conditioner™ circuit compensates for voltage variation. Its digitally controlled inverter delivers continuously adjustable, constant-current output from 20 to 60 A. The design permits cuts over a wide range of metal thicknesses. This plasma cutting system is engineered to work under harsh environmental conditions.

Hypertherm, Inc.
Hanover, NH 03755

Magnet Lifting Systems Handle Oxygen-Cutting Operations

The EP-1000 magnet lifting systems meet the application needs for handling plates in steel service centers, steel processing, plants, fabricating shops, and oxygen-cutting operations. The systems lift and move bundles of tubes, pipes, or any kind of structural steel. They require only one operator and eliminate the need for slings, hooks, or chains. Plates up to 5 x 10 ft and 3/8 to 2 1/2 in. thick can be lifted.

Walker Magnetics
Rockdale St., Worcester, MA 01606

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Circle No. 25 on Reader Info-Card
Perhaps the best way to improve the properties of a metallic component, be it new or used, is to coat it with another material, one that will extend the part life by providing greater resistance to corrosion, to heat, to abrasion, to impact. Industry is still learning to make excellent use of many conventional processes, such as submerged arc welding, arc welding, plasma arc surfacing, laser cladding, high velocity oxygen-fuel spray, explosive cladding, and roll bonding, to provide this necessary surface protection. Several newer technologies are starting to become more prominent on the wear-resistance scene. Among these newer processes are electrospark alloying, braze cladding, and cold gas dynamic spray. There are many methods that can be used to keep steel mills and power plants running, to keep road construction equipment in operation, to keep cars operating, and to keep mining machinery on the job. What are they and how can they be used to improve the profits of your company?

The answers can be found in the Conference on Cladding, Surfacing and Thermal Spray, set for April 17-19, 2002, in Chicago.

American Welding Society
Founded in 1919 to Advance the Science, Technology and Application of Welding

Cladding, Surfacing and Thermal Spray Conference
April 17-19, 2002 Chicago, Illinois

Learn the keys to making your metals last.

The American Welding Society presents a two-and-a-half-day conference featuring the most efficient metal-coating technologies ensuring resistance to the atmospheric effects of corrosion, wear, heat, abrasion, and impact. Valuable talks on past and present coating methods from submerged arc welding and plasma arc surfacing, to electrospark alloying, braze cladding, and cold gas dynamic spray processes will be reviewed in several technical presentations. Experts from leading car manufacturers and research laboratories, including Ford and Sandia National Laboratories, will discuss these topics and provide insight on the future of the field. Manufacturing professionals in attendance can gain the needed understanding to secure the cost-effective construction and extended product life of metallic components.

Metal-Coating Conserves:
• Automotive Components
• Power Plants
• Steel Mills
• Road Construction Equipment
• Mining Machinery

Conference Cost:
AWS Member .......................................................... $575.00
Nonmember .............................................................. $675.00

The nonmember conference fee includes a two-year AWS membership.

For more information, or to register, contact the AWS Conference Department at (800) 443-9353, ext. 449, or visit the AWS Conferences webpage at: www.aws.org
TIPS FOR SUCCESSFULLY WELDING SHEET METAL

Proper equipment, electrodes, and welding techniques can prevent typical sheet metal welding problems such as warping and melt-through.

BY MIKE BRACE AND JIM BROOK

For fabricators and others with bottom-line goals, welding sheet metal often means a constant battle between productivity and equipment investment vs. melt-through, warping, excessively large heat-affected zones (HAZ), and weld appearance. For the individual occasionally welding sheet metal, success can be ensured by learning the proper techniques.

MIKE BRACE and JIM BROOK are Welding Engineers at Miller Electric Mfg. Co., Appleton, Wis. (920) 734-9821.
Process Selection

When welding thin metal, the main objective is to avoid warping, melt-through, and excessive heat-affected zones while still ensuring the weld has sufficient mechanical strength for the application. The welding processes that provide the most control over heat are short-circuiting transfer gas metal arc welding (GMAW), pulsed gas metal arc welding (GMAW-P), gas tungsten arc welding (GTAW), and pulsed GTAW. Table 1 provides a brief overview of the processes. The right process for your operation will depend on the relative influence of the factors shown in the table on your operation.

Table 1: Process Selection

<table>
<thead>
<tr>
<th>Process</th>
<th>Electrode Type</th>
<th>Shielding Gas</th>
<th>Deposition Rate</th>
<th>Heat Affected Zones</th>
</tr>
</thead>
<tbody>
<tr>
<td>GMAW</td>
<td>Solid or Filler</td>
<td>Argon-based</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Pulsed GMAW</td>
<td>Solid or Filler</td>
<td>Argon-based</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>GTAW</td>
<td>Solid or Filler</td>
<td>Argon-based</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Pulsed GTAW</td>
<td>Solid or Filler</td>
<td>Argon-based</td>
<td>Low</td>
<td>High</td>
</tr>
</tbody>
</table>

Table 2: Electrode Polarity

<table>
<thead>
<tr>
<th>Polarity</th>
<th>Heat Input</th>
<th>Arc Behavior</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive</td>
<td>High</td>
<td>Constant</td>
</tr>
<tr>
<td>Negative</td>
<td>Low</td>
<td>On-Off</td>
</tr>
</tbody>
</table>

Electrode Selection

For welding with solid wires, use electrode positive (EP) polarity. While EP directs more heat into the base metal than electrode negative (EN) polarity, you will obtain the best results with EP and the guidelines provided here. If you've been using flux cored wire, be sure to change your machine's polarity from EN to EP.

GTAW Electrode Selection and Preparation

Forget the ubiquitous ½-in.-diameter tungsten electrode and use a smaller one. They come in diameters down to 0.020 in. Smaller electrodes carry less heat and allow you to better focus the arc in a smaller area. For steel and stainless steel applications, keep the tungsten pointed and be sure to grind parallel with the length.

For the best results on thin aluminum, use an inverter-based power source (see GTAW power source recommendations).
and forget the popular practice of welding with a pure tungsten electrode and balling the end. Instead, select a 1/8-in.-diameter tungsten with 2% cerium (2% thorium as a second choice), grind it to a point, and put a small land on the end. Compared to the balled tungsten used with conventional GTAW machines, a pointed electrode provides greater arc control and enables you to direct the arc precisely at the joint, minimizing distortion.

**Aluminum Preparation**

Clean all metals before welding, especially aluminum. Remove oil and dirt with a degreaser/solvent. An oxide layer forms on aluminum when it is exposed to air. This aluminum oxide melts at a temperature 2000°F higher than plain aluminum. Therefore, just prior to welding, remove the oxide with a stainless steel wire brush, grinder, or chemical oxide cleaner. Any slacking in weld preparation degrades weld quality and integrity, so be diligent.

If you store aluminum in cold places (outside, unheated warehouses), bring it to room temperature and eliminate condensation. Do not heat cold metal with an oxyfuel torch — a common practice, but not a good idea. This can drive carbon into the oxide coating.

**Universal Advice**

**Weld Technique**

Direct the arc at the middle of the weld pool. Normally, you would keep the arc on the leading edge, where the weld pool is thinnest, to drive the arc into the work for more penetration. However, staying back enables the pool to insulate the base metal from the arc's full force.

To prevent melt-through and warping, do not whip or weave the torch because the longer you keep the arc in an area, the hotter it becomes. Always travel in a straight line and use the fastest travel speed possible that maintains a good bead profile.

**Intermittent Welding**

Unevenly distributed heat causes distortion and warping, which in turn wreaks havoc on parts that theoretically fit together. To minimize warping, distribute the heat as evenly as possible. You can accomplish this by using an intermittent welding technique, commonly called skip or stitch welding.

For example, imagine you're welding a 2 x 2 ft piece of 18-gauge stainless steel to repair the side of a tank. Start by making a 1-in.-long weld. Skip 6 in. and make another 1-in.-long weld. Continue to work your way around the plate's circumference, welding 1 in. out of every 6 in. You may have heard of this as a "1 on 6" weld. After you've traveled around once, make your next 1-in.-long weld 3 in. from the first weld. Continue to place the second set of welds between the ones you made on the first pass and so on, until you achieve the integrity desired.

The same technique holds true for welding linear parts. If the metal starts to warp or pull to one side, solve the problem by:
- Increasing the distance skipped between welds
- Welding at the beginning, middle, and end of the piece, then repeating the sequence
- Welding on alternate sides of the joint.

**Backing Bars**

To dissipate heat from the weld area faster than with atmospheric cooling alone, place the heat-affected zone in contact with a backing bar. A backing bar can be as simple as a metal bar (usually copper or aluminum because they dissipate heat best) clamped to the back of the weldment. This simple technique enabled one fabricator to use an all-in-one pulsed GMAW power source to weld a continuous joint on 0.040-in. aluminum.

In higher-duty-cycle applications, you may need to consider a water-cooled backing bar. Elaborate versions feature water coolers that circulates chilled water or special coolant through holes drilled in the bar. Simple, homemade versions feature a water cooler circulating coolant through PVC pipe touching the back of the bar.

**Fit-Up and Joint Design**

Welding thin metal demands tight fit-up. Imagine a butt-joint weld on 20-gauge metal. If the parts fail to touch for even 1/16 in., you will have just created a hole that hags for melt-through and has left a gap that cannot absorb the heat. On thicker metal, the edges of the metal can support the arc, but not here. Gaps cause nothing but trouble. To avoid rework caused by melt-through, adhere to the old saying “Measure twice, cut once.”

If you can redesign the part with joints that can withstand more heat, do so. For example, instead of a butt-joint weld, can you make a lap joint? If you can, you will double the amount of metal available to absorb heat.
Don’t Overweld

Most people, especially those without formal training, feel compelled to overweld a joint to obtain greater strength. Assuming you have sufficient heat, the leg of the joint (the long side of the triangle) does not need to be any longer than the thinnest plate. For example, when welding a ¼-in. plate to a ½-in. plate in a T or lap joint, the weld only needs to be ¼ in. wide. Excessively wide welds reduce travel speed, waste time, waste filler metal and gas, may lead to unnecessary postweld grinding, and may affect the temper of the metal.

GMAW Power Sources

When selecting a power source for short circuit GMAW, use one with good voltage control at the low end for good arc starts and stability.

If you plan to buy an all-in-one power source that uses 115-V household current, go with one from a major manufacturer of industrial welding equipment. Often, very low priced machines simply do not have the slope and inductance necessary for good control over the short circuit. Be sure the unit comes with a contactor and gas solenoid valve; some units designed for good control over the short circuit. Be sure the unit comes with a contactor and gas solenoid valve; some units designed only for flux cored welding do not.

If you plan to weld with an all-in-one power source in the 200-250 A range, look for one with a spool gun that connects directly to the front panel. This eliminates a lot of hook-up headaches by letting you switch instantly between two different wires, such as 0.023 hard wire in the spool gun. To weld aluminum, use an inverter with advanced square-wave technology such as Miller's Dynasty™ 300 DX. These machines feature extended balance control (up to 90% EN vs. 68% EN for conventional technology) and an adjustable output frequency (typically from 20 to 250 Hz). Inverters create the narrowest arc possible and let you weld in the AC mode with a pointed tungsten — Fig. 3. You can precisely direct the arc, establish the weld pool faster, and place the filler metal right where you want it.

GTAW Power Sources

GTAW power sources come in two basic categories: those with a DC output for ferrous metals and those with an AC/DC output for nonferrous metals as well.

For welding thin steel or stainless steel, but not aluminum, invest in one of the new GTAW inverters that feature pulsing controls and high-frequency arc starts. Pulsed GTAW, which allows the weld pool to cool between pulses, is one of the easiest methods for the prevention of warping and melt-through — Fig. 2.

For welding thin aluminum, use a GTAW machine with an adjustable square-wave output. By fine tuning its “balance control,” or adjusting the EN to EP ratio, you can narrow the weld bead and take heat off the base plate.

For unbeatable results on thin aluminum, use an inverter with advanced square-wave technology such as Miller’s Dynasty™ 300 DX. These machines feature extended balance control (up to 90% EN vs. 68% EN for conventional technology) and an adjustable output frequency (typically from 20 to 250 Hz). Inverters create the narrowest arc possible and let you weld in the AC mode with a pointed tungsten — Fig. 3. You can precisely direct the arc, establish the weld pool faster, and place the filler metal right where you want it.

Table 1 — A Comparison of the Welding Processes

<table>
<thead>
<tr>
<th>Process</th>
<th>GMAW (short arc)</th>
<th>Pulsed GMAW</th>
<th>GTAW</th>
<th>Pulsed GTAW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of metal it can weld</td>
<td>Steel, stainless, aluminum</td>
<td>Steel, stainless aluminum</td>
<td>Steel, stainless aluminum</td>
<td>Steel, stainless aluminum</td>
</tr>
<tr>
<td>Metal thickness</td>
<td>24 gauge and up 1/8 in. and up</td>
<td>0.020 in. and up</td>
<td>0.020 in. and up</td>
<td>0.020 in. and up</td>
</tr>
<tr>
<td>Heat input</td>
<td>Moderate</td>
<td>Moderate—High</td>
<td>Lowest</td>
<td>Lowest</td>
</tr>
<tr>
<td>Welding speed</td>
<td>Very fast</td>
<td>Very fast</td>
<td>Slow</td>
<td>Slow</td>
</tr>
<tr>
<td>Bead appearance</td>
<td>Good. Some spatter</td>
<td>Better. Almost no spatter</td>
<td>Best. No spatter</td>
<td>Best. No spatter</td>
</tr>
<tr>
<td>Skill required</td>
<td>Some skill</td>
<td>Most skill</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Purchase cost</td>
<td>Low</td>
<td>Moderate—High</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Operating cost (including labor)</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>

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American Welding Society
Founded in 1919 to Advance the Science, Technology and Application of Welding
Nanette Samanich on the job measuring fillet welds on roof panels of a treated water tank at a 1100-MW APROX generating station being constructed near Las Vegas.

BEHIND THE MASK: Nanette Samanich
Nanette Samanich’s first foray into welding might have gotten her evicted if her landlord had known what was going on in the kitchen of her studio apartment.

“We had this shopping cart and a little Miller machine,” she explained. “We put it on the shopping cart with a piece of plywood, rolled the tank in, hooked it up, hot wired it to where the stove was, and sat there and TIG welded on the kitchen counter.”

Nanette’s unusual introduction to welding came in 1994 from her then-boyfriend, now-husband, Richard. She had moved to Las Vegas, Nevada, from the East Coast a year or two earlier and was employed as a bookkeeper. “I’d done bookkeeping for 20 years and decided it was boring and it was time for a change,” she explained. Richard, whom everyone calls Sam, was nearing his retirement from the U.S. Air Force and was trying to decide what he wanted to do in civilian life.

Since Sam had been a welder in the Air Force, Nanette suggested they start a welding business. When Sam said he couldn’t do all the welding himself, Nanette told him “Show me, I’ll learn.” That’s when they set up the welding machine in her kitchen. Sam’s aim was to find out if Nanette had a feel for welding and if she liked it well enough to pursue it as a career.

With Sam serving as mentor and partner, Nanette has come a long way since those first two weeks practicing in her kitchen. The couple has established a business in Las Vegas and have both become AWS Certified Welding Inspectors (CWIs) and officers of the AWS Nevada Section. In addition, Nanette works with students at two area schools and has become a strong supporter of nontraditional careers for women.
Getting Started

First, however, she had to receive her own education in welding. "Sam said if I was really interested in learning how to do it, I should go to school and get some education and some basics," Nanette explained. "So that’s what I did."

Nanette enrolled at the Community College of Southern Nevada in Las Vegas. "I started out with a theory class so I could learn the correct terminology," she recalled. She followed that up with classes in shielded metal arc, gas metal arc, oxyacetylene, and gas tungsten arc welding (GTAW). "I was really good at [GTAW] because I sew. I was used to using my hands and my feet to sew and that was my original goal, to [GTA] weld," Nanette recalled. "You have to be very well coordinated to do that." To further improve her gas tungsten arc welding skills, she took a GTAW class at the Hobart Institute of Welding Technology.

While Nanette was still in school, she and Sam opened their business, A-1 Precision Welding. Since much of the welding work in the Las Vegas area is either structural steel or pipe welding, they concentrated on welding aluminum, stainless steel, chromium-molybdenum steel, titanium, and other, more specialized, metals. "What we were looking to do was something new that we didn’t find a lot of shops in town did," she explained.

Many of their jobs now are mobile service repair work, often for the hotels and casinos Las Vegas is known for. They’ve repaired an aluminum swimming pool, modified a stainless steel bridge for the Mandalay Bay Hotel, and completed repairs on titanium and magnesium parts for a Sikorsky sky crane, among other work. "We also do a lot of small production parts for the slot machines," Nanette said. "Those are a lot of stainless steel and aluminum parts."

In working with a wide variety of metals, Nanette said, "you get to learn a lot more about welding and how the different metals and filler metals work together. It’s a very interesting field. Every day there’s something new."

Spreading the News about Welding Careers for Women

Nanette is currently serving as chair of the AWS Nevada Section, as well as chair of its Education and Certification Committees. Through her Section activities, Nanette has become involved with the Southern Nevada Vocational High School and the Area Technical Training Center. She participates in the schools’ training days by reading résumés and conducting mock interviews and brings new welding products to the schools for demonstrations. "I also act as a liaison between the high schools and the community" to let them know what jobs, educational programs, and scholarships are available to students.

During 2000-2001, Nanette attended the AWS Leadership Symposium in Miami. She also served as Deputy District Director for District 21. "The girls in the [high school] weld shop thought it was a big deal that a woman could get so far in this organization, especially at the district level," she said. "They only see at a local level, they don’t see anything more than that.

She’s quick to point out to them that AWS’s president from 1998-99 was Shirley Bollinger.

Nanette tries to impress upon the students, especially female students, the many career opportunities welding offers in areas such as research and development, metallurgy, sales, inspection, and engineering. "You don’t have to weld," Nanette said. "There are other fields in welding that you can go to. But I always let them know the first basic necessity should be to learn how to weld because that way you’ll know what a weld should look like. You’ll know how the metal should be cleaned, how the bevel should match. To me, it’s a basic need to learn how to weld first, then, if you’re not really happy with that, pursue another career."

Nanette’s advice to women who are interested in advancing in the welding industry is “there’s always room for progression. You just have to want it bad enough.”

Moving Forward

Nanette has followed her own advice. In May 2000, she became a CWI and these days does more inspection work than welding. While Sam preceded her in becoming a CWI, he continues to concentrate on the welding side of their business.

Recent jobs she has worked on have included weld and structural steel inspections for a $123 million expansion for the Las Vegas Convention Center and a $20 million central power plant cooling tower project. With a new monorail system going up in Las Vegas, expansions to many of the casinos, and three new power plants being constructed in the area, Nanette sees plenty of opportunities for inspection work. To help her take advantage of those opportunities, she is studying for the International Conference of Building Officials’ certification test. She is also considering entering the ultrasonic testing field.

The Pitfalls and Benefits of Being a Woman in Welding

The biggest disadvantage in being a woman in this field is the necessity of having to prove yourself over and over again. Nanette said, “They’ll say, ‘you don’t know anything about welding.’ She carries her welding helmet and leathers with her at all times and whenever her credentials are challenged, she puts them on and demonstrates her welding skills.

The advantage is that male welders are much more willing to teach her than they are another man. “Welders are willing to show me and teach me things that I don’t know,” she said. “Even if I’m out there as a CWI, I’ll get my head and put it on and watch them. Some of them have great techniques that I don’t know about.”

While men still greatly outnumber women, the welding industry isn’t nearly as lonely a place for women as it once was. “I think what’s important is that the roles of women have really changed in the past 20 years and there are now more women in nontraditional roles or fields than there used to be,” she said. “And the other thing that we have to remember is that we can’t hold women back.” Nanette said she often reminds the students she works with that “women once ran this country’s [manufacturing industry] back in World War II when all our men went to war.” While most of those women returned to traditional roles following the war, they had proved women could handle manufacturing jobs such as welding. “It’s time to let women do things that men have been doing over the past 40 years,” she said, “if they can do it, let them do it, and let’s put them on the back for going out there and doing something that women normally don’t do.”
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The 1994 Northridge, Calif., earthquake challenged the way steel moment-frame buildings are designed, built, and inspected. Shortly after the earthquake, several steel moment-framed structures were discovered to have fractures at the beam-to-column connections — Fig. 1. Initially, as many as 200 buildings were believed to contain cracks caused by the earthquake. However, subsequent investigation determined actual earthquake cracks occurred in significantly lower numbers than the original estimate, but of significant concern nevertheless.

An AWS Presidential Task Group was established to address the welding-related issues and possible implications to the *AWS Structural Welding Code — Steel* (AWS D1.1) (Ref. 1). As a result of this study, the AWS Structural Welding Committee Position Statement on Northridge Earthquake Welding Issues was released in November 1995, addressing 38 issues with specific recommendations.
Also in 1995, the Federal Emergency Management Agency (FEMA) and the State of California, Office of Emergency Services, provided funding to address both immediate and long-term solutions to the problems discovered with steel moment-frame connections. The project was managed by the SAC Joint Venture, a partnership of the Structural Engineers Association of California (SEAOC), the Applied Technology Council (ATC), and the California Universities for Research in Earthquake Engineering (CUREe).

The efforts of the SAC Joint Venture have resulted in several FEMA documents. In August 1995, FEMA published the Interim Guidelines: Evaluation, Repair, Modification and Design of Welded Steel Moment Frame Structures (FEMA 267). Then, in July 2000, FEMA 350, 351, 352, and 353 (Ref. 2) were published with final recommendations for new design, upgrading, evaluating, repairing existing structures, and specifications and quality assurance guidelines.

Most of the welding-related issues are found in FEMA 353 (Ref. 3), which will be the focus of this article.

**FEMA 353 Guideline**

FEMA 353 — Recommended Specifications and Quality Assurance Guidelines for Steel Moment-Frame Construction for Seismic Applications contains recommended specifications and quality assurance guidelines deemed necessary to achieve the design objectives for steel moment-frame buildings subject to seismic loading. The document was prepared in two parts. Part I provides supplemental recommendations for structural steel fabrication and erection subject to seismic loading. Part II was prepared to provide design professionals, building officials, and contractors with recommendations for quality control and quality assurance.

FEMA 353 has not been subjected to a formal consensus adoption process. However, these recommendations have received extensive review by practicing engineers, researchers, fabricators, and erectors. The American Institute of Steel Construction (AISC) and the American Welding Society (AWS) are considering incorporating portions of FEMA 353 into the AISC Seismic Provisions (Ref. 4), AWS D1.1, and new seismic welding guidelines.

The guideline is not intended to be a stand-alone specification. Rather, it is meant to be used as a supplement to, and in coordination with, a complete specification for steel construction. For example, when specified in contract documents, it may augment AWS D1.1. The requirements of AWS D1.1 would govern in addition to the recommendations in FEMA 353. Although a recommendation, FEMA 353 becomes a requirement when incorporated into contract documents.
Application of the Recommendations

Incorporation of FEMA 353 into construction projects has increased in the past several months. Several municipalities are requiring compliance in their local building codes. While most of the projects requiring this document have been located in the western states, a few projects have been in other U.S. regions. FEMA 353 requires more documentation than does AWS DI. For contractors involved with their first FEMA 353 project, particular attention to these new details is required. In some instances, contractors may need to use different welding consumables or procedures. The good news is consumables are available that have been tested and are recommended for use in seismic applications.

Welding Recommendations

The following summarizes some of the specific welding issues. Please note that FEMA 353 includes design, inspection, quality control, quality assurance, joint details, and other fabrication/erection issues beyond the scope of this article. Readers are encouraged to review the document for these and other guidelines.

Also, FEMA 353 will usually augment AWS and AISC specifications. Those provisions are not repeated here. Rather, requirements that are new or different from these standards are outlined below.

Seismic Weld Categories

FEMA 353 recommends the engineer of record designate performance categories for welds in the seismic force resisting system. These are to be listed on the shop and erection drawings. Each weld should have a Seismic Weld Demand Category and a Seismic Weld Consequence Category. These categories will, in turn, dictate the weld property requirements, the level of inspection, and other fabrication issues.

Essential Variables: Filler Metal Trade Name and Electrode Diameter

FEMA 353 considers the filler metal trade name and electrode diameter to be essential variables and requires they be specified on the welding procedure specification (WPS).

Weld Strength Requirements

FEMA 353 recommends an AWS E70 filler metal (70 ksi minimum tensile strength) for ASTM A992 and A913 wide-flange members, except for A913 grade 65, where an E80 filler metal should be used.

Charpy V-Notch Toughness Requirements

In addition to the AWS A5 filler metal conformance requirements, filler metals must be tested, according to AWS B4.0 (Ref. 5), at the additional temperature of 70°F. Charpy V-notch (CVN) toughness must meet the following minimum requirements:
1. 20 ft-lb average at 0°F (on the AWS filler metal conformance test)
2. 40 ft-lb average at 70°F (on the FEMA 353 Appendix A Test).

WPS Toughness Verification Test

Similar to the AWS Bridge Welding Code (AWS D1.5) (Ref. 6), FEMA 353 Appendix A specifies welding high and low heat-input test plates. Suggested parameters are listed in Table 1. However, a wider or narrower range may be used. The test plates must meet 70 ksi tensile, 58 ksi yield, 22% elongation, and CVN toughness of 40 ft-lb at 70°F. The production WPS is bound by the range tested.

A toughness verification test is required for each filler metal production lot, as defined in AWS 5.01 (Ref. 7). Alternatively, lot testing may be waived if the engineer approves the filler metal manufacturer's quality assurance program. This waiver is similar to that found in the AWS Bridge Welding Code, Section 12, Fracture Control Plan, where lot testing requirements may be waived for fracture critical members.

The Bridge Welding Code states "welding consumables produced under continuing quality assurance programs audited and approved by one or more of the following agencies shall be exempt from heat and lot testing...1) American
Bureau of Shipping (ABS), 2) Lloyd’s Register of Shipping, or 3) American Society of Mechanical Engineers (ASME)” (Section 12.6.1.1, AWS D1.5-95). With the engineer’s approval, the typical certificates of conformance and typical Appendix A test certificates should satisfy this requirement.

**Diffusible Hydrogen Requirement**

Filler metals are required to meet the H16 diffusible hydrogen requirement, as defined in AWS A4.3 (Ref. 8), and reported on the manufacturer’s typical certificate of conformance.

**Packaging**

Flux cored arc welding (FCAW) electrodes are required to be in a sealed, undamaged, moisture-resistant package until ready for use.

**Supplemental Welder Qualification Testing**

Welders are required to pass an additional test, the “Supplemental Welder Qualification Test” detailed in Appendix B, within 12 months prior to starting on the project.

The Appendix B test is a test joint mock-up, simulating the bottom beam flange to column flange connection, as shown in Fig. 2. Testing is performed with each process at the highest deposition rate used in production and is required to pass radiographic testing (RT) or side bends.

**Intermixing FCAW-S Test**

When flux cored self-shielded arc welding (FCAW-S) is used with another welding process, the Appendix C test is performed to confirm the CVN toughness of the intermixed zone.

The Appendix C test plate is filled to one-third thickness with the first (or root) filler metal, then completed with the second filler metal. CVN toughness specimens are taken from the plate at mid-thickness and are required to meet 40 ft-lb at 70°F.

**Electrode Exposure — Time Limits**

Electrode exposure time is restricted to minimize the risk of hydrogen cracking. If welding stops for more than 8 h, the electrode may not be used unless it has been removed from the machine and stored in an oven. Also, electrodes are allowed a maximum of 24 h of accumulated exposure, unless 1) manufacturer’s testing proves redrying restores the electrode to its designated diffusible hydrogen level, or 2) Appendix D testing is performed as explained below.

**Extended Exposure Test**

The exposure time for FCAW electrodes may be extended by passing the extended exposure test detailed in Appendix D. The electrode is placed in an environment chamber at 80°F and 80% relative humidity for the desired exposure time limit. Diffusible hydrogen testing is then conducted. If the results meet the AWS H16 classification, the electrode can be exposed for the extended period.

**Wind Velocity Limit**

The loss of shielding gas has a detrimental effect on weld metal mechanical properties of gas-shielded processes. Therefore, gas metal arc welding (GMAW), gas-shielded flux cored arc welding (FCAW-G), gas tungsten arc welding (GTAW), and electrogas welding (EGW) are allowed only where wind velocities do not exceed 3 mph.

**Maximum Preheat and Interpass Temperature**

The maximum allowed preheat and interpass temperature is 550°F to avoid excessively slow cooling rates, which may affect mechanical properties.

**Welded Joint Details**

Tack welds attaching steel backing should be placed in the weld joint. After welding has been completed on the bottom beam-to-column flange, backing shall be removed, where indicated, and back-welded with a ¼-in. leg fillet, to minimize stress concentrations.

**Filler Metal Solutions**

Filler metal manufacturers have taken steps to meet the recommendations. A product need not be reformulated to meet the new guidelines, but an existing product can be packaged, tested, and manufactured in accordance with FEMA 353. The areas that can be addressed by manufacturers are packaging, intermix testing, extended exposure testing, lot control, and mechanical testing.

The document recommends FCAW electrode manufacturers provide filler metals in moisture-resistant packaging. Foil bags are resistant to puncture and can be vacuum-sealed. Hermetically sealed pails also offer protection from the elements during shipment and are resistant to puncture. These packages can accommodate coils and spools up to 60 lb. For bulk packages, sealed fiber drums can offer moisture and damage resistance.

Intermix testing is required when a FCAW-S electrode is used in the same joint with a non-FCAW-S electrode. This may occur if a field weld is made over a shop weld, if a repair weld is made, or if a different process is used for the root pass. Filler metal manufacturers can offer intermix test data for their product combinations intend-
ed for FEMA 353 applications.

Extended exposure testing is not required, but without it, flux cored electrodes are limited to 24 h of atmospheric exposure. Manufacturers can provide data allowing additional exposure by testing and reporting the exposure time permitted. Smaller FCAW wire packages, 60 lb and under, require less exposure time than packages of several hundred pounds or more. FCAW-G electrodes, often used in the shop from bulk packages, may require longer exposure periods. In any case, the end user must monitor the exposure time of the electrode using a method acceptable to the inspector.

FEMA 353 specifies filler metal lot control with mechanical testing, unless waived by the engineer of record. Typical test results accompanied with quality program certification enables the engineer to waive these requirements. Otherwise, lot control with mechanical testing in accordance with FEMA 353 results in extended delivery times. To alleviate this situation, manufacturers can stock lot-controlled material and initiate testing before the product is purchased.

**Conclusion**

The FEMA 353 guideline causes all parties involved with structural fabrica-
tion in seismic areas to examine their techniques and practices in a new light. Manufacturers are in the best position to enhance filler metal products and provide testing to meet the guideline. Products may be augmented through packaging, intermix testing, extended exposure testing, lot control and mechanical testing to meet the guideline. With these enhancements to filler metals, a product can be specified with a high level of confidence and used by fabricators and erectors with minimal additional effort or cost.

**References**


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For high-strength and mild steels, this low heat input, nearly spatter-free joining process offers many advantages over conventional welding methods.

BY U. DRAUGELATES, B. BOUAIFI, A. HELMICH, B. OUAISSA, and J. BARTZSCH

With conventional welding, heat input is too high for high-strength and mild steel sheets. However, plasma brazing can be used as an alternative, complementary joining process. A characteristic feature of the process is energy input independent of filler material. Plasma brazing reduces joint and panel distortion and is surface contamination and metallic surface coating tolerant. Brazed joints are aesthetic in appearance and exhibit good mechanical properties. The process is practically spatter-free.

U. DRAUGELATES, B. BOUAIFI, A. HELMICH, B. OUAISSA, and J. BARTZSCH (office@isaf.in-claustal.de) are with the Institute for Welding and Machining (ISAF), Technical University, Clausthal, Germany.
Introduction

Higher material strength must compensate for the decreased thickness of steel sheet materials used for lightweight construction (Ref. 1). Besides deep-drawn sheet steels, the use of high-strength polyphase steels is increasing. In view of the complex, heat-sensitive microstructure of these materials, arc brazing is an appropriate joining method because of the low heat input and low melting points of the filler metals.

Technology

Brazing and welding have the following fundamental feature in common: The space between two workpieces to be joined is filled with molten metal or metal alloy. The essential difference between the two processes concerns the metallurgical reaction. In contrast to welding, brazing, by definition, does not involve fusion of the base metal. Only the brazing filler melts during the joining process (Ref. 2). The suitability of brazing for joining of heat-sensitive materials was recognized a long time ago. However, the real breakthrough for industrial application was achieved with gas metal arc brazing (Refs. 3-4) — Fig. 1. Bronze alloys were employed for this purpose. Since the melting point of these alloys is relatively low, the necessary energy input is also lower. Since gas metal arc brazing is characterized by a stable, nearly spatter-free process, it is most commonly used (Ref. 5).

However, in gas metal arc brazing, the energy input and filler metal feed are coupled, which limits the freedom of design and configuration in feeding and depositing the filler metal. Furthermore, the required current strength is relatively high because of the low energy density of an uncontrolled arc. The resulting wide joints cause severe distortion of the brazed components, especially with thin sheet metal.

Plasma arc brazing is an alternative to gas metal arc brazing because of the high energy density. The advantages of this method have been described in several publications and include lower thermal and metallurgical effects on the base metal, high brazing speed, low distortion, and narrow joints (Refs. 7-10). The method is highly promising for the joining of higher-strength sheet metal (Ref. 10). Specific applications of this technique are described in detail in Refs. 11-12.

Basic Description

During plasma arc brazing, the torch operates with two independently adjustable arcs, the pilot arc and the main arc. The pilot arc, designated as the nontransferring arc, operates between the tungsten electrode and a water-cooled copper nozzle. The pilot, or nontransferring arc, is connected to the negative pole of the power source and is indirectly water cooled. The water-cooled copper nozzle is connected to the positive pole and constrains the plasma jet. The main arc, designated as the transferring arc, is constrained by the directed gas feed and the plasma nozzle and operates between the negatively polarized tungsten electrode and the positively polarized workpiece.

Most available industrial torches operate with a pilot current of 15 to 30 A at an arc voltage usually between 15 and 20 V. The operating voltage of the main arc is usually about one-half the value of the current strength, which lies in the range of 40 to 80 A. However, current values up to 200 A are also possible.

Brazing Filler Metals

Experience in various fields of application shows bronze wires provide an economical filler material. Bronze fillers are usually employed for hard brazing of steels as conventional furnace brazing fillers. The wetting behavior of such fillers is ultimately controlled by the process temperature, not the alloy composition. Together with the standard brazing filler, CuSi3, numerous other versions are currently available on the market and are applicable over a wide range of brazing requirements (Table 1).

Table 1 gives properties of copper-based brazing fillers. Brass and nickel-silver fillers are not included since they are not suited for arc brazing. Lack of standardization aggravates the difficulty of selecting appropriate copper-based brazing filler metals.

When using copper-based fillers, a wire-feed unit equipped with a four-roll drive system, as well as semicircular groove rolls must be used because of the material softness. The length of the hose bundle should be as short as possible. If this is not feasible, a second wire feed motor should be employed.

Pilot and Inert Gas

Because of its low ionization energy and inert character, argon is employed as pilot gas. This gas is well suited for this purpose and ensures long electrode life.

If the torch is ignited with gas mixtures such as argon-helium or argon-hydrogen, the pilot current must be increased, which
will, in turn, make electrode load and wear more severe. This applies especially to the ignition of the main arc. If pure nitrogen is employed as the inert gas, for instance, the pilot current will have to be almost twice as high. The resulting brazed joint will have a rough surface and the area near the joint will be blackened.

With inert gas mixtures such as argon-helium or argon-hydrogen, an increase in pilot current of 5 to 7 A is sufficient. The authors' own investigations have confirmed that brazing speeds can be increased by about 10% with the addition of helium to the inert gas and by 30% with the addition of hydrogen (Ref. 13). Furthermore, the addition of 15% hydrogen to the inert gas resulted in a very smooth joint surface when using aluminum bronze fillers — Fig. 2. With low-alloy, copper-based fillers and tin-bronze fillers, this effect is achieved only up to 6.5% hydrogen, beyond which the resulting joint becomes porous. Because of the higher energy input, current values for the main arc must be decreased to match the energy input.

### Investigation Results

#### Torch Position and Wire Feed

In contrast to gas metal arc brazing, the filler metal is fed into the arc without current in plasma brazing. Consequently, the meltdown of the brazing filler metal is independent of the heat input per unit length of the joint. Thus, the heating process for metallic bonding of the brazing filler and its deposition can be adapted to match a wide variety of base and filler metals.

To ensure better fusion of the filler metal, especially in the case of flux-cored wires, the torch was inclined by about 20 deg (angular torch position), and the brazing filler metal was introduced directly into the arc (wire feed in front of the arc) — Fig. 3. The torch stand-off was 2.5 mm. Voltage hardly changed with a torch stand-off of up to 8 mm.

### Brazing Parameters

ISAF investigations have revealed the thermal effect on the workpiece is decidedly less severe because of the far lower energy input at a frequency of 10 Hz and a current strength ratio $I_{\text{pulse}}/I_{\text{Base}}$ of 3/1. Adequate joint properties are maintained, making a pulsed arc well suited for plasma brazing.

With an appropriate selection of parameters, precisely one molten drop of brazing filler metal can be detached per pulse — Fig. 4. The joint is narrow and the joint width can be easily controlled by adjusting the torch stand-off.

Figure 4 shows that at frequencies below 5 Hz, the side walls of the brazed joints are not parallel. At frequencies above 100 Hz, the pulse effect is cancelled. For all tests, the pulse-duty factor was set to 50%.

#### Table 1 — Filler Metals for Plasma-Arc Brazing (Refs. 14-15)

<table>
<thead>
<tr>
<th>Solder Material Number</th>
<th>Melting Range °C</th>
<th>Yield Strength N/mm²</th>
<th>Tensile Strength N/mm²</th>
<th>Strain A5 %</th>
</tr>
</thead>
<tbody>
<tr>
<td>SG-CuAl2(b)</td>
<td>1030-1040</td>
<td>180</td>
<td>380</td>
<td>46</td>
</tr>
<tr>
<td>R-CuAl1-AP CF300G(c)</td>
<td>1030-1050</td>
<td>230</td>
<td>&gt;340</td>
<td>25</td>
</tr>
<tr>
<td>SG-CuAl8Ni2(a)</td>
<td>1030-1050</td>
<td>180</td>
<td>380-450</td>
<td>40</td>
</tr>
<tr>
<td>SG 31-150G(c)</td>
<td>1030-1050</td>
<td>290</td>
<td>600</td>
<td>&gt;16</td>
</tr>
<tr>
<td>SG-CuAl8Ni6(a)</td>
<td>1015-1045</td>
<td>300</td>
<td>&gt;600</td>
<td>&gt;10</td>
</tr>
<tr>
<td>CR CuAl4CF 31BG(c)</td>
<td>2.0923</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SG-CuAl8Mn13(a)</td>
<td>945-985</td>
<td>&gt;400</td>
<td>&gt;650</td>
<td>&gt;10</td>
</tr>
</tbody>
</table>

*Note: DIN 1733, DIN 17633-52, prEN13347, AWS/ASME, DIN 8555, Not standard, Guide value for minimum, not for approval testing, Unpublished proposed standard, DIN-NAS, 1999, For rods*
Investigations of plasma arc brazing of a 1-mm-thick sheet with linear and oscillating torch guidance have demonstrated the excellent joint clearance-bridging ability of this method. Variable joint clearance widths from 0 to 2 mm have thus been bridged with linear torch guidance (Ref. 11).

Joint Properties

During plasma arc brazing of DP 600 with filler metal CuSn10SiMn, a frequency of 10 Hz, a current strength of 55 A, and a pulse-duty factor of 50% proved to be optimal for a lap joint. A current strength of 45 A was employed for preparation of the square butt joint. Under these settings, flawless joints have been obtained.

The low energy input results in negligible fusion of the base metal and hardly any thermal effect — Figs. 5, 6.

Figure 5 shows the surface of the brazed joint to be smooth, uniform, and uninterrupted. The joint is narrow, with a width between 3 and 4 mm. Moreover, the sheet is free of spatter. The joints are free of notches, cracks, and pores.

Figure 6 shows good wetting and bonding between the base metal and brazing filler. In an enlarged view of the joint, a decided boundary is evident between different structural zones of the steel and of the filler metal — Fig. 7. In contrast to welded joints, no diluted transition zones are present here. Good wetting and gradual transition between the base metal and brazing filler metal are evident.

For determining the distribution of elements in various zones, a mapping has been prepared for the elements Fe, Cu, and Sn — Fig. 8. The base metal is visible at the right. Immediately adjacent is a narrow diffusion zone with increased copper content. The scanning electron micrograph of a square butt joint also indicates almost no material erosion has occurred on the base metal. This is evident from analysis of the elemental distribution — Fig. 8.

In addition, wetting and bonding between the base metal and brazing filler metal are ensured by a diffusion process — Fig. 9.

Conclusions

Plasma arc brazing provides an alternative and supplementary method for joining of sheet metal, especially in vehicle body construction. Because of the separate heat input and material feed in combination with the higher power density, smooth and spatter-free joints can be produced with excellent properties for applications (Ref. 11).

For the joining of higher-strength steels, however, new brazing filler metals are a prerequisite for this method. ISAF
is currently studying the metallurgical prerequisites for plasma-powder brazing of such steels. In the course of this study, a special objective is the development of appropriate copper- and nickel-based brazing fillers in powdered form, as well as optimizing strength, brazing temperature, and wetting properties. Moreover, the metallurgical processes during brazing of these polyphase steels and the associated effects on the joint properties will be examined.

References


Recognizing the growing importance of brazing and soldering in the advancement of materials, the American Welding Society will organize the next International Brazing & Soldering Conference (IBSC). The German Welding Society (DVS) joins us as an endorsing sponsor of this event, linking its well-known International Brazing Conference (LOI), which will alternate between Germany and the United States every two years in a four-year cycle. The British Association for Brazing and Soldering (BABS) will also be an endorsing sponsor of this exciting new event.

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Malcolm Plastic Welding School. A comprehensive two-day, hands-on course that leads to certification in accordance with the latest European DVS-approved plastic welding standards for hot gas and extrusion welding techniques. Contact: Sheila Carpenter, Administration, Malcolm Hot Air Systems, 1676 E. Main Rd., Portsmouth, RI 02871, (888) 807-4030, FAX: (401) 682-1904, e-mail: info@malcom.com; www.plasticweldingtools.com.

Hellier NDT Courses. A course schedule is available from Hellier, 277 W. Main St., Niantic, CT 06357, (860) 739-8950, FAX: (860) 739-6732.

Shielded Metal Arc Welding of 2-in. Pipe in the 6G Position — Uphill. Hobart Institute of Welding Technology, Troy, Ohio. This course is designed to develop welding skills necessary to produce quality multipass welds on 2-in.-diameter, schedule 160 mild steel pipe (0.436-in. wall thickness) in the 6G position using E6010 and E7018 electrodes. For further information, contact: Phil Pratt, President, Hobart Institute of Welding Technology, 400 Trade Square East, Troy, OH 45373, (937) 332-9448, FAX: (937) 332-5200; www.welding.org.

2002 Motor Sports Welding School. Classes are scheduled at Lincoln Electric headquarters in Cleveland, Ohio. For more information and a complete schedule, contact: Lincoln Electric Motorsports Welding School, 22801 St. Clair Ave., Cleveland, OH 44117, (216) 383-2461, FAX: (216) 383-8188, e-mail: lori_bolster@lincolnelectric.com; www.lincolnelectric.com.

Boiler and Pressure Vessel Inspectors Training Courses and Seminars. To obtain a 2002 schedule of training courses and seminars conducted by the National Board of Boiler and Pressure Vessel Inspectors at its Training and Conference Center in Columbus, Ohio, Contact: Richard McGuire, Manager of Training, (614) 988-8320, e-mail: rmcguire@nationalboard.org; www.nationalboard.org.

Welding Skills Training Courses. Courses include weldability of ferrous and nonferrous metals, arc welding inspection and quality control, preparation for recertification of CWIs, and others. For a complete schedule, contact: Hobart Institute of Welding Technology, 400 Trade Square E., Troy, OH 45373, (800) 332-9448 or outside the U.S., (937) 332-5000, FAX: (937) 332-5200; www.welding.org.


2002 Metallforming Seminars. Conducted by the Precision Metalforming Association (PMA). Seminar topics include stamping, tool and die, press operation, punch and die, metalforming controls, lean manufacturing, advance quality planning, and more. Many programs are available as on-line seminars. For a complete PMA 2002 Educational Program schedule, contact, PMA, 6363 Oak Tree Blvd., Independence, OH 44151-2503, (216) 901-8800, FAX: (216) 901-9190, e-mail: pma@pma.org; www.metallforming.com.
## Educational Opportunities

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

Exam application must be submitted six weeks before exam date. For exam information and an application, contact the AWS Certification Dept., (800) 443-9353 ext. 273. For prep course information, contact the AWS Education Dept., (800) 443-9353 ext. 229.

<table>
<thead>
<tr>
<th>Cities</th>
<th>Exam Prep Courses</th>
<th>CWI/CWE Exams</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anchorage, Alaska</td>
<td>April 8-12</td>
<td>April 13</td>
</tr>
<tr>
<td></td>
<td>(API 1104 Clinic also offered)</td>
<td></td>
</tr>
<tr>
<td>Atlanta, Ga.</td>
<td>April 29-May 3</td>
<td>May 4</td>
</tr>
<tr>
<td></td>
<td>(API 1104 Clinic also offered)</td>
<td></td>
</tr>
<tr>
<td>Beaumont, Tex.</td>
<td>June 3-7</td>
<td>June 8</td>
</tr>
<tr>
<td></td>
<td>(API 1104 Clinic also offered)</td>
<td></td>
</tr>
<tr>
<td>Birmingham, Ala.</td>
<td>EXAM ONLY</td>
<td>May 25</td>
</tr>
<tr>
<td>Boston, Mass.</td>
<td>June 3-7</td>
<td>June 8</td>
</tr>
<tr>
<td>Columbus, Ohio</td>
<td>May 13-17</td>
<td>May 18</td>
</tr>
<tr>
<td>Corpus Christi, Tex.</td>
<td>EXAM ONLY</td>
<td>May 11</td>
</tr>
<tr>
<td>Detroit, Mich.</td>
<td>April 22-26</td>
<td>April 27</td>
</tr>
<tr>
<td></td>
<td>(API 1104 Clinic also offered)</td>
<td></td>
</tr>
<tr>
<td>El Paso, Tex.</td>
<td>June 17-21</td>
<td>June 22</td>
</tr>
<tr>
<td></td>
<td>(API 1104 Clinic also offered)</td>
<td></td>
</tr>
<tr>
<td>Fargo, N.D.</td>
<td>June 17-21</td>
<td>June 22</td>
</tr>
<tr>
<td></td>
<td>(API 1104 Clinic also offered)</td>
<td></td>
</tr>
<tr>
<td>Houston, Tex.</td>
<td>March 18-22</td>
<td>March 23</td>
</tr>
<tr>
<td></td>
<td>(API 1104 Clinic also offered)</td>
<td></td>
</tr>
<tr>
<td>Jacksonville, Fl.</td>
<td>April 8-12</td>
<td>April 13</td>
</tr>
<tr>
<td></td>
<td>(API 1104 Clinic also offered)</td>
<td></td>
</tr>
<tr>
<td>Kansas City, Mo.</td>
<td>June 3-7</td>
<td>June 8</td>
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<tr>
<td></td>
<td>(API 1104 Clinic also offered)</td>
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</tr>
<tr>
<td>Long Beach, Calif.</td>
<td>June 24-28</td>
<td>June 29</td>
</tr>
<tr>
<td></td>
<td>(API 1104 Clinic also offered)</td>
<td></td>
</tr>
<tr>
<td>Los Angeles, Calif.</td>
<td>April 8-12</td>
<td>April 13</td>
</tr>
<tr>
<td></td>
<td>(API 1104 Clinic also offered)</td>
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</tr>
<tr>
<td>Miami, Fl.</td>
<td>March 18-22</td>
<td>March 23</td>
</tr>
<tr>
<td></td>
<td>(API 1104 Clinic also offered)</td>
<td></td>
</tr>
<tr>
<td>Miami, Fl.</td>
<td>April 15-19</td>
<td>April 20</td>
</tr>
<tr>
<td></td>
<td>(API 1104 Clinic also offered)</td>
<td></td>
</tr>
<tr>
<td>Miami, Fl.</td>
<td>April 29-May 3</td>
<td>May 4</td>
</tr>
<tr>
<td></td>
<td>(API 1104 Clinic also offered)</td>
<td></td>
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<tr>
<td>Miami, Fl.</td>
<td>June 10-14</td>
<td>June 15</td>
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<tr>
<td></td>
<td>(API 1104 Clinic also offered)</td>
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<tr>
<td>Milwaukee, Wis.</td>
<td>April 22-26</td>
<td>April 27</td>
</tr>
<tr>
<td>Minneapolis, Minn.</td>
<td>June 24-28</td>
<td>June 29</td>
</tr>
<tr>
<td>Newark, N.J.</td>
<td>April 15-19</td>
<td>April 20</td>
</tr>
<tr>
<td>New Orleans, La.</td>
<td>May 13-17</td>
<td>May 18</td>
</tr>
<tr>
<td></td>
<td>(API 1104 Clinic also offered)</td>
<td></td>
</tr>
<tr>
<td>Perryburg, Ohio</td>
<td>EXAM ONLY</td>
<td>March 23</td>
</tr>
<tr>
<td>Pittsburgh, Pa.</td>
<td>May 6-10</td>
<td>May 11</td>
</tr>
<tr>
<td></td>
<td>(API 1104 Clinic also offered)</td>
<td></td>
</tr>
<tr>
<td>Portland, Me.</td>
<td>April 15-19</td>
<td>April 20</td>
</tr>
<tr>
<td></td>
<td>(API 1104 Clinic also offered)</td>
<td></td>
</tr>
<tr>
<td>Sacramento, Calif.</td>
<td>June 10-14</td>
<td>June 15</td>
</tr>
<tr>
<td></td>
<td>(API 1104 Clinic also offered)</td>
<td></td>
</tr>
<tr>
<td>San Diego, Calif.</td>
<td>May 6-10</td>
<td>May 11</td>
</tr>
<tr>
<td></td>
<td>(API 1104 Clinic also offered)</td>
<td></td>
</tr>
<tr>
<td>Spokane, Wash.</td>
<td>May 13-17</td>
<td>May 18</td>
</tr>
<tr>
<td></td>
<td>(API 1104 Clinic also offered)</td>
<td></td>
</tr>
<tr>
<td>St. Louis, Mo.</td>
<td>April 22-26</td>
<td>April 27</td>
</tr>
</tbody>
</table>

## AWS Schedule — CWI Nine-Year Recertification Course

AWS is now offering a six-day CWI nine-year recertification course. This program is rated very good to excellent by the majority of participants and eliminates the need for CWIs to retest by satisfying the 80 hour continuing education required for recertification.

For a registration package, call the AWS Education Department at (800) 443-9353 ext. 229 or e-mail chacon@aws.org.

<table>
<thead>
<tr>
<th>Cities</th>
<th>Course Dates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sacramento, Calif.</td>
<td>June 10-15</td>
</tr>
<tr>
<td>Houston, Tex.</td>
<td>July 29-August 3</td>
</tr>
<tr>
<td>Pittsburgh, Pa.</td>
<td>September 16-21</td>
</tr>
<tr>
<td>Detroit, Mich.</td>
<td>October 21-26</td>
</tr>
<tr>
<td>Sacramento, Calif.</td>
<td>November 18-23</td>
</tr>
<tr>
<td>Miami, Fl.</td>
<td>December 9-14</td>
</tr>
</tbody>
</table>

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

### MEXICO:

In Monterrey, N.L.

- March 11-15, Training, March 16 Examination
- June 24-28, Training, June 29, Examination
- November 4-8, Training, November 9, Examination

Contact: Martha Laura Garcia, DALUS S.A., Tel: (5281) 83861717, FAX: (5281) 83864780, e-mail: martha.garcia@ dalus.com
Developing D1.9, Structural Welding Code — Titanium

Titanium and its alloys are engineering materials well-known for their high strength-to-weight ratios and corrosion resistance. Since the 1950s, titanium has been commonly used in such aerospace applications as gas turbine engines, space vehicles, and airplanes. Because of its high resistance to corrosion, titanium is also used in chemical process, heat exchange, and saltwater piping systems. More recently, titanium has been applied to consumer products ranging from golf clubs to sunglasses.

In addition, new applications are continually being developed in areas as diverse as oil risers, military combat vehicles, ice hockey facemasks, and automotive exhaust systems.

To be utilized in so many applications, titanium is frequently welded. But, surprisingly, a titanium structural welding specification does not exist. In some ways, the necessity for a code has been mitigated by the industries themselves. For example, the aerospace and pressure vessel industries have each established their own codes to suit their particular needs. The growing number of structural applications in the commercial and military sector has further underscored the need for a titanium welding specification. With this in mind, this article will illustrate the need for a new specification, define the scope and purpose of the specification, and report what is being done to develop it.

Need for a New Specification

The need for a new specification definitely exists in the military. For example, the U.S. army has incorporated welded titanium in the design of many vehicle and armament systems in order to transform itself into a lighter, more transportable force. Army research and development facilities now use titanium in the design of the Crusader self-propelled howitzer (Fig. 1), the XM777 lightweight howitzer (Fig. 2), and the M240 machine gun. These welded structures are complex and must withstand the relatively high impulse loads of firing over a desired lifetime of weapon system performance. In these designs, allowable stresses, which are based on factors of safety, fatigue loading, and predicted lifetimes, are of critical importance.

Similar needs are seen in the commercial sector. For example, titanium alloys have been specified in building applications because of their high strength-to-weight ratios and excellent corrosion resistance. These alloys have been used to construct lightweight structures with stunning visual impact — Fig. 3.

Current weld specifications for titanium are generally specific to the aerospace industry or grouped under the umbrella of the ASME Pressure Vessel Code. The U.S. Army has also adopted these specifications, as well as any available and appropriate commercial codes, whenever possible. But, these specifications are inappropriate for many nonaerospace or nonpressure-vessel applications. For this reason, the Army and many of its suppliers have been forced to develop welding specifications specific to each item, using available specifications as a guide. This practice is costly and duplicative; from this, a uniform, optimized practice for welding titanium cannot emerge.

In summary, the Army's own internal need, the unavailability of a commercial structural code, and broadening commercial markets have focused attention on the necessity of developing a realistic specification. The American Welding Society formally recognizes this need and has answered the call by chartering a D1 subcommittee to create a new specification to be known as D1.9, Structural Welding Code — Titanium.

Scope and Purpose of Publication of a New Code

The scope is to develop a structural welding code in the tradition of D1.1 or D1.2. The code document will address design, process qualification, welder qualification, and acceptance standards for titanium welds in structural applications. This document will deviate from the traditional codes when required: for example, the prequalification of weld joints, the limitations in cross-qualification of groove and fillet welds, process-essential variables and limits, qualification test methods, and nondestructive examination techniques. In essence, the document will deviate from more conventional codes only when required by the uniqueness of titanium alloys — much like the differences between the D1.1 and D1.2 codes, which allow for the differences in welding aluminum. 

Fig. 1 — Crusader self-propelled howitzer.

Fig. 2 — XM777 lightweight howitzer.

Fig. 3 — Lightweight tank.
and steel. As an example, the requirements and need for shielding titanium (i.e., trailing and backing shielding) are relatively severe, due to its high susceptibility to atmospheric contamination. In this case, the code may require the dew point for the torch, trailing, and backing and shielding gases as essential variables.

The purpose of this code is to establish a common document that can be used effectively in the design, procurement, and welding of structural fabrications involving titanium alloys where none currently exist. A significant challenge will be to create a document appropriate to all relevant industries, based upon what is currently known to be best practice. The success of the code in its formative years depends on the following three key elements:

- A broad-based D1.9 membership,
- Members contributing to the limited public database on titanium weld performance, and
- Prompt addition of any information needed to complete the code.

What is Being Done to Develop the Code

Currently, D1.9 membership represents the major domestic titanium producers, defense contractors, oil/gas fabricators, welding academia, the U.S. Army, the U.S. Navy, and independent welding contractors. International D1.9 representation includes foreign defense contractors and oil/gas fabricators. A total of approximately 25 members/advisors currently participate. The subcommittee meets twice a year, in conjunction with the D1 Committee. So far, the D1.9 Subcommittee has met twice, in March and October of 2001. Members of D1.9 will meet again in March 2002.

As a relatively new committee, the D1.9 Subcommittee has made good progress toward publication of a code. The committee has generated an initial draft document, which has been circulated for review among subcommittee members. The design and acceptance criteria rely a great deal on data generated by the U.S. Army and Edison Welding Institute (EWI), under a titanium weld fitness-for-purpose program sponsored by the U.S. Army Joint Program Management Office, XM777 Lightweight Howitzer (Welding Journal, Vol. 80, no. 3, March 2001). Further data has been gathered from other committee members and literature sources, including DNV (Norway), GKSS (Germany), National Maritime Institute (Japan), VSEL (U.K.), Conoco, and Grumman.

As a whole, the committee, due to limited public data regarding the performance of titanium alloy welds, especially for structural applications, recognizes the need for more data from a larger population of users. In addition, the committee recognizes that the code could benefit by further refinement of nondestructive evaluation methods and alternative weld qualification methods. To achieve the best code possible, the committee has defined a test program, for which it is soliciting industry support. In particular, the U.S. Army is funding a multiyear, multimillion dollar program for the design and development of robotic pulse, GMAW welding of titanium. Along with this program, validation testing on weld performance and acceptance is being conducted by the U.S. Army. This work, along with work sponsored by other individual committee members, is adding to the code database. At this time, the support of other interested parties would be greatly appreciated.

For more specific information, including how to participate in the project, visit the code development activities section of the EWI Web site at www.ewi.org. Interested parties may also contact Subcommittee Chairman Stephen Luckowski, U.S. Army ARDEC, (973) 724-5752 or Subcommittee Vice Chairman John Lawmon, EWI, (614) 688-9000.

Number of AWS Accredited Test Facilities Grows in 2001

The American Welding Society would like to congratulate the following facilities for becoming AWS Accredited Test Facilities (ATFs) in 2001.

Plumbers Local #12
Contact: Joseph Conley
1240 Mass Dr.
Boston, MA 02125
(617) 288-1010

Central Piedmont Community College
Contact: Anver Classens
315 West Hebron St.
Charlotte, NC 28273
(704) 330-4428

Northeast Carpenters Training Center
Contact: John Sadowski
4100 Maple Dr.
Richfield, OH 44286
(916) 484-8354

American River College
Contact: Frank Ramos
4700 College Oak Dr.
Sacramento, CA 95841
(330) 659-9495

Southeast Technical Institute
Contact: Terry Schneider
2301 Career Pl.
Sioux Falls, SD 57107
(605) 357-7284

Welding & Joining Management Group, West
Contact: Jesse Grantham
7100 N. Broadway 1C
Denver, CO 80221
(303) 451-6759

These facilities have successfully passed an on-site audit conducted by qualified assessors and are currently offering welder qualification testing to the public.

If you would like information on how your facility can become an AWS Accredited Test Facility (ATF), or how individuals can become an AWS certified welder, call the AWS Certification Department at (800) 443-9353, ext. 476.
AWS Conferences

Second Welding in Food Industry Applications Conference

On April 17–18, AWS will present the Second Welding in Food Industry Applications Conference in St. Louis, Mo. Prominent speakers from the Nickel Development Institute, Proctor & Gamble, and other organizations will speak on procedures and related AWS standards that have been dedicated to this field. A morning tutorial will be open to attendees.

This one-and-a-half-day conference will offer welding professionals an overview of stainless steel properties, equipment welding and design, and in-field. A morning tutorial will be open to attendees.

The Second Welding in Food Industry Applications Conference is available for $480 for AWS members, $580 for nonmembers. Registration includes all sessions, a morning tutorial, handout materials, two lunches, one reception, and refreshment breaks. Special hotel rates have been reserved for attendees.

Cladding, Surfacing, and Thermal Spray

AWS will present the Cladding, Surfacing, and Thermal Spray Conference on April 17–19 in Chicago, Ill.

Industry experts will present sessions such as Opportunities for Surface Engineering in the Automotive Industry, Explosion Clad-Cost Effective Solutions for Corrosion, New Hardfacing Alloys and Their Applications, and Recent Advances in Hardfacing with Cored Wires. You will learn about newer technologies on the wear-resistance scene, including electrospark alloying, braze cladding, and cold gas dynamic spray. In all, 22 sessions will be presented at this two-and-a-half-day conference.

AWS Publishes New Metric Guide

The American Welding Society has released an updated version of its Guide for Metric Practice (A1.1:2001). The A1 Committee on Metric Practice has carefully reviewed all the latest practices relating to the use of the modern metric SI standards to ensure its use by the welding industry conforms to the best practices of the technical community.

Conversions from the U.S. Customary inch-pound units are provided in several new tables giving factors for measurements commonly used by welding technical personnel. Table 1 shows the available standard sizes of filler metals along with the international standard given in the new ISO 544, which will be published this year. Table 2 shows standard fillet weld sizes and gives rational metric sizes, allowing the use of whole numbers to replace the awkward fractional inch measurements. Conversion factors are singled out for such measurements as pressures and flow rates of shielding gases, heat input, travel and wire feed speeds, and mechanical properties (strength, impact, and fracture toughness). These, along with numerous conversions, are available to engineers, designers, and others who face the task of meeting metric regulations often encountered in foreign trade, both exports and imports from countries overseas.

<table>
<thead>
<tr>
<th>Fractional in.</th>
<th>Decimal in.</th>
<th>ISO 544 mm</th>
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<tbody>
<tr>
<td>3/64</td>
<td>0.047</td>
<td>1.2</td>
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<td>1/16</td>
<td>0.052</td>
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<td>3/32</td>
<td>0.062</td>
<td>1.6</td>
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<tr>
<td>1/8</td>
<td>0.078</td>
<td>2.0</td>
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<tr>
<td>5/32</td>
<td>0.094</td>
<td>2.4 or 2.5</td>
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<tr>
<td>3/16</td>
<td>0.125</td>
<td>3.2</td>
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<tr>
<td>1/4</td>
<td>0.156</td>
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<td>7/32</td>
<td>0.188</td>
<td>4.8 or 5.0</td>
</tr>
<tr>
<td>1/8</td>
<td>0.250</td>
<td>6.0 or 6.4</td>
</tr>
<tr>
<td>5/32</td>
<td>0.313</td>
<td>8.0</td>
</tr>
</tbody>
</table>


AWS Welcomes New Supporting Companies

New Educational Institutions

Campbell County High School
1000 Camel Dr.
Gillette, WY 82716

Galena Park ISD
1001 Parkside
Galena Park, TX 77547

Gatesville Independent School District
311 S. Lovers Lane
Gatesville, TX 76528

Heyward Career and Technology Center
3560 Lynhaven Dr.
Columbia, SC 29204

Millennium Development Corp., Ltd.
93 Alice St.
Bel Air, La Romain
Trinidad, West Indies

North Valley High School
6741 Monument Dr.
Grants Pass, OR 97526

Parkside High School
1015 Beaglin Park Dr.
Salisbury, MD 21804

Sabin Skills Center
14211 SE Johnson Rd.
Milwaukie, OR 97267

Washington Local Schools
Whitmer Career & Technology Center
5719 Clegg Dr.
Toledo, OH 43613

New Supporting Companies

City Machine & Welding, Inc.,
of Armadillo
9701 Interchange 552
Amarillo, TX 79124-2333

Dayton T. Brown, Inc.
Church St.
Bohemia, NY 11717

NUCOR Building Systems
600 Apache Trail
Terrell, TX 75160

Spellman High Voltage Corp.
475 Wireless Blvd.
Hauppauge, NY 11788-3951

World Fabricators Ltd.
13135 - 116 Ave.
Surrey
British Columbia V3R 2S8
Canada

Distinguished Member

The following member has attained the status of Distinguished Member for his or her participation in the Society’s leadership, technical, and education activities.

Lynn E. Showalter
Tidewater

To qualify for distinguished membership status, applicants must accrue 21 points or more from at least three of these four categories: national AWS service, local AWS leadership, continuing AWS education, and membership activities. If you believe you qualify, contact the AWS Membership Department at (800) 443-9353 ext. 480 or FAX (305) 443-7559.

AWS Detroit Section to Host Sheet Metal Welding Conference

The AWS Detroit Section is sponsoring Sheet Metal Welding Conference X at the Conference Center in the Sterling Inn Best Western Hotel in Sterling Heights, Mich., May 15-17. This two-and-half-day conference includes technical presentations covering theory and application of sheet metal welding. A one-day tutorial on aluminum joining technology will be offered on May 14.

The purpose of the conference is to advance science in the areas of resistance welding of coated steels, aluminum, and high-strength steels; arc, laser, and resistance welding equipment, and monitoring; advanced joining methods for sheet metal; and numerical methods for modeling sheet metal joining processes.

Vendor contact booths with the latest in welding equipment and technology will also be present at the conference.

Attendance at this conference and tutorial entitles participants to receive 2.8 Continuing Education Units.

The cost for attending the Sheet Metal Welding Conference and tutorial is $800 for AWS members; $875 for nonmembers. The price for the Conference only is $650 for AWS members; $725 for nonmembers. Full-time students pay $75. The price for nonmembers includes a one-year AWS membership.

For further information, visit the AWS Detroit Section’s Web site at www.sheetmetalwelding.org, or call (810) 231-2502.

AWS Membership

<table>
<thead>
<tr>
<th>Grades</th>
<th>February 1, 2002</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sustaining Companies</td>
<td>416</td>
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<tr>
<td>Supporting Companies</td>
<td>263</td>
</tr>
<tr>
<td>Educational Institutions</td>
<td>258</td>
</tr>
<tr>
<td>Total Corporate Members</td>
<td>937</td>
</tr>
<tr>
<td>Individual Members</td>
<td>43,754</td>
</tr>
<tr>
<td>Student Members</td>
<td>4,604</td>
</tr>
<tr>
<td>Total Members</td>
<td>48,358</td>
</tr>
</tbody>
</table>
Central Massachusetts/Rhode Island Section members observe pipe welding demonstrations at the November meeting.

Ferri presented a plaque to Cybex Welding Supervisor Tim Heywood in appreciation for hosting the Section’s Visual Welding Inspection Course.

**GREEN & WHITE MOUNTAINS**

**NOVEMBER 15, 2001**

**Speakers:** Wilder Moffit and Ed Evans.

**Affiliation:** Claremont-Concord Railroad.

**Topic:** Restoration of the 1935 Flying Yankee and a tour of the all-stainless high-speed (90 mph) train shop.

**DISTRICT 2**

**Director:** Alfred F. Fleury

**Phone:** (732) 868-0768

Attending the New York Section’s January meeting are, from left, Jim Szmania, Tom Sosler, and Tom White.

**NEW YORK**

**JANUARY 21**

**Speaker:** Jim Szmania, sales engineer.

**Affiliation:** Special Metals Welding Products Co.

**Topic:** Producing successful welds when using nickel-based alloys with arc processes.

**DISTRICT 3**

**Director:** Claudia Bottenfield

**Phone:** (717) 397-1312

York-Central Pennsylvania Section Chairman George Bottenfield, right, presenting speaker’s gifts to Mike Robinson, left, and Richard Gallagher.

Affiliations: Wilson Products and Fibre Metal Products Co., respectively.

Activity: This was an oxyfuel gas and head, eyes, and ears safety seminar. Attending members received certificates.

**DISTRICT 4**

**Director:** Roy C. Lanier

**Phone:** (232) 321-4285

Ray Thomas during his presentation to the South Carolina Section.

**SOUTH CAROLINA**

**JANUARY 17**

**Speaker:** Ray Thomas, district manager.

**Affiliation:** Miller Electric Mfg. Co.

**Topic:** Miller’s XR Edge and the 354 mp Power Source.

Activity: Members were given hands-on demonstrations of the equipment.
DISTRICT 6
Director: Gerald R. Crawmer
Phone: (518) 385-0570

ROCHESTER
JANUARY 23
Activity: Local welding supply vendors, including Rochester Welding Supply, Jackson Welding Supply, and Mahany Welding, presented and demonstrated new equipment for Section members.

DISTRICT 7
Director: Robert J. Tabernik
Phone: (614) 488-7913

Columbus Section officers, from left, Treasurer Tom Kuntzman, Chairman Jim Worman, District 7 Director Robert Tabernik, Vice Chairman Phil Pence, and Secretary John Lawmon, at the Section's holiday party.

Pittsburgh Section past chairmen pose for a group photo during the Section's Past Chairmen's Night in January.

Guest speakers Bryan Worley, left, and Jeremy Brumbaugh at the Dayton Section's December meeting.

PITTSBURGH
JANUARY 15
Activity: The Section held Past Chairmen's Night. Eleven past chairmen attended and spoke about their time in office. Past Chairman W. D. Doty has been a member of AWS for 60 years.

DAYTON
DECEMBER 4, 2001
Speakers: Bryan Worley, welding engineer; Dan Kidder, welding technician;

Columbus Section Chairman Jim Worman, left, presenting Fritz Saenger, Jr., with a speaker's gift.

DISTRICT 8
Director: Wallace E. Honey
Phone: (256) 332-3366

NASHVILLE
DECEMBER 13, 2001
Activity: Members attended the Section's annual Holiday Party/Ladies' Night celebration.

CHATTANOOGA
SEPTEMBER 20, 2001
Speaker: Jeff Henry.
Affiliation: Alstom Power Inc.
Topic: Pre- and postweld heat treatment.
Activity: District 8 Director Wallace Honey presented awards to David Hamilton and Richard Daffron.
District 8 Director Wallace Honey, left, with Don Russell, center, and Richard Daffron at the Chattanooga Section's September meeting.

OCTOBER 18, 2001
Activity: Ron Smith and Gary Crowson led members on a tour of the BOC Gases facility in Chattanooga, Tenn.

November 15, 2001
Activity: Delbert Butler, Wayne Turner, and Tom Lawson of Alstom Power guided members on a tour of the plant.

DISTRICT 9
Director: John Bruskotter
Phone: (504) 367-0603

BIRMINGHAM
November 13, 2001
Speaker: Myron Laurent.
Affiliation: B E & K Construction.
Topic: Training in the construction industry with high school relations.

NEW ORLEANS
December 18, 2001
Activity: The Section held its annual holiday party. Terry Ann Pajak, wife of Section Treasurer John Pajak, was given an Appreciation Award for her loyalty, devotion, and generous contribution of time and effort to the Section's Executive Committee.

DISTRICT 10
Director: Victor Y. Matthews
Phone: (216) 383-2638
NORTHWESTERN PENNSYLVANIA
January 8
Speaker: Dean Peters, editor.
Earl Lipphardt, right, presenting a speaker's gift to Dean Peters at the Northwestern Pennsylvania Section's January meeting.

Affiliation: Welding Design and Fabrication.
Topic: Metallurgy from 10,000 B.C. to 1900 A.D., and current problems facing welders.

**DISTRICT 11**
Director: Scott C. Chapple
Phone: (734) 241-7242

Detroit Section member Robert Wilcox, right, presenting Sivakumar Ramasamy with a speaker's gift.

**DETROIT**
November 7, 2001
Speaker: Sivakumar Ramasamy.
Affiliation: Emhart Fastening Technologies.
Topic: Latest innovations in short-duration, drawn arc welding and an introduction to “CLEANFLASH” technology to address the challenge of welding to wax-coated aluminum.

December 7, 2001
Activity: The Section held its annual holiday party and Vegas Night.

January
Speaker: Tina M. Hurkin, director of education.
Affiliation: Focus: HOPE Center for Advanced Technologies.
Topic: Overview and tour of Focus: HOPE Center for Advanced Technologies.

**DISTRICT 12**
Director: Michael D. Kersey
Phone: (262) 650-9364

From left are Fox Valley Section Vice Chairman Sean Moran; scholarship recipients, Dan Grewe, Jon Radue, Mike Oaks; and Section Student Affairs Chairman Lori Kuiper.

**FOX VALLEY**
January 10
Speaker: Adam Weitzel, president.
Affiliation: Badger Cryogenics, Inc., Baraboo, Wis.
Topic: Cryogenic treating of materials.
Activity: Dan Grewe, Jon Radue, Mike Oaks, and Jason Baus were awarded Section scholarships.

**CHICAGO**
January 16
Speaker: Dagmar Ziegler.
Affiliation: Wegener N.A.
Topic: Plastics and welding and where AWS is headed with guidelines and certification.
DISTRICT 14

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

District 14 Director Hil Bax, left, and AWS Vice President Ernest Levert at the St. Louis Section’s Student Appreciation Night.

ST. LOUIS

NOVEMBER 9, 2001
Activity: The Section held Student Appreciation Night with guest speaker AWS Vice President Ernest Levert. More than 180 guests attended the event, which was hosted by Larry Shaaf. St. Louis Section Chairman Don Kimber welcomed students and educators in his opening remarks. Gold and silver VICA/Skills USA winners were present to discuss welding with those interested.

INDIANA

JANUARY 7
Activity: Brian Gann, Scott Copp, and James Berg led Section members on a tour of the Cooperheat-MQS Inc. facility in Indianapolis, Ind.

DISTRICT 15

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

District 15 Director Jack Heikkinen, left, presenting an award to Arrowhead Vice Chairman Loren Kantola.

ARROWHEAD

DECEMBER 20, 2001
Speaker: Carey Rude, president.
Affiliation: Electric Power Door Co., Hibbing, Minn.
Topic: Manufacturing large, power doors for industrial building.
Activities: Section Chairman Tom Baldwin received the Section Meritorious Award, a District 15 Director’s Award, and the Dalton E. Hamilton CWI of the Year Award. Section Vice Chairman Loren Kantola was presented with the Section Meritorious Award and a District 15 Director’s Award.

KANSAS CITY

OCTOBER 27, 2001
Activity: The Section held a Blueprint Reading and Welding Symbols seminar. More than 40 people attended the event.

Attendees at the Kansas City Section’s Blueprint Reading and Weld Symbols seminar.
JANUARY 10
Speaker: Craig Wright, vice president of quality assurance.
Affiliation: Black & Veatch Corp.
Topic: Welding in the construction industry.

DISTRICT 17
Director: Oren P. Reich
Phone: (254) 867-2203

CENTRAL ARKANSAS
November 29, 2001
Activity: The Section held a business meeting.

JANUARY 23
Speaker: Morgan Golden.
Affiliation: Arkansas Welding, Inc.
Topic: Shielding gases, types and effects.
Activity: The meeting was held at the Sheet Metal Workers International Association Local Union #36L Apprentice School in North Little Rock. Doug Smith won the evening's drawing for $100 in AWS money.

NORTH TEXAS
January 22
Speaker: Ernest Levert, vice president.
Affiliation: AWS.

DISTRICT 18
Director: John Mendoza
Phone: (210) 860-2592

SABINE
January 15
Speaker: Rick Gerads, general manager.
Affiliation: METCO, Houston, Tex.
Topic: Selenium 75 — a new industrial radiography source.
Activity: Members discussed the Radiographic Film Interpretation seminar to be held on April 13 and 14.

HOUSTON
January 17
Speakers: Jean-Marc Teteuville of Durum USA and Bill Thomas.
Topics: Teteuville spoke on the use of tungsten carbide for hardfacing weld cladding. Thomas presented a case study of cutting applications titled Cutting the front bow of KURSK, a Russian submarine that sank in the Barents Sea.

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

ALASKA
January 18
Speakers: Ray Shepard and Brian Walsh.
Affiliations: UAA and KCC, respectively.
Topic: A Denali Commission welder training program for Alaska villages.

SOUTHERN COLORADO
December 5, 2001
Speaker: Patrick Mulville, technical representative, CWI, and CWE.
Topic: Qualification or certification of a welder by code.
Activities: Jack Dammann, an AWS Foundation trustee, was presented with a Lifetime Membership Certificate by John Cantlin. Ed Golding was introduced as the new Section chairman for this year. District 20 Director Jesse Grantham attended the meeting and brought members up to date on plans for the District 15 Conference in Albuquerque, N. Mex., and on what is happening at AWS headquarters in Miami.

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

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

SAN DIEGO
December 9, 2001
Speaker: Santa Claus.
Affiliation: North Pole.
**SANTA CLARA VALLEY**

**JANUARY 8**

Speaker: **Don Isaac.**
Affiliation: Tamin Enterprises.
Topic: The Sterling engine.

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**SECTION EVENTS CALENDAR**

**ALASKA**

All meetings in Anchorage unless otherwise noted.

**MARCH 15**

Topic: Subject open.
Location: Fairbanks.

**APRIL 8-13**

A CWI seminar and examination will be held.

**APRIL 12**

Activity: Section elections.

**MAY 18**

Activity: The Annual AWS Picnic will be held in Palmer, Alaska.

**DETROIT**

**MARCH 14**

Speaker: **John F. Hinrichs, PE.**
Topic: Robotic friction stir welding: Bringing FSW to high-volume production.

**APRIL (date to be announced)**

Activity: The Section will once again be hosting the annual Quiz the Experts Night. The AWS Detroit Section challenges the best District 11 has to offer.

**MAY 15-17**

Activity: Sheet Metal Welding Conference X will be held in Sterling Heights, Mich. This conference will have technical presentations of thin material joining technologies and a tutorial on automotive aluminum welding. Visit the Web site www.sheetmetalwelding.org for registration and further information.

For further information, call the AWS Detroit Section office at (810) 231-2502.

**FOX VALLEY**

**APRIL 9**

Speaker: **James Hennessy.**
Affiliation: AZCO, Inc.
Topic: Welding issues related to commercial electric power plant construction.

**MAY (date to be announced)**

Activity: The Section will hold the Spring Sporting Clay Shoot at the J&H Hunting Club and Game Farm.

**NEW ORLEANS**

**MAY 4**

Activity: The Section will hold the 4th Annual Speckled Trout and Redfish Rodeo at Sea Way Marina, Highway 45, Lafitte, La.

For further information on the Rodeo, please contact Mike Skiles at (504) 348-8500 or Byron Landry at (504) 367-7449.

**SANTA CLARA VALLEY**

**APRIL 9**

Speaker: **Gregg Martsching.**
Affiliation: Precision Welding Technologies.
Topic: Automated welding.

**MAY 14**

Speaker: **Ted Savage.**
Affiliation: ISYS Manufacturing.
Topic: Welding technology education.
Technical Committee Meetings

All AWS technical committee meetings are open to the public. Persons wishing to attend a meeting should contact the staff secretary of the committee as listed below at AWS, Technical Services Business Unit, 550 NW LeJeune Rd., Miami, FL 33126; telephone (800) 443-9353.

March 3-6, G1A Subcommittee on Hot Gas Welding and Extrusion Welding, New Orleans, La. Standards preparation meeting. Staff contact: J. L. Gayler, ext. 472.

March 3, A1 Committee on Metric Practice. Chicago, Ill. Standards preparation meeting. Staff contact: S. P. Hedrick, ext. 305.


March 4, C3 Committee on Brazing and Soldering. Chicago, Ill. Standards preparation meeting. Staff contact: C. Jenney, ext. 304.

March 4, D10 Committee on Piping and Tubing. Chicago, Ill. Standards preparation meeting. Staff contact: A. Oseitutu, ext. 314.


March 5, D11 Committee on Welding Iron Castings. Chicago, Ill. Standards preparation meeting. Staff contact: A. Oseitutu, ext. 314.

March 5, D14 Committee on Machinery and Equipment. Chicago, Ill. Standards preparation meeting. Staff contact: A. Oseitutu, ext. 314.

March 5, D17D Subcommittee on Resistance Welding. Chicago, Ill. Standards preparation meeting. Staff contact: E. F. Mitchell, ext. 254.

March 5, D17X D17 Executive Subcommittee. Chicago, Ill. Standards preparation meeting. Staff contact: E. F. Mitchell, ext. 254.

March 5, D18 Committee on Welding and Sanitary Applications. Chicago, Ill. Standards preparation meeting. Staff contact: L. P. Connor, ext. 302.

March 5, D18A Subcommittee on Qualification. Chicago, Ill. Standards preparation meeting. Staff contact: L. P. Connor, ext. 302.

March 5, D18B Subcommittee on Inspection. Chicago, Ill. Standards preparation meeting. Staff contact: L. P. Connor, ext. 302.

March 6, B1 Committee on Methods of Inspection. Chicago, Ill. Standards preparation meeting. Staff contact: A. Davis, ext. 466.

March 6, C1 Committee on Resistance Welding. Chicago, Ill. Standards preparation meeting. Staff contact: E. F. Mitchell, ext. 254.

March 6, D9 Committee on Structural Welding. Chicago, Ill. Standards preparation meeting. Staff contact: E. F. Mitchell, ext. 254.
Standards Notices

ISO Draft Standards For Public Review

Copies of the following Draft International Standards are available for review and comment through your national standards body, which in the United States is ANSI, 25 W. 43 St., Fourth Floor, New York, NY 10036, (212) 642-4906. Any comments regarding ISO documents should be sent to your national standards body.

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


Revised Standards Approved By ANSI


March 6, D16 Committee on Robotic and Automatic Welding. Chicago, Ill. Standards preparation meeting. Staff contact: J. L. Gayler, ext. 472.

March 6, D17 Committee on Welding in the Aircraft and Aerospace Industries. Standards preparation meeting. Staff contact: E. F. Mitchell, ext. 254.


March 6, G2C Subcommittee on Nickel Alloys. Chicago, Ill. Standards preparation meeting. Staff contact: J. L. Gayler, ext. 472.

March 6, G2E Subcommittee on Stainless Steel Alloys. Chicago, Ill. Standards preparation meeting. Staff contact: J. L. Gayler, ext. 472.

March 7, C5 Committee on Arc Welding and Cutting. Chicago, Ill. Standards preparation meeting. Staff contact: A. Oseiutu, ext. 314.


March 7, C5D Subcommittee on Gas Metal Arc Welding. Chicago, Ill. Standards preparation meeting. Staff contact: A. Oseiutu, ext. 314.


March 7, C5O Subcommittee on Shielding Gases. Chicago, Ill. Standards preparation meeting. Staff contact: A. Oseiutu, ext. 314.

March 7, C6 Committee on Friction Welding. Chicago, Ill. Standards preparation meeting. Staff contact: L. P. Connor, ext. 302.


March 7, G2 Committee on Joining Metals and Alloys. Standards preparation meeting. Staff contact: J. L. Gayler, ext. 472.


2001-2002 Member-Get-A-Member Campaign

Listed below are the people participating in the 2001-2002 Member-Get-A-Member Campaign. For campaign rules and a prize list, please see page 65 of this Welding Journal.

If you have any questions regarding your member proposal points, please call the Membership Department at (800) 443-9353 ext. 480.

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

J. Compton, San Fernando Valley**
E. H. Ezell, Mobile**
J. Merzthal, Peru*
B. A. Mikeska, Houston*
W. L. Shreve, Fox Valley*
G. Taylor, Pascagoula*
T. Weaver, Johnstown/Altoona*
G. Woomer, Johnstown/Altoona*
R. Wray, Nebraska*

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

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

G. W. Taylor, Pascagoula* — 38
R. L. Peaslee, Detroit — 28
J. Merzthal, Peru — 22

President's Roundtable
(AWS Members sponsoring 11-19 new Individual Members between June 1, 2001, and May 31, 2002.)

A. W. Stephenson, Reading — 10
T. A. Ferri, Boston — 10
J. Compton, San Fernando Valley — 14

President's Club
(AWS members sponsoring 6-10 new Individual Members between June 1, 2001, and May 31, 2002.)

S. R. Bollihorst, Indiana — 9
D. W. Peters, Chicago — 7
M. Hyzny, North Central Florida — 6
S. Johnson, Central Texas — 6
L. G. Kvidahl, Pascagoula — 6
R. Merreighn, Missouri Valley — 6
D. J. Schulte, Siouxland — 6

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

N. Goel, Long Island — 5
B. Walsh, Alaska — 4

M. Bliek, Colorado — 3
R. De Los Santos, Mexico — 3
T. Flynn, Atlanta — 3
B. Huff, Sangamon Valley — 3
J. M. Hunt, Tulsa — 3
R. Johnson, Detroit — 3
C. Mezick, New Orleans — 3
P. Patel, Mobile — 3
J. S. Armstrong, East Texas — 2
P. Baldwin, Peoria — 2
T. L. Bertwich, Colorado — 2
J. Bobo, Lake Charles — 2
D. L. Hatfield, Tulsa — 2
R. A. Hauk, Syracuse — 2
W. Heintz, San Francisco — 2
M. Hernandez, L.A./Inland Empire — 2
Z. Keniston, Syracuse — 2
J. Koster, Western Michigan — 2
S. Moran, Fox Valley — 2
A. Mydland, Spokane — 2
S. W. Rouch, Haslam Valley — 2
D. Russell, Jr., Chattanooga — 2
E. Soto Ruiz, Puerto Rico — 2
J. S. Stiles, Florida West Coast — 2
R. Wiese, New Jersey — 2
R. R. Wittmer, Birmingham — 2
R. Wright, Southern Colorado — 2
R. Zabel, Southeast Nebraska — 2

Student Sponsors
( AWS members sponsoring 3 or more new AWS Student Members between June 1, 2001, and May 31, 2002.)

P. Baldwin, Peoria — 01
A. Demarco, New Orleans — 44
B. Huff, Sangamon Valley — 43
E. S. Ruiz, Puerto Rico — 37
J. H. Sullivan, Mobile — 33
B. Huff, Sangamon Valley — 30
A. Reis, Pittsburgh — 26
T. Huston, Pittsburgh — 25
S. E. Hower, Reading — 23
R. A. Large, Manchester — 23
R. Durham, Cincinnati — 21
P. Walker, Ozark — 21
J. Cox, Northern Plains — 21
K. Geist, Olympic — 21
P. Walker, Ozark — 21
K. Ellis, Maryland — 19
D. Reskovich, Philadelphia — 19
K. Langdon, Johnny Appleseed — 17
L. R. Vann, South Carolina — 17
F. Juckem, Madison—Beloit — 16
A. Blakeney, New Orleans — 15
L. C. Davis, New Orleans — 13

F. Wernet, L.A./Inland Empire — 13
R. Grays, Korn — 12
L. Heath, Maryland — 12
H. Madron, Maryland — 12
W. P. Miller, Jr., New Jersey — 12
S. Green, North Texas — 11
W. Kielhorn, East Texas — 10
D. Nelson, Puget Sound — 10
P. Betts, Mobile — 9
P. Childers, Oklahoma City — 9
J. Pelster, Southeast Nebraska — 9
G. Diseth, Puget Sound — 8
S. Caldera, Portland — 7
A. Honegger, L.A./Inland Empire — 7
D. Marquis, Ozark — 7
J. Swoner, L.A./Inland Empire — 7
S. Zwilling, Louisville — 7
K. Kipp, L.A./Inland Empire — 6
D. Hatfield, Tulsa — 6
R. Brown, L.A./Inland Empire — 5
R. Felix, Long Beach/Orange County — 5
S. Gore, Charlotte — 5
J. Livesay, Nashville — 5
J. Smith, Jr., Mobile — 5
R. Zabel, Southeast Nebraska — 5
R. J. DePue, Oleastrostate — 4
J. McKay, Jr., Cleveland — 4
T. Kienbaum, Colorado — 4
S. Hoff, Sangamon Valley — 3
H. Jackson, L.A./Inland Empire — 3

Announce Your Section’s Activities

Stimulate attendance at your Section’s meetings and training programs with free listings in the Section Meeting Calendar column of Society News. Useful information includes your Section name; activity date, time and location; speaker’s name, title, affiliation and subject; and notices of golf outings, seminars, contests and other special Section activities.

If some of your meeting plans are sketchy, send the name and phone number of a person to contact for more information.

Send your new calendar to Susan Campbell, Associate Editor, Welding Journal Dept., AWS, 550 N.W. LeJeune Rd., Miami, FL 33126, (800) 443-9353 ext. 244, FAX: (305) 443-7404, e-mail: campbell@aws.org.
GUIDE TO AWS SERVICES
550 NW LeJeune Rd., Miami, FL 33126
Phone (800) 443-9353; (888) WELDING
FAX (305) 443-7559; Internet: www.aws.org
Phone extensions appear in parentheses.
E-mail addresses available on the AWS Web site.

AWS PRESIDENT
Richard L. Arr
Teletherm Technologies, Inc.
37104 Laughton Rd.
Lisbon, OH 44432

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Corporate Director of Quality Management Systems
Linda K. Henderson (298)
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Provides liaison activities involving other professional societies and standards organizations, nationally and internationally.

GOVERNMENT LIAISON SERVICES
Hugh K. Webster
Webster, Chamberlain & Bean
Washington, D.C.
(202) 480-2976
FAX (202) 835-0243
Identifies sources of funding for welding education and research & development. Monitors legislative and regulatory issues important to the industry.

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Welding Industry Network (WIN)
Jeff Weber (246)

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Exhibiting Information
(242, 256, 295)
Director of Exposition Sales
Dennis Bileca (458)

Director of Convention & Expositions
John Ospina (462)
Organizes the week-long annual AWS International Welding and Fabricating Exposition and Convention. Regulates space assignments, registration materials, and other Expo activities.

PUBLICATION SERVICES
Department Information (348)
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WELDING JOURNAL
Publisher
Jeff Weber (246)
Editor/Editorial Director
Andrew Cullison (249)
National Sales Director
Rob Saltzstein (243)

WELDING HANDBOOK
Welding Handbook Editor
Annette O'Brien (303)

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

MARKETING AND DESIGN
Corporate Director
Jeff Weber (246)
Plans and coordinates marketing of AWS products and services. Responsible for print advertising, as well as design and print production of the Welding Journal, Inspection Trends, the annual Welding Show Program, and other AWS promotional publications.

MARKET RESEARCH AND PRODUCT DEVELOPMENT
Corporate Director
Debrah C. Weir (482)
Investigates and/or proposes new products and services. Researches effectiveness of existing programs.

MEMBER SERVICES
Department Information (480)
Associate Executive Director
Cassee R. Burrell (253)
Director
Rhenda A. Mayo (260)

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

EDUCATION AND CONFERENCE SERVICES
Education
Director
Christopher B. Potlock (219)

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

CONFERENCES
Director
Giselle I. Rodriguez (278)

RESPONSIBLE for national and local conferences/exhibitions and seminars on industry topics ranging from the basics to the leading edge of technology.

CERTIFICATION OPERATIONS
Information and application materials on certifying welders, welding inspectors, and educators.
Managing Director
Wendy S. Reeve (215)
Director
Terry Perez (470)

AWARDS, FELLOWS, AND COUNSELORS
Managing Director
Wendy S. Reeve (215)

INTERNATIONAL BUSINESS DEVELOPMENT
Director
Walter Herrera (475)

For information about AWS technical publications, contact the Technical Services personnel listed below.

TECHNICAL SERVICES
Department Information (340)
Managing Director
Leonard P. Connor (302)
Qualification, Friction Welding, Food Processing Equipment, Computation
Andrew R. Davis (466) International Standards Program Manager, Welding in Marine Construction, Inspection
Stephen P. Hedrick (305) Safety and Health Manager, Metname Practices, Mechanical Testing, Metals & Alloys
Engineers
John L. Gayler (472) Structural, Plastics and Composites, Personnel Qualification
Rakesh Gupta (301) Filler Metals, Instrumentation, Sheet Metal

Ed F. Mitchell (254) Thermal Spray, High-Energy Beam Welding and Cutting, Resistance Welding, Automotive, Aerospace, Railroads

Antony Y. Otutu (314) Oxyfuel Gas Welding & Cutting, Arc Welding and Cutting, Machine and Equipment, Welding on Castings, Plating & brazing, Robotics

Technical Editor
Cynthia Jenney (304) Definitions & Symbols, Brazing, Soldering

Senior Publications Coordinator
Rosemary O'Neill (451)

AWS publishes more than 160 volumes of material, including standards that are used throughout the industry.

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

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

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

To be considered a candidate for positions of President, Vice President, Treasurer or Director-at-Large, the following qualifications and conditions apply:

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

Vice President: To be eligible to hold the office of Vice President, an individual must have served at least one year as a Director, other than Executive Director and Secretary.

Treasurer: To be eligible to hold the office of Treasurer, an individual must be a member of the Society, other than a Student Member, must be frequently available to the National Office, and should be of executive status in business or industry with experience in financial affairs.

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

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

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

The next meeting of the National Nominating Committee is currently scheduled for March 5, 2002, in Chicago, Ill. The terms of office for candidates nominated at this meeting will commence June 1, 2003.

Honorary-Meritorious Awards

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

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

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

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

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

Honorary Membership Award: An Honorary Member shall be a person of acknowledged eminence in the welding profession, or who is accredited with exceptional accomplishments in the development of the welding art, upon whom the American Welding Society sees fit to confer an honorary distinction. An Honorary Member shall have full rights of membership.
Flux Cored Arc Welding Process

The flux cored arc welding process (FCAW) uses the same types of power sources and wire feeders as the gas metal arc process. However, the FCAW process uses a tubular electrode with its core containing deoxidizers, scavengers, and slag- and vapor-forming ingredients. Variations of the process are self-shielded flux cored arc welding (FCAW-S), which produces shielding from the electrode, with no external gas shielding required, and gas-shielded flux cored arc welding (FCAW-G), which requires shielding from an external gas source. Externally gas shielding is commonly accomplished with CO$_2$ or a mixture of CO$_2$ and argon. The welding gun for FCAW-S is designed without a nozzle, as is required with externally gas shielded processes.

If used under windy or drafty conditions, the FCAW-G process requires some barrier to prevent the external gas shielding from being dissipated; the FCAW-S process does not need such a barrier. The FCAW process is commonly used on mild steel, but the electrodes can be manufactured to contain alloying elements in the core for welding low-alloy and stainless steels.

The process is noted for its high deposition rates and somewhat forgiving arc characteristics. Its overall efficiency is slightly less than the gas metal arc process, but significantly better than the shielded metal arc process. It is a versatile process, adaptable to welding both thick and thin steel.
Matheson Tri-Gas Appoints President/CEO

Randy J. Kempf has been named as successor to Johnston as president. Kempf has more than 20 years of experience in manufacturing, engineering, sales, and marketing. He received his bachelor's degree in electrical engineering from Purdue University and his M.B.A. from the University of Iowa.

ITW Announces Appointments

Randall Haberman [AWS] has been named vice president of operations for ITW's Bernard and Weldcraft product lines. In this position, he is responsible for all production operations at the Beecher, Ill., and Burbank, Calif., facilities manufacturing Bernard, Weldcraft, or PlazCraft products. Haberman previously served as vice president of manufacturing for DovaTech, Ltd.

Randy Haberman

Eric Frei

Justin C. "Moe" Messenger

Justin C. "Moe" Messenger, a pioneer in the hardfacing industry, died on December 28, 2001, at Loma Linda Hospital in California. Messenger began his career in the welding industry with Stuart Oxygen Co. in central California in the mid-1950s. In 1957, he joined Stoody Company as a field engineer. He quickly moved up the ladder at Stoody becoming field sales manager, general sales manager, and, finally, president of Stoody International Company, where he established and trained a network of distributors in more than 50 countries.

Messenger authored scores of "how-to" articles on hardfacing and parts salvage and was often requested as a guest speaker at AWS functions.

After his retirement from Stoody, Messenger worked as a consultant for Rankin Industries, Inc., San Diego, Calif. Most recently, he was involved in administrative functions with the AZTEX Trailer Company, Fontana, Calif.

CMW President Retires; Successor Named

CMW Inc., Indianapolis, Ind., has announced the retirement of Howard D. Johnston, one of the company's founders and longtime president. He will continue to work for the company as a consultant to the company and member of its Board of Directors.

HI TecMetal Announces Appointment

HI TecMetal Group (HTG), Cleveland, Ohio, announced the appointment of Keith Lane Moore to process engineer for HTG Metal Methods in Frankfort, Ky. Prior to joining the company, Moore worked as a manufacturing engineer, project engineer, lab technician, and quality assurance auditor.

Eric Frei

Justin C. "Moe" Messenger
Catalog Features High-Temperature Materials

The company’s 16-section, 43-page, bound catalog describes its line of high-temperature materials and specialized machinery. High-temperature adhesives, coatings, potting compounds, and ceramic materials used in design, process, and industrial maintenance applications to 3200°F are featured. The company’s dicing saws, screen printers, and industrial furnaces are also highlighted.

Aremco Products, Inc.
787-B Executive Blvd., Valley Cottage, NY 1098

Visual Reference for Surface Preparation Published

The Society for Protective Coatings (SSPC) has published two collections of surface preparation reference photographs illustrating the appearance of steel surfaces prepared by waterjetting (SSPC-VIS 4) and wet abrasive blast cleaning (SPRC-VIS 5). Both contain a written guide and explanatory notes, as well as additional photographs depicting degrees of flash rust after cleaning. SSPC-VIS 4 is $112.50 for SSPC members, $125 for nonmembers. SPRC-VIS 5 is $67.50 for SSPC members, $75 for nonmembers. To order, call (877) 281-7772 or send e-mail to books@sspc.org.

The Society for Protective Coatings
40 24th St., 6th Fl., Pittsburgh, PA 15222-4666

Sign and Safety Products Catalog Offers Marking Solutions

The company’s 384-page, full-color catalog features signs, tags, labels, and other items designed to fulfill traffic, maintenance, security, lock-out, and directional marking needs. Custom-made products are available.

emecdo
P.O. Box 369, Buffalo, NY 14304

Brochure Highlights Air Cleaning Products

The company’s 12-page, full-color brochure features products that clean smoke, dust, powder, coolant mist, oil mist, and other fluid mists from plant air. Mist and dust collectors and source capture units are described including filter cartridge cleaning systems, sealed cabinet designs, mist filters, odor-control options, and recommended plant applications and configurations.

Micro Air
PO Box 1138, Wichita, KS 67201

Catalog Features Thermocouple and RTD Sensors

The company’s 2001 catalog has added a manufacturing division for sensors. The sensor division manufactures thermocouples and RTDs to customer specifications. The 80-page catalog shows the complete product line.

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IFC = Inside Front Cover
IBC = Inside Back Cover
OBC = Outside Back Cover

MARCH 2002
Monte Carlo Simulation of Heat-Affected Zone Microstructure in Laser-Beam-Welded Nickel Sheet

Reasonable agreement was obtained between experimental results and simulated grain growth in the heat-affected zone

BY M.-Y. LI AND E. KANNATEY-ASIBU, JR.

ABSTRACT. The heat-affected zone grain structure that evolves during welding of a nickel 270 sheet was simulated using Monte Carlo techniques. A matrix consisting of 200 x 200 sites with 100 possible grain orientations was used for the simulation, and the temperature histories measured during welding were used as inputs to perform the simulation. The unit length of each site is 10 μm, with the overall simulation region being 2 x 2 mm. The simulation pertained to microstructure in the vertical plane where the temperatures were measured, i.e., along the welding direction.

The grain size throughout the heat-affected zone, as obtained by simulation, showed reasonable agreement with the experimental results obtained from metallographic examination. The differences in average grain size measurements obtained experimentally and by simulation were 12.9% and 5.8% at locations 1.26 mm and 1.70 mm below the weld centerline, respectively. The advantages of using this simulation method are to predict grain size distribution in the HAZ. The results could subsequently be used for predicting other mechanical properties of a weldment.

Introduction

In their classic work, Burke and Turnbull proposed a parabolic grain growth relationship, hypothesizing that grain growth is the result of grain boundary migration (Ref. 1), and assuming surface tension of the boundaries is the driving force for grain growth after recrystallization. A similar relationship was subsequently developed by Feltham (Ref. 2), Hilbert (Ref. 3), and Sætre, et al. (Ref. 4). This parabolic relationship has been verified experimentally in nickel (Ref. 5), copper (Ref. 6), and alpha brasses (Ref. 7).

The properties of a material are not only affected by the size of its grains but also by the geometry (shape and orientation) of the grains (Ref. 8). To predict grain geometry and grain size, use of topological simulation methods is necessary. A Monte Carlo-based grain growth simulation technique was developed by Srolovitz, Anderson, and their coworkers (Refs. 9, 10). Their algorithm provides a nondimensional simulation applicable only to isothermal grain growth. Gao and Thompson developed a real-time, temperature-dependent technique using isothermal matrices to predict grain size at different temperatures (Ref. 11). Defining a probability of MCS(x)/MCSmax for grain growth simulation and using the Rosenthal equation for calculating temperature cycles, Radhakrishnan and Zacharia predicted the grain growth of the HAZ of Cr-Mo-V steel (Ref. 12).

In this research, a matrix containing sites with a distributed temperature is considered necessary for predicting the HAZ microstructure. Toward this end, a dimensionalized simulation method has recently been developed (Ref. 13) to simulate grain growth in the heat-affected zone. This simulation requires temperature histories at various locations of the heat-affected zone as input. The unit length of the simulation matrix is determined by the region of interest, being 10 μm for a 2 x 2 mm region.

Background Theory

Measurement of temperature histories during laser beam welding is a difficult process. Moon and Metzbower imbedded thermocouples in a laser-beam-welded steel plate and measured the peak temperatures in the molten metal (Refs. 14 and 15). In this research, temperature histories at different distances from the root of a weld centerline were measured by imbedding thermocouples into the specimen at different depths from the root side.

KEY WORDS

HAZ
Heat-Affected Zone
Monte Carlo
Grain Growth
Nickel Sheet
Ni 270
Temperature History
Simulation
the average size of crystals in a system increases. The driving force for grain growth is the decrease of free energy in the system and is associated with reorientation of the atoms. Therefore, the average grain size of a microstructure increases by some of the grains consuming other grains, thereby reducing the number of grains in a specific aggregate. Two grain-growth mechanisms have been widely studied: normal and abnormal grain growth. Normal grain growth has a relatively narrow range of grain sizes and shapes. However, unlike normal grain growth, abnormal grain growth usually has a wide range of grain sizes and shapes. Abnormal grain growth, sometimes called secondary recrystallization, is usually caused by heterogeneous system energy distribution or the existence of impurities.

Most normal grain growth theories assume negligible heat transfer, so the process may be considered to be isothermal. Assuming solid-state transformation in a pure substance starts from a stable spherical nucleus in which grain boundary energy is isotropic, and neglecting surface energy or capillary effects, and finally, assuming that growth occurs continuously on the grain boundary where the atoms can successfully attach themselves, the expression for normal grain growth can be written as (Ref. 1)

\[ G = \lambda v \exp \left( \frac{-\Delta E}{RT} \right) \]  

where \( G \) is the growth rate, \( \lambda \) is the atomic spacing, \( v \) is the jump frequency of the system, \( E_A \) is the energy barrier for grain growth per mole atom, \( \Delta E \) is the average free energy change per mole atom during grain growth, \( T \) is the absolute temperature, and \( R \) is the universal gas constant. Assuming the energy change \( \Delta E \ll RT \) during isothermal grain growth at high enough temperatures, the last term of Equation 1, \( \exp \left( \frac{-\Delta E}{RT} \right) \)

may be approximated as \( \frac{\Delta E}{RT} \)

using exponential series and neglecting higher order terms. Equation 1 then reduces to the form

\[ G = \frac{\lambda v \Delta E}{RT} \exp \left( \frac{-\Delta E}{RT} \right) \]  

(2)

where \( C_0 \) is a constant, \( \gamma \) is the grain boundary interfacial energy, \( V \) is the volume per mole atom, and \( r \) is the grain boundary radius (Ref. 1). Equation 2 then becomes

\[ \frac{dr}{dt} = \frac{C_0 \gamma V}{RT} \exp \left( \frac{-E_A}{RT} \right) \]  

(3)

Equation 3 can be rewritten as

\[ \frac{dr}{dt} M \]  

where \( M \) is defined as the atomic mobility and is constant for an isothermal system.

\[ M = \frac{C_0 \gamma V}{RT} \exp \left( \frac{-E_A}{RT} \right) \]  

(5)

For isothermal grain growth, Equation 4 can be integrated to give

\[ r^2 - r_0^2 = 2M t \]  

(6)

where \( r_0 \) is the initial average grain radius.

### Grain Growth Simulation

#### Dimensionless Simulation

The dimensionless Monte Carlo grain growth simulation employs a two-dimensional triangular lattice in which each site has six nearest neighbors at identical distances. Each site is initially assigned a random orientation \( S_{ij} \). A grain is defined by a group of contiguous sites with the same grain orientation \( S_{ij} \). Grain boundaries are assumed to exist between grains with different orientations. The simulation starts by selecting a random orientation \( S_{ij} \) from 1 to \( Q \), where \( Q \) is the number of possible orientations for a randomly selected site \((i, j)\). In their research, Anderson, et al. (Ref. 10), found that for \( Q \approx 30 \), the grain size distribution from Monte Carlo simulation approaches a limit form. Therefore, \( Q = 100 \) is used in this research. \( N \) reorientation trials are referred to as a Monte Carlo step (MCS), where \( N \) is the number of sites in the matrix.

As in the case of Strolovitz, et al. (Ref. 9), the grain boundary energy \( E_{\gamma} \) is the driving force for the motion of a grain boundary and is defined as

\[ E_{\gamma} = -J \sum_{n=1}^{m} \delta_{j,i} \]  

(7)

where \( \delta_{j,i} \) is the Kronecker delta and \( m \) is the number of nearest neighbor sites, \( \delta_{j,i} = m \) for a triangular lattice. In Fig. 1, \( J \) is the system energy contribution from two nearest neighbor sites with different orientations, and it is a positive constant. The value of \( J \) is not necessary for the dimensioned simulation since the probability \( P_2 \) (to be defined later)
only considers its sense. \( E_{ij} \) is positive when the two nearest neighbor sites are of unlike orientation and zero otherwise. The sum is taken over all nearest neighbor sites. The energy change associated with a reorientation is calculated as

\[
\Delta E_{ij} = E_{ij,\text{new}} - E_{ij,\text{old}}
\]

(8)

where \( E_{ij,\text{new}} \) is the energy of site \((i,j)\) after reorientation and \( E_{ij,\text{old}} \) is the energy of site \((i,j)\) before reorientation.

A probability \( P \) was introduced by Anderson, et al. (Ref. 10), and defined as

\[
P = \frac{1}{\exp\left(\frac{\Delta E_{ij}}{RT}\right) + 1}
\]

(9)

A positive \( \Delta E_{ij} \) indicates the system energy change increases after reorientation. On the other hand, a negative \( \Delta E_{ij} \) indicates a decrease of system energy after reorientation. Thus, this probability can be modified and defined as probability \( P_2 \)

\[
P_2 = \begin{cases} 1 & \text{if } \Delta E_{ij} \leq 0 \\ 0 & \text{if } \Delta E_{ij} > 0 \end{cases}
\]

(10)

The probability \( P_2 \) forces the simulation to accept only those reorientation trials associated with decreasing total system energy. A reorientation trial is accepted if this probability criterion is satisfied. A flow chart of the simulation procedure is shown in Fig. 2.

**Dimensionalized Simulation**

**Simulation Algorithm**

The isothermal simulation algorithm developed by Anderson and coworkers (Ref. 10) was modified to incorporate temperature variation by using the original Burke and Turnbull grain growth theory. Figure 3 shows the modified procedure. Unlike the dimensionless simulation, a new probability term \( P_1 \) was introduced to incorporate absolute temperature into the new simulation. Considering Equation 2, \( P_1 \) is determined by

\[
P_1 = \exp\left(-\frac{E_A}{RT}\right)
\]

(11)

where \( E_A \) is the activation energy for grain growth. \( P_1 \) represents the probability that an atom will overcome the energy barrier of grain growth \( E_A \). A simulation trial satisfying the \( P_1 \) criterion implies that the atom overcomes the energy barrier and has a potential to change its orientation. As mentioned in the preceding section, another probability term \( P_2 \) is considered when an atom attempts to change its location relative to its neighboring atoms, by which the grain orientation is changed, after satisfying the \( P_1 \) criterion. The new orientation is accepted when \( P_2 \) is also satisfied, i.e., the system total energy is lowered. Therefore, a reorientation trial is successful when both criteria \( P_1 \) and \( P_2 \) are satisfied.

**Grain Growth Exponent \( n \) and Coefficient \( K_s \) for Simulation**

In addition to temperature, two other parameters are required for dimensionalization, viz. temporal and spatial parameters. Isothermal simulations at various


Table 1 — Parameters Used in the Simulation

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Units</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\delta$</td>
<td>$\mu$m</td>
<td>10</td>
</tr>
<tr>
<td>$k_{gi}$</td>
<td>$m^2/s$ (Ref. 16)</td>
<td>$1.36 \times 10^{-3}$</td>
</tr>
<tr>
<td>$E_A$</td>
<td>kcal/(mol°K) (Ref. 16)</td>
<td>27.5</td>
</tr>
<tr>
<td>$K_s$</td>
<td>$\delta^2$/MCS</td>
<td>0.0151</td>
</tr>
<tr>
<td>$t_s$</td>
<td>s</td>
<td>$1.11 \times 10^{-9}$</td>
</tr>
<tr>
<td>$Q$</td>
<td>NA</td>
<td>100</td>
</tr>
</tbody>
</table>

Table 2 — Activation Energies for the Grain Boundary Self-Diffusion of Nickel

<table>
<thead>
<tr>
<th>Misfit Angle (degrees)</th>
<th>Activation Energy (kcal/g mole)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>27.1</td>
</tr>
<tr>
<td>30</td>
<td>25.6</td>
</tr>
<tr>
<td>40</td>
<td>25.3</td>
</tr>
<tr>
<td>45</td>
<td>25.7</td>
</tr>
<tr>
<td>50</td>
<td>24.6</td>
</tr>
<tr>
<td>60</td>
<td>26.2</td>
</tr>
<tr>
<td>70</td>
<td>27.3</td>
</tr>
<tr>
<td>80</td>
<td>33.7</td>
</tr>
</tbody>
</table>

Temporal and Spatial Parameters

Experimental results have shown the grain growth exponent $n$ for nickel is 2 (Ref. 16). To incorporate the experimental data into the simulations, the grain growth exponent $n = 2$ was employed. That gives the units of the experimental grain growth coefficient, $K_0$, as $m^2/s$ and those of the simulations as $\delta^2$/MCS, where $\delta$ is the unit length of the matrix and MCS is the Monte Carlo Step or the simulation step. $\delta$ is determined by the region of interest and the size of the matrix. Since $K_s$ and $K_0$ are equivalent, we have

$$K_s = \frac{\delta^2}{MCS} = K_0 \left( \frac{m^2}{s} \right) \quad (16a)$$

or

$$MCS = \frac{K_0}{K_s} \left( \frac{\delta^2}{m} \right) \quad (16b)$$

Equation 16b determines the amount of time that an MCS represents when the length of $\delta$ is set. For example, for a $2 \times$...
Fig. 5 — Results of isothermal simulations with various n values.

![Graph](image)

Fig. 6 — A laser welding specimen with ten holes drilled for mounting thermocouples.

![Image](image)

2-mm region, a δ of 10 μm is selected to give a 200 x 200 matrix. Inserting δ into Equation 16b gives

\[ \text{MCS} = \frac{K_0}{K_1} \left( \frac{1}{1 - \delta} \right) \text{sec} \]  

The grain growth coefficient \( K_0 \) of nickel is 1.36 x 10⁻³ m²/s (Ref. 16). Substituting the values of \( K_0 \) and \( K_1 \) into Equation 17 gives the equivalent time for an MCS as 1.11 x 10⁻³ s.

Heat-Affected Zone Microstructure Simulation

The material selected for the simulation was commercially pure nickel, Ni 270. The unit length used in the simulation was 10 μm, which implies a 2 x 2-mm parallelogram (200 x 200 elements) with a height of 1.732 mm as the simulation matrix. Temperature histories measured during welding were applied to the simulation for each MCS. The location of the second thermocouple (Fig. 6) corresponds to the top of the simulation matrix. Thus, the matrix contains thermocouples 2, 3, 4, 5, and 6. The corresponding temperature histories used in the simulation are shown in Fig. 7A. Figure 7B shows the temperature histories superimposed on each other. Assuming quasisteady-state welding conditions, the curves in Fig. 7B correspond to the temperature histories at depths of 1.26, 1.70, 2.06, 2.52, 2.90, and 3.32 mm.

Two activation energies were used in the simulation. The energy amount used in the simulation was 27.5 kcal/(mol·K) and the grain growth coefficient \( K_w \) was 1.36 x 10⁻³ m²/s (Ref. 16). The activation energy was selected to be the average of activation energies with grain orientation misfit angle from 20 to 80 deg, shown in Table 2.

The computation time required for a 200 x 200 matrix can be overwhelming. This is especially true with the normally low probability values obtained from Equation 11. To save computation time, a probability factor, \( P_{\text{factor}} \), is introduced for the simulations. The basic assumption is that the growth behavior for simulations at low probabilities is similar to that at high probabilities. From Equation 12, it is evident the growth behavior is governed by the \( K_0P_1t_1 \) term. A higher probability essentially reduces the time required to reach a particular grain size. The probability factor, \( P_{\text{factor}} \), is then defined as

\[ P_{\text{factor}} = \frac{P_{\text{new}}}{P_{\text{old}}} \]  

where \( P_{\text{new}} \) is the new probability, usually equal to 1, and \( P_{\text{old}} \) is the original probability given by Equation 11.

The probability factor for welding simulations is determined by setting the new probability for the point that experienced the highest temperature to 1. The peak temperature of the first curve in Fig. 7B is 1089.3°C (1362.3 K). Therefore, the maximum probability for this simulation, \( P_{\text{max}} \), is 3.74 x 10⁻⁵ and the probability factor for this simulation is the inverse of \( P_{\text{max}} \), 2.6773 x 10⁵, and thus reduces the simulation steps from 4.80 x 10⁹ to 1.80 x 10⁵.

Table 1 shows the parameters used in the simulation.

Experiments

Specimen Preparation

The material used in the experiment was originally hot-rolled (in the as-received condition) nickel 270 (Ni 270), with purity 99.9% or greater, and was tempered in the laboratory at 600°C for 30 min to relieve any residual stresses that might have been produced during manufacturing. The tempered Ni 270 was then cold rolled from 13.72 to 6.86 mm with a 50% thickness reduction and was subsequently machined to 6.35-mm thickness, 12.70-mm width, and 76.20-mm length for laser beam welding. The specimen was first cut to approximate dimensions on a band saw and then milled to the final dimensions. Cutting fluids, water, and cutting oil for the band saw and mill, respectively, were used to minimize the impact of heat from material removal and to enhance the surface finish. Specimens for the normal grain growth investigation were then subjected to a recrystallization treatment, heated at 700°C for 30 min, to produce homogeneous grain size distribution in the material before laser beam welding.

Specimen surface conditions are important in laser beam welding. The specimens were, therefore, dry sanded using 400-grit silicon carbide paper to remove oxides and produce uniform scratches in the welding direction for a consistent surface condition. Ten blind holes were then drilled to different depths at different locations on the back of the specimen — Fig. 6. Each hole was initially drilled using a regular drill bit. The root of each hole was then flattened using a flat-headed drill bit. The actual depths were measured using a microscope after welding.

Laser Beam Welding

Autogeneous welding was done using a CO₂ laser at 1000-W power focused by a 125-mm (5-in.) focal length lens. The out-
put beam is D-mode [combined TEM$_{60}$ (60%) and TEM$_{61}$ (40%) modes], with a corresponding beam quality $M^2$ of about 2.0 (Ref. 17). The focal point was located on the specimen top surface with a diameter of about 250 $\mu$m and an incident angle of 3 deg. The welding speed was 5 mm/s. Argon was used as shielding gas at a flow rate of 21 L/min. To minimize heat conduction to the ambient, the specimen was supported by two ceramic tubes, each of 3.175 mm diameter.

Temperature Measurement

Temperature histories at various locations are necessary for dimensional grain growth simulations. K-type thermocouples (chromel-alumel) of 0.005 in diameter were used in the experiments. These were mounted in the plane along the welding direction, to measure temperatures vertically below the centerline of the weld — Fig. 6. Bare thermocouple wires were protected by two-hole ceramic tubes, 1.5875-mm outer diameter and 0.3969-mm inner diameter, mounted into the predrilled holes on the back of the specimen. The thermocouples were welded to the flattened bottoms of the blind holes by capacitive discharge welding to firmly attach them to the specimen. Due to the guiding two-hole ceramic tubes, each thermocouple tip was centered very well, as observed after laser beam welding, microscopically. Each contact was carefully examined by measuring the electric resistance between the thermocouple and the specimen.

A 486 PC with a 10-channel, 12-bit data acquisition system was used to record the temperature variations during welding. The channels were connected to the thermocouples at a selected sampling rate of 146.4 Hz per channel. A high sampling rate allowed more temperature data to be recorded during welding, en-
Results and Discussion

Due to the low heat input rate (1000 W), only conduction mode of fusion was observed in the weld. That is, no keyhole formation was obtained. Figure 7A shows the temperature histories at eight locations, channels one through eight. The discontinuity observed in the first channel was due to the fact the thermocouple mounted in that hole smelted during welding. Subsequent cross-sectional examination showed the actual depth of that thermocouple was 1.08 mm, and that was very close to the fusion zone, 0.98 mm deep. Figure 7B shows the modified temperature histories obtained by shifting each temperature history toward the second channel by an amount of time equal to its distance to the second channel divided by the welding speed. For example, channel 3 was shifted 1 second while channel 4 was shifted 2 seconds to the left. Under quasi-equilibrium welding conditions, it is assumed each point of the same depth, except those points near the ends of the specimen, experienced the same temperature history following a certain amount of time delay. Therefore, the curves in Fig. 7B relate to temperature histories at the locations of depths equal to 1.26, 1.70, 2.06, 2.52, 2.90, and 3.32 mm. These depths were determined after welding using a microscope at 100X magnification, to measure the cross-section of the sample along the center of the weld line. Temperatures at sites located between two thermocouples were approximated by linear interpolation for the Monte Carlo simulation. Cooling rates for the temperature histories in Fig. 7B were calculated and are shown in Fig. 7C. Each data point in the cooling rate chart (Fig. 7C) was calculated by taking the average of 11 consecutive cooling rate data points, 5 before and 5 after the point of interest. From the cooling rate profiles, it was found channels 3 and 4 reached their peak temperatures at about the same time. This might have resulted from a small contact area between the joint nugget of the third thermocouple (channel 3) and the specimen. The actual contact area could not be measured.

Figure 8 shows an optical micrograph of the microstructure of the vertical cross-section located under the weld and parallel to the welding direction. The specimen was etched using an etchant containing 50% nitric acid and 50% glacial acetic acid. Locations 1, 2, 3, and 4 correspond to the locations of thermocouples 1, 2, 3, and 4, respectively. Average grain size at each location was measured by the Heyn lineal intercept method (Ref. 18) with at least 50 interceptions on an intercept line, using an optical microscope at a magnification of 100.

Each grain size value of the simulation results was taken as an average of five measurements around the location of interest. Figure 9A, simulated with a homogeneous temperature distribution starting with a randomly oriented matrix, illustrates a typical initial grain structure before welding, and Fig. 9B shows the heat-affected zone grain structure obtained by Monte Carlo simulation after welding. The location of the second thermocouple shown in Fig. 6 is the top of the simulation matrix shown in Fig. 9. Therefore, the matrix of the simulation contains thermocouples 2, 3, 4, 5, and 6. Temperatures at sites located between two thermocouples were approximated by linear interpolation. The average initial grain size of the material (obtained after the recrystallization treatment) was 113.1 \( \mu m \), taken from three measurements in the unaffected zone, while the average initial grain size obtained for the simulated microstructure was 111.2 \( \mu m \). The slight difference in the two average initial grain sizes is due to the fact that it was...
very difficult getting the average grain size of the simulated microstructure to a specific value that would exactly match that of the actual material.

The simulated grain size distributions at channels 2, 3, 4, and 5 are shown in Fig. 10. Compared to the experimental results, the simulation errors in average grain size were 12.9%, 5.8%, 5.0%, and 9.2% at locations 1.26, 1.70, 2.06, and 2.52 mm below the weld centerline, respectively. The larger error of the simulation results at locations close to the fusion zone boundary is due to the missing of the peak temperature at the second channel. This resulted in a smaller total heat input to the corresponding location in the simulation. The second reason causing the deviation of the simulation results from experimental results was a slight difference in compositions for the materials used for the experiments and the simulations. The experimental material was a commercially pure nickel, Ni 270. However, due to the unavailability of all the data needed for this material, the activation energy $E_A$ and grain growth coefficient $K$ values used for the simulation were those of nickel bicrystals with a small amount of aluminum inside the crystals. Despite the slight difference in material properties, the results show reasonably good agreement on grain size prediction, with the simulation and experimental results following the same trend.

**Conclusions**

Normal grain growth was assumed to be the major growth mechanism in the heat-affected zone during welding for a commercially pure annealed nickel. Compared to the experimental results, the simulation errors in average grain size were 12.9 and 5.8% at locations 1.26 and 1.70 mm below the weld centerline, respectively. The trend of grain size distribution is similar in both experimental and simulation results.

Complete development of the grain growth simulation methodology will enable it to be applied to other manufacturing processes that involve high temperatures, such as heat treatment. This is provided the temperature history is either available or predictable and the grain growth properties (such as activation energy and grain growth coefficient) of the material are available.

**References**

17. PRC Corp., manufacturer’s specification, PRC, Landing, N.J.
Prediction of Heat-Affected Zone Characteristics in Submerged Arc Welding of Structural Steel Pipes

Mathematical models were developed to study the effects of process variables and heat input on the HAZ of submerged arc welds in structural steel pipes

BY V. GUNARAJ AND N. MURUGAN

ABSTRACT. In submerged arc welding (SAW), selecting appropriate values for process variables is essential in order to control heat-affected zone (HAZ) dimensions and get the required bead size and quality. Also, conditions must be selected that will ensure a predictable and reproducible weld bead, which is critical for obtaining high quality. In this investigation, mathematical models were developed to study the effects of process variables and heat input on various metallurgical aspects, namely, the widths of the HAZ, weld interface, and grain growth and grain refinement regions of the HAZ. The color metallography technique and response surface methodology were also used. Direct and interaction effects of the process variables and heat input on the characteristics of the HAZ were presented in graphical forms. The study revealed: 1) heat input and wire feed rate have a positive effect, but welding speed has a negative effect on all HAZ characteristics; 2) width of grain growth and grain refinement zones increased and weld interface decreased with an increase in arc voltage; and 3) width of HAZ is maximum (about 2.2 mm) when wire-feed rate and welding speed are at their minimum limits.

Introduction

In any welding process, the microstructure of the weldment undergoes considerable changes because of the heating and cooling cycle of the weld zone, which in turn is directly related to the welding process and techniques employed. Only by improving the microstructure of the HAZ can the properties of a welded joint be improved. In general, a number of welding process variables and operating conditions influence the characteristics and microstructure, and, therefore, hardness, toughness, and cracking susceptibility of the HAZ in steel fusion welds (Ref. 1). Excessive heat input could result in a wide HAZ with low impact strength, particularly in high-heat-input submerged arc welds.

From a metallurgical point of view, the heat-affected zone of a fusion weld in steel may be divided into three zones (Ref. 2), supercritical, intercritical, and subcritical, as shown in Fig. 1A. The supercritical region may, in turn, be divided into two regions — grain growth and grain refinement — as shown in Fig. 1B. The microstructure of the grain growth and grain refinement regions of the HAZ's supercritical zone influence the properties of the weld joint. To predict the properties of this zone, one must know the amount and extent of grain growth and the weld thermal cycle. Heat input from the welding process must be limited so as to keep the width of the HAZ's supercritical zone as narrow as possible. Also, the supercritical zone undergoes considerable microstructural changes that compare to small, negligible, structural changes in the HAZ's intercritical and subcritical zones. These microstructural changes affect the mechanical and metallurgical properties of the weldment (Ref. 3). Therefore, the size of the HAZ is an indication of the extent of structural changes. Because HAZ dimensions are controlled by process variables and heat input, they have to be correlated through development of mathematical models.

With a view to achieving the above-mentioned aim, statistically designed experiments based on the factorial technique were used to reduce cost and time, as well as to obtain the required information about the main and interaction effects of process variables on response parameters (Refs. 4, 5). The mathematical models thus developed are useful for selecting correct process variables for achieving the desired weld bead HAZ characteristics and mechanical properties and to predict HAZ dimensions for the given process variables (Ref. 6). They also help to improve understanding of the effect of process parameters on head quality, for quantitative evaluation of the interaction effects of process variables on HAZ characteristics, and to optimize the size of the weld bead's HAZ in order to obtain a better quality welded joint with desirable properties at a relatively low cost.

Experimental Procedure

The experiment was conducted at M/s. Sri Venkateswara Engineering Corp., Coimbatore, India, with the following setup.

ADORE semiautomatic welding equipment with a 1200-A-capacity, constant voltage, rectifier-type power source was used to weld 300 x 150 x 6-mm IS: 2062 structural steel plates. ESAB SAI
Investigation Plan

The research was carried out using the following steps (Ref. 7):

1) Identifying the important process control variables and finding their upper and lower limits;
2) Developing the design matrix;
3) Conducting the experiments as per the design matrix;
4) Recording the responses;
5) Developing the mathematical models;
6) Calculating the coefficients of the polynomials;
7) Checking the adequacy of the models developed;
8) Calculating the significance of the coefficients and arriving at final mathematical models;
9) Conducting the conformity test;
10) Determining the quantitative effects of process variables and heat input on weld bead HAZ.

Identification of the Process Variables and Finding Their Limits

The independently controllable process parameters affecting bead geometry and weld bead quality were arc voltage (V), wire feed rate (F), welding speed (S), and nozzle-to-plate distance (N). Trial runs were carried out by varying one of the process parameters while keeping the rest at constant values (Ref. 8). The working range was decided upon by inspecting the bead for a smooth appearance without any visible defects such as surface porosity and undercut. The upper limit of a factor was coded as +2 and the lower limit as -2. The coded values for intermediate values were calculated from the following relationship: $X_i = 2(X - (X_{max} + X_{min}))/X_{max} - X_{min}$, where $X_i$ is the required coded value of a variable $X$; $X$ is any value of the variable from $X_{min}$ to $X_{max}$; $X_{min}$ is the lower level of the variable; and $X_{max}$ is the upper level. The process variables with their units and notations are given in Table 1.

Developing the Design Matrix

The selected design matrix, shown in Table 2, is a five-level, four-factor, central composite, rotatable factorial design (Ref. 9) consisting of 31 sets of coded conditions. It comprises a full replication of $2^{4}$ (+16) factorial design plus seven center points and eight star points. All welding variables at their intermediate level (0) constitute the center points and the combinations of each of the welding variables at either its lowest (-2) or highest (+2), with the other three variables at their intermediate level, constitute the star points. Thus, the 31 experimental runs allowed estimation of the linear, quadratic, and two-way interactive effects of the welding variables on the bead geometry.
Conducting the Experiments as Per the Design Matrix

The experiments were conducted as per the design matrix at random to avoid systematic errors infiltrating the system. Weld beads were deposited on the surface of the 6-mm-thick structural steel plates with the experimental setup explained previously.

Recording the Responses

The welded plates were cut at the center of the bead to obtain 10-mm-wide test specimens. The standard metallographic technique, i.e., metal polishing with a series of emery sheets and disc polishing using diamond paste with particle sizes ranging from 5μ to 0.5μ, was carried out. The established color etching procedure for steel was employed to identify different regions of the weldment. An optical research microscope (NEOPHOT-32) was used. With the help of built-in linear measuring devices in the microscope that had an accuracy of 0.001 mm, dimensions (width) of the weld interface and different regions of the HAZ were measured. These were the width of the heat-affected zone (widths of supercritical zone + intercritical zone + subcritical zone) and the width of the weld interface (WI). The observed and calculated values are given in Table 2. A cross section of a typical welded specimen (Specimen No. 2) is shown in Fig. 2.

Development of Mathematical Models

The response function representing any of the HAZ dimensions can be expressed as \( y = f(V, F, S, N) \). The relationship selected, being a second-degree response surface, is expressed as follows (Ref. 10):

\[
Y = b_0 + b_1V + b_2F + b_3S + b_4N + b_{11}V^2 + b_{22}F^2 + b_{33}S^2 + b_{12}VF + b_{13}VS + b_{14}VN + b_{23}FS + b_{24}FN + b_{34}SN
\]

Evaluation of the Coefficients of Models

Regression analysis, with the help of the following equations, was used to calculate the values of the coefficients (Ref. 11):

\[
b_{11} = 0.142857 \frac{\sum Y - \frac{1}{2} \sum (XY \cdot Y)}{\sum X^2 - \frac{1}{2} (\sum X)^2}
\]

\[
b_{12} = 0.041667 \frac{\sum XY - \frac{1}{2} \sum X \sum Y}{\sum X^2 - \frac{1}{2} (\sum X)^2}
\]

A computer program was used to calculate the values of these coefficients for different responses. The calculated values are presented in Table 3.

Checking the Adequacy of the Developed Models

The adequacy of the models was then tested by the analysis-of-variance technique (ANOVA) (Ref. 11). As per this technique:

1) If the calculated value of the model's F-ratio does not exceed its tabulated value for a desired level of confidence (say 95%); and
2) if the calculated value of the model's R-ratio exceeds its standard tabulated value for a desired level of confidence (again 95%), then the models are adequate (Refs. 11, 12). From Table 4, it is evident that for all models, the above conditions were satisfied and, hence, adequate.

### Table 2 — Design Matrix and Observed Values of the HAZ

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<th>Sl. No.</th>
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<th>N</th>
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For each experimental run, arc voltage and arc current were noted. The corresponding heat input was calculated by using the formula

Heat input, kJ/cm = Arc voltage (volts) x Arc current (amperes) x (Arc Efficiency)

Welding speed (cm/s) x 100

Arc Efficiency for SAW is taken as 1.
The final mathematical models follow. The process control variables are in their coded form. Significance of the coefficients was tested using the SYSTAT software package (Ref. 13). The software's step backward option was used to eliminate insignificant coefficients and to recalculate the values of significant coefficients. Reduced models with significant coefficients were developed. It was found the reduced models were better than the full models because they have higher values of $R^2$ (adjusted) and lesser values of standard error estimates. The $R^2$ values and standard error of estimates for both models are given in Table 5. The final reduced mathematical models with the significant coefficients follow:

Heat Input, kJ/cm = $9.78 + 0.996 V + 1.22 F + 1.78 S - 0.244 F^2 + 0.244 S^2 - 0.244 F S$ (2)

Width of Heat-Affected Zone, mm = $1.029 + 0.013 V + 0.144 F - 0.159 S - 0.05 N + 0.032 V^2 + 0.004 F^2 + 0.078 S^2 + 0.03 V F + 0.029 V N - 0.056 F S + 0.037 F N$ (3)

Width of Weld Interface, $\mu$m = $26.94 + 0.924 V + 4.529 F - 6.305 S + 0.221 N^* + 1.431 F^2 + 2.431 S^2 - 2.169 F S + 1.044 F N - 1.956 S N$ (4)

Width of Grain Growth Zone, mm = $0.591 + 0.017 V + 0.073 F - 0.089 S - 0.023 N + 0.018 F^2 + 0.031 S^2 + 0.02 FS - 0.026 SN$ (5)

Width of Grain Refinement Zone, mm = $0.282 + 0.061 F - 0.091 S - 0.024 N + 0.039 F^2 + 0.045 S^2$ (6)

Conducting the Conformity Test

Validity of the developed models was further tested by drawing scatter diagrams that show the observed and predicted values of weld bead dimensions. A representative scatter diagram is shown in Fig. 3. To determine accuracy of the models, conformity test runs were conducted. For these runs, process variables were assigned some intermediate values. Responses were measured and presented in Table 6. A comparison was made between actual and predicted values (Table 6). The results show the models' accuracy was above 97%.

Results and Discussions

Effects of process variables on HAZ parameters are shown in Figs. 4-14. These results were used to predict values of the process variables and weld bead HAZ geometry for any given set of process variables for SAW of 6-mm structural steel plates without preheating. Also, values of the control variables and heat input can be obtained for any desirable HAZ parameter value.
Table 4 — Calculation of Variance for Testing the Adequacy of the Models

<table>
<thead>
<tr>
<th>Bead parameters</th>
<th>First-order terms</th>
<th>Second-order terms</th>
<th>Lack of fit</th>
<th>Error terms</th>
<th>F ratio</th>
<th>R ratio</th>
<th>Whether model is adequate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SS</td>
<td>DF</td>
<td>SS</td>
<td>DF</td>
<td>SS</td>
<td>DF</td>
<td>SS</td>
</tr>
<tr>
<td>Heat input</td>
<td>138.7</td>
<td>4</td>
<td>7.52</td>
<td>10</td>
<td>1.740</td>
<td>10</td>
<td>0.334</td>
</tr>
<tr>
<td>Width of HAZ</td>
<td>1.172</td>
<td>4</td>
<td>0.366</td>
<td>10</td>
<td>0.079</td>
<td>10</td>
<td>0.026</td>
</tr>
<tr>
<td>Width of weld interface</td>
<td>1472</td>
<td>4</td>
<td>374.8</td>
<td>10</td>
<td>136.1</td>
<td>10</td>
<td>31.72</td>
</tr>
<tr>
<td>Width of grain growth zone</td>
<td>0.34</td>
<td>4</td>
<td>0.063</td>
<td>10</td>
<td>0.051</td>
<td>10</td>
<td>0.011</td>
</tr>
<tr>
<td>Width of grain refinement zone</td>
<td>0.30</td>
<td>4</td>
<td>0.100</td>
<td>10</td>
<td>0.021</td>
<td>10</td>
<td>0.004</td>
</tr>
</tbody>
</table>

\[ R_{ratio} = \frac{SS_{first-order terms} + SS_{second-order terms}}{DF_{first-order terms} + DF_{second-order terms}} \times \frac{MS_{error terms}}{MS_{error terms}} \]

\[ F_{ratio} = \frac{MS_{lack of fit}}{MS_{error terms}} \]

SS = Sum of squares; DF = Degree of freedom; MS = Mean square = SS/DF

Fig. 5 — Direct effect of wire-feed rate on HAZ characteristics.
Fig. 6 — Direct effect of welding speed on the width of the different HAZ regions.

Effects of Heat Input

Figure 4 shows the effect of heat input on various dimensions, namely, the widths of the weld interface (WI), grain growth zone (GGZ) and grain refinement zone (GRZ) of the HAZ’s supercritical zone, and of the HAZ. From the figure, it is observed these widths all increase with an increase in heat input or are energy. This is because an increase in heat input results in a decrease in cooling rate. Also, increased heat input generally results in a larger weld pool size and fused area.

Christensen (Ref. 14) developed a relationship based on Rosenthal’s equations to correlate operating parameter (n) and cross-sectional areas of weld zone and the “recrystallized” portion of the base metal heat-affected zone where

\[ n = \frac{qs}{4 \pi K \alpha (t_f - t_i)} \]  

In Equation 7, q = net heat input (cal/s), K = thermal conductivity of plate, \( \alpha = \) thermal diffusivity, \( t_f = \) melting temperature of plate, \( t_i = \) initial temperature of plate, and \( s = \) welding speed, cm/s.

It is also reported both the fused weld zone and recrystallized HAZ areas increase as the operating parameter (n) increases for almost all materials.

From the equation, the HAZ and, therefore, the widths of the different zones of the HAZ increase steadily with the increase in heat input. The trends shown in Fig. 4 confirm the findings of Christensen (Ref. 14) and other researchers.

Direct Effect of Process Variables

The direct effect of process variables on the dimensions of different zones of the HAZ are shown in Figs. 5–8. The effects are presented in order of their influence on HAZ dimensions.

Direct Effect of Wire Feed Rate (F)

Figure 5 shows the effects of F on different HAZ parameters. From the figure, it is clear all dimensions of the different HAZ regions, namely, width of the HAZ, WI, GGZ, and GRZ, increase with the increase of FF these effects are due to the fact that as F increases, the heat-input value also increases more or less proportionally. But the increase in heat input level results in a decrease in cooling rate, as explained previously. Therefore, the width of GGZ, GRZ, and WI all increase with the increase in F.

Effect of Welding Speed (S)

Many researchers have found that next to current, welding speed is the main factor controlling heat input and the dimensions of the HAZ. Figure 6 shows the effects of S on HAZ parameters. From the figure, the following facts are evident: the value of WI, GGZ, GRZ, and HAZ all decrease with the increase in S. This is because heat input is inversely proportional to welding speed. As S increases, heat input decreases. Also, as per Christensen’s (Ref. 14) empirical relationship...
between welding speed and HAZ dimensions, S has a negative effect on HAZ dimensions because of its influence on heat input. But, keeping heat input at a constant level, if S is increased, it will have a positive effect on most of the dimensions of the HAZ because faster travel speeds allow a greater portion of arc energy per unit length to be utilized in melting the base metal rather than just extending the magnitude of heating into the base metal beyond the boundary of the fused zone.

In this investigation, heat input was not controlled. Therefore, S has a negative effect on heat input and on all the dimensions of the HAZ.

**Direct Effects of Arc Voltage**

Many investigators (Refs. 1, 15) found voltage in a consumable electrode process has no significant effect on HAZ dimensions. In this investigation, it was found the effect of V is less than that of F on HAZ. Figure 7 shows the effect of V on the dimensions of different zones of the HAZ. From the figure, it is apparent WI, GRZ, and HAZ increase slightly with the increase in V. GGZ increases significantly with the increase in V. The reason for these effects is the slight increase in heat input (heat input increases by about 4 kJ/cm) with the increase in V from its lower limit (-2 level) to upper limit (+2 level). This slight increase in heat input reduces the cooling rate. Therefore, the dimensions of the different HAZ layers increase with the increase in V.

**Effects of Nozzle-to-Plate Distance (N)**

It is found N has a negligible effect on most HAZ dimensions within the range evaluated — Fig. 8. From this figure, it is clear WI increases slightly with the increase in N. It was also found GGZ, GRZ, and, therefore, HAZ decrease slightly with the increase in N. This slight decrease in HAZ (from 1.02 to 0.97 mm) might be due to the decrease in heat input from 10.2 to 9.5 kJ/cm when N is increased from the -2 to +2 level (as evident from the 23rd and 24th experimental runs shown in Table 2). As heat input has a positive effect on the HAZ, the slight decrease in heat input by about 0.7 kJ/cm as N is increased from 30 to 40 mm results in a slight decrease in the values of the GGZ, GRZ, and HAZ.

**Interaction Effects of Process Variables**

From the final mathematical models, it is noted the process variables have many interaction effects on the HAZ dimensions, but only a few select and important interaction effects are presented in graphical form for analysis. Interaction effects of the selected process variables on various HAZ dimensions are shown in Figs. 9–14.

**Interaction Effects of Wire-Feed Rate and Welding Speed on HAZ**

Figure 9 shows the HAZ increases with the increase in F for all values of S, but the rate of increase in HAZ is steady and greater when S is at its lower limit (-2 level). This is because F has a positive effect, but S has a negative effect on HAZ, as discussed previously. HAZ is maximum (about 2.1 mm) when F and S are, respectively, at their upper (+2) and lower (-2) limits. This slight increase in heat input reduces the cooling rate. Therefore, the dimensions of the different HAZ layers increase with the increase in V.

**Table 5 — Comparison of Squared Multiple R Values and Standard Error of Estimates for Full and Reduced Mathematical Models**

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Bead Parameters</th>
<th>R² Value (adjusted)</th>
<th>Standard Error of Estimate</th>
</tr>
</thead>
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<tr>
<td></td>
<td></td>
<td>Full models</td>
<td>Reduced models</td>
</tr>
<tr>
<td>1</td>
<td>Heat input</td>
<td>0.975</td>
<td>0.978</td>
</tr>
<tr>
<td>2</td>
<td>Width of HAZ</td>
<td>0.872</td>
<td>0.914</td>
</tr>
<tr>
<td>3</td>
<td>Width of weld interface</td>
<td>0.863</td>
<td>0.880</td>
</tr>
<tr>
<td>4</td>
<td>Width of grain growth zone</td>
<td>0.751</td>
<td>0.789</td>
</tr>
<tr>
<td>5</td>
<td>Width of grain refinement zone</td>
<td>0.893</td>
<td>0.990</td>
</tr>
</tbody>
</table>
Table 6 — Comparison of Actual and Predicted Values of HAZ Characteristics

<table>
<thead>
<tr>
<th>S. No.</th>
<th>V</th>
<th>F</th>
<th>S</th>
<th>N</th>
<th>Predicted values of HAZ characteristics</th>
<th>Actual values of bead characteristics</th>
<th>error %</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>HAZ WI GGZ GRZ HAZ WI GGZ GRZ</td>
<td>HAZ WI GGZ GRZ HAZ WI GGZ GRZ</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>mm µm mm mm mm µm mm mm mm µm mm mm</td>
<td>mm µm mm mm µm mm mm mm µm mm mm mm</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>1.5</td>
<td>-0.5</td>
<td>-1.5</td>
<td>1.5</td>
<td>1.38 49.8 0.86 0.46 1.35 51 0.88 0.47</td>
<td>-2.2 2.4 2.3 2.17</td>
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<td>2</td>
<td>-0.5</td>
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<td>-0.5</td>
<td>1.15 33.7 0.68 0.36 1.12 32.9 0.70 0.36</td>
<td>-2.6 2.9 2.9 2.0</td>
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<td>3</td>
<td>1.2</td>
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<td>-1.2</td>
<td>1.02 29.1 0.55 0.25 1.05 30 0.54 0.26</td>
<td>2.9 3.1 -1.8 4.0</td>
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<tr>
<td>4</td>
<td>-1.5</td>
<td>1.5</td>
<td>-1.2</td>
<td>1.5</td>
<td>1.56 62.6 0.88 0.60 1.5 63.9 0.89 0.62</td>
<td>0 2.0 2.3 3.33</td>
<td></td>
</tr>
</tbody>
</table>

Average Error = (Actual value - Predicted value) / Predicted value x 100

Fig. 9 — Interaction effect of wire feed rate and welding speed on HAZ width.

Fig. 10 — Response surface model for interaction effect of wire-feed rate and welding speed on HAZ width.

These effects are further explained with the help of a response surface plot, as shown in Fig. 10. From the contour surface, it is noted HAZ is maximum (about 2.2 mm) when F and S are respectively at their maximum (+2) and minimum (-2) limits, and the lowest value of HAZ (about 1.0 mm) is obtained when F and S are at their minimum and maximum limits, respectively. It is also observed that maximum value of the HAZ is obtained when both V and N are at their +2 limits and vice versa.

Interaction of Wire-Feed Rate (F) and Welding Speed (S) on Width of Weld Interface (WI)

Figure 11 represents the interaction effect of F and S on the width of the weld interface. From the figure, it is clear WI increases with the increase in F for all values of S, but the rate of increase in WI gradually decreases with the increase in S. This is because F has a positive effect but S has a negative effect on heat input. Maximum WI value is obtained (about 72 mm) when F is at its upper limit (+2 level) with S at its lower limit (-2 level). Minimum WI value (about 22 mm) is obtained when F is at its lower limit (-2 level) with S at 0.67 m/min (+1 level). These effects show that at lower values of S, the combined effects of F and S are the net effect on WI, but at higher values of S, the negative effect of S in decreasing WI is found to be stronger than the positive effects of F.

This is also shown clearly by the response surface plot depicted in Fig. 12. It is evident from the contour plot that WI is maximum for all values of F and S when V and N are at their upper limits, and WI is minimum for all values of F and S when V and N are at their lower limits.

Interaction of F and S on Width of Grain Growth Zone (GGZ)

Figure 13 shows the interaction effects of F and S on GGZ are similar to that of F and S on WI. The reason for the increasing trend of GGZ with the increase in F is the positive effect of F. The gradual decrease in the increasing rate of GGZ with the increase in F is due to the negative effect of S. At lower values of S, heat input increases with the increase in F. As the heat input has a positive effect on GGZ, as explained previously, it increases with the increase in F. This shows the net effect is the combined effect of F and S on GGZ, but, at higher values of S, the negative effect of S is stronger than the positive effect of F on GGZ. Therefore, the increasing trend of GGZ decreases gradually as S is increased.

It is also evident from the contour plot...
shown in Fig. 14 that width of the GGZ is maximum when F and S are at the +2 and -2 levels, respectively. It is also evident from the plot the width of the GGZ surface is shifted below when V and N are changed from their +2 to -2 levels; therefore, the GGZ decreases for all values of F and S when V and N are lowered.

**Conclusions**

1) The second order quadratic mathematical models are useful for predicting and controlling the dimensions of different regions of the HAZ of a weldment.

2) Validation of the models and comparison of the predicted and observed values of bead parameters revealed the models' average accuracy is about 97%.

3) Heat input — calculated using welding current, welding voltage, and welding speed — had a considerable positive effect on almost all HAZ dimensions.

4) Wire-feed rate had a positive effect but welding speed had a negative effect on all HAZ dimensions.

5) Within the values evaluated, nozzle-to-plate distance had no considerable effect on most HAZ dimensions. The dimensions of the grain growth zone, grain refinement zone, and, therefore, the width of the heat-affected zone decreased slightly with the increase in nozzle-to-plate distance.

6) Out of the different process variables, wire-feed rate and welding speed had a strong interaction effect on HAZ dimensions.

7) The increasing trend (rate) of the widths of the weld interface, grain growth zone, and HAZ with the increase in wire-feed rate gradually decreased with the increase in welding speed. For instance, maximum value of the HAZ width was 2.1 mm when F and S were, respectively, at
their upper and lower limits, but the HAZ
width was minimum (0.7 mm) when F and
S were, respectively, at their lower and
upper limits.

References
vol. 1. 4th ed. Miami, Fla.: American Welding
Society.
2. Lancaster, J. F. 1987. The Metallurgy of
crostructure and mechanical properties in SA
and GMA weld metals. Proceedings of an In-
ternational Symposium on Welding Metallurgy of
Structural Steels, Colorado, pp. 189–199.
4. Adler, Y. E, Markov, E. V., and Gra-
ovsky, Y. V. 1975. The Design of Experiments
to Find Optimal Conditions. Moscow, USSR:
MIR Publishers.
Research Workers. 12th ed. Edinburgh, Scot-
tland: Oliver and Boyd.
Fractional factorial techniques to predict di-
mensions of the weld bead in automatic sub-
merged arc welding. Journal of Inst. of Engi-
ners (India) 76: 67–71.
perimenters: An Introduction to Design Data
Analysis and Model Building, 10th ed. New
York, N.Y.: John Wiley and Sons.
Mathematical models for predicting angular
distortion in CO2-shielded flux cored arc weld-
ing. Proceedings of the International Conference
on Joining of Metals (JOM–3), Helsingor, Den-
mark, pp. 240–245.
fects of MIG process parameters on the sur-
facing of stainless steel. Journal of Materials
Processing Technology 41: 381–398.
Experimental Designs. India: Asia Publishing
House.
11. Montgomery, D. C., and Peck, E. A.
1962. Introduction to Linear Regression Anal-
12. Davis, O. L. 1978. The Design and
Analysis of Industrial Experiments. New York,
N.Y.: Longman.
13. Wilkinson, L. 1990. SYSTAT: The Sys-
tem for Statistics. SYSTAT, Inc., Evanston, Ill.
14. Christensen, N. 1965. Distribution of
temperature in arc welding. British Welding
15. Easterling, K. E. 1983. Introduction to
the Physical Metallurgy of Welding. London,
U.K.: Chapman and Hall.
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<td></td>
</tr>
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</table>
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